Using Mobile Technology to Record Patient Observations: Impact on Care Management and Clinical Practice

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Abstract

The CareFlow Vitals system was introduced by health boards in Wales to enable staff working at the bedside to record patient observations on iPads. This software automatically calculates the early warning score (used to monitor patients' health and determine the degree of illness) and time to the observation. Although research in this area is quickly evolving as similar systems are introduced in healthcare settings worldwide, little is known about the impact these systems have on clinical decision making and patient care management. This study aimed to explore the impact of CareFlow Vitals installed on iPads on patient care management and clinical practice from the perspectives of a range of healthcare staff using the technology.

This research is a mixed methods study utilising case study and survey designs. The case studies comprise two hospitals within the one health board: Castle Plains, a smaller hospital and an initial pilot site for implementation of the system; and South Fields, a larger hospital that introduced the system during the Covid-19 pandemic.

Participants (n=50) were observed using the mobile devices with CareFlow Vitals over 109 hours across different wards alongside semi-structured interviews (n=14) with health care support workers, nurses, ward managers, clinicians, and hospital management staff. A survey gathered responses (n=105) from a wider population and offered opportunities to triangulate quantitative data with the qualitative data from interviews and observations.

The results detail how the devices are used in practice. Benefits (time-saving, safer patient care, and remote access for clinicians) and disadvantages (less patient contact time with doctors, system/WiFi failure, and low battery) are identified and explored in the context of technology acceptance models. This research provided decision makers with insights into the effectiveness of a digital patient vital signs recording system against the backdrop of an overloaded healthcare system recovering from a global pandemic.

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Abbreviations

AWTTS	Aggregate Weighted Track and Trigger System
CASP	Critical Appraisal Skills Programme
CDSS	Clinical Decision Support System
COPD	Chronic Obstructive Pulmonary Disorder
COREQ	Consolidated Criteria for Reporting Qualitative Research
CWS	Clinical Workstation
EBM	Evidence-Based Medicine
EDIS	Emergency Department Information System
eHandover	Electronic Handover
EHR	Electronic Health Record
EMR	Electronic Medical Record
eObs	Electronic Observation
EPR	Electronic Patient Record
EPSS	Electronic Physical Surveillance System
EWS	Early Warning Score
HCRW	Health and Care Research Wales
HCSW	Health Care Support Worker
HLE	Healthy Life Expectancy
HRA	Health Research Authority
ICU	Intensive Care Unit
IDT	Innovation Diffusion Theory
IRAS	Integrated Research Application System
IVF	In-Vitro Fertilisation
LOS	Length of Stay
MDT	Multi-Disciplinary Team

mEMR	Mobile Electronic Medical Record
MMAT	Mixed Methods Appraisal Tool
MRI	Magnetic Resonance Imaging
NEWS	National Early Warning Score
PDA	Personal Digital Assistant
PEWS	Paediatric Early Warning Score
PIS	Participant Information Sheet
POC	Point of Contact
PPE	Personal Protective Equipment
PPI	Patient and Public Involvement
REA	Rapid Evidence Assessment
REC	Research Ethics Committee
TAM	Technology Acceptance Model
TAM-2	Extended Technology Acceptance Model
UTAUT	Unified Theory of Acceptance and Use of Technology
ViEWS	VitalPAC Early Warning Score
WNCR	Welsh Nursing Care Record
WoW	Workstation on Wheels

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Chapter 1. Introduction

1.1. Overview

This chapter introduces the different aspects of the research thesis to lay a groundwork for the chapters that follow. First, the reader will be familiarised with the context of the research including digital healthcare systems, Welsh policy in regard to digital healthcare, and the health and social care system during the research period. Following this, the CareFlow Vitals software, and the Welsh Nursing Care Record (WNCR) are detailed. The background of the researcher and the research study is then illustrated before the remaining thesis chapters are outlined.

1.2. Context

This section provides background context, specifically in relation to digital health and social care systems, healthcare policy in Wales, and the context of the healthcare system during the research study. The NHS Long Term Plan seeks to provide digital services to the public to give people more control over the health and care that they receive, give healthcare staff the technology they require to help them complete administrative tasks to free up time to spend with patients, and make sure information technology systems talk to each other to provide healthcare staff complete access to integrated patient records (NHS, 2023). Welsh Government (2021a) states that digital change can offer a range of tools for solving problems, enhance people's lives, and strengthen the delivery of public services. Digital transformation in secondary care seeks to improve clinical outcomes, patient safety, the quality of care, and consistency across health and care services which could potentially lead to a reduction in clinical variation and fewer clinical errors (NHS Providers, 2023). The ways in which new technologies are being used in hospitals will be illustrated in Chapter 2.

1.2.1. Welsh Context

‘A Healthier Wales’ was published as a plan for health and social care in response to a parliamentary review of the long-term future of health and social care (Welsh Government, 2021b). This document details an ambition to integrate health and social care services with a greater emphasis on keeping the people of Wales healthy and well. The parliamentary review described increasing demands and challenges that face the NHS and social care at the present moment. A challenge that is happening across the globe is an ageing population caused by advancements in medical care and improved living standards. Although this is a positive development resulting in a population that lives longer, it has increased demands on a health service designed to meet the needs of a post-war population. By 2039, it is projected that over 885,000 people in Wales will be aged over 65, which is an increase of over 271,000 on the population levels seen in 2014 (StatsWales, 2023) As people get older, it is more likely that they will face co-morbidities, including dementia. The interim report from the parliamentary review makes it clear that the Welsh Government will need to understand how to manage this impact on health and social care services (Welsh Government, 2017). Although, in 2018 (most recent report), life expectancy at birth in the UK was 79.0 years for males and 82.9 years for females (Office for National Statistics, 2021), healthy life expectancy (HLE) was 62.8 years for males and 63.6 years for females (Office for National Statistics, 2022) and improving HLE is a priority across the UK Government. HLE is defined as a “measure of the average number of years a person would expect to live in good health based on contemporary mortality rates and prevalence of self-reported good health” (Office for Health Improvement and Disparities, 2023). The risk factors for disability and death include smoking, poor diet, high blood pressure, obesity, misuse of alcohol and drugs, and a lack of exercise (Welsh Government, 2017). These are factors that are amenable to change with lifestyle and behavioural changes. The main conditions causing premature death in Wales include ischaemic heart disease, lung cancer, cerebrovascular disease, chronic obstructive pulmonary disease (COPD), lower respiratory infections, Alzheimer’s disease, colorectal cancer, breast cancer and self-harm. Conditions causing disability and contributing to the lower HLE in Wales include back and neck pain, sense organ diseases, depression, asthma, skin disease, and migraine (Welsh Government, 2017). This highlights that preventable illness is a key cause of lost lives, reduced quality of life, and lower economic productivity in Wales.

There is also a changing expectation of services being offered by health and social care by the general population in Wales. More people are now using online services to find help, access information, and book consultations. This has led to a general anticipation of a rapid response from online-facing services (Welsh Government, 2017). These changing patterns and expectations are leading to complex ramifications for services which hold implications for health boards in Wales. Increased pressures on services are arising from heightened patient expectations. For example, patients want GP appointments sooner than they are available because of the demands on the system. This can result in patients seeking support from already over-stretched accident and emergency departments. The Welsh Government (2017) also explains how changing community and family patterns are contributing to these ramifications in the form of carer wellbeing. For example, recently retired people are playing important roles in the care and support of their older parents alongside caring for grandchildren; and there are instances of children and young people taking on a caring role for siblings and parents. Such informal caregiving can be isolating and lead to feelings of loneliness which is an important factor that can result in the diminished health and wellbeing of the carer which in turn adds to the demand on health systems, for themselves and for those they may no longer be able to care for. A solution to these societal changes which the parliamentary report acknowledges, is new and emerging medical technologies which are in high demand (Welsh Government, 2021b). The interim report of the parliamentary review recognises the use of new technologies in Wales. For example, the use of My Health Online at some GP practices allows patients to manage their appointments and prescriptions online (Welsh Government, 2017).

Welsh Government (2021b) outlines the core values for NHS Wales which include putting quality and safety above all else by providing evidence-based care for patients at all times, integrating improvement into everyday working, focusing on prevention, health improvement and inequality for future generations, and investing in staff through training and development. To achieve the vision of ‘a healthier Wales’ the Welsh Government (2021b) proposed a set of whole system values that would be required. These values are to coordinate health and social care services seamlessly, to measure the health and wellbeing outcomes that are important to people and using that information to support improvement and collaborative decision making, proactively supporting people throughout the whole life course, driving transformative change through strong leadership and clear decision making, and promoting the

distinctive values and culture of the Welsh whole system approach which, it is argued, will make Wales a better place in which to live and work.

In terms of the Welsh Government's approach to technology, they describe using technology to support high quality, sustainable services as part of their vision to implement an integrated whole system approach. They describe technologies that will predict poor health, detect early deterioration, diagnose more precisely, help detect and specify types of cancer, and assistive technologies that enable independence in the home. They predict that new technologies will make services safer and more effective, support better clinical decisions, and help to prioritise and speed up treatments for patients (Welsh Government, 2021b).

An important aspect of the 'A Healthier Wales' plan is the quadruple aim with four themes interpreted specifically for the context in Wales: 1) improved population health and wellbeing, 2) better quality and more accessible health and social care services, 3) higher value health and social care, and 4) a motivated and sustainable health and social care workforce (Welsh Government, 2021b). The inclusion of digital healthcare is an aspect of the second aim as it is stated that improving the use of technologies will improve the quality and value of health and social care services. The document states specific actions the Welsh Government needs to take to meet this aim. These actions include:

- Accelerating progress towards a fully integrated digital architecture and creating an online digital platform for the general population,
- Investing in the skills that the health and social care workforce will need in the future to accelerate digital change and maximising wider benefits for the Welsh society and economy,
- Developing an open platform approach to digital innovation by publishing national standards for the ways that technologies and software can work together,
- Increasing investment in digital infrastructure, technologies, and workforce capacity, and
- Establishing a national data resource allowing for large scale information to be shared appropriately and securely (Welsh Government, 2021b).

In 2023, the Welsh Government published its digital and data strategy for health and social care in Wales, which incorporates the 'A Healthier Wales' framework and builds on the previously published strategy from 2015 (Welsh Government, 2021b). In this strategy, it is explained that great strides have been made in supporting digital and data implementation by appointing a Chief Digital Officer and establishing Digital Health and Care Wales which focuses on transforming how the digital health and care

services are delivered. In the development of health and social care digital services, the Welsh Government (2021b) outlined principles that align with the Centre for Digital Public Services. According to these principles, digital services will 1) be user-centred, inclusive, and accessible, 2) empower staff and service owners, 3) use open, interoperable, and resilient infrastructure, 4) establish trust in how the Welsh Government use people's data, and 5) standardise and optimise how the Welsh Government works.

Further, the strategy details three aims that are proposed to help health and social care organisations be ready to deliver digital services using these principles (Welsh Government, 2021b). Aim one is to transform digital skills and partnerships. It is intended that this aim will be addressed through improved digital skills and digital economy. A digital economy is defined as "that part of economic output derived solely or primarily from digital technologies with a business model based on digital goods or services" (Bukht and Heeks, 2017, p.13). Measuring the digital economy comes with challenges such as poor data quality, problems with pricing, and the hidden activity of much digital activity (Bukht and Heeks, 2017). The second aim is to build digital platforms fit for Wales through improved collaboration, digital infrastructure, and connectivity. The third and final aim is to make services digital first that will be delivered with user centred services and digital inclusion. These aims are important to rationalise the need for software that digitalises the process of recording patient observations in Wales.

1.2.2. Healthcare Context

It is important to note that this research was conducted during a tumultuous period of time for healthcare services. The research was designed during the Covid-19 pandemic so there were measures that were considered when designing the methods that are discussed in more detail in Chapter 4. The British Medical Association (2023)[1] explains that when going into the pandemic, health and care systems across the UK were experiencing sustained underinvestment in healthcare and acute staffing

[1] The British Medical Association is the trade union and professional body for doctors and medical students in the UK and therefore this may be a biased opinion.

shortages with a significant backlog of care. Targets were being missed with increasing frequency as waiting time for diagnostics and elective care were also increasing. Further, access to emergency care was worsening and hospitals had low numbers of beds. During the Covid-19 pandemic, only essential staff in the UK including those who worked in hospitals were allowed to leave their homes for work. The general public were asked to stay in their homes with the people in their household forming a 'unit', maintain social distancing when outside of the home, and practice regular hygiene measures. Despite these measures, over 195,000 people have died with Covid-19 since the beginning of the pandemic (UK Health Security Agency, 2023). The lasting effects of the Covid-19 pandemic are still being felt in hospitals as there is a backlog of patients caused by a drastic reduction in elective services during 2020 (Institute for Fiscal Studies, 2021).

The pandemic was reported to have had a lasting effect on healthcare staff who worked throughout the period. In a survey of 141 surgeons, 85.8% reported being negatively affected by the Covid-19 pandemic (Al-Ghunaim et al., 2021). Qualitative themes that emerged from this survey included 1) a changing and challenging work environment where healthcare staff had to adapt to constant change, an increased workload and lack of work-life balance, and a lack of personal protective equipment (PPE), 2) challenges to professional life and development including a negative impact on job performance, 3) management of change and loss in personal lives, and 4) emotional and psychological impacts such as anxiety, low mood, stress and burnout (Al-Ghunaim et al., 2021). In another study, healthcare workers felt unsupported from the management team at their hospitals (Vindrola-Padros et al., 2020). This led to a sense of unpreparedness and an inability to cope. However, healthcare workers felt supported by their colleagues on the front-line despite feeling fatigued from the challenges of the pandemic (Vindrola-Padros et al., 2020). Most of the members of staff I planned to recruit in this study had worked through the pandemic and it was expected that these themes may reflect the recent experiences of the sample.

Further, this research was conducted during a period of unrest with regular industrial action taking place in NHS hospital-based services since December 2022. Throughout the UK, approximately 900,000 appointments have had to be rescheduled during strike action, and there were 22 critical care incidents declared due to industrial action (Department of Health and Social Care, 2023). In some instances, some patients were required to move hospitals because of staff shortages (Department of Health and Social Care, 2023). Because of regular staff shortages,

hospitals were reliant on agency and locum staff, and were still often understaffed in this period. This context highlights that CareFlow Vitals was introduced to the hospitals within the health board during a turbulent period in the NHS.

1.2.3. Early Warning Scores

Early warning scores are clinical prediction models that use measured vital signs to monitor patients' health while they are in the hospital (Gerry et al., 2020). The National Early Warning Score (NEWS) is a tool that has been developed by the Royal College of Physicians to improve the detection and response to the clinical deterioration of patients by having a system-wide instantly recognisable documentation that facilitates recording, scoring and response to changes (Williams, 2022). NEWS2, an updated version of the tool, has been in use in the NHS since 2017 (NHS England, 2024; Royal College of Physicians, 2022). NEWS2 is being used in 100% of ambulance trusts, and 76% of acute trusts in England (NHS England, 2024), and has also been implemented in other healthcare settings worldwide (Williams, 2022).

The NEWS score is calculated by giving a score to six physiological parameters of the patient which are collected routinely: respiration rate, oxygen saturation, systolic blood pressure, pulse rate, level of consciousness or new onset confusion, disorientation and/or agitation, and temperature. The score reflects how extremely the parameter varies from the norm (the norm being 0). The score is then aggregated and uplifted by two points if a patient requires supplemental oxygen (Royal College of Physicians, 2022).

1.3. Technology

Technology is a word that is used regularly in modern society lexicon. However, technology is not a modern concept, and it is accepted that humans have been using technology since the Palaeolithic period (Agar, 2018). Agar (2018) defines technology as a "designed, material means to an end" (p.381) which is inclusive of a wide array of objects such as tools, computers, and diagnostic equipment. In recent decades, technology has developed to include the digital. Tardieu et al. (2020) define digital as

“a mindset that seeks to leverage technology, data, and ways of working to establish new business and service models for the achievement of a higher purpose and value” (p.3). They argue that digital will become an integrated part of the new norm of society due to the pervasiveness of digital technology in physical spaces.

In this research, I will be focused on mobile digital technology. Mobile devices are an abundant technology in our personal lives, and increasingly our occupational lives. Mobile phones in particular can be seen as extension of the self, forming part of the identity of heavy users in both positive and negative ways (Park and Kaye, 2019). However, although there could be advantages to blending our personal and professional uses of this communication technology, such as improved occupational connectivity, mobile phone use in public spaces can present challenges as the boundaries between the private and public spaces are constantly negotiated (Campbell and Park, 2008). For example, mobile phones can present the opportunity to take work-related calls outside of work hours or even during holidays, blurring the line between work and personal time (Wajcman et al., 2008). Research in human behaviour using mobile devices has been widely explored in the general consumer space, as well as specific domains (e.g., sport, education, and personal use), however less so in practicing medicine, such as primary care scenarios.

1.3.1. CareFlow Vitals

The CareFlow Electronic Patient Record (EPR) system is a product supplied by System C, a British technology company that have been working with the NHS and social care for 40 years across development, deployment, and adoption (System C, 2023a). The entire CareFlow EPR system includes different modules including maternity, patient flow, and medicine management (System C, 2023b). The health board that introduced CareFlow into their hospitals in this study, specifically introduced the module CareFlow Vitals (formerly known as VitalPAC). CareFlow Vitals is an electronic observation and decision support system which has been designed to improve patient safety and outcomes whilst removing the need for paper charts (System C, 2023c). CareFlow Vitals immediately calculates the early warning score (EWS) and clinical risk of the patient and gives the staff member using the software the suggested next steps in the patient’s care. The vital signs that are recorded in the software to calculate the EWS include blood pressure, heart rate,

temperature, oxygen saturation, respiratory rate, whether the patient is receiving supplemental oxygen, pain score (as directed by the patient), the patient's level of consciousness, whether the patient has urinated and how much if catheterised, whether the patient has opened their bowels and the type of stool. Finally, the member of staff is asked whether they are concerned about their patient. CareFlow Vitals has a number of tools that support the collection and recording of observations including a timer that can be used when counting the breaths of the patient for the respiratory rate, and a stool chart so the staff member can use a visual aid with patients.

CareFlow Vitals also has an optional attached module used to identify potential patients with sepsis which health board decision makers can choose to use. With this module, an alert is generated where there are signs of sepsis, and the person entering the data are given guidance on the next steps including doing a full sepsis assessment, and completion of the Sepsis 6 checklist (System C, 2023d). After implementation of the sepsis module in Barnsley Hospital NHS Foundation Trust, there was an almost immediate improvement in screening in both inpatients' wards and the emergency department. The Trust also recorded a 1.5-day reduction in the average length of stay (LOS) for sepsis patients identified through intensive care unit (ICU) admissions (System C, 2023d). A reduction in LOS has personal benefits for the patient who most likely wants to be home, and financial and organisational benefits for the hospital as beds will be available for future patients. CareFlow Vitals can also be adapted to include the paediatric early warning score (PEWS) designed specifically to monitor potential deterioration in children. This was introduced at Alder Hey Children's NHS Foundation Trust. At the end of the first year of implementation, the Trust reported a 32% reduction in unplanned transfers to critical care and a 30% reduction in critical care bed day utilisation. This releases capacity equivalent to three critical care beds per day (System C, 2023e)[2].

[2] This evidence is authored by System C who supplies the CareFlow product and the potential for bias is noted.

1.3.2. Welsh Nursing Care Record

WNCR was implemented in 2021 across several health boards and trusts in Wales (Welsh Government, 2021a) with it being in widespread use by March 2024 (Welsh Government, 2023). Although not a direct focus of this research, WNCR was present in one of the hospitals during the data collection period. WNCR standardises the nursing documentation into a digital form. This documentation includes freehand patient notes which could detail the patients' current status, future actions and potential concerns. WNCR is available on the mobile technology and computers at the nurse's station, however WNCR and CareFlow Vitals are two different systems that do not interact with the other. Digital Health and Care Wales aims to improve consistency and accuracy through the use of WNCR by uploading these digital assessments to the Welsh Clinical Portal which is a national digital patient record. This means that the patient information is available at any secondary care site in Wales (Digital Health and Care Wales, 2021).

Health boards and hospitals in Wales have reported benefits to the use of WNCR. One health board reported that in a two-year period the use of WNCR saved 1,357,827 pieces of paper which is equivalent to 135 trees. This amounted to annual savings of approximately £132,800 (Welsh Government, 2023). There were 3.9 million patient notes captured for over 86000 patients using WNCR with further developments set to include paediatric inpatient notes to be added (Informed Communications Ltd., 2023).

1.4. The Researcher

This section illustrates the experiences and predispositions of the researcher. This is done so that the reader can understand my motivations for undertaking this research and provides insight into why certain approaches and methods were chosen over others. By being explicit about my background, I intend to give an insight into factors shaping how I collected data to provide a degree of reflexivity to the study (Mays and Pope, 2000). I adopted a largely qualitative approach to data collection in this mixed methods study and reflexivity is important as readers of qualitative research need to understand who is doing the research and the researcher's positionality in relation to

what is being studied. Unlike quantitative based approaches, objectivity is not a goal and it has been said that 'the researcher is the research instrument' and understanding the context surrounding the research instrument is pertinent (Dodgson, 2019).

I have not always been affiliated with healthcare research or social sciences. Prior to doctoral study, I undertook a BSc in Social Work and intended a career as a social worker. However, during practical placements I became dissatisfied with social work practice as I could see that the sector needed significantly more investment in order to meet service user needs. What I found I did enjoy was the research for my dissertation which was concerned with the accommodation and service provisions of people with dementia. I felt that researching and evaluating services for the public could enact change, or at least a discussion, that might improve the lived experiences of vulnerable people in our society. This sparked a passion to pursue research opportunities. Due to my interests changing in the latter stages of my undergraduate degree, I pursued a postgraduate degree in Ageing Health and Disease. This degree was located in the School of Medicine which represented a change. Where I had previously been exposed to ideologies such as the social model of disability - the idea that society is the cause of the problems which disable an individual- I was then exposed to alternative theories from a medical perspective such as the medical model of disability. This is the standard medical approach to thinking about disability which involves viewing it as a problem that exists in a person's body. Therefore, put simply, the solution is to apply treatment or care to fix the disability and regain normal functioning. The last measure would be to help the individual adapt and learn to function with the disability (Goering, 2015). This contrasts with a social science approach which tends to see solutions in terms of societal change.

When the opportunity arose to pursue the current research project as a PhD studentship funded by Health and Care Research Wales (HCRW), I felt that the interdisciplinary approach fitted well with my past experiences. Pursuing a social sciences doctoral project in a medical setting created a good blend of my undergraduate and postgraduate education. I also had a consistent interest in the use of technology in medical and social care settings to improve the lived experiences of vulnerable people and the move towards a digital society. For example, during my undergraduate degree I became familiar with the use of assistive technology being used in social care settings to enable more independence for people who had limitations with their mobility or cognitive functioning. I also experienced the extent to

which technology is being used in medical settings during my postgraduate degree to improve diagnosis and prognosis outcomes, particularly during the rehabilitation of neurological disorders.

1.5. The Research Study

The National ePatient Flow Management Programme is an all-Wales programme which was designed to improve decision making and the management of workflow through the development and implementation of a digital solution for real-time hospital clinical and operational patient care information. The health board involved in this study was hosting the programme on behalf of the other health boards and trusts in Wales by implementing the technology for recording patient observations in the clinical setting. This research incidentally contributed to the health board's evaluation strategy for CareFlow Vitals although this was not an aim by design.

Before the start of this research, the health board implemented a pilot study of the CareFlow Vitals software on mobile technology in two hospitals within the health board before potential implementation in more hospital sites. At the time of data collection, the CareFlow Vitals software was available at all sites. To date, very little research has been conducted that explores the impacts of the technology in clinical practice, specifically relating to the clinical care of patients, and professional practice. This research was specifically designed to explore the infrastructure and human factors that are potentially facilitating or impeding the implementation and the use of technology (specifically software for recording patient observations) when managing patient care and clinical practice. It is expected that this research will be useful for other hospital sites and health boards that implement new technology to support patient care in Wales and further afield.

1.6. Overview of Thesis

This thesis is presented over nine chapters. Chapter 2 contains the Rapid Evidence Assessment (REA) which summarises relevant literature relating to the use of mobile technology in secondary care practice and states the research questions with which

this thesis is concerned. This is followed by Chapter 3 which engages with theoretical frameworks that this study employs. It presents the innovation diffusion theory (IDT) and an evolution of technology acceptance theories.

Chapter 4 presents the methodology used to conduct this research. Although primarily qualitative in nature, this research is a mixed-methods study utilising case study and survey designs in two hospitals in Wales. This chapter includes the context of the case study sites and an exploration of ethical concerns and patient and public involvement (PPI).

Chapters 5-7 present the results of the research study. Chapter 5 specifically focuses on reporting the use of the iPads with CareFlow Vitals in the case study sites. Chapter 6 presents analysis of the survey findings to attain an understanding of the preference in practice for data-entry of patient observations. Chapter 7 reports the participants' perceptions of benefits and disadvantages related to using the mobile technology to conduct patient observations in clinical practice.

Following this, Chapter 8 presents a discussion of the findings in this study, specifically how they relate to the theoretical framework and previously identified literature. Chapter 9 then concludes the thesis by highlighting how the research questions have been addressed in the context of the strengths and limitations of the study. Opportunities for future research are also identified.

1.7. Conclusion

This chapter has laid the foundations for this research by introducing the developments of the digital transformation agenda in Wales. Digital healthcare systems are advancing globally to replace paper-based forms with the aims of improving consistency and accuracy in patient care and clinical practice. This study specifically looks to understand the human factor impacts of using CareFlow Vitals and their influences on patient care management. The next chapter details the REA that reports international literature on the uses of mobile technology involved in patient care and clinical practice.

Chapter 2. Rapid Evidence Assessment

2.1. Overview

Mobile devices are being used in the clinical setting for different purposes relating to patient care management worldwide. The purpose of this rapid evidence assessment (REA) was to explore the academic literature and distil what is known about: 1) the purposes of using mobile technology in the hospital setting; 2) what mobile devices and software have been used in hospital settings; 3) the reported benefits and drawbacks of using mobile technology in hospital settings; and 4) the impact of mobile technology on patient care management in the hospital workplace. The justification for this approach is in section 2.2.

The REA involved an inductive multi-stage literature search. Initially databases were searched using key words relevant to the subject matter. Backward and forward citation tracking was then employed on all relevant publications. In total 45 research papers were identified, critically appraised, and synthesised using a textual narrative approach (Lucas et al., 2007).

The selected publications comprised 20 quantitative, five qualitative, eight mixed methods studies, and 12 reviews. To provide an initial overview of the findings, they are outlined in brief here. A range of benefits and drawbacks were identified for a plethora of different devices (smartphones, tablet computers, personal digital assistants (PDA)) designed for multiple purposes (up-to-date vital signs monitoring and EWS calculations, accessing the electronic health record (EHR) or electronic medical record (EMR), supporting learning and clinical decision-making) in the clinical setting. Benefits included: a reduced need for printing, improved interpersonal relationships, improved workflow for clinicians, assistance in making clinical decisions, a reduction in opportunities for human error, perceptions of improved patient safety, and reduced LOS and mortality rate. Drawbacks included: preference for using the desktop and print resources, perceptions of the devices being burdensome and unnecessary, poor wireless connection affecting use, inconsistent and subjective use amongst professionals, reluctance to embrace change, and poor perceptions from patients and families. A need was identified for institutional and

national consensus on how to best use mobile devices in the clinical setting. Further research is needed to gather qualitative evidence of the implementation of mobile devices into hospitals, how the workflow of staff has been affected, and how clinical and organisational decision-making processes are supported by the data collected by mobile devices. The research questions of this study are informed by the gaps in the literature and presented at the end of the chapter.

2.2. Purpose and Method

The purpose of this review was to explore what is known in the academic and empirical literature on the impact of mobile technology for patient care management in the hospital workplace. To address this broad aim, the more specific objectives were to identify what mobile devices and software have previously been used in clinical settings, what the primary purposes of these devices and associated software were, and the reported benefits and drawbacks of using mobile technology for patient care in hospitals.

It was an expectation of the funder that a REA would be conducted rather than a more traditional literature review typically seen in the social sciences. The aim of REAs is to provide an overview of the available evidence addressing a research question related to a single topic (Varker et al., 2015). Healthcare organisations increasingly demand rapid access to ensure up-to-date evidence-informed decision making and practice (Ganann et al., 2010). REAs are a methodological approach that can be used in health services research to deliver evidence summaries of high value which can inform decisions and initiatives in a timely and user-friendly manner (Khangura et al., 2012). There are difficulties in categorising what constitutes a rapid time frame simply based on the length of time it takes to conduct the review. A survey conducted by Watt et al. (2008) that was distributed to and responded by 18 International Network of Agencies of Health Technology Assessment members, reporting on 36 rapid review products, demonstrated that there appears to be no standardised methodology for REAs, and evidence appears to be included subjectively based on the availability of evidence rather than on methodological criteria. REAs have also been critiqued for bias arising from the omission of material that is difficult to obtain, introducing an opportunity to neglect relevant material, and examining literature in a restricted time period which could introduce further bias. Criticisms have also been

raised in relation to complexities surrounding the transparency of methods used to identify relevant studies (Varker et al., 2015; Gannan et al., 2010). An REA was deemed an appropriate methodology to utilise given the desire for a review that was systematic but restricted by resource in terms of researcher time (just the author conducting the search and synthesis) (Barends et al., 2017).

The Centre for Reviews and Dissemination (2008) highlights the importance of integrating both quantitative and qualitative evidence and this approach was adopted in this REA. Quantitative and qualitative research can complement one another in the process of triangulation which provides a more holistic and nuanced understanding of the subject. Triangulation therefore compensates for the weaknesses or absences that each method allows (Flick, 2009). For example, quantitative methods have more strength in reliability compared to qualitative methods, but qualitative methods have more strength in validity (Carr, 1994). In recognition of the value of different methods, research papers with a quantitative, qualitative or mixed methods methodology were included.

The journey to gathering the final sample of relevance-scored papers was more complex than originally expected for this REA. As familiarity with the research area increased, it was clear an iterative search process was required due to the nature of the subject area which lacked consistent use of key words, arising from the plethora of different software and systems studied. Therefore, the methods are described in stages. At stages 1-4 MEDLINE, CINAHL, SCOPUS, Web of Science and the Cochrane Library databases were searched. All duplicated studies were removed using Endnote, and the remaining articles were screened at the title, abstract and full-text stages respectively. The search was limited to English language but not to date since the majority of published works returned by the search were dated after the year 2010. The database search was conducted twice during the research period to remain up to date with the literature in a fast-paced field of novel technology implementation in secondary care settings. The overall PRISMA diagram is detailed in Figure 1.

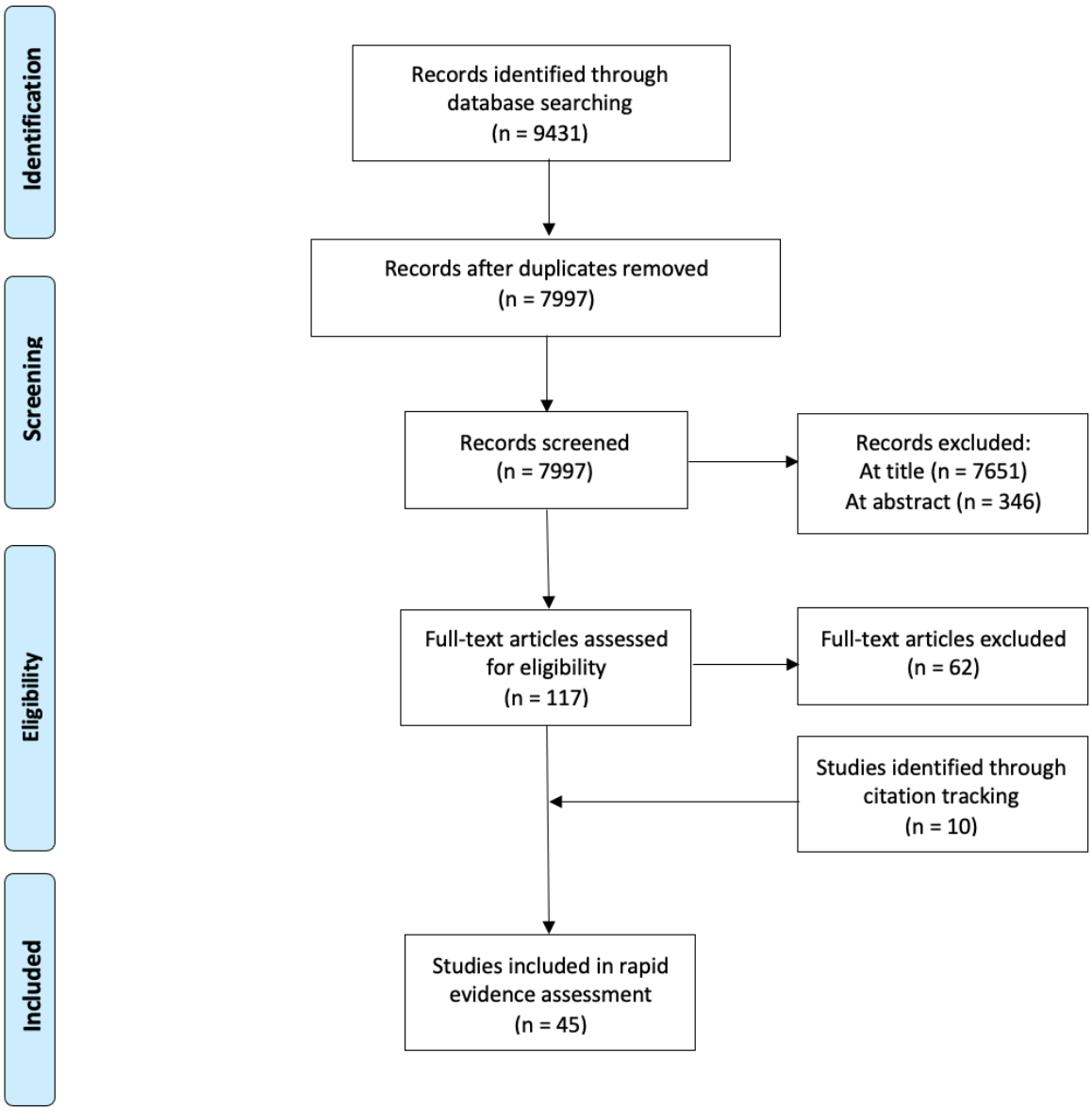

Figure 1 PRISMA diagram to show the identification of included studies for the rapid evidence assessment.

Studies were included in the review if they met the following inclusion criteria: 1) the study included a mobile technology[3] being used in some way to support direct patient care, and 2) the study was based in a hospital(s). Other settings outside of the

[3] For the purposes of this REA, mobile technology is defined as a portable two-way communications device with an interactive screen and/or keyboard designed for use in the clinical setting. Traditional devices such as pagers were therefore excluded.

hospital, e.g., social care settings, were considered out of scope due to the focus on the impact of mobile technology on variables within the clinical setting i.e., clinical decision making, multi-disciplinary team (MDT) working and ward management.

Studies were excluded from the review if they met the following exclusion criteria: 1) were not based in a hospital, 2) focused on telehealth, or 3) were anecdotal, not research. Reviews were excluded during the first search due to the large amount of literature being returned. However, they were included during the second literature search. The search strategy is detailed in the next sections.

2.2.1. Stage 1: Initial Search Strategy

The search strategy is detailed in Table 1. The search was conducted between October and November 2020. MEDLINE was used to develop the search strategy. This was then adapted and extended to: CINAHL, SCOPUS, Web of Science and the Cochrane Library.

The electronic database search identified 3443 research papers. 2678 research papers were screened after removing duplicates. After reviewing the title and abstract of these papers, a further 2641 research papers were excluded because they did not meet the selection criteria. The remaining 37 texts were scanned fully and another 31 were excluded for not meeting the selection criteria. These were for reasons such as: evaluating clinical guidelines being available on mobile devices rather than being used for direct patient care, mobile devices being used remotely from patients' homes, and evaluating how prevalent clinician mobile phone use was in hospitals with no regard to using the devices for patient care. Ultimately, six articles from the initial database search were included in the REA.

Table 1 Search strategy developed for stage one using MEDLINE.

#	SEARCH TERM
1	mobile technolog*.mp.
2	digital technolog*.mp.
3	mobile health.mp.
4	mhealth.mp.
5	electronic health.mp.
6	ehealth.mp.
7	mobile applications/
8	1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7
9	patient care management/
10	patient care/
11	9 OR 10
12	hospitals/
13	medicine/
14	health care.mp.
15	healthcare.mp.
16	clinical setting.mp.
17	secondary care/
18	12 OR 13 OR 14 OR 15 OR 16 OR 17
19	8 AND 11 AND 18
20	Limit 19 to English language

2.2.2. Stage 2: Including “Patient Flow” Terms

The stage two search strategy illustrated in Table 2 was developed after identifying key terms in the 37 texts that were fully screened in the previous stage. For example, the names of software and systems such as “VitalPAC” and “care flow” were not included in the previous stage but were common throughout the relevant journal

articles identified at stage 1 and were considered relevant to the aim of this review. The search was conducted in December 2020.

The electronic database search returned 262 studies. 100 studies were excluded after removing duplicates using Endnote. The remaining 162 studies were reviewed against the selection criteria. Only one text (Hands et al., 2013) was not excluded after reviewing the title or abstract. This text was included in the REA.

Table 2 Search strategy for stage two developed using MEDLINE.

#	SEARCH TERM
1	mobile technolog*.mp.
2	digital technolog*.mp.
3	mobile health.mp.
4	mhealth.mp.
5	electronic health.mp.
6	ehealth.mp.
7	mobile applications/
8	1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7
9	VitalPAC.mp.
10	patient flow.mp.
11	care flow.mp.
12	health flow.mp.
13	9 OR 10 OR 11 OR 12
14	8 AND 13
15	Limit 14 to English language

2.2.3. Stage 3: Searching for “VitalPAC”

VitalPAC was a software that was identified in some of the highly relevant papers that had already been gathered. The decision to search for “VitalPAC” independently in

the database was conducted to ensure that the other key words were not impeding on finding the relevant literature. The search was conducted in December 2020.

The search in the electronic databases returned 111 studies. 57 articles were excluded after removing duplicates using Endnote. After reviewing the title and abstract of the remaining 54 articles, a further 50 studies were excluded because they did not meet the selection criteria. The remaining four studies were scanned fully, and another one article was excluded. The remaining three studies were included in the REA.

2.2.4. Stage 4: Searching for "Electronic Physiological Surveillance System"

Electronic physiological surveillance system was a term that was uncovered through reading the literature, in particular the studies surrounding recording the vital signs of patients using mobile technology. This motivated looking at the system in isolation of other key words to ensure that other key words were not preventing from finding the relevant literature.

The electronic database search identified 72 studies. After the exclusion of 14 studies by removing duplicates using Endnote, 57 studies were excluded after reviewing the title and abstract of the remaining 58 studies against the selection criteria. The one remaining study (Wong et al., 2018) was fully screened and included in the REA.

2.2.5. Stage 5: Backward Citation Tracking

Backward citation tracking is a method of collecting related references from articles included in the literature review to ensure a comprehensive literature search characteristic of a systematic review (Sutton et al., 2019; Hirt et al., 2020). The reference list on the 11 articles identified through this multi-stage process were scanned and reviewed with the inclusion and exclusion criteria. Through this process another four studies were identified and included.

2.2.6. Stage 6: Forward Citation Tracking

Forward citation tracking involves searching for the papers that have cited the papers identified through the initial literature search (Centre for Reviews and Dissemination, 2008). Using Google Scholar, forward citation tracking was performed on the 15 articles previously identified and included in the REA in stages 1-5. The search was performed in May 2021. The research papers identified through this process were scanned and reviewed for relevance. Through this process six studies were identified and included.

2.2.7. Stage 7: Second Literature Search

In August 2022, the database search detailed in stages 1-4 was repeated to ensure all evidence was collected in a quickly evolving field. During this search reviews were collected as time and availability allowed. The search gathered another 5543 articles. 5043 titles were screened after removing duplicates. 377 abstracts were then screened for relevancy. Overall, another 74 articles were read for inclusion in the REA. Ultimately, 24 more texts were incorporated into the REA, including 12 reviews.

2.3. Results

The results are organised as follows: firstly, the synthesis and critical appraisal is detailed, followed by an introduction to the relevant literature. Then, the mobile devices and software used in the studies identified in this review are outlined and the purposes discussed; this is followed by a report and discussion of the benefits, and drawbacks of using mobile technology for direct patient care, as identified from the literature.

2.3.1. Synthesis

Data were extracted from 33 primary research papers and from 12 reviews. The selected studies were synthesised using a textual narrative synthesis. This approach typically reports on study characteristics, context, and quality findings, and compares similarities and differences across studies (Barnett-Page and Thomas, 2009). It is particularly useful when describing non-heterogenous studies as it makes explicit the diversity in study design and contexts. Textual narrative synthesis also describes gaps in the literature by showing where evidence is absent and evaluating the strength of any available evidence (Lucas et al., 2007). Each paper was read fully, and themes were extracted based on the results. The methods and participants were compared across all included studies. The synthesis of the 33 highly relevant primary research papers can be found in Appendix 2. Papers are presented in date order (from most recently published e.g., 2022) and then alphabetical within year published. Reported information includes: the aim of the study, the study design, the setting of the study, the participants, the technology used, the measures, and the key findings.

Further, the synthesis of each of the 12 highly relevant reviews are illustrated in Appendix 3. As in Appendix 2, papers are presented in date order (from most recently published e.g., 2020) and then alphabetical within year published. Reported information includes: the aim of the study, the setting, the device, which was studied, the number of studies identified, and the key findings.

2.3.2. Critical Appraisal

Each of the primary research papers in the final sample of studies used for this REA was critically appraised for quality using the Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018). Using an adapted algorithm from the National Institute for Health Care Excellence (2018), the MMAT is a critical appraisal tool designed to appraise the quality of empirical studies for systematic mixed studies reviews. This includes reviews which include both quantitative and qualitative studies, and studies which utilise a mixed methods approach. The MMAT guides the researcher to identify the category of the study design as either qualitative, quantitative randomised controlled trials, quantitative non-randomised, quantitative descriptive and mixed methods. In

this case, mixed methods collected both quantitative and qualitative data. After two screening questions, the researcher is required to assess the studies using the methodological quality criteria questions. Guidance is provided to ensure that the process is followed correctly. This process can be seen in Appendix 1. Using the MMAT adapted algorithm it was reasoned that the final sample of relevant primary research studies comprised of 20 quantitative studies (including one randomised controlled trial) five qualitative studies and eight mixed methods studies. By using the MMAT tool it was identified that the sample includes 21 high quality studies, eight medium quality studies and four low quality studies. The MMAT guidance states that excluding studies based on quality is discouraged and therefore all 33 studies continued to be included.

Overall, most of the papers included a clear aim and/or research questions. However, the papers deemed low or medium quality often omitted this information. This made identifying whether the information collected had adequately answered the research questions difficult. In most cases, the methodological design was justified with a statement explaining why the researchers conducted the study the way that they did. Low quality studies commonly did not justify the design of the study, simply explaining the methods without reason. According to MMAT the qualitative studies scored highly as the authors coherently explained how the findings were derived from the data, and how these findings were interpreted. The randomised controlled trial was deemed to be high quality, as the only weak point was that the outcome assessors were not blinded to the intervention provided. Low and medium quality studies were often assigned as quantitative descriptive studies or mixed methods studies. Weak aspects of the quantitative descriptive studies included being vague about the appropriateness of the measurements and statistical analysis, not explaining whether the target population was represented in the study, and not addressing nonresponse bias. Low quality mixed methods studies did not adequately address inconsistencies between the quantitative and qualitative results and did not integrate the different components of the study effectively.

The 12 reviews included in this REA were critically appraised using the Critical Appraisals Skills Programme (CASP) systematic review checklist (Critical Appraisals Skills Programme, 2018). The CASP checklist was designed to be used as an educational pedagogic tool that does not have a scoring system for quality. Instead, the CASP tool is used to engage the researcher to delve deeper into the broader issues that need to be considered when appraising a systematic review.

2.3.3. Details of the Relevant Literature

As illustrated in Figure 2, 21 studies were conducted in the United Kingdom, 10 studies were conducted in the United States of America, four studies were conducted in Canada, two in Germany and Australia, and one study was conducted in Oman, South Korea, Taiwan, and Sweden, and one study was conducted in both Switzerland and Germany.

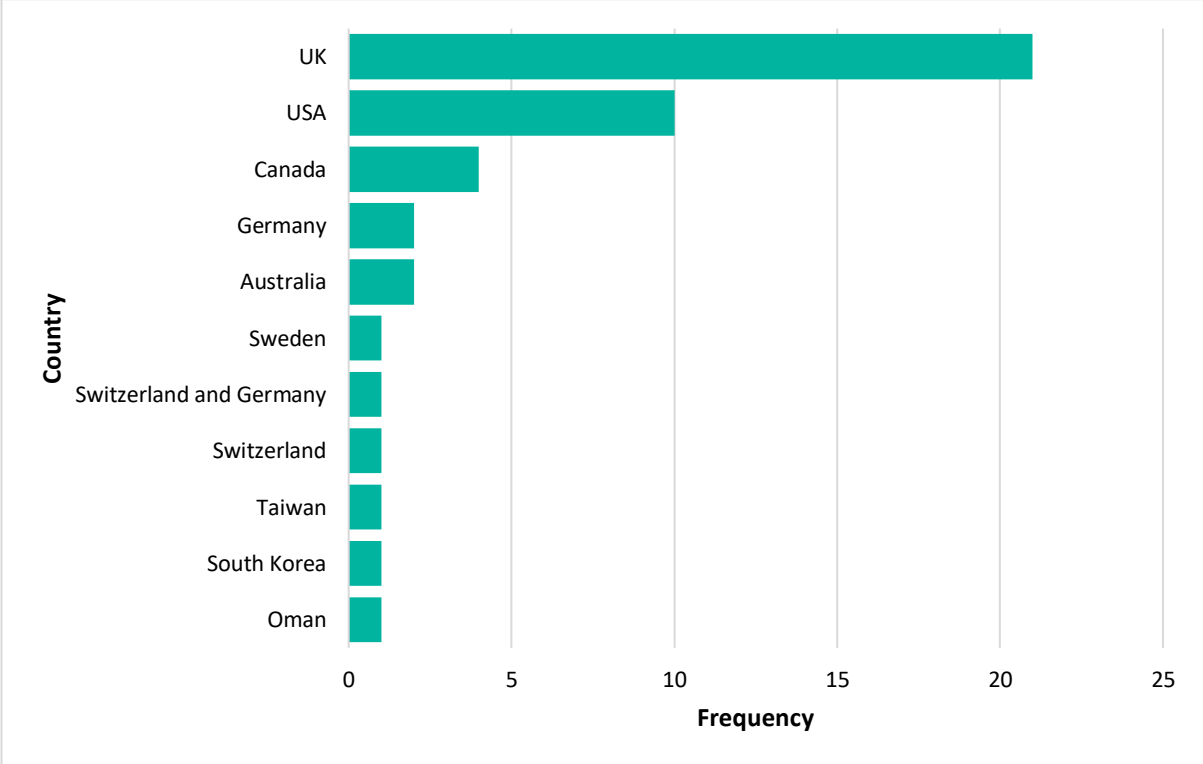

Figure 2 Setting of included studies.

All identified relevant papers were published between 2003 and 2022. As can be seen in Figure 3, most studies (n=35) were published after 2013. A small number of relevant studies (n=6) were published before 2010 highlighting that this topic is becoming more prominent in healthcare as technology evolves.

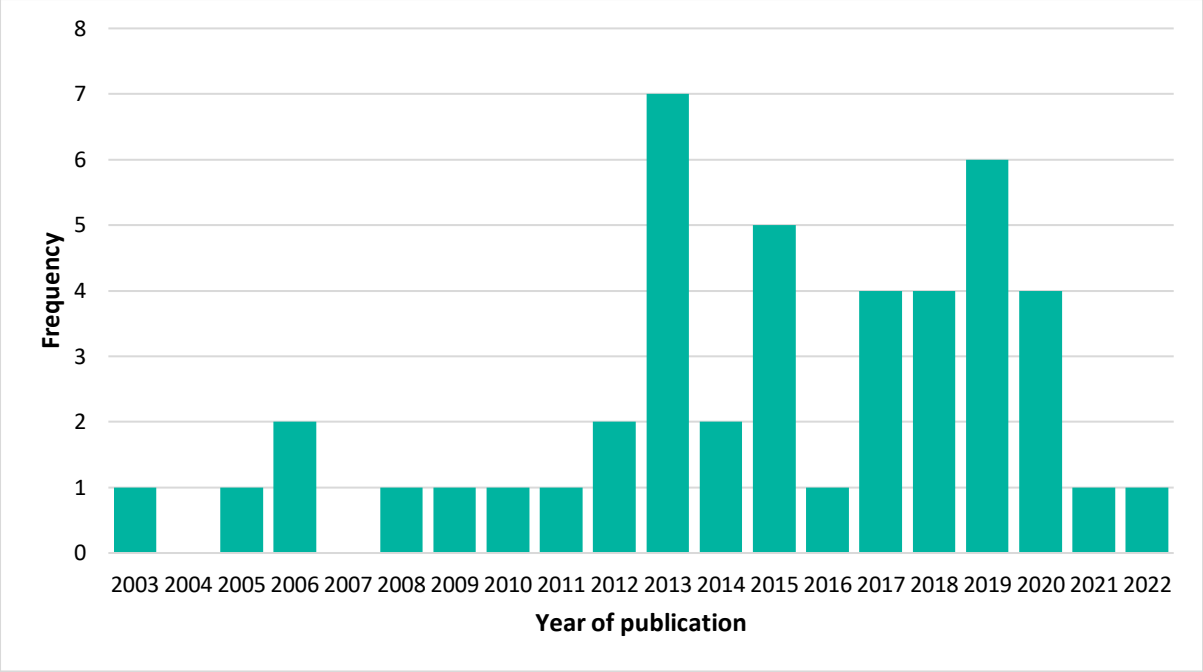

Figure 3 Year of publication of included studies.

As seen in Figure 4, there was a range in the types of participants in the studies included. Nurses, doctors, medical students and patients were most often the participants. However, other participants included in the 33 studies were patient care technicians, nursing students, health care assistants, non-specified clinicians on the wards, and other professionals. The most utilised methods in these studies were surveys, data analysis, interviews and review, as portrayed in Figure 5. Other methods used included observation and focus groups. Data analysis could refer to using secondary data gathered for example from the EHR/EMR, safety incident reports, and usage logs.

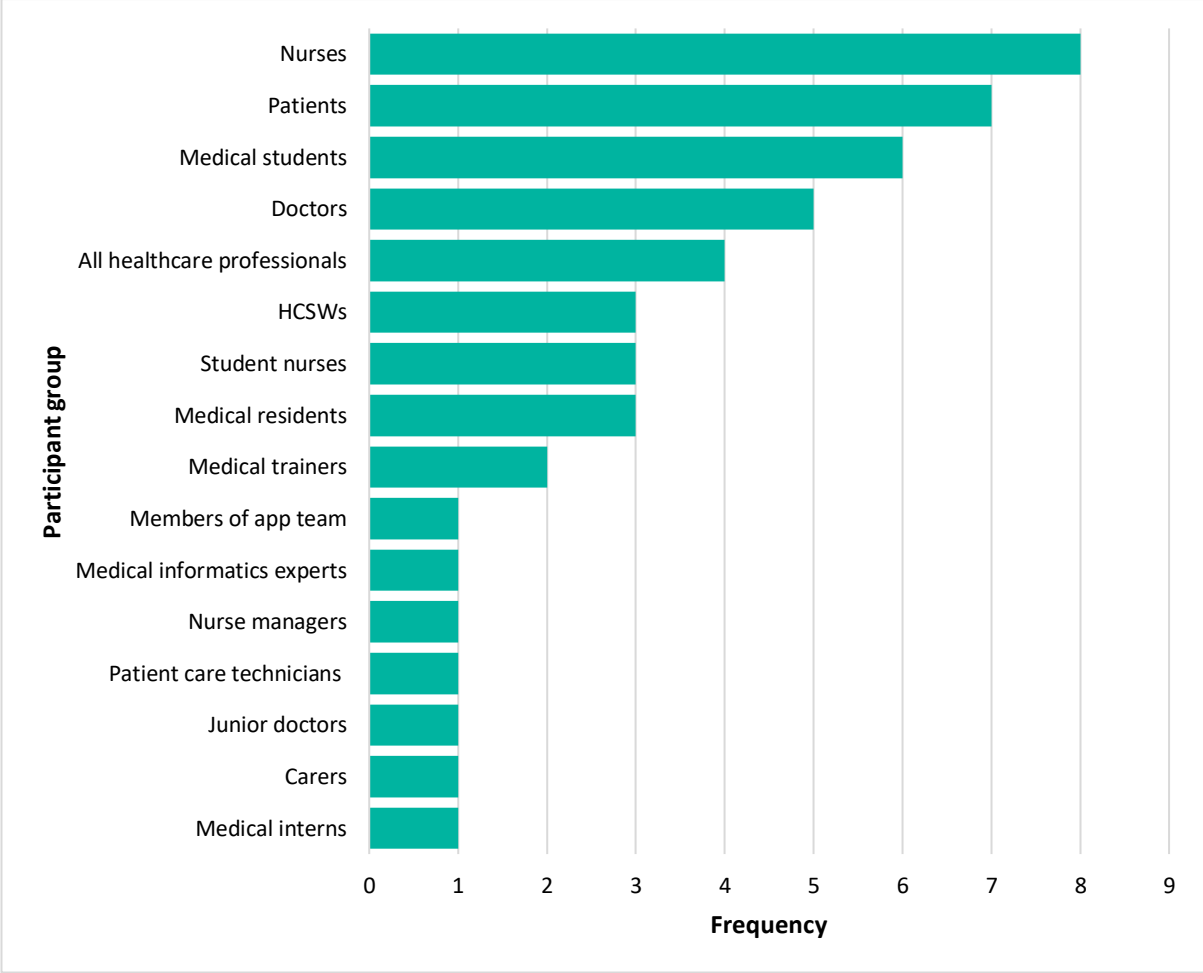

Figure 4 The range of participants included in the studies in the REA.

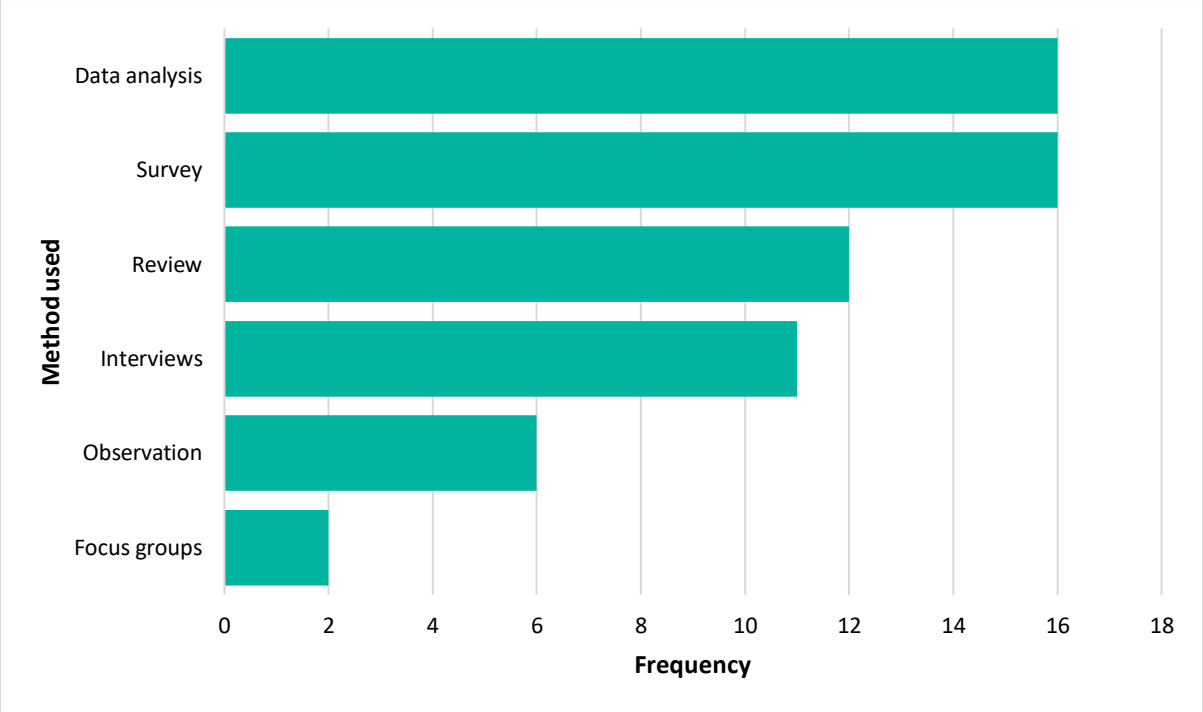

Figure 5 Methods used in the studies of the REA.

2.3.4. Mobile Devices Used in Studies

There was a range of devices used in the studies with each having different purposes which will be discussed throughout this section. The devices that were studied in the primary research articles along with the software employed and primary purpose of each device are illustrated in Table 3. The earlier studies evaluated the use of the personal digital assistant (PDA) reflecting the year and the technological advances made at that time. Among the more recent studies there was a preference to use Apple products such as the iPhone and iPad, or alternative Android tablets and smartphones. Other studies reported on a 'bring-your-own-device' model issuing software that could be used on the personal devices of staff. In the study by Chase et al. (2018) the participants showed a preference for the bring-your-own-device model due to the inconvenience of carrying a second device in addition to their own smartphone.

Table 3 The range of devices described in the primary research studies, the software employed, and primary purpose of the medical technology in use.

Reference	Device	Software	Primary purpose
Ehrler et al. (2022)	Apple iPhone X	"Patients In My Pocket in my Hospital" app (PIMPmyHospital)	Access information about patients in real time including laboratory and imaging results
Al Harrasi et al. (2021)	Clinician's own devices	N/A	Supporting residents' clinical practice
Jacob et al. (2020a)	Not specified	imitoCam app	Clinical photo and wound documentation
Kim et al. (2020)	Not specified	mDARWIN (EMR system)	Provide interns clinical tasks and mark their completion
Burkoski et al. (2019)	Institutional smartphones	Integrated patient call-bell system	Patient call-bell system
Hill et al. (2019)	3rd generation iPad	Pre-loaded with relevant apps	Access medical knowledge resources and support clinical decision making
Hope et al. (2019)	Handheld devices	VitalPAC e-Obs system	Up-to-date vital signs monitoring and EWS calculations
Lang et al. (2019)	iPhones and iPads	eObs and eHandover	Up-to-date vital signs monitoring and EWS calculations
Chase et al. (2018)	Apple iPad minis	Pre-loaded with relevant apps	Support placement-based learning
Downey et al. (2018)	SensiumVitals remote continuous monitoring device (the "patch") and a mobile device	Live e-Obs system	Up-to-date vital signs monitoring and EWS calculations
Gale-Grant and Quist (2018)	MioCare A200 Handheld Tablet	Live e-Obs system	Up-to-date vital signs monitoring and EWS calculations
Wong et al. (2018)	Handheld devices	VitalPAC e-Obs system	Up-to-date vital signs monitoring and EWS calculations
Motulsky et al. (2017)	Clinician's own devices	V-Sign app installed with the module The FLOW	Informal documentation for admitted patients
Sefton et al. (2017)	iPod Touch 4th generation	VitalPAC Pediatric, System C Healthcare Ltd.	Up-to-date vital signs monitoring and PEWS calculations
Wong et al. (2017)	Tablet mounted on a roll-stand alongside the vital sign monitor	e-Obs system 'SEND' app	Up-to-date vital signs monitoring and EWS calculations
Crowson et al. (2016)	iPads with iOS 5.0 installed	Epic EHR platform through a Citrix Receiver software	Place orders, look up clinical data, view EHR, facilitate education and patient 'handoff' transfers
Alexander et al. (2015)	Smartphone	N/A	Not stated- focused on patient's and carer's

			perceptions of what devices were used for.
Bullock et al. (2015)	Clinician's own devices	iDoc app (Dr Companion software)	Access five key medical textbooks at any time
Schmidt et al. (2015)	Handheld devices	VitalPAC e-Obs system	Up-to-date vital signs monitoring and EWS calculations
Youm and Wiechmann (2015)	iPads	Pre-loaded notetaking and productivity applications, and digital textbooks	Support clinical learning
Nuss et al. (2014)	3rd Generation iPad, 64Gb of storage	Mobile device management programme and pre-loaded with relevant apps	Learning and clinical decision support
Albrecht et al. (2013)	iPads	"xprompt multilingual assistance" app	Alleviate communication problems between nursing staff and non-German speaking patients
Drayton (2013)	Panasonic Toughbook	N/A- does not state	Care delivery
Furness et al. (2013)	Motion C5t Tablet PC	Image-viewing software	Involve patients in the explanation of their injury and proposed management plan
Hands et al. (2013)	PDA	VitalPAC e-Obs system	Up-to-date vital signs monitoring and EWS calculations
Wu et al. (2013)	iPads	Cancer Agency Information System and configurable health record viewer using Citrix	Read-only access to patient information and access to clinicians' clinic schedule and patient appointments
Davies et al. (2012)	Hewlett Packard iPAQ 114 Classic handheld PDA	DrCompanion software	Access key medical textbooks at any time
Horng et al. (2012)	Tablet computer	N/A- custom web-based dashboard rather than a dedicated client software	Access to the Emergency Department Information System (EDIS)
Jones et al. (2011)	PDA	Patientrack	Record patient observations and deliver automated clinical alerts
Wager et al. (2010)	Two types of tablet PCs-Motion Computing LE1600 and C5	Clinical documentation system/EHR	Document vital signs data at the point of care
Lee (2006)	PDA	N/A- does not state	Charge capture and charting patient intake/output records

Prytherch et al. (2006)	PDA	VitalPAC e-Obs system	Up-to-date vital signs monitoring and EWS calculations
Holleran et al. (2003)	PDA (Palm VII)	Pre-installed apps	View patient lab results, radiology and transcribed reports, patient data in real time, and access the contact directory of all staff members

Papers reporting reviews of the literature often focused on generic devices with a variety of software and purposes rather than a specific type of device as the studies show in Table 3. Table 4 highlights the reviews and the devices in clinical practice that they sought further information about.

Table 4 The range of devices described in the reviews.

Reference	**Device**
Wilson et al. (2020)	Mobile technology (e.g., tablet computers, PDAs)
Jacob et al. (2020b)	Smart devices
DeWane et al. (2019)	Mobile phones
Martin et al. (2019)	Mobile technology (handheld devices that facilitated two-way communication or data transfer which directly impacts patient care)
Valle et al. (2017)	Smartphones
Aungst and Belliveau (2015)	Mobile smart devices
Cartwright and Spina (2014)	Smartphones
Divall et al. (2013)	PDAs
Mickan et al. (2013)	Handheld computers
Prgomet et al. (2009)	Mobile handheld technology
Lindquist et al. (2008)	PDAs
Baumgart (2005)	PDAs

A common purpose of having these devices embedded in the delivery of patient care was to connect to the institution's EHR or EMR. However, there were other purposes which will be elaborated on to provide insight into the scope and potential of mobile technology in secondary care settings.

The smartphones in the study at Humber River Hospital were integrated into the patient call-bell system which aimed to improve nurses' ability to manage patient calls and prioritise patient needs (Burkoski et al., 2019). Additionally, by incorporating the patient call-bell system into the smartphone device, it was argued that the nurse

would not have to shift their focus from their present task, thus decreasing the risk to patient safety because of interruptions.

The institution where the study conducted by Crowson et al. (2016) was based used the "Epic" EHR platform which could be accessed on the iPad through a Citrix Receiver software. The full EHR was able to be viewed akin to using a desktop computer. Using the tablet devices participants were able to place orders, look up clinical data, and facilitate education and patient data transfers at handover periods. The EHR had a handover tool that allowed users to generate messages and free-form text for each patient and displayed clinical data such as vital sign measurements and active medications. This made paper lists obsolete. Similarly, at the hospital where Motulsky et al.'s (2017) study was based, a web-based app (V-Sign) was built to allow all types of mobile devices to connect to the hospital's EMR and information system in a 'bring-your-own-device' model. In 2013 the module *The FLOW* was added to V-Sign which allowed care team members to enter and share short free-text notes or *flows*. *Flows* themselves are not part of the EMR but are informal documentation. In the study by Kim et al. (2020) medical interns accessed their mobile EMR system mDarwin to access their intern task lists and mark items as completed (Kim et al., 2020). The PIMPmyHospital app disseminated in the study by Ehrler et al. (2022) allowed clinicians to access real time information about their patients in a paediatric emergency department, as well as facilitate communication between the healthcare team. The imitoCam app also integrated with the EMR at the clinical sites and enabled photo and wound documentation via the app (Jacob et al., 2020a). The iPads in the study by Wu et al. (2013) gave participants a read-only access to patient records available on the Cancer Agency Information System, as well as access to their own clinic schedule and patient appointments.

Other studies used applications that were accessible through the devices' app stores. For example, iPads used in the study by Hill et al. (2019) were installed with apps designed to allow participants to access medical knowledge resources and productivity tools for clinical decision making. Examples of the pre-loaded apps include PocketLab Values, Epocrates, First Consult, VisualDX and Pubmed on Tap Lite. Similarly, iPads used in the study by Nuss et al. (2014) were pre-loaded with apps such as PDF Expert, MedlinePlus and Penultimate. Furthermore, users were able to purchase and install other apps with their own funds. Youm and Wiechmann (2015) also pre-loaded the iPads given to participants in their study with notetaking and productivity applications, alongside digital textbooks to support clinical learning.

Bullock et al. (2015) focused on an app called iDoc (DrCompanion software) which could be installed on the participants' own devices which had five key medical textbooks added to it for instant access. Comparably, Davies et al. (2012) also focused on the DrCompanion software. In another example, the Motion C5t Tablet PC was used in the study by Furness et al. (2013) to illustrate radiology images to patients to involve them in an explanation of their injury and proposed management plan. Participants in the study conducted by Al Harrasi et al. (2021) used their own devices to support their clinical judgement by accessing the internet, checking drug references, taking pictures related to their clinical practice, reading e-books, and using medical calculators. Participants reported using their devices before, during and after patient encounters. Albrecht et al. (2013) studied a multilingual mobile translation app (xprompt) to facilitate communication between nurses on the ward and non-German speaking patients.

A number of the studies used the electronic observation (eObs) software VitalPAC. Hands et al. (2013) explains that VitalPAC is a commercially available electronic system that is used for the routine documentation and charting of vital signs which can be recorded at the bedside. Clinicians enter vital signs into the devices such as the Apple or Android tablets and smartphones with VitalPAC installed, which is integrated with the hospital patient administration system. Each dataset is assigned a timestamp by the software. VitalPAC warns if out-of-range data or erroneous values are entered. A VitalPAC early warning score (ViEWS) value is then automatically calculated accurately. ViEWS is an aggregate weighted track and trigger system (AWTTS) designed to be a detection of a patient's level of physical derangement based on six of the essential vital signs recommended by National Institute for Health and Clinical Excellence (2007) (heart rate, respiratory rate, systolic blood pressure, level of consciousness, oxygen saturation and temperature) as well as fractional inspired oxygen concentration (Prytherch et al, 2010). Prytherch et al. (2010) reported this as having the highest discriminative ability compared to 34 other AWTTS. According to the hospital's clinical escalation protocol, the time to the next vital signs observation measurement is determined by the ViEWS value. VitalPAC also provides instant bedside decision support to the clinician recording the vital signs such as whether the care should be escalated to senior staff e.g., the rapid response team and the required speed of any response (Schmidt et al., 2015). Sefton et al. (2017) focused their study on the software VitalPAC Pediatric. This works in the same way as the standard VitalPAC software but was developed to recognise that age is an important factor when calculating the PEWS.

The eObs and electronic handover (eHandover) tools enabled on the devices in the study conducted by Lang et al. (2019) work in a similar way to the studies using the VitalPAC software. Similarly, the SEND app in the study by Wong et al. (2017) is also used to enter patients' vital signs and calculate the EWS. In this case patients are identified using a barcode on the ID wristband. The two types of tablet PCs (Table 3) utilised in Wager et al. (2010) made available the EHR and clinical documentation system to also document vital signs data at the point of care.

The software studied, named Patientrack by Jones et al. (2011) is an 'intelligent' alert response system that tracks the clinical response and if inappropriate, unsuccessful, or absent, the alerting process is repeated to a series of predefined clinical responses indefinitely until the clinical response has been resolved. Patientrack, now acquired by Alcidion, which is used at over 300 NHS locations including NHS Fife, Basildon and Thurrock University Hospitals NHS Foundation and Manchester University NHS Foundation Trust, offers six 'solutions': improve patient safety, increase operational efficiencies, understand data, streamline patient journeys, inform clinical decision making and power productive teams (Alcidion, 2021).

The study by Downey et al. (2018) differed to the other studies in that they had additional hardware to the handheld devices carried by the nurses- the SensiumVitals remote continuous monitoring device. This is a patch that is placed on the patient's body and monitors their vital signs, sending this data wirelessly every two minutes to the handheld devices. By doing this, nurses did not have to manually conduct and record patient observations.

2.3.4.1. Summary of the Mobile Devices and Uses

In this section multiple uses of mobile technologies in secondary care settings were illustrated from the REA sample. A summary is listed below:

- Earlier studies in the sample focused on the use of PDAs whereas more recent studies included Apple or Android devices.
- Commonly the devices connected to the EMR or EHR.
- Devices could be integrated into the patient call-bell system, used for handovers, recording wounds into the EMR, accessing medical knowledge resources, or informally or formally documenting patient notes.

- Devices could be used to facilitate communication within the interprofessional team.
- Devices were also used to monitor patient observations and calculate the EWS.

Before reporting on the benefits of the mobile technologies in practice, a short section is included next which offers insight into staff behaviour on the hospital wards based on a set of studies focused on the analysis of observation data collected via the handheld devices.

2.3.5. Insights Into Observation Behaviour

Several of the studies focused on eObs tools that were new to the hospitals that were included in the studies, noting the benefits and barriers of such software. Notably, Hands et al. (2013) analysed their UK hospital's database to study the pattern of vital sign observations throughout the day. They discovered that the pattern of vital signs recording varied throughout the 24h period. During the period 23:00-05:59 only 12.81% of all vital signs were recorded. During the period 10:00-17:59 there was an increase in the percentage of vital signs collected each hour illustrating a difference in patient observation behaviour during the day and night shifts. It was concluded that the pattern of observation was identical each day of the week with two peaks of recording activity at 06:00-06:59 and 21:00-21:59 every day. The authors hypothesise that this may be because shift handover is around these time periods so vital signs are being observed and recorded just before or after the new staff arrive for their shift.

Hands et al. (2013) also noted key differences in the adherence to the vital signs monitoring protocol when comparing EWS of patients. Patients with lower ViEWS (0-6) were more likely to have a time to next observation closer to that expected than patients with a higher ViEWS (≥7). On the other hand, patients with a higher ViEWS score were more likely to have their vital signs measured during the night than patients with a lower ViEWS score. Overall, adherence to the hospital vital signs monitoring protocol was always greater during the daytime period irrespective of ViEWS values. In another study utilising Live Obs software on handheld tablets similar findings were reported as the cumulative percentage of observations recorded within 60 minutes of the scheduled time improved gradually and significantly on a month-by-month basis (Gale-Grant and Quist, 2018).

Hope et al. (2019) however identified reasons why there may be non-compliance with an observation schedule determined by the VitalPAC software. Patients with chronic conditions such as chronic obstructive pulmonary disorder (COPD) or asthma had chronically abnormal vital sign values due to the nature of the conditions, which in turn elevated the EWS value. This created an observation schedule perceived by many participants as inappropriately frequent. Patients who were moved to a different specialty area to create bed space on another ward could also have their vital signs missed at night. Therefore, certain groups may be disproportionately affected by non-compliance, even when overall ward compliance was high. Further, at night, observations of people with dementia could be delayed or missed for non-clinical reasons such as challenging behaviour, or to prevent other patient's sleep being disturbed.

2.3.6. Benefits

Many of the studies reported benefits to the use of the mobile technology in hospitals and these are described further in this section.

2.3.6.1. Clinician Perceptions of Increased Safety

A common benefit, and a central concern for innovative projects in healthcare was the improvement of patient safety. Burkoski et al. (2019) identified in their study that nurses who were involved in direct patient care in a Canadian hospital perceived an increase in patient safety as calls to the institutional smartphones that were supplied could be delegated to a secondary nurse in the instance that they were busy. They were also given the option to prioritise alarms for patients that presented at an increased safety risk e.g., having an increased falls risk due to being frail. Motulsky et al. (2017) in their study of *The Flow* concluded that clinicians in their organisation perceived that the use of the app improved patient care and safety. Wager et al. (2010) identified that having a tablet PC affixed to the vital signs monitor improved patient care and safety compared to a computer workstation on wheels (WoW) situated outside of patient's rooms. This is because when the WoW became busy and overcrowded, the patient care technicians would delay entering vital signs which they

had recorded separately on paper. Physicians reported their concerns that vital signs were not available during their rounds, ultimately leading to patient care concerns with the hospital leadership team. Importantly, in the study by Downey et al. (2018) patients reported a perceived increase in safety owed to the devices and the SensiumVitals patch due to the continuous monitoring of their vital signs. This was particularly prevalent for patients who had experienced the benefit of this firsthand for example, from a nurse coming to check on them because of an abnormal vital sign. Jacob et al (2020a) likewise reported a perceived increase in patient safety owed to having instant access to the photograph and wound documentation integrated with the EMR.

2.3.6.2. Reduction in Opportunities for Error

Inaccurate documentation of vital signs and consequently potentially inaccurate calculations of EWS can create incorrect clinical decisions that can present a safety risk for patients. Error can be reduced from eight potential error opportunities arising from the paper-based observation system to three potential error opportunities for the eObs system (Lang et al. 2019). The five aspects of the clinical observation process that could have introduced an opportunity for error, but, according to Lang et al (2019) were eliminated by the eObs system were: 1) calculation of EWS manually, 2) when the EWS requires escalation for review of observation frequency or treatment interview, 3) when the EWS does not require escalation and so observations continue as before, 4) when a nurse decides who to communicate escalation to, and 5) when the information is escalated to members of staff. This can be observed in Figure 6.

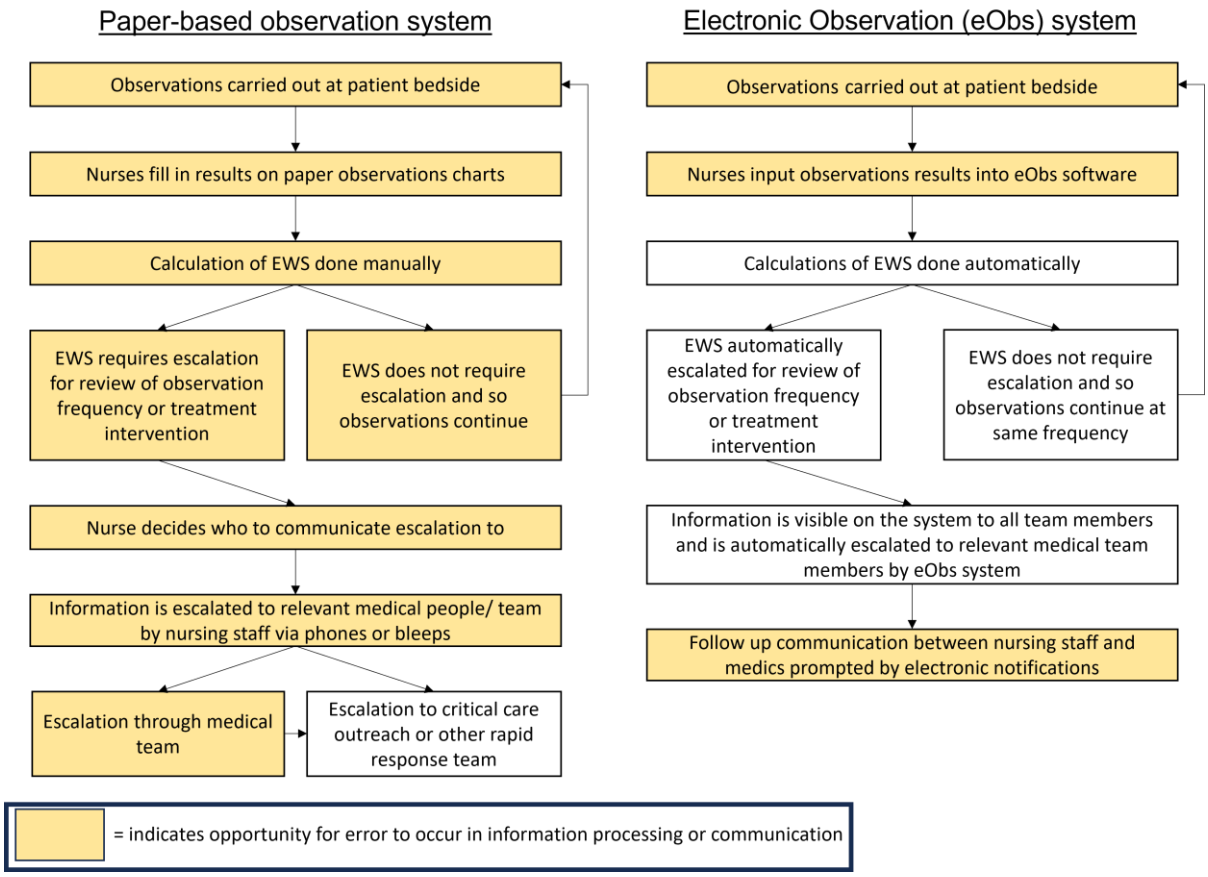

Figure 6 The processes of using paper-based observation systems compared to the eObs system adapted from Lang et al. (2019).

Errors can be made during the initial observations, and again during the input either on the paper-based forms or through the eObs system. The calculation of the EWS is done automatically via software such as VitalPAC or Patientrack (discussed previously) which alleviates the potential errors that can be made by calculating the EWS manually. As the EWS decides the frequency of observation or treatment intervention, if the EWS has been calculated incorrectly then future intervention may potentially be incorrect. After allocating the observation frequency and treatment intervention, information is visible to all medical team members on the eObs system compared to information being communicated only to relevant people in the medical team using the paper-based observation system. After this, an error can be made using both systems due to the follow-up communication between staff. Overall, this shows that the technology could reduce human error.

In an early study of the use of the eObs tool VitalPAC, Prytherch et al. (2006) aimed to compare the speed and accuracy of recording vital sign data and calculating EWS

using the institutional PDA installed with VitalPAC and the traditional pen and paper method. In entering individual raw physiological entries, participants made fewer errors using the PDA with VitalPAC. Moreover, fewer errors were made calculating the EWS using the VitalPAC method compared to the pen and paper method. In a methodologically similar study, Sefton et al. (2017) further corroborated that the accuracy of vital sign documentation using the electronic physical surveillance system (EPSS) was higher at 98.5% compared with the pen and paper method at 85.6%. The accuracy of the EWS calculations using EPSS was also significantly higher at 94.6% compared to 55.7% for the paper-based method. Furthermore, they identified that paper-based documentation provided more potential opportunities for error compared to the EPSS. More accurate EWS calculations was a finding that was also supported by Jones et al. (2011) who reported that EWS accuracy improved from 81% to 100% after the introduction of the 'intelligent' alert response system. Jones et al. (2011) also go on to suggest that clinical attendance increases with the introduction of a PDA installed with Patientrack to the workflow as the documentation of a clinical response to a patient with an EWS 3, 4 or 5 increased from 29% at baseline to 78% and increased from 67% to a notable 96% for patients with a EWS >5. Lang et al. (2019) further affirms these findings as they identified that adherence with the EWS policy improved, and this brought an association of an approximate 50% reduction in reported EWS policy-related patient safety incidents. In addition, Wager et al. (2010) noticed a decline in documentation errors from 16.8% using pen and paper to 5.6% using the tablet PCs. Wong et al. (2018) explain in their study that paper documentation errors tend to be biased towards lower values than the true EWS. Prytherch et al. (2006) identified that the 21 nurses surveyed in their study showed a preference for VitalPAC compared to the traditional pen and paper method when recording vital signs. They showed that this preference was due to the VitalPAC software being perceived as more accurate, more convenient, simpler, quicker and it allowed for easier detection of errors compared to the paper-based forms.

2.3.6.3. Improved Communication and Working Relationships

Not only does the literature suggest that the various devices improve patient care and safety, but also that they facilitated relationships between patients and their families and communications between staff using the devices. The devices could be used as a means of communication with patients and families (Lang et al., 2019) and it could

make interactions at the bedside easier to facilitate with patients (Hill et al., 2019). The nurses participating in the study by Burkoski et al. (2019) reported that the smartphones that they were issued with assisted them to develop a one-to-one relationship with the patients in their care as they would be able to talk to the patients directly when called, rather than messages being relayed via the nursing station. Crowson et al. (2016) concurs with this finding as 70% of the residents in their study felt that the tablets helped them spend more time with their patients. Further, Lang et al. (2019) observed that patient contact time with doctors more than doubled with the introduction of the eObs tool. DeWane et al. (2019) reported in their review that mobile devices also improved interprofessional communication between physicians and nursing staff. Smartphone apps have the potential to enhance communication in this way due to the built-in features such as email, voice calls and texting capabilities (Valle et al., 2017).

2.3.6.4. Efficiency and Organisation

A noticeable benefit reported in these studies was that time was saved by using electronic devices in the clinical environment. Firstly, both doctors and nurses were observed spending less time in the office doing administrative tasks which allowed them to spend more time doing other tasks such as interacting with patients (Lang et al., 2019). Drayton et al. (2013) also reported that time with patients increased with the introduction of the Panasonic Toughbook, and doctors were able to increase their capacity to see new patients. This led to healthcare professionals feeling more satisfied as they could fulfil their role more effectively. When tablets were used for recording patient observations during formal rounding, it was observed that rounds were significantly shorter after the implementation of the EHR-accessible iPads (Crowson et al., 2016). Prytherch et al. (2006) supports this finding as participants were asked to enter and chart five different fictitious physiological vital signs datasets using either the pen and paper method used traditionally or using the PDA with VitalPAC installed. The time taken for the participant to complete the processing of each dataset was recorded and it was significantly less time to enter the data using the VitalPAC-installed PDA. Sefton et al. (2017) demonstrates similar findings as they reported that it took 30 seconds less to record vital signs and clinical observations and calculate EWS using the EPSS documentation compared to the paper-based method. To support further, Wong et al. (2017) conducted a before-and-after

observational study using time-motion methods and found that there was a 30% reduction in time taken to complete the recording of a set of vital signs and compute the EWS when using the e-Obs system on the device compared to the traditional method. Kim et al. (2020) found that using the mobile electronic medical record (mEMR) system only one time reduced the task completion time by 16 seconds. Those who used the system more frequently took a shorter time to complete tasks compared to the less frequent users. Interns were also able to use the mEMR system in areas without computers such as the cafeteria, operating rooms, while walking around the hospital, or when they were outside the hospital. Horng et al. (2012) also reported that the use of a tablet resulted in an average of a 38-minute decrease per shift of health professionals accessing the Emergency Department Information System (EDIS) at a computer workstation. Physicians therefore reported being able to spend more time with patients at the bedside. Wager et al. (2010) also reported that when using a tablet PC, it on average took 49 less seconds to record vital signs compared to pen and paper. Time was also saved by the facilitation of faster information transfers such as laboratory reports, test results, medical information (Crowson et al., 2016; Hill et al., 2019; Ehrler et al., 2022) and real-time patient data (Nuss et al., 2014). Further, students in the study conducted by Chase et al. (2018) overall felt that the devices made the hours that they worked more efficient. From a patient perspective, patients in the study involving the SensiumVitals patch appreciated that the nurses involved in the study had more time freed up from their busy work schedules due to the remote vital signs monitoring (Downey et al., 2018).

A benefit of note is the reduction in the need for printing (Wu et al., 2013). Crowson et al (2016) even go as far as to report that no pieces of paper were used after the implementation of the electronic recording of patient observations. During the 2-week pre-intervention period in this study 607 pieces of paper with greater than 50% double-sided pages were used. After the iPads were implemented, zero pieces of paper were used. The researchers extrapolated these numbers to state that for a full 52-week year, 15,782 pieces of paper could be used. In essence the added security of the handheld devices in use could prevent 15,782 potential instances where confidential medical information could be compromised . The authors conclude that the paper and ink cost savings from becoming paperless , plus the incalculable costs related to a breach of confidential data prove the financial benefits of implementing technology in healthcare systems (Crowson et al., 2016).

Burkoski et al. (2019) noted that having an institutional smartphone was essential due to the size of the physical space of the hospital. One of the participants explained that if the nursing station was not staffed at this hospital, it could take a very long time for the patient's call to be answered, but having the smartphone circumvented this issue as the call was directed to the smartphone instead. The 12 nurses in this study perceived the smartphone as an essential time management tool and a significant improvement in efficiency due to lab results and calls from doctors being delivered directly to them via their smartphone and so they no longer had to walk the extensive walking distance around the hospital unnecessarily, thereby also reducing interruptions to answer call-bells during direct patient care. These devices also had the benefit of reducing the overhead noise created by the traditional call-bell system. By alarms being directed to the institutional smartphones, the nurse could hear the alarm without waking or disturbing the patients on the wards. Patients at the hospital using the SensiumVitals patches wondered if this type of remote monitoring could replace observations conducted during the night to reduce interruptions while trying to sleep (Downey et al., 2018).

Devices in the study by Lang et al. (2019) were also used as a workload management tool which improved the awareness of team capacity. The nursing staff interviewed stated that this awareness provided through greater visibility of information had the ability to potentially alleviate stress. Some participants interviewed in the qualitative interpretative study by Hope et al. (2019) described benefits of having external reminders from their devices such as having their attention focused to doing scheduled observations during a busy period on the ward. The participants in the study by Wu et al. (2013) also reported an improved workflow due to the easier facilitation of the retrieval of information from the Cancer Agency Information System. Furthermore, participants identified a reduction in the number of interruptions during patient care, although not recognising why this was the case.

2.3.6.5. Device Users Perceived Personal Benefits

In a survey Crowson et al. (2016) identified that 13 Otolaryngology inpatient residents felt that the iPads with the accessible Epic EHR platform improved morale. Although the researchers do not expand on why this is, it could be attributed to one of the benefits reported in the survey such as the improved ease of documentation in the

medical record which saved time and facilitated more detailed communication. The multilingual assistance app xprompt also facilitated daily communication with foreign-language patients at the hospitals where it was in use, although it was avoided in more complex discussion around delicate procedures (Jacob et al., 2020a). In another study, Wu et al. (2013) sent post-iPad implementation surveys to 50 oncologists who reported the personal benefit that the iPads were reliable to use, although the researchers do not comment on whether this was compared to the paper-based forms previously used. Medical staff in the study conducted by Lang et al. (2019) explained that the iPads and iPhones installed with eObs and eHandover provided them with clinical reassurance of their patients which was seen to be a benefit to them. This is because they could check on their patients using the devices even when they were off duty and physically not at the hospital. Similarly, the participants in the study by Holleran et al. (2003) stated that they found it extremely helpful and reassuring to have the ability to access real time patient data at any time with the majority of the 20 participants using the PDA while off campus.

2.3.6.6. Perceived Benefits to Studying Using Devices

Before their clinical clerkships, students in the American study by Youm and Wiechmann (2015) had positive perceptions of the iPad as a clinical tool. The students felt that the iPad would make a positive impact on their learning and allow them to be more efficient during their clinical rotations. During their rotations, the top three benefits for using the iPad were: access to EMRs during rounds, the ability to study during downtime, and quick or 'on the go' access to information (Youm and Wiechmann, 2015). Valle et al (2017) in their review of smartphones in the clinical and educational setting reported that a benefit was the convenience of being able to carry the smartphones which enabled them to become a "learn anywhere" resource. The 37 third-year medical students in the study conducted by Nuss et al. (2014) indicated that being able to access various medical resources on the iPads enhanced personal learning and productivity. Chase et al. (2018) reported that students participating in their study increased their time studying by an average of 3.1 hours as a direct result of having iPads issued to them. These students found that the most useful place for using their iPads was when studying in the student hub, compared to the least useful place being clerking on the ward. Personal advantages reported by the medical students in Chase et al.'s (2018) study on Apple iPad minis included:

speed of information access, ability to do administration, multimedia learning, up-to-date resources, size and portability of the device, and access to core textbooks as e-books.

2.3.6.7. Clinical Benefits

Smartphones have been used to aid in diagnosis, prognosis, and treatment of medical conditions (Valle et al., 2017). Clinical benefits were reported in the research such as the reduction in the LOS (length of stay) of patients (Jones et al., 2011). After the implementation of PDAs installed with the Patientrack software, the hospital LOS of patients was significantly reduced from 9.7 days to 6.9 days (Jones et al., 2011). Al Harrasi et al. (2021) also relayed that both medical residents and their trainers perceived that using the devices shortened the LOS of their patients. As well as contributing to the reduced LOS of patients, the mobile technology was reported to have an effect with the mortality rate. For example, Schmidt et al. (2015) reported a reduced mortality rate after the implementation of the VitalPAC software. Wong et al. (2018) suggested an immediate mortality benefit in favour of eObs, but this was not sustained at 30 days. Lang et al. (2019) inferred that there was an association of an approximate 10% reduction in total unplanned admissions to critical units from eObs-equipped wards. The authors report that this reduction in critical care admissions equates to approximately £250k savings per quarter since the eObs deployment. In their systematic review, Divall et al. (2013) added that PDA use significantly reduced unsafe prescribing.

In two of the studies an important benefit of the implementation of the mobile devices was the assistance in making clinical decisions. Most of the respondents in the study by Wu et al. (2013) believed that the iPad enhanced their clinical decision making and 67% of the supervising doctors in the study conducted by Hill et al. (2019) corroborated this notion. Clinical decision making was assisted by having instant access to additional information and resources (Nuss et al., 2014). Some nurses explained that having the EWS available through the handheld devices used on the ward assisted them to explore the reasons why a patient may be unwell and used clinical judgement to decide on the next step. Furthermore, both students and doctors in Hill et al.'s (2019) case study reported that the time that they spent using the iPads increased over time, as well as their expertise. This was seen as a benefit as with

more use of the iPads, participants could tailor the way they used them for patient care. This was a finding further supported by Nuss et al. (2014). There is some evidence that patients also report that using mobile devices in the clinical setting can have a significant improvement in perceived involvement in decisions made about their care and treatment (Furness et al., 2013). Additionally, when given the opportunity to view their own radiographs on a mobile device, there was an improvement shown in patients reporting being given the right amount of information about their condition or treatment. Seeing the images helped the patients to understand what the consultant had told them about their condition, and participants reported that seeing their images had a positive effect on their overall experience of their hospital treatment (Furness et al., 2013).

2.3.6.8. Summary of the Benefits of Using Mobile Devices

- Clinicians perceived that the mobile devices could lead to improved patient safety. Reasons for this include the routing of calls to an available clinician, or being better able to prioritise patients who presented as safety risks Devices could be used as a workload management tool, improving the awareness of team capacity, and improving clinician workflow.
- Mobile devices assisted clinicians in making clinical decisions by providing instant access to information and resources.
- Clinical benefits were reported such as reduced LOS of patients, reduced critical care admissions, and reduced mortality rate.
- There is evidence of a reduction in opportunities for human error when using software on devices to input vital signs and calculate EWS compared to traditional paper-based forms. Furthermore, vital signs are recorded faster on handheld devices.
- Mobile devices were also seen as an improvement to WoW which could become overcrowded and delay input of vital signs recordings.
- Mobile devices were seen in some studies to improve communications facilitating relationships with patients and families and between staff. Additionally, devices could have the benefit of helping clinicians to spend more time with their patients because of the reduced amount of time that they spent conducting administrative tasks.

- The introduction of mobile devices can reduce the need for printing, which could prevent confidential information being compromised, as well as saving money.
- Users of the devices reported personal benefits such as improved morale, clinical reassurance of patients and being able to access resources for enhanced personal learning.
- Mobile devices also assisted medical students and trainees on their placements or rotations to use ‘spare’ time to study.

2.3.7. Drawbacks of Using Mobile Devices

Overall, there were fewer drawbacks of using mobile devices compared to the benefits, but there were some reported. Motulsky et al. (2017) discovered that most users preferred using the desktop version of *the FLOW* app. Although *the FLOW* was initially designed for use on the smartphone, physicians requested for it to be available on the desktop so they could print out patient lists and notes attached, suggesting that the participants in this study preferred paper notes to still be available during ward rounds. Furthermore, medical units had completely stopped using the app and male users were far less comprehensive in their documentation than their female counterparts, highlighting that technology can be used subjectively and inconsistently. This is perhaps more pronounced in situations where the new technology is optional and there is a need for further training to gain familiarity.

Lang et al. (2019) also found a lack of engagement in the device and its uses by senior medical personnel. In the interviews with 40 staff members, several rationales for this were uncovered including the perceived loss of expertise and therefore a potential source of embarrassment, or a general reluctance to embrace change. The perceived loss of expertise was explained by the “step change” in practice as it became common practice, and a running joke, to ask younger and less experienced staff for technical support. This finding formulated one of the main barriers to realising the full potential benefits of the new mobile technology in ward settings.

The device was found to be burdensome by some. Half of the participants in one study reported that the system was cumbersome to use (Gale-Grant and Quist, 2018). Hill et al. (2019) identified that students in their study perceived that taking their iPads on rounds was not ideal or necessary. Some feared misplacing the iPad,

while others simply did not find it a useful tool in communicating with patients and so were not observed using it during rounds at all. Other disadvantages that were described in this study were that iPad use was not conducive in environments where full personal protective equipment (PPE) coverage is required, and the mobile network did not always run at top efficiency due to overload. There were three participants who did not use the iPads studied by Nuss et al. (2014). The reasons for this choice were worry about losing the iPad, a preference for the traditional use of paper and books, and the lack of time they had to learn to use the iPad.

In the study by Wager et al. (2010) their focus was to measure the accuracy and timeliness of entering vital signs data using different data-entry devices. The tablet PC affixed to the WoW outside of the room would often be overcrowded and so vital signs data entry would be delayed, creating a concern about patient care. Participants also described competing demands, such as responding to rapid patient deterioration, which could interfere with their ability to take scheduled observations when they were due (Hope et al., 2019). Although this is not a drawback of the device being used in the study, it helps to exemplify the challenges of introducing new technology into the demanding clinical setting. This illustrates that mobile technology needs to fit well into the workplace and staff workload to work effectively and safely benefit inpatients.

Additional drawbacks that were reported include: technical issues such as interference and a poor call quality, patients not knowing how to use the devices, stress from receiving multiple notifications, and the perception that patients and families would not perceive the use of devices in a positive light (Burkoski et al., 2019). Although at first patients tended to mistakenly think the nurses were making personal use of their phones, as the hospital became more renowned for being digital, this perception dissipated, and patients (and staff) recognised the smartphone was a device employed for work purposes.

The top challenge for the students participating in the study conducted by Youm and Wiechmann (2015) was the lack of WiFi internet access. There were concerns reported by DeWane et al. (2019) that staff could experience interruptions and distractions, decreased face-to-face interactions between clinicians, a loss of autonomy for trainees, and using the devices inappropriately. Valle et al. (2017) noted that the Agency for Healthcare Research & Quality reported that a patient was harmed due to inappropriate use of a smartphone where a medical resident became distracted by an incoming text and forgot to discontinue the patient's medication. It

was also a concern of patients that mobile devices were potentially distracting the healthcare professionals in charge of their care (Alexander et al., 2015). Participants of a study where they used their own mobile devices to access medical information and applications reported drawbacks such as having limited time to use the devices, receiving a lack of training, the small screen size of the devices, the lack of applications for their devices, and a lack of comfort with the technology (Al Harrasi et al., 2021).

2.3.7.1. Summary of the Drawbacks of Using Mobile Devices

- There was evidence of a preference for using software on a desktop to enable printouts to be available. This also suggests that some clinicians may not prefer a paperless environment.
- The technology could be used inconsistently and subjectively, particularly in situations where the new technology is optional.
- Some clinicians were reluctant to embrace the new technology for reasons such as a perceived loss of expertise resulting in a potential source of embarrassment, or a general reluctance for change. Furthermore, the new technology required a time investment and training.
- The devices could be perceived as burdensome and unnecessary. Others did not want to risk losing the devices.
- The devices were not efficient in areas where there was a poor wireless connection to the internet.
- Clinicians also worried about the poor perception from patients and families when using the mobile devices, although poor perception lessened over time.

2.4. Consensus and Debates

The 45 papers included in this REA examine different types of devices with a range of functions. Although mobile technology use for direct patient care in hospitals is a fairly modern concept, it is fast evolving as evidenced in the 19 years (2003-2022) that these studies spanned. From PDA usage to the adoption of Apple and Android

tablets and smartphones, institutions are developing more initiatives to use mobile technology in the clinical setting.

2.4.1. Patient Care and Safety

One of the common benefits identified in the papers examined in this REA was the perception that the use of the devices could enhance patient care and safety (Burkoski et al., 2019; Motulsky et al., 2017; Downey et al., 2018). There is empirical evidence in the literature that affirms this finding. For example, Giles-Smith et al. (2017) with their aim of describing the current knowledge and use of mobile devices and apps by nurses on inpatient wards in a Canadian hospital, found that there were concerns about distractions from using devices having a detriment on patient care before the deployment of educational sessions about using mobile devices at work. However, after the educational sessions the nurses perceived that using mobile devices within the hospital could increase patient care and safety, although they were still concerned about distractions when using the devices. Whitlow et al. (2014) observed that after the implementation of smartphones at the bedside that there were fewer interruptions during patient care. Additionally, Payne et al. (2014) conducted a pilot study to investigate the impact of a hospital-specific smartphone app upon the workflow of junior doctors in a UK hospital. They identified that 38.7% of the junior doctors who took part in the study viewed the app as having a moderate positive impact upon patient care compared to the pre-implementation stage of the study.

In the American study conducted by Tielbur et al. (2015) which aimed to evaluate the formation of a multi-disciplinary discharge huddle fitted with cellular and tablet technology found that there was a 25% decrease in the patients' LOS post-implementation of the huddle highlighting an improvement in patient care at the discharge stage of hospital admission.

However, not all studies confirmed the finding of enhanced patient safety, and some provided contrasting evidence. In an observational study that aimed to describe the role that electronic devices play in nursing workflow and the relationship to patient falls, there was no indication that the use of a mobile device could predict patient falls (Sun and Cato, 2020). Further contrary evidence was found in a survey of 258 certified registered nurse anaesthetists in Michigan, USA (Hranchook et al., 2018). Seventeen responded that they were aware of a near-miss or accident attributable to

the use of a mobile computing device during direct patient care, illustrating that if used incorrectly patient safety can be compromised. More than half of respondents in this study (57%) felt that the use of mobile computing devices posed a serious risk to patients due to concerns about lapses in patient focus caused by distraction, a potential for poor outcomes and the perception that mobile device use was inappropriate for non-clinical applications or during critical or demanding times. In another study (Sclafani et al., 2013), when asked in a survey whether mobile technology "makes you a better doctor", there was a decreasing trend for positive responses relative to level of training suggesting that potentially mobile technology is more beneficial to less experienced clinicians who do not have the expertise of more senior medical personnel who have become more confident in their skills and abilities.

2.4.2. Security and Confidentiality of Patient Data

Surveyed clinicians in the USA perceived that standard text messaging posed a risk to the privacy and confidentiality of patient information (O'Leary et al., 2017). In a UK-based survey of 287 doctors and 564 nurses, 27.5% of doctors believed that they still had patient-related clinical information on their personal smartphones (Mobasheri et al., 2015) perhaps indicating that there may be some need to worry about the risks to privacy and confidentiality of patients if mobile devices are used incorrectly or unwisely by the medical profession. However, 57% of survey respondents in a Canadian-based study believed that the efficiency of communication with colleagues through text and email on their mobile devices outweighed the risk to the privacy and confidentiality of patient health information, despite 26% of all respondents lacking any type of security feature on their personal devices (Tran et al., 2014).

2.4.3. Inconsistent Uses for Mobile Devices in the Clinical Setting

There was a range of studies that evaluated the use of recording patient vital signs and calculating EWS at the bedside using software installed on the mobile devices in use. These studies identified a higher accuracy in both activities when using the devices (Prytherch et al., 2006; Sefton et al., 2017; Jones et al., 2011). However, it has been identified that when mobile devices designed to be used at the bedside can

receive telephone calls there is an association with a significantly increased odds of committing errors (Bonafide et al., 2020). This perhaps shows the need for a consensus about what functions should be enabled on mobile devices that are used at the bedside. For example, would an institutionally-issued smartphone limited to workload management tools (such as inputting vital signs and providing real-time overviews of inpatient wards) cause less distraction than a 'bring-your-own-device' model where there is the potential to conduct and receive personal phone calls? This was a finding in a study by Tran et al. (2014) who identified that 64% of the participating medical students frequently or always used their phone for personal matters during clinical rotations. In contrast, in a survey sent to almost 3000 clinicians in the USA, only 56% of the medical institutions supported mobile technology where respondents worked, despite over 90% of respondents feeling that their workplace should support mobile technology integration (Sclafani et al., 2013). This shows a disjointed opinion between hospital management and medical staff which again highlights the need for a consensus from the in-hospital level to the national level about how developing technologies can support the delivery of the most efficient and safe patient care.

2.4.4. Perceptions of Older Clinicians and Patients

The mobile devices in use at the various hospitals promoted a better relationship with patients and families due to facilitating an easier means of communication (Lang et al., 2019; Hill et al., 2019). This is a sentiment echoed by the vast majority (92%) of the members of the technology-outfitted discharge huddle being assessed in Tielbur et al.'s study (2015) who felt that the mobile phone made them more accessible to families of patients. However, a contentious topic that is mentioned in the literature is the perception of older patients, or more generally, the assumption that patients seeing a staff member using a mobile device will initially assume that it is for personal use. In the two-phase study by Giles-Smith et al. (2017) there was a perception in phase one (pre-deployment) that older patients would find the use of the mobile devices inappropriate and disrespectful. However, in phase two (post-deployment) no nurse who had participated in the study had reported negative interactions with any patients or colleagues.

The perception of older people having a negative view of the mobile devices was not limited to patients. Patel et al. (2016) aimed to assess the quality of information transfer using pager-based and app-based communication systems (Hark). They found that users reported a greater overall satisfaction when using the Hark communication system. However, compared to their younger counterparts, older clinicians were more likely to rate the pager more highly than the app on both sending and receiving communications. Furthermore, in the qualitative interviews conducted by Payne et al. (2014) study participants discussed the perception that using mobile devices in the clinical setting was unprofessional; they felt uncomfortable using the smartphones in front of other colleagues and patients regardless of their ages. This suggests that potentially a shift is required for greater acceptability of mobile technology in clinical settings.

A number of the studies in the REA also commented on how patient contact time was increasing and relationships with patients were developing due to the use of the mobile devices being studied (Burkoski et al., 2019; Crowson et al., 2016., Lang et al., 2019). On the contrary, it was suggested in the study by Sun and Cato (2020) that contact time with patients may be steadily declining as the use of electronic devices increase. This finding perhaps shows that there is a need for further research into this area due to these conflicting but limited findings.

2.4.5. Efficiency and Organisation

Over half of the studies included in the REA identified the benefit of time saving by using mobile devices in the clinical environment. This is confirmed by an astounding 98% of participants in the study by Tielbur et al. (2015) who stated that the mobile phone that they were supplied with saved them time compared to pre-deployment, and 67.7% of the participants in the study conducted by Payne et al. (2014) reported the same benefit. This is further reinforced by Al-Ghamdi (2018) who identified that by allowing for faster access to medical information and resources, medical practitioners found that they saved time. Additionally, time was saved by doctors being able to respond to messages more quickly than when responding to the traditional pager system (Patel et al., 2016).

Time-saving was not limited to doing clinical tasks, but to also making decisions more quickly. For example, nursing students participating in the study conducted by Choi

et al. (2018) reported that using the app that allowed them access to the academic EMR in their clinical practicum enabled them to make decisions more quickly. In focus groups conducted by Dahri et al. (2016) the facilitation of the mobile devices to make quicker decisions was also a common theme.

The time-saving benefit is further strengthened by Whitlow et al. (2014) who aimed to measure the response time between nurses and physicians when using smartphones (Apple iPhone 4) compared with the usual paging device. They found a reduced wait time at the nurses' station for a return call, and a reduced time away from patients to answer phone calls. The time spent for clerical staff to locate a nurse reduced by 79% showing a benefit also for non-clinical members of the patient care team. Furthermore, there was a 100% decrease for the travel time of the nurse to answer a phone call, and a 100% decrease in the time callers spent on hold.

2.4.6. Preference to Not Carry the Mobile Device

An interesting finding reported from Motulsky et al. (2017) was that participants preferred using the desktop version of *the FLOW* app which was also available on the participants' own devices. This finding is reinforced by Farrell et al. (2011) who found that none of the participants in the study used the PDA that they were supplied with to access resources online as this was readily available on the patient computer at the end of each patient cubicle which they found more preferable to use. This was further affirmed in qualitative interviews by Payne et al. (2014) who also identified a preference by staff for the desktop computer due to it having a larger screen. Hill et al. (2019) also found that the device could be perceived as burdensome to clinicians, which is supported by Tielbur et al. (2015) who reported that clinicians who participated in their study felt that carrying a mobile device secondary to their own personal mobile device was burdensome and unnecessary. They also reported a frustration in trying to learn a new technology which can take some time to develop the required skills. This again demonstrates a lack of consensus among medical institutions about how mobile technology can be used to benefit both clinicians and patients without feelings of burden or unease. It is noteworthy that some of these findings may be outdated, and screen size may be less of an issue to people now due to the normality of smartphones in society in the modern day.

2.4.7. Poor Wireless Connection

A common disadvantage among the literature is the wireless connection being unreliable (Giles-Smith et al., 2017; Tielbur et al., 2015). Most of the mobile devices that are used in clinical settings require a wireless network, particularly if they are connected to the EHR or EMR as this is constantly updated throughout the day. Choi et al. (2018) reported that if there was an unstable wireless connection then the app which was connected to the academic EMR would not work reliably which was localised to particular practicum wards. This highlights the need for a stable connection throughout the whole hospital as clinicians travel between wards. Poor WiFi could be an issue for downloading the latest updates for the mobile device apps (Charani et al., 2013) or downloading vital images used for diagnostic assistance (Kabanda and Rother, 2019). Poor wireless connection also affected studies where the connectivity caused such frustration that participants used bedside computers, with all but one out of 14 participants choosing not to continue use of the supplied PDAs (Farrell et al., 2011). This is because in the absence of good connectivity using mobile apps can be almost impossible if they are relying on real-time data from the EHR (Giraldo et al., 2018).

2.5. Conclusion

By following the REA process, 45 studies that focused on mobile technology used for patient care management in hospitals were identified, appraised, and synthesised. A range of devices were included in these studies, from smartphones that were integrated into the patient call-bell system to physician's own devices with their own choice of medical applications.

Benefits and drawbacks of using mobile technology in the clinical setting were highlighted. Benefits included: more accurate and timely documentation and EWS calculation, support for clinical decision making, improved patient care, improved communication with patients and families, increased contact time for patients, and reduced requirement for print resources. Drawbacks of the various mobile devices and software included: a preference for using the desktop, inconsistent and subjective usage, the need for further training, the perception of burden and necessity, and

technical issues such as poor wireless connection. It is clear that there is a need for institutional and national consensus on how to use mobile devices that can present a benefit to clinical settings if used correctly.

Through examining the literature identified in this REA there are gaps that need to be addressed by further research. The participants in the studies were mainly doctors, nurses, medical students, and patients (Figure 4). Allied health professionals who also work in hospitals such as physiotherapists, occupational therapists, and pharmacists, were infrequently or not at all included in the studies. Allied health professionals are an important group to also include as participants as they form part of the MDT for the patients. It is unknown exactly how these professionals use mobile technology for direct patient care, if at all, after disseminating the literature included in this review.

A common benefit illustrated through this REA was the assistance in making clinical decision making. However, there was little focus on *how* device use assisted clinical decision making. Having instant access to informational resources was seen to have improved clinical decision making but there is no further explanation to support this finding. Furthermore, generally qualitative evidence outside of reporting on benefits and drawbacks was not used. For example, the research papers did not fully discuss how the adoption of the mobile devices was undertaken in the hospitals which might have implications to staff responses to their introduction. Further research is also needed to gather qualitative evidence of the adoption process of mobile devices into the clinical arena. Of all 45 pieces of evidence gathered for this review, five pieces of research were qualitative, and eight were classified as mixed methods as they collected both quantitative and qualitative data. These pieces mainly focused on the opinions of users on the devices and associated software, rather than the implementation process or training opportunities. The papers reported in this review also do little to explain how and why the devices have affected the workflow of healthcare professionals or explain how they have supported the clinical and organisational decision making processes. In other words, how and why has having instant access to patient data at the bedside impacted on the day-to-day mechanisms of working on hospital wards? The MDT also needs some focus. Some of the research mentioned that interprofessional communication has improved due to having instant access to contact details, but have the devices themselves prompted any dynamic changes? For example, if a team once huddled around a computer

workstation to discuss patients, are they now huddled around a tablet computer or smartphone which can move around the ward with the team?

2.5.1. Reflections on the Rapid Evidence Assessment

The review process of the REA was complex which meant that I felt it necessary to conduct twice. This is because the topic of novel mobile technologies in healthcare is vast as innovation progresses worldwide. Nonetheless, the REA was vital to the formation of this thesis. I was able to delve into the existing literature on this topic and formulate research questions and a methodology based on what I learned. However, despite a reported benefit of the REA being the need to utilise less resources, this was a time-consuming venture for only one researcher. On reflection, in future research I could hire one or more research assistants to assist in a review. Because of the time-consuming nature of this particular REA, I had to omit certain evidence, such as grey literature. With multiple researchers, all evidence could have been collected and reviewed within the timescale. Multiple researchers could also increase the confidence of the findings of the REA, as decisions about the evidence and findings could be made in a group, rather than by one individual which risks inserting bias.

2.5.2. Research Questions

The research questions developed from this review are as follows:

1. How were the mobile devices equipped with CareFlow Vitals implemented in the hospitals in Wales?
    a. How did the users of the mobile devices perceive the introduction of the technology into the hospitals?
2. How are mobile devices used to record patient observations?
    a. Who is using the devices on the hospital ward?
    b. What processes are being followed when recording patient observations on the mobile devices?
    c. What are the attitudes of staff towards mobile devices equipped with CareFlow Vitals?

3. How did staff respond to the change from pen and paper records to the use of the iPads with CareFlow Vitals?
    a. Do the demographic characteristics of the participants affect the preference for iPads and CareFlow Vitals in practice?
4. How have mobile devices used to record patient observations at the bedside impacted clinical decision making?
    a. At what stage(s) of care planning have mobile devices supported decision making? i.e., immediately, medium/long term.
    b. What has been useful or not useful about the mobile devices and software when supporting clinical decision making?

The next chapter outlines and discusses theoretical frameworks that inform the thesis, including technology acceptance theories, innovation diffusion theory, and sociological approaches to studying new technologies in healthcare.

Chapter 3. Theoretical Framework

3.1. Overview

In this chapter I explore the biomedical and sociological approaches to medical technology followed by insights from evidence-based practice. An in-depth discussion of technology acceptance models follows. This discussion covers the innovation diffusion theory (IDT) which includes a dialogue about the categories of adopters of new technologies from 'the innovators' to 'the laggards', the technology acceptance model (TAM), extended technology acceptance model (TAM-2), and the unified theory of use and acceptance and use of technology (UTAUT).

3.2. Approaches to Research

Modern Western medicine has historically assumed its position within the biomedical model. Atkinson (1988) described this approach as reductionist in form and reasoned that seeing diseases as existing as distinct entities that are revealed as 'signs' and 'symptoms', leaves the individual as a passive site of disease manifestation, and that diseases are to be understood as deviations from normality. This understanding has been criticised, both within medicine and sociology, for overplaying the efficacy of medicine, failing to locate the body within the socio-environment context, treating patients as passive objects, taking control of health away from individuals (and notably women), assuming that the body and disease are not social constructs, and assuming superiority over other forms of healing (Nettleton, 2021). Alternatively, the sociological approach towards medicine draws on methodologies and theories to elucidate issues about health, health services organisations and health care utilisation (Mechanic, 2001). Turner (1995) suggested a levels-of-analysis approach to the study of health and illness in society. These three-fold levels are (1) at the level of the 'individual' where the focus is on examining individual perceptions of health and illness, (2) the 'social' level, where the attention is on observing the social creation of disease categories and healthcare organisations, and (3) 'the societal' level where

the focus is on healthcare systems within the political context. In summary, although contrasting, both sociology and medicine are concerned with the empirical study of human bodies (Nettleton, 2021). The biomedical and sociological approaches to the study of medical technologies are each explored further in this chapter, followed by an exploration of evidence-based medicine (EBM).

3.2.1. Biomedical Approach

The biomedical model is based on six assumptions (Nettleton, 2021). The first assumption is of mind/body dualism which is the belief that the mind and body can be treated separately. Next, the assumption of mechanical metaphor is the idea that the body can be treated like a machine by doctors who act as the engineers. Thirdly, there is the assumption of technological imperative which is the tendency within medicine to prioritise the development and use of new technologies (Fuchs, 1968). Further, the fourth assumption is named reductionist which is that the explanations of disease are focused on biological changes. The fifth assumption is the doctrine of specific aetiology. This is the belief that every disease is caused by a specific, identifiable agent. Finally, there is the assumption of a universalised worldwide application of the model that is imposed as the legitimate way of approaching the treatment of disease, the management of illness and the education of doctors.

Importantly for this research, the biomedical model assumes a technological imperative. Technologies have been present throughout healthcare since its inception and, if understood very broadly, include the mundane, such as pens as well as more sophisticated technologies such as magnetic resonance imaging (MRI) scans to drugs or genetic tests (Timmermans and Berg, 2003). The reductionist biomedical model assumes that technological innovations, vaccinations, and treatments are benefiting society. However, in direct contrast but with equal importance, McKeown (1976) suggests that the overall decline in mortality in Western societies can be attributed to nutritional, environmental, and behavioural factors such as water and food control, and changes to reproductive practices limiting population growth.

3.2.2. Sociological Approach

Timmermans and Berg (2003) identified three sociological approaches to understanding technology in medicine: technological determinism, social essentialism, and technology-in-practice. Technological determinism identifies technological innovations as influencing social change often with detrimental consequences disproportionately affecting the politically and socially disadvantaged. For example, the use of in-vitro fertilisation (IVF) has been identified by radical feminist theory as a technology used as a form of patriarchal social control of women. This is because the technology is used with the premise of infertility and childlessness being seen as the cause of a medical problem, rather than a symptom itself of a medical problem that could be prevented. IVF is then administered by what radical feminists refer to as a male-dominated medical profession. Therefore, IVF is seen by radical feminists to be a patriarchal attempt to control fertility, rather than a tool to empower women, as the women who use IVF are perceived to not control the use of it (Denny, 1994). Technological determinists assume a technology to have an overall harmful effect; an example is the unsuccessful use of resuscitative efforts, which employ technology in a separate room from friends and family. This ultimately leads to a prolonged dying experience surrounded by professionals rather than loved ones which could be perceived as undignified (Timmermans, 1998). Although technological determinism has been criticised profoundly for its reductionist position, mainly by social constructivists, Dafoe (2015) suggests that technological determinism should not be seen as either right or wrong. Instead, technological determinism could be useful in setting questions of degree, scope and context.

Timmermans and Berg (2003) propose that the social essentialism perspective views medical technology as blank slates that need to be interpreted and rendered meaningful by culture. The theoretical underpinnings of this perspective relate to social constructivist thinking. The technologies themselves function as social catalysts to generate interactions or social meanings, but do not act, affect, or evolve in themselves. What is of particular sociological interest from the social essentialism perspective relates to how technologies are deployed and used, and how meanings are invested in them.

Further, Timmermans and Berg (2003) explain that the technology-in-practice perspective treats medical technologies as active players in the healthcare setting.

What the technology does, and how it accomplishes something remains an empirical question as the technology itself co-ordinates clinical and organisational aspects of the healthcare setting. This is in direct contrast to the social essentialism perspective as the technology is not a blank slate needing to be rendered meaningful. Technologies are embedded in relation to other tools, practices, groups, patients, and professionals. Action and treatment in the healthcare setting is possible due to the technology's location in these complex networks.

All three of these perspectives (technological determinism, social essentialism, and technology-in-practice) can provide a framework for analysing data and interpreting the findings. The latter perspective can also direct an observer to consider how the political shifts in the autonomy of patients, the professionalisation of healthcare professions, or the goals of government regulators are implemented, resisted, or otherwise ignored (Timmermans and Berg, 2003).

3.2.3. Evidence-Based Medicine

The move to EBM arose as an institutional and policy response to the criticisms of the traditional biomedical model (Nettleton, 2021). EBM is defined as the "the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients" (Sackett et al., 1996, p.71). It is now accepted practice that all medical and healthcare interventions and innovations are evaluated to ensure effectiveness for both patients and organisations. The National Institute for Health and Clinical Excellence (2011) for example states that medical technologies are selected and evaluated to determine whether evidence supports the case for adoption into the health and social care system in the UK. This is with the aim that this will support collaborative research to generate evidence on the clinical utility or system benefits of selected technologies and promote faster uptake of new medical technologies in the health and care sector that are shown to be useful.

EBM has been criticised by Harrison (1998) who proposed that EBM is based on three naiveties. The first naivety concerns problems related to implementation. It is assumed that clinicians will always act upon guidelines. However, Harrison (1998) suggests that there is evidence to indicate that clinicians are unlikely to act on the basis of information unless it is patient-specific or includes incentives or disincentives. The second naivety relates to its political appeal as politicians can use what seems

like objective evidence to justify their reasoning or resource allocation. Nevertheless, in practice it may seem that resources are more needed in places other than those suggested by using EBM. The final naivety is that the epistemological underpinnings of EBM relate to relying on evidence that is based on more authoritative scientific studies. The pinnacle of this is the randomised controlled trial. Clinicians, on the other hand, are in practice more likely to act on their own experiences and observations with their own patients, rather than on the publication of meta-analyses of a large number of cases. This suggests the need for greater use of observational methods of clinicians in practice to understand what motivates and drives them to work the way that they do in the clinical environment, as they may not behave as expected from EBM.

3.3. Technology Acceptance and Implementation

Since the 1970s studying the adoption, acceptance and use of information technologies has become a prerequisite for technology's utilisation and realisation (Momani and Jamous, 2017). Technology adoption concerns the implementation of hardware and software technology into an organisation with the aim of increasing productivity, competitive advantage, improving processing speed, and making information readily available (Davis et al., 1989). All technology acceptance theories are designed to measure the degree of acceptance and satisfaction the individual users attach to the technology or information system (Momani and Jamous, 2017). It was anticipated therefore, that technology acceptance theories would be useful in analysing and explaining the adoption processes of the devices in the hospitals and perceptions regarding this process.

3.3.1. Innovation Diffusion Theory

Rogers (2003) developed the IDT. IDT has been described as a good application for studying technology adoption, evaluation, and implementation (Fichman, 1992), as is the intention in this study. Diffusion is defined as having four main elements:

- An innovation
- That is communicated through certain channels

- Over time
- Among the members of a social system

These elements are each considered in turn.

3.3.1.1. Innovation

An innovation is described as “an idea, practice or object that is perceived as new by an individual or other unit of adoption” (Rogers, 2003, p.12). In the case of the present study, the innovation would be the iPads installed with CareFlow Vitals. Innovations have five different attributes perceived by individuals which aid in explaining their different rates of adoption:

1. Relative advantage

Relative advantage is the degree to which an innovation is perceived to be better than the idea that it supersedes. The greater the perceived relative advantage, the faster it will be adopted. The amount of relative advantage could be measured in economic terms, social prestige factors, convenience, and/or satisfaction.

2. Compatibility

Compatibility is the degree to which an innovation is perceived as being consistent with the existing values, needs and experiences of the potential adopters. An innovation that is compatible with the value system of the potential adopters will be adopted more quickly than that of an incompatible innovation. An incompatible innovation often requires the very slow process of the social system adopting a new value system prior to the innovation.

3. Complexity

Complexity is the degree to which an innovation is perceived as difficult to use and understand. New innovations that are easier to understand and use are adopted more rapidly than innovations that require the user to develop new skills.

4. Trialability

Trialability is the degree to which an innovation can be experimented with on a limited basis before adoption. An innovation that can be trialled represents less uncertainty to an individual who is considering it for an adoption, as they can try it first and learn from doing.

5. Observability

Observability is the degree to which the results of adopting an innovation are visible to others. If the results of the innovation are easier for others to see, the rate of adoption will be faster in the social system.

3.3.1.2. Communication

Communication is defined as the “process in which participants create and share information with one another in order to reach a mutual understanding” (Rogers, 2003, p.18). The process involves the innovation, an individual or unit with knowledge or experience of the innovation, another individual or unit who does not have this knowledge or experience, and a communication channel that connects the two units. A communication channel is described as the means by which messages get from one individual to another. Usually, mass media channels (channels involving a mass medium, e.g., television, radio, and newspaper) are the most efficient and rapid way of informing the potential adopters of a new innovation as they can reach a larger audience. However, interpersonal channels are more effective in persuading an individual to adopt the new innovation. These can be more effective where the interpersonal channel connects individuals who are similar in socioeconomic status or education. Interpersonal channels are face-to-face exchanges between two or more individuals (Rogers, 2003). In a hospital, communication channels could include MDT meetings, email newsletters, and workshops.

3.3.1.3. Time

Time is the third element in the diffusion process described by (Rogers, 2003). The time dimension is involved in the diffusion process in multiple ways. Firstly, the process in which an individual passes from first gaining knowledge of an innovation through either its adoption or rejection. Secondly, time is involved with the relative earliness/lateness in which an individual adopts the innovation suggesting their inclination towards new technologies. Finally, the dimension of time is involved in the rate at which a new innovation is adopted into a system, usually measured by the number of members who adopt the innovation in any given time period.

3.3.1.4. Social System

A social system is expressed as a set of interrelated units that are engaged in joint problem solving to accomplish a common goal. The social system in this study is the staff members of hospitals in Wales. The social system is the boundary within which an innovation diffuses, in this case iPads installed with CareFlow Vitals.

3.3.1.5. Innovation-Decision Process

The innovation-decision process is described by Rogers (2003, p. 168) as:

> *"The process through which an individual (or other decision-making unit) passes from gaining initial knowledge of an innovation, to forming an attitude toward the innovation, to making a decision to adopt or reject, to implementation of the new idea, and to confirmation of this decision."*

The IDT decision making process consists of five stages illustrated in Figure 7. The first stage is knowledge which is when the individual (or other decision making unit) is exposed to the innovation's existence and gains an understanding of the function. The second stage is known as the persuasion stage which is when the individual (or other decision making unit) forms an opinion which could be favourable or unfavourable towards the innovation. The next stage is the decision stage and this is where the individual (or other decision making unit) engages in activities that leads to a decision to adopt or reject the innovation. After this comes the implementation stage where the individual (or other decision making unit) puts the new idea to use. The fifth and final stage is the confirmation stage where reinforcement is sought for the innovation-decision that has been made. They may reverse their previous decision if exposed to conflicting messages about the innovation.

Overall, the innovation-decision period is the length of time required for an individual or organisation to pass through these five stages. This may be impossible or impractical as the confirmation stage may continue over an indefinite period. Hence, Rogers (2003) suggests that this period is a gestation period in which a new idea ferments in an individual's mind.

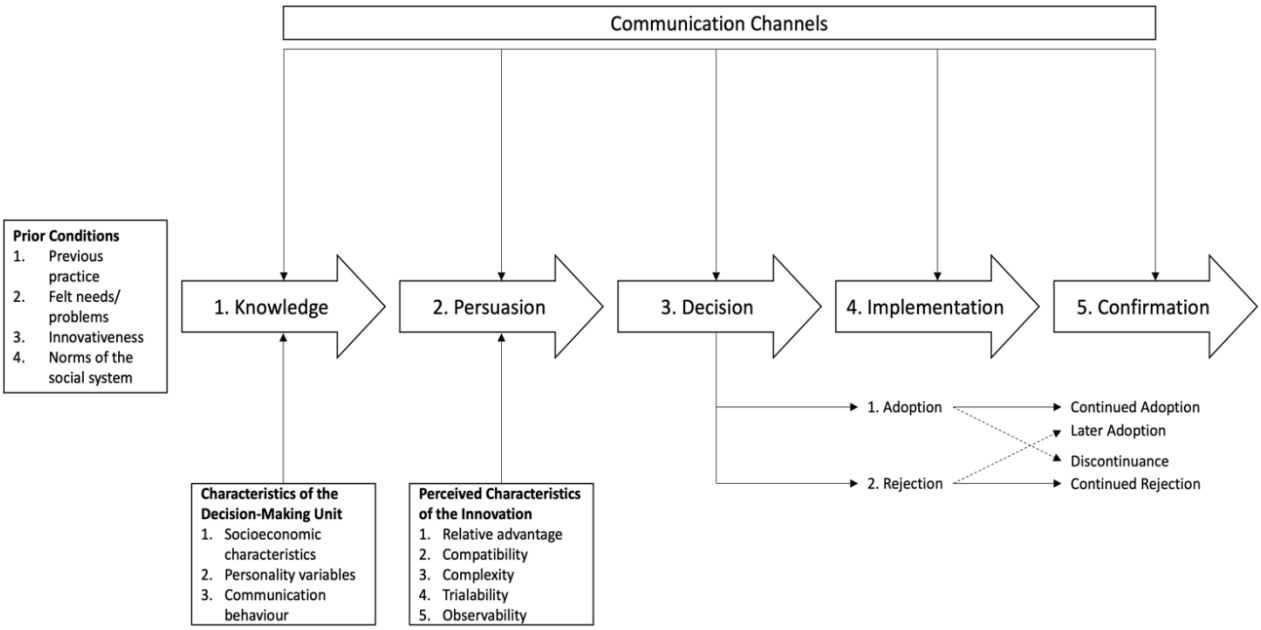

Figure 7 The innovation-decision process as illustrated in Rogers (2003).

3.3.2. Adopter Categories

Rogers (1958) developed innovation adopter categorisations. The criterion for adopter categorisation is innovativeness which Rogers (2003, p.267) describes as:

> *"The degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than other members of a system."*

Figure 8 illustrates the normal frequency distribution divided into the five adopter categories. The first adopter category at the left of the normal distribution is the innovators category which includes the first 2.5% of individuals in a system to adopt an innovation. The second category is the early adopters which include the next 13.5% individuals who adopt the innovation. The next 34% of adopters are labelled the early majority. To the right of the mean is the 34% of the adopters of the innovation who are the late majority, followed by the laggards which represent the last 16% of the system to adopt the innovation.

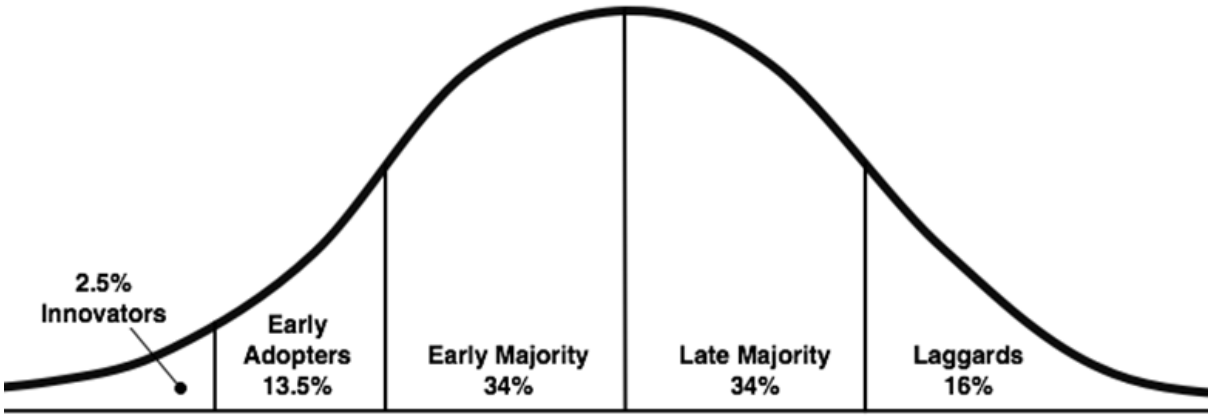

Figure 8 Rogers (1962) Adopter Categorisations on the Basis of Innovativeness.

3.3.2.1. The Innovators and Early Adopters

It is stated that the innovator needs to have control of substantial financial resources to absorb any possible losses from unprofitable innovations, the ability to understand and apply complex technical knowledge, and they must be able to cope with a high degree of uncertainty about an innovation at the time of adoption. The innovator plays a gatekeeping role in the flow of new ideas into a system as the innovator launches the new idea into the system by importing the innovation from outside of the system's boundaries. This may not be respected by the other members of the system, but the diffusion process would not begin without this group (Rogers, 2003). These could potentially be the decision makers at the health board who control the financial resources and started the implementation of the iPads and CareFlow Vitals into the hospitals.

Rogers (2003) theorised that the early adopters are respected by their peers and hold the highest degree of opinion leadership in most systems. The early adopter knows that to continue to earn the esteem of colleagues, they must maintain a central position in the communication networks of the system by making judicious innovation decisions. The role of the early adopter is to decrease uncertainty about a new idea by adopting it and providing a subjective evaluation of the innovation to peers.

3.3.2.2. Early Majority and Late Majority

Rogers (2003) describes the early majority as following with deliberate willingness in adopting innovations but seldom leading. Rogers (2003) argues that the early majority makes up one-third of the total system and adopt new ideas just before the average member of that system does. According to Rogers, the decision period to adopt a new innovation is longer than the innovator or the early adopter as they take their time to deliberate. It is proposed that the late majority adopt new ideas just after the average member of the system because it may be both an economic necessity to do so, and the result of increasing peer pressures. The late majority are sceptical and cautious of new innovations so most of the uncertainty about a new idea must be removed before the late majority feel safe enough to adopt it (Rogers, 2003).

3.3.2.3. Laggards

Laggards are the very last of the social system to adopt a new innovation as they must be absolutely certain that an innovation will not fail before they choose to adopt it. Laggards hold relatively traditional values and will interact primarily with others with those same values. The laggards point of reference is the past and decisions are often made in terms of what has been done previously (Rogers, 2003). In Chapter 2 it was reported that some studies highlighted that older and more senior members of hospital staff did not use the new technology being implemented in their hospitals. Therefore, these members of the clinical team would be the laggards due to their continued reluctance to adopt the technology when other members of staff embraced it.

3.3.2.4. The Strengths and Limitations of the Innovation Diffusion Theory

As part of my research, I wanted to understand how the iPads with CareFlow Vitals were disseminated into the hospitals of the health board. Although I would be exploring this dissemination retrospectively through the lens of the participants of the study, the IDT is useful for understanding how the characteristics of the innovation,

the users of the devices, and the organisation affected the acceptance and continued use of the innovation.

As with the previous theories, a strength of IDT is the interdisciplinary applications as it has been used in a vast number of disciplines including epidemiology, rural sociology, medical sociology, and communications (Greenhalgh et al., 2005). Caution does need to be taken by researchers when applying this theory as much of the evidence that informed it does not originate in public health or health technology, although it has been applied extensively in this area (Iqbal and Zahidie, 2022).

3.3.3. Technology Acceptance Model

Davis (1985) proposed the TAM as a means of understanding the system characteristics on user acceptance of computer-based information systems. The model can be seen in Figure 9. Alternative systems are represented by the “design features” variable and the arrows represent causal relationships. It is proposed that a user’s overall attitude towards using the technology, positive or negative, will be a major determinant to whether the user will actually use it. Attitude toward using the technology is a function of two beliefs: perceived usefulness and perceived ease of use. Perceived ease of use also has a causal effect on perceived usefulness. This is because, other things being equal, the easier the system is to use, the more useful it can be (Venkatesh and Davis, 2000). Perceived usefulness is defined as “the degree to which a person believes that using a particular system would enhance his or her job performance” (Davis, 1989, p.320). Perceived ease of use is described as “the degree to which a person believes that using a particular system would be free of effort” (Davis, 1989, p.320) . In lay terms, if a technology is deemed useful and easy to use, the attitude formed about it will be more positive.

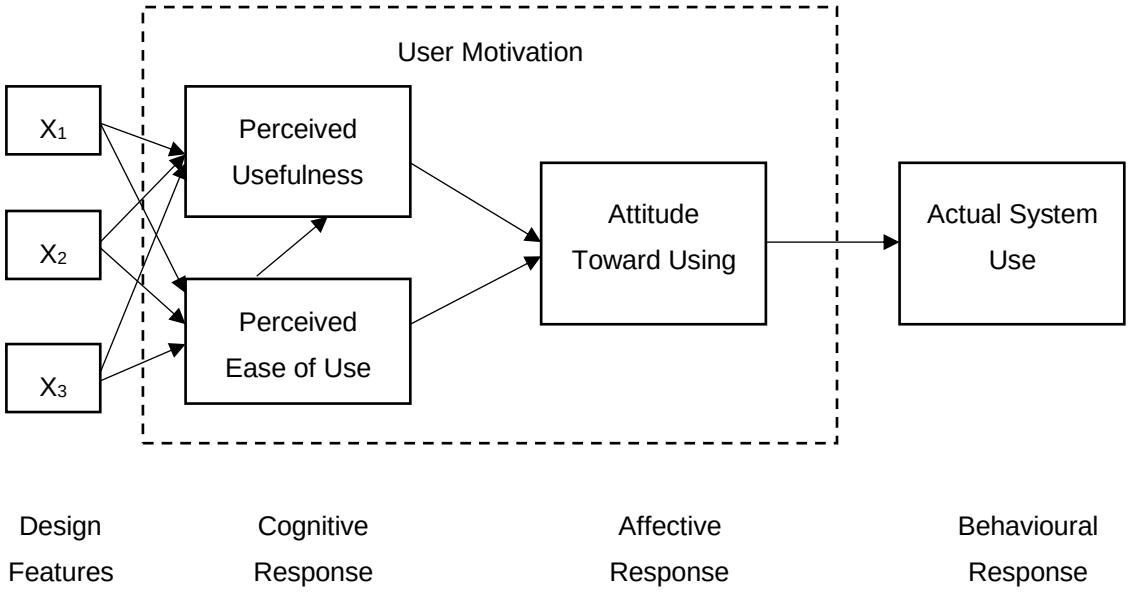

Figure 9 Technology Acceptance Model (Davis, 1985).

3.3.4. Extended Technology Acceptance Model

Venkatesh and Davis (2000) extended the TAM to develop the TAM-2 to include additional key determinants related to TAM's perceived usefulness and usage intention constructs. These additions concern social influence and cognitive instrumental processes. The model is illustrated in Figure 10.

Social influence processes refer to three interrelated social forces that an individual faces when given the opportunity to adopt or reject a new technological system: subjective norm, voluntariness, and image. Subjective norm refers to an individual's perception that most of the people who are important to them believe they should or should not perform the behaviour (Fishbein and Ajzen, 1975). Subjective norm has a direct effect on intention to use the technology as an individual may choose to perform a behaviour if they believe one or more important referents think they should, even if they themselves are not favourably inclined towards this behaviour or the consequences of it (Venkatesh and Davis, 2000). Voluntariness is a moderating variable that explores the extent to which potential users of the new technology perceive the decision to adopt to be non-mandatory (Hartwick and Barki, 1994). This is included as even when users perceive system use to be organisationally mandated, usage intentions vary because some individuals are unwilling to comply with the mandates (Hartwick and Barki, 1994; Venkatesh and Davis, 2000). Subjective norms

can influence or establish an individual's favourable image within a group. TAM-2 proposes that subjective norms will positively influence image because, if the important members of a person's social group believe that the individual should perform a behaviour such as using the new technological system, then their performing it will elevate their standing within the group (Venkatesh and Davis, 2000)

TAM-2 includes four cognitive determinants of perceived usefulness: job relevance, output quality, result demonstrability, and perceived ease of use (Venkatesh and Davis, 2000). Job relevance is defined as "an individual's perception regarding the degree to which the target system is applicable to his or her job" (Venkatesh and Davis, 2000, p. 191). Output quality refers to the consideration of how well the technological system performs the tasks that match the individual's job goals. Result demonstrability is described as the tangibility of the results from using the innovation (Moore and Benbasat, 1991) which it is argued will directly influence perceived usefulness (Venkatesh and Davis, 2000). TAM-2 retains that perceived ease of use developed in TAM is a direct determinant of perceived usefulness.

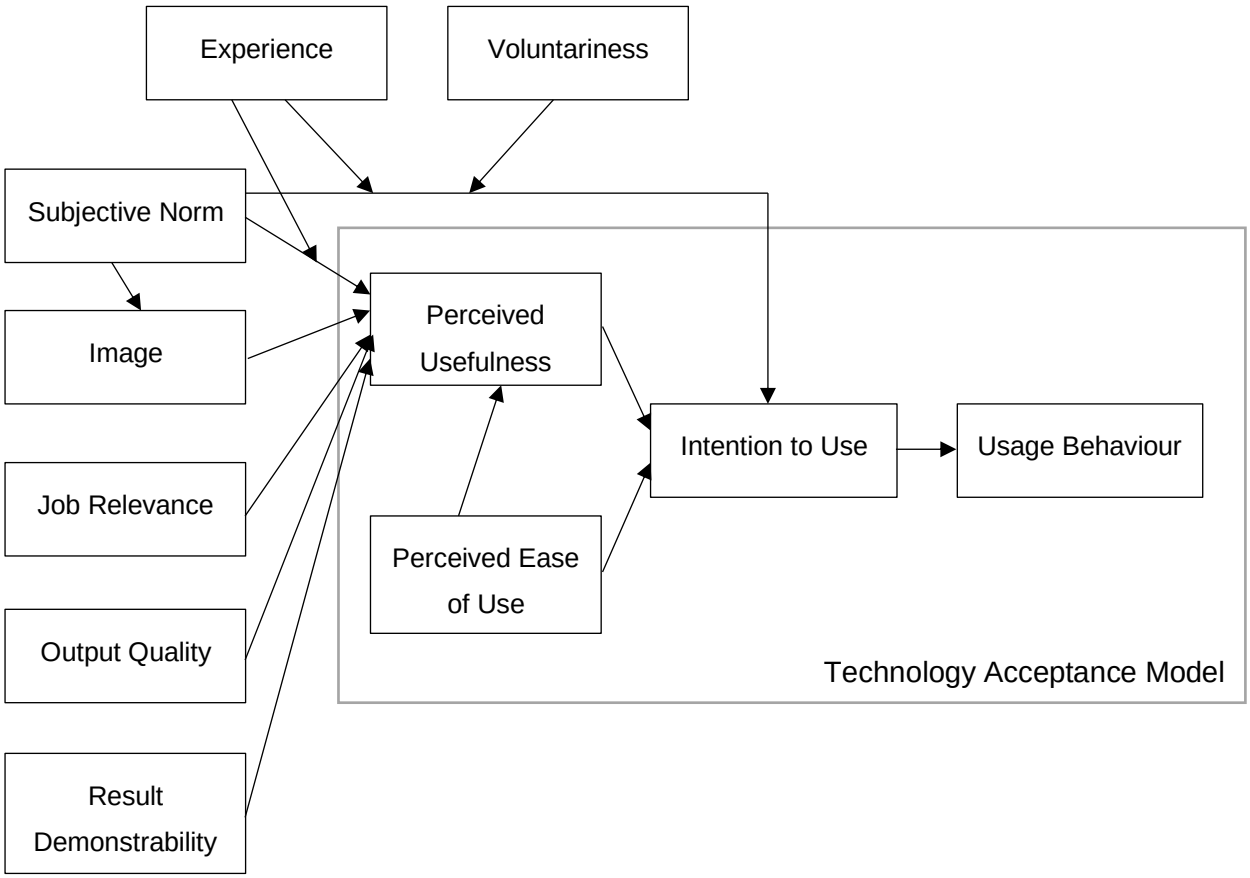

Figure 10 Extended Technology Acceptance Model (TAM-2) (Venkatesh and Davis, 2000).

3.3.4.1. The Strengths and Limitations of the Technology Acceptance Model and the Extended Technology Acceptance Model

I chose to review TAM and TAM-2 as my research questions were concerned with the acceptability and use of the iPads with CareFlow Vitals, which is exactly what TAM and TAM-2 model. The emphasis is on the perceptions of the potential users of the devices, which is ultimately what I was focusing my research on. Ultimately, I used the UTAUT (section 3.3.5) to discuss my findings as this theory combined the strongest influences of TAM, TAM-2, and IDT.

A major strength of these theories is the interdisciplinary application, as they have been used in different contexts such as marketing, finance, and agriculture. These models can also be used to facilitate the acceptance of technologies by pre-empting the perceived usefulness and perceived ease of use and adapting implementation

strategies by doing so. This can make the transition to the post-implementation period easier for both the disseminating group and the users of the technology. However, the theories have been criticised for their simplicity which has driven the creation of other models with more constructs such as the UTAUT. Researchers have suggested that the contribution of these theories has hit a plateau and research needs to be guided in a different direction to move the field forward (Shachak et al., 2019).

3.3.5. Unified Theory of Acceptance and Use of Technology

The UTAUT model combines commonalities with the strongest influence for technology acceptance of previous theories of technology acceptance models including IDT (Section 3.3.1), TAM (Section 3.3.3) and TAM-2 (Section 3.3.4) (Venkatesh et al., 2003). Just as the TAM and TAM-2, the UTAUT model as seen in Figure 11 strives to explain the usage behaviour by describing the behavioural intention. Four of the constructs (performance expectancy, effort expectancy, social influence and facilitating conditions) act as direct determinants of usage behaviour and user acceptance. Gender, age, experience, and voluntariness of use act as key moderators in the model.

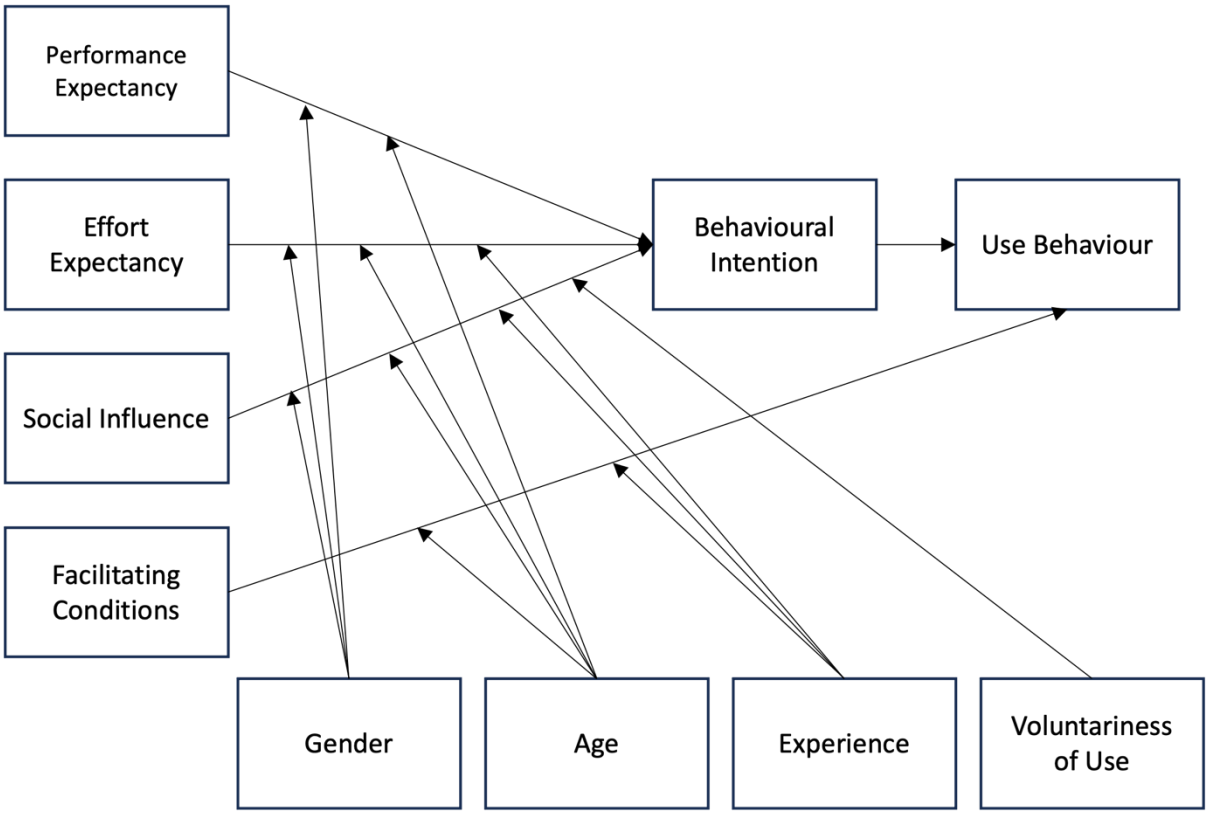

Figure 11 The Unified Theory of Acceptance and Use of Technology model (Venkatesh et al., 2003).

Performance expectancy is defined as "the degree to which an individual believes that using the system will help him or her to attain gains in job performance" (Venkatesh et al., 2003, p.447). This domain relates to perceived usefulness in TAM and TAM-2, as well as relative advantage in IDT. Performance expectancy is moderated by gender and age. From a theoretical standpoint, gender difference indicates that men tend to be more highly task orientated due to socialisation processes reinforced from birth. Age may also be a moderating variable due to younger workers placing more importance on extrinsic rewards compared to their older counterparts (Venkatesh et al., 2003).

Effort expectancy has been captured previously by the perceived ease of use domain in TAM and TAM-2, and ease of use in IDT. To summarise, effort expectancy is about the ease of using the new system. Venkatesh et al. (2003) propose that effort expectancy will be moderated by gender, age and experience such that the effect is stronger for particularly older women at the early stages of experience with the new system.

Social influence is described as "the degree to which an individual perceives that important others believe he or she should use the new system" (Venkatesh et al., 2003, p.451) which is represented by subjective norm in TAM and TAM-2, and image in IDT. Theory suggests that women tend to be more sensitive to the opinion of others, with the effect declining with increased experience suggesting that gender and experience will have a moderating role on this aspect. Research also suggests that older workers are more likely to place increased salience on social influence within the workplace highlighting a moderating role with age (Venkatesh et al., 2003).

Facilitating conditions are defined as "the degree to which an individual believes that an organisations and technical infrastructure exists to support the use of the system" (Venkatesh et al., 2003, p.453). This has been previously captured in the compatibility construct of the IDT, particularly in items that fill the gap between the individual's work style and the use of the system in the organisation. Facilitating conditions do not have an influence on behavioural intention, instead directly influencing use behaviour. The effect of facilitating conditions is hypothesised to be stronger for older workers with increasing experience (Venkatesh et al., 2003).

3.3.5.1. The Strengths and Limitations of the Unified Theory of Acceptance and Use of Technology

I ultimately chose to use the UTAUT theory to drive the discussion of my findings (chapter 8) due to the strengths listed for the TAM and TAM-2 (section 3.3.4.1) with the additional benefits of the added constructs. The social influence, facilitating conditions, and voluntariness of use constructs provide a more insightful perspective of the nuanced structure of a hospital organisation. The moderation effects (age, gender, and experience) are also useful in identifying why/how certain demographics accept or abandon the technology in use.

UTAUT has been criticised for not having included other important individual characteristics as moderators such as attitude, computer self-efficacy, and personal innovativeness. In their literature review of the use of the UTAUT model, Dwivedi et al. (2019) found that only approximately 25% of studies that used the UTAUT model did not include other constructs not found in the original model. Therefore, other research groups such as Dwivedi et al. (2019) have continued to attempt to evolve the model into more applicable versions with further constructs for wider use.

3.4. Conclusion

In summary, there are a number of sociological approaches and technology acceptance theories that can be utilised in understanding and discussing the present research. The biomedical model of medicine assumes a technological imperative, meaning that technology is a benefit to society and should be developed for this purpose. The sociological approaches described here include three perspectives: technological determinism, social essentialism, and technology-in-practice. Each perspective can provide insight into the results of this study from a different lens. Further, I have outlined four technology adoption models: IDT, TAM, TAM-2, and UTAUT. IDT provides an in-depth exploration of the way a new innovation is adopted throughout an organisation, such as a healthcare system in this study.

In the next chapter I describe and present a rationalisation for the methodology of the present study including the epistemological position, study design, participants, and ethical considerations.

Chapter 4. Methodology

4.1. Overview

Following the rapid evidence assessment (REA) and the influence it had on the research questions, this chapter focuses on the methodology and methods, including further exploration of the rationale of the research questions. I begin by presenting the research questions before discussing the philosophical position of the research. After this, the study design alongside a brief examination of mixed methodology research is discussed. This research follows a mixed methods approach incorporating case study and survey design in two hospitals in one health board. The justification for the choice of case study wards, and participants is set out. This chapter also describes the methods used for data collection and the approach to analysis. Details of the advisory group set up with medical professionals and public volunteers is also provided. Although patients were not the participant group in this study, they were present in their hospital rooms at a time of vulnerability. Therefore, an ethical approval application via the Integrated Research Application System (IRAS) was made. A section on the ethics involved in this study is included at the end of this chapter.

4.2. Research Questions

The REA influenced the development of the research questions. Findings from synthesising the literature highlighted gaps in the evidence (section 2.5). Methodological gaps included qualitative approaches to data collection on the impact of the use in hospital settings of mobile devices and associated software for recording patient data. Furthermore, the participants in most studies were mainly doctors, nurses and medical students. Allied health professionals who also work in hospitals, such as physiotherapists, occupational therapists, and pharmacists were infrequently or not at all included in the studies. Allied health professionals are an important group to also include as participants as they form part of the MDT contributing to patient

care. It is unknown exactly how patient observational data recorded on the mobile technology supports care decisions, if at all.

As a result, the research questions were formulated as presented in Chapter 2. The first research question is concerned with the implementation of the mobile devices equipped with CareFlow Vitals into the hospitals in Wales. The sub question focused on the perception of the users of the mobile devices about the implementation. The second research question is concerned with how the mobile devices are being used to record patient observations, including sub questions which related to who uses the devices, the processes followed in recording patient observations, and staff attitudes to device use. The third research question asked how staff responded to the change from pen and paper records to the use of iPads with CareFlow Vitals, with a sub question that intended to explore how the demographic characteristics of the participants affect the preference for the devices and the allocated software. The fourth and final research question seeks to explore how having the mobile devices at the bedside had impacted clinical decision making, including sub questions on the stage(s) at which care planning was supported (i.e., short, medium, long term) and what had been useful or not useful about the mobile devices and software when supporting clinical decision making.

4.3. Position of the Research

Two broad research paradigms are frequently discussed in methodology literature and contrasted: these are interpretivism and positivism. Either approach might be adopted in the investigation of these research questions.

Interpretivists argue that there is no single shared reality and reality is composed through socially constructed meanings. Ryan (2018) reflects on the proposition that there are multiple realities based on individuals' different perceptions in a hospital setting. For example, every patient on a hospital ward has his or her perspective and experience of the care that they have been provided, informed by their interactions with other patients, staff, visitors, and their own previous experiences. Similarly, the experience of staff is individual, affected by their interactions with others and the wider ethos of the ward and more broadly the hospital and the health board. A common way of uncovering individual perspectives is by conducting qualitative research to unearth their thoughts and feelings about the focus of the research.

It would have been possible to adopt a positivist approach to the design of the study, for example, using data gathered directly from the mobile devices to identify usage patterns, or to use an experimental pre-test/post-test design to compare the difference between pen-and-paper forms and electronic software (e.g., CareFlow Vitals) as exemplified by studies conducted by Prytherch et al. (2006). Positivists hold the ontological belief that every person experiences the same single objective reality independently of other individual's perceptions. The social and physical world also exists independently of these perceptions as a concrete and unchanging structure (Hudson and Ozanne, 1988).

A clear gap in the literature identified in Chapter 2 was the qualitative evaluations of the perspectives of the members of staff using the mobile devices. This research has been designed using a mixed methods approach to address this gap while also providing context using quantitative data. Mixed methods research has been described as the third research paradigm that combines qualitative and quantitative research methods (Ma, 2012). Nevertheless, qualitative and quantitative methods have apparent differences in respect of ontological and epistemological positions (Ansari et al., 2016). Therefore, mixed methods research can be questioned as to whether it is a new distinct paradigm in its own right or a mix of different paradigms (Ghiara, 2019). The stance that mixed methods research should be recognised as a paradigm is endorsed by the existence of a community of people who share the same position about the nature and conduct of the research, creating a research culture (Johnson and Onwuegbuzie, 2004; Ghiara, 2019). Alternatively, the position in which mixed methods research is a combination of different paradigms can be attributed to the status of the different methods in the design i.e., dominant, less dominant and equal (Ghiara, 2019). Ultimately, the choice of methods should be guided by the research question. This is a position taken by Johnson (2012) who advocated for the metaparadigm dialectical pluralism which requires the researcher to listen to each research question and purpose, enabling a combination of ideas from competing paradigms. The methods chosen for this study were guided by the research questions in this way, as seen in Section 4.6.1.

4.4. Study Design

4.4.1 Mixed Methods Approach

The methodological approach is designed to enable a wider exploration across hospitals, wards, and professional roles. By employing a mixed methods design, quantitative and qualitative data could be gathered to provide more holistic insight from multiple perspectives into the use of the devices at each level of the hospital system. In a study investigating why mixed methods research is undertaken in health services research, O'Cathain et al. (2007) identified that researchers often justified this approach by arguing that different methods were needed to address different aspects of the research questions within a single study where the research environment was complex, making the study more comprehensive, as is the case in this study.

Schifferdecker and Reed (2009) identify and define four design models for mixed methods research in medical and nursing education: the triangulation model, the instrument development model, the explanatory model, and the longitudinal transformational model. These models were identified from a previous review of mixed methods studies in medical and nursing education conducted over a 20-year period (Schifferdecker, 2007).

4.4.1.1. Triangulation Model

When using the triangulation model for mixed methods research, qualitative and quantitative data are collected simultaneously, often in a relatively short timeframe and involving a single population (Schifferdecker and Reed, 2009). Triangulation is a term that can be used to describe corroboration between two sets of findings or to describe a process of studying a problem using different methods to gain a more complete picture, with the latter meaning being more commonly used in mixed methods research (O'Cathain et al., 2010). To illustrate the use of this model, Racine et al. (2020) used quantitative data gathered from a questionnaire and qualitative data gathered from observations and interviews, to compare participants' experiences of

taking part in one of three types of consensus meetings for people with diabetes and healthcare professionals. My research is positioned within the triangulation model. All methods occurred simultaneously alongside data analysis. Quantitative data were collected from the survey, and qualitative data were collected from observations, interviews, and free text responses on the survey. Data were collected simultaneously to corroborate findings, rather than influence the development of a further method, or clarify findings from a previous method.

4.4.1.2. Instrument Development Model

The instrument development model was designed for the collection of qualitative data for the purpose of developing a quantitative instrument. This approach allows for the quantitative instrument to be grounded in the views, experiences, and language of the participants (Schifferdecker and Reed, 2009). Instruments that could be developed from this model include questionnaires and observational checklists. For example, in a study by Sampson et al. (2010) which aimed to compare satisfaction at intervention hospitals offering angioplasty-based care and control hospitals offering thrombolysis-based care, qualitative interviews were used to identify the positive and negative experiences of the patient experience from the onset of symptoms to their discharge home. Using the findings from these interviews, a questionnaire was developed for the second phase of that study. This model was not deemed to be appropriate as all data collection instruments were designed to be used concurrently, rather than in phases due to the nature of PhD research and the associated time constraints.

4.4.1.3. Explanatory Model

The explanatory model is designed for results or questions arising from quantitative data to be explored qualitatively, producing data that are used to complement or clarify the original findings. It is generally recommended when using this model that participants from the qualitative component are recruited from the quantitative component to best represent their views (Schifferdecker and Reed, 2009). Brenner et al. (2014) used the explanatory model in their study which aimed to evaluate the

causal impact of providing supply-side performance-based incentives in combination with a demand-side cash transfer component on equitable access to, and quality of, maternal and neonatal healthcare services in four districts in Malawi. The quantitative component of their study design consisted of a controlled pre- and post-test employing a quantitative measure of 'equitable access to healthcare services' and 'healthcare quality'. To further explain the quantitatively observed effects, the researchers used qualitative interviews and focus group discussions with different stakeholder groups. As with the instrument development model (section 4.4.1.2), my research did not employ this model as it was not designed as a multi-phase study.

4.4.1.4. Longitudinal Transformation Model

In this model, data are collected using multiple methods at multiple points in time, generally from more than one population. The data are analysed and integrated throughout the project and often build on one another (Schifferdecker and Reed, 2009). For example, de Kruif et al. (2019) recruited breast cancer patients, and a control group of women without cancer to collect data to provide a better understanding of the changes in body weight and body composition during chemotherapy four times throughout the course of the study. Quantitative measurements included changes in body weight, body composition and lifestyle factors, whereas qualitative measurements explored the perception of the women on physical activity and dietary intake, as well as factors related to coping with diagnosis and treatment. The findings from this study could be useful for healthcare researchers and professionals to develop tailored intervention schemes. This could ultimately improve the quality of life and reduce the risk of co-morbidity health issues for women with breast cancer. A longitudinal design was out of the scope of this study as the research questions did not require multiple measures over time.

4.4.2. Case Study Research

Case studies can be defined as an intensive study about a person, a group of people or a unit, with the aim of generalising over several units (Heale and Twycross, 2018). Case studies are a design suitable for gathering in-depth, multi-perspective

information regarding real-life everyday interactions such as professional activities in the medical setting (Crowe et al., 2011) involving the collection and analysis of information from more than one source (Watling and Lingard, 2012). The selection of a case study design is guided by the research questions. Stake (1995) identified three types of case study design: 1) intrinsic- where a case is studied for the intrinsic interest in the case itself, 2) instrumental- where a case is chosen to explore an issue or research question determined on some other ground, and 3) collective- where several cases are studied to form a collective understanding of the issue or question. The current study aligns with the collective design as multiple case studies were selected for comparison.

Benefits of case study research include flexibility due to not being constrained by method or time, having the potential to engage participants in the research process and being useful when exploring and understanding the process of change through closely describing, documenting and interpreting events as they unfold in the real-life setting (Simons, 2009). Despite their advantages, case study research is not without limitations. Limitations can include the difficulty of organising the amount of data collected from using multiple methods in multiple case studies (Swanborn, 2010; Heale and Twycross, 2018), the time-consuming nature of conducting multiple methods particularly when this involves qualitative methods such as interviews (Swanborn, 2010) and a temptation to veer away from the original focus of the research questions (Heale and Twycross 2018).

A case study design was chosen for this study as I wanted to ensure that the research questions were addressed effectively with a collective response from a wide range of participants in the same setting (a hospital) using a wide range of methods to fully explore the outcomes of a new technology being implemented into secondary care settings in Wales to record patient observational data. A case study design enables this nuanced overall perspective.

4.4.3. Selection of Case Study Sites

This research is located in one NHS health board in Wales. The health board employs over 14,000 staff, two-thirds of which are involved in direct patient care. The health board catchment area contains an approximate population of about 600,000. CareFlow has been introduced to 90 in-patient wards across the 10 hospitals in this

health board. The case studies in this research were the two hospitals- South Fields Hospital and Castle Plains Hospital (names changed)- and a selection of their wards within. South Fields Hospital is designed to treat the most seriously ill, or those who have complex problems or conditions that cannot be safely managed elsewhere. This contrasts with Castle Plains Hospital which is designed to deliver general and routine care. Castle Plains Hospital is also one of the two hospitals that were included in the CareFlow pilot in the health board, and so was well placed to provide longer-term perspectives on the use of the devices. Two hospitals were chosen as they provided enough similarity and difference to compare and contrast. Although the inclusion of more case studies may have enhanced the robustness of the conclusions to do so would have been unmanageable given the time constraints and single-handed nature of the doctoral study.

Five wards in South Fields Hospital, and five wards in Castle Plains Hospital were chosen during the data collection period. Only adult covid-safe wards were eligible for participation. It was originally designed so that only three wards would be chosen as the focus in each case study site, but opportunity allowed me to observe more wards on different floors and different specialties. Different floors and different specialties were of interest as it was unknown whether these were factors in the acceptance rate of the new innovation. Time and availability allowed for this so more wards were included, which improved participant recruitment. Case study wards are listed below including the floor that the wards were on, and the type of ward:

- South Fields Hospital
    - Ward 1- ground floor, surgical/general specialty.
    - Ward 2- first floor, surgical assessment unit.
    - Ward 3- ground floor, surgical/medical specialty.
    - Ward 4- ground floor, surgical/ENT (ears, nose and throat) specialty.
    - Ward 5- fourth floor, medical specialty.
- Castle Plains Hospital
    - Ward 1- first floor, medical assessment unit.
    - Ward 2- first floor, care of the elderly specialty.
    - Ward 3- second floor, elderly frailty specialty.
    - Ward 4- third floor, care of the elderly specialty.
    - Ward 5- third floor, care of the elderly specialty.

As can be seen, a wide range of wards and patient groups, not including children or those deemed not to have mental capacity were observed. Wards that had the potential for multiple night-stays were of interest to understand the way that device use with CareFlow Vitals impacted clinical decision making during the patient care

journey. Ward 1 in South Fields Hospital was originally designed to be a pilot study ward. However, the data were deemed to be rich and valuable, so it became part of the main study, as little had to change regarding data collection. It did give insight into the way the study would be carried out. Initially, I planned to collect most of the data from qualitative interviews. However, after spending time on Ward 1 in South Fields Hospital I realised that staff were often too busy to participate in an interview during the shift or could not commit to a follow-up interview. It became clear that the place of observation and informal interviewing would be both more feasible and appropriate. Thus, observation and the informal interviewing of staff while working and the recording of interactions and observations infield notes is a central pillar of the approach to data collection.

4.4.4. Survey Research

Survey research involves collecting information from a sample of individuals through their responses to questions (Ponto, 2015). A survey questionnaire allows for a large population to be accessed. Questionnaires may be designed to be distributed in different forms. This can include paper or online format and handed directly or mailed to participants, delivered in an electronic form via email or via an internet-based programme such as SurveyMonkey (Ponto, 2015).

Benefits of survey research include the high representativeness of the population being studied, low development time, and the low costs when compared to other alternatives (Queirós et al., 2017). Limitations include a risk of having a low response rate (Jones et al., 2013), gathering improper or inaccurate answers which could affect the statistical power in the analysis not being able to capture emotions, behaviour, and changes of emotions of respondents (Jones et al., 2013; Queirós et al., 2017). The reliability of the survey is dependent on the survey structure (Queirós et al., 2017). A well-designed, piloted, and implemented survey can improve response rates and enable the application of suitable statistical analysis (Jones et al., 2013). Using multiple methods can balance the strengths and limitations of each which is the benefit of aligning this methodology with the triangulation model outlined in the previous sections.

A questionnaire survey was deemed to be appropriate for this study to complement the deeper insights from participants in the case study wards by gathering data from

healthcare professionals beyond the case study sites. This was especially helpful in collecting perspectives from clinicians such as doctors and physiotherapists as they were often too busy to be approached when they were visiting patients on the wards.

4.5. Data Collection

Methods were informed by the research questions that had been developed, as well as the literature gathered during the REA. Methods that were ultimately included were interviews and observations within a case study design, and a wider questionnaire survey. Qualitative methods such as the observations and interviews have become more commonplace in health technology assessment and health services research (Mays and Pope, 2000).

4.5.1. Observations

Observations have the merit that there are no forced changes to a participant's circumstances unless there is an intervention (Gilmartin-Thomas et al., 2018), which was not the case in this study. This type of research has the potential to document a process and address questions difficult to answer using other methods.

Observations of the case study wards were included in the methodological design to systematically observe and record the way that the devices are used in clinical practice. This provided an insight into the way the devices actively play into the healthcare system and how users interacted with the technology. Observations also allowed me to be immersed in the culture of the hospital and individual wards, giving me an understanding of the way that the devices were incorporated into established settings. Observations also enabled an opportunity to recruit potential participants for the formal semi-structured interviews.

The Chief Nursing Information Officer and I approached the relevant ward sisters at South Fields Hospital and briefed them fully at the beginning of a potential observation. Dates for the observations were negotiated with the ward sisters who informed their staff about the intended observations. Further information was provided on a participant information sheet (PIS) (Appendix 4) which was made

available during observation periods. A consent form was completed by staff members who were observed (Appendix 5). Patients were also issued with an information sheet (Appendix 6) to inform them of the study and their right to not be observed, although every patient was happy for me to be there. Welsh translations of these documents were also made available. No personal data were collected on patients such as name, age, location, health condition etc.

Multiple shift periods were observed to gather a thorough overview of the way the devices are used by different staff members. It was proposed after speaking to the local collaborator at the health board that each shift period at each ward was observed once: day (7am-7pm) and night (7pm-7am). In total this was 12 observations. In practice these times were not adhered to strictly as the mobile devices were used less frequently than expected. In reality I did more observations at each ward over shorter time periods which allowed me to meet more potential participants and not take up as much time for individual members of staff. In total I conducted 27 observations that totalled 109 hours. As I was a non-participant in that I was not using the devices myself or working in the hospitals. I observed participants and recorded detailed fieldnotes in a research journal, noting their pattern and behaviour in using the devices with CareFlow. This included informally interviewing staff as they conducted their duties on the ward. These interviews were not audio recorded and notes on the conversation were documented in the field notes.

During observations I located myself centrally or near the devices so that I could approach the users. I recorded all interactions with the devices, or interactions with paper-based forms implying a non-interaction with the devices. I also recorded the process that each participant of the observation conducted when doing their vital signs with the iPads and CareFlow Vitals. Further, I recorded anything that I thought may be of interest when writing up the findings such as multi-disciplinary team interactions, the role of different team members when engaging with patients, and emergency situations such as a patient coding.

A potential limitation of observational research is the risk of observer effects. An observer effect can be defined as “any form of artifact or consequence of research participation on behavior” (McCambridge et al., 2014, p.268). Put simply, the risk of participants potentially altering their behaviour in the presence of the researcher. In previous research addressing the experience of being observed as a healthcare practitioner or patient, the overall sentiment was good and a neutral experience. The healthcare practitioners described being observed as being part of their ordinary

workday and felt little discomfort, whereas patient described not being affected by the presence of observers at all (Svensberg et al., 2021). In my experience during this research, participants were nervous when first approached as they thought that I may be an inspector for the Care Quality Commission (CQC). When I explained who I was, and the purpose of the research alongside the information sheet, participants were relaxed and very welcoming.

4.5.2. Interviews

Semi-structured interviews have the scope to explore participants' thoughts, feelings and beliefs about a particular topic in a flexible manner allowing for follow-up questions and probes (DeJonckheere and Vaughn, 2019). In a research interview, the interviewer can elicit the behaviour, attitudes, norms, beliefs and values of the person being interviewed (Bryman, 2016). There are historical criticisms of qualitative methods such as interviews from a positivist perspective. Examples include a lack of trustworthiness and objectivity (Shenton, 2004). However, being prepared with robust interview schedules in the context of semi-structured interviews including potential prompts to the designed interview schedule to elaborate on what the participants have discussed can provide rich and detailed data (DeJonckheere and Vaughn, 2019) that would not be accessible in a solely quantitative research design.

Qualitative semi-structured interviews were used to gather in-depth information about the opinions and experiences of participants about the phenomenon of having mobile devices to record and use patient observational data in the hospital setting. Four interview schedules were designed based on participant groups (Section 4.6.1). Questions for the interview schedules were designed to reflect the research questions (Section 4.3).

The interviews lasted between 10 and 45 minutes. I sought to recruit participants from case study wards during observation periods by giving staff members a leaflet (Appendix 7) illustrating key information about the study. Interested potential participants were able to use the contact information on the leaflet to request the PIS (Appendix 8) and arrange an interview. Welsh translations of these documents were also available. All interviews were audio recorded with the participant's consent, transcribed, and anonymised. Interviews were conducted in a private room at the hospitals or on Microsoft Teams.

4.5.3. Questionnaire Survey

A questionnaire was utilised to collect data from a wider range of staff within the case study hospital sites, including those on the case study wards, thus broadening the data base of opinions and enriching the overall picture. This allowed for triangulation to enhance the validity of the study (Schifferdecker and Reed, 2009). The survey can be found in Appendix 9.

The questions that were deemed suitable to ask in the survey concerned the implementation of the devices, and perceptions on how having the devices have changed a) the workflow of the people using them, b) the benefits and drawbacks of having the devices and c) the way decisions are made. A question was also designed to inquire whether the Covid-19 pandemic had altered the way the devices were used. Part 4 of the survey was specifically informed by the Prytherch et al. (2006) study. Questions were designed to understand whether pen and paper or the CareFlow Vitals software are more accurate, simpler, quicker, more convenient, and easier to use. The questionnaire included a mixture of open and closed questions, including Likert scales, allowing for qualitative and quantitative data to be collected.

All clinical or managerial staff who use CareFlow Vitals or CareFlow Vitals data in both hospitals were sent an email with a link attached for an online self-completion questionnaire via the CareFlow Vitals team. Screening questions were designed to determine whether participants have used the devices in their clinical practice. At first the response rate to the survey was low. To combat this problem, I had meetings with different senior healthcare professionals from both hospitals including doctors, nurses, and allied health professionals. The response rate improved as the senior member of staff sent the survey to their network. Another improvement was seen when I took paper versions of the survey to my observations and personally asked potential participants to complete a survey if they had time. This was especially useful on the night shift when patients had gone to sleep, and healthcare professionals were concentrating on administrative tasks such as writing patient notes.

4.6. Participants

4.6.1. Participant Groups

Potential participants were grouped in to four participant groups based on their job role[4], and asked questions from a corresponding interview schedule (Appendix 10):

Participant group 1: the recorders- the staff members who use the mobile devices to record patient observations. This includes health care assistants and nursing staff.

Participant group 2: the clinical decision makers- the staff members who use the data from the mobile devices to make clinical decisions for their patients. This includes nursing staff, clinicians, and allied health professionals such as physiotherapists and occupational therapists.

Participant group 3: the ward organisational decision makers- the staff members who use the data from the mobile devices to make organisational decisions at ward level e.g., ward managers.

Participant group 4: the hospital management decision makers- the staff members who use the data from the mobile devices to make decisions regarding hospital management.

Table 5 shows how the research methods were tailored to different participant groups and the research questions seen in Section 4.3. Data collection materials were designed based on the research question that they were made to answer alongside the participant group they were intended for. For example, interview schedules (Appendix 10) designed for participant group 4 (hospital management decision makers) for research question 1.

[4] It is noteworthy that the job role of potential participants may fall into more than one participant group. In this case, the potential participant was asked which group their current role relates to the most.

Table 5 Mapping of methods to the research questions, relevant participant group(s) and commentary.

Research Question	Proposed Method	Participant Group(s)	Commentary
1) How were the mobile devices equipped with CareFlow Vitals implemented in the hospitals in Wales?	In-depth interviews	4	Group 4 were the people who were part of the decision-making process about implementing the devices. Interviews were the best method for collecting data relating to this question as Group 4 were not present in case study wards.
1a) How did the users of the mobile devices perceive the introduction of the technology into the hospitals?	In-depth interviews, observation	1 and 2	Groups 1 and 2 (specifically health care support workers and nurses) were the primary users of the iPads on the wards. Participants gave their opinions during interviews, or while being observed.
2) How are mobile devices used to record patient observations?	Observation	1	Observation of the way the iPads were being used in clinical practice.
2a) Who is using the devices on the hospital ward?	Observation, survey	1, 2 and 3	I was able to observe the role of the person using the devices whilst on the hospital wards. The survey also sought to gather information about who also may be using the iPads and CareFlow Vitals that were not observed on the wards, e.g., doctors and allied health professionals.
2b) What processes are being followed when recording patient observations on the mobile devices?	Observation	1	Observation ofthe process of using the iPads and CareFlow Vitals on the hospital wards.
2c) What are the attitudes of staff towards mobile devices equipped with CareFlow Vitals?	In-depth interviews, observation, survey	1, 2, 3 and 4	This question was aimed at all participant groups as all professional roles have access to the software and therefore had opinions. Staff explained their thoughts during interviews and observations, and the survey asked about attitudes and gained further reach.
3) How did staff respond to the change from pen and paper records to the use of the iPads with CareFlow Vitals?	In-depth interviews, survey	1, 2 and 3	These participant groups were the people using both pen and paper records and iPads on the hospital wards. Interviews asked about the change of method of data recording and the survey directly asked comparative questions between the two methods.

3a) Do the demographic characteristics of the participants affect the preference for iPads and CareFlow Vitals in practice?	Survey	1, 2, 3 and 4	Demographic characteristics were collected for all survey participants to ascertain any correlations with the preference for the iPads with CareFlow Vitals compared to paper-based forms.
4) How have mobile devices used to record patient observations at the bedside impacted clinical decision making?	In-depth interviews	2	The clinical decision makers (group 2) were using the data to make decisions on their patient's care. In interviews they explained how they did this.
4a) At what stage(s) of care planning have mobile devices supported decision making? i.e., immediately, medium/long term.	In-depth interviews	1, 2, 3 and 4	Every participant group made care-planning decisions. Interviews with each group gave me in-depth reasoning as to how the iPads have affected this.
4b) What has been useful or not useful about the mobile devices and software when supporting clinical decision making?	In-depth interviews, survey	1 and 2	Both participant groups 1 and 2 were able to describe advantages and disadvantages in interviews and survey questions.

4.6.2 Research Participants

This section lists the participants that took part in the study. All participants have been anonymised and given pseudonyms. Table 6 details the role of the participants of the observations, and the wards in which they work. All of these participants were either health care support workers (HCSWs), nurses, agency nurses or student nurses. This is because they were the people using the iPads to collect vital signs using CareFlow Vitals in practice. Overall, 50 participants were observed.

Table 6 The role and ward of the participants of the observations.

Ward	Staff Role	Number of Participants
South Fields Hospital		
Ward 1	HCSW	5
	Staff nurse	3
	Student nurse	1
Ward 2	HCSW	3
	Staff nurse	1
Ward 3	HCSW	4
	Staff nurse	1
	Student nurse	2
Ward 4	HCSW	6
	Staff nurse	2
	Student nurse	1
Ward 5	HCSW	5
	Student nurse	1
Castle Plains Hospital		
Ward 1	HCSW	8
	Staff nurse	1
Ward 2	HCSW	1
Ward 3	HCSW	3
Ward 4	Student nurse	1
Ward 5	Agency nurse	1

Table 7 includes the roles of the interviewees listed in their participant groups. All interviewees worked at South Fields Hospital, but some also had experience of working at Castle Plains Hospital. Possible reasons for the lack of interviewees at Castle Plains Hospital include that although each potential interviewee was happy to be observed, they were unwilling to be interviewed because of time pressures arising from staffing levels. Furthermore, I did not know the key contacts at this hospital as I did at South Fields Hospital. South Fields Hospital was a larger hospital that had a research and development office in-house who was also able to direct me to potential contacts. There were 14 interviewees in total.

Table 7 The roles of the interview participants.

Staff Role	Number of participants
Group 1: The Recorders	
HCSW[5]	9
Group 2: Clinical Decision Makers	
Consultant haematologist	1
Staff nurse	1
Group 3: Ward Organisational Decision Makers	
Ward manager	2
Group 4: Hospital Management Decision Makers	
N/A[6]	2

Table 8 illustrates all the survey participants and their professions. The sample size of the survey was 105 participants. The sample comprised of 37.1% (n=39) nurses. This group was made up of staff nurses, ward managers/sisters, clinical nurse specialists, critical care nurses, nurse practitioners, student nurses and a deputy ward manager/sister. HCSWs covered 30.5% (n=32) of the sample, 7.6% (n=8) were doctors, 6.7% (n=7) were critical care outreach practitioners, and 8.6% (n=9) were physiotherapists, including a clinical specialist physiotherapist. A further 9.5% (n=10) were classified as other, including participants who did not state their job role.

[5] Seven of these participants also participated in observations at South Fields Hospital; two in Ward 2, two in Ward 3, and three in Ward 4, respectively.

[6] I have not included the job title for group 4 participants as this could easily identify them.

Table 8 Occupational roles of survey participants.

Occupational role	Percent (n)
Nurse	37.1 (39) [total]
Staff nurse	22.9 (24)
Nurse practitioner	4.8 (5)
Ward manager/sister	2.9 (3)
Clinical nurse specialist	1.9 (2)
Critical care nurse	1.9 (2)
Student nurse	1.9 (2)
Deputy ward manager/sister	1.0 (1)
Health care support worker	30.5 (32) [total]
Physiotherapist	8.6 (9) [total]
Physiotherapist	7.6 (8)
Clinical specialist physiotherapist	1.0 (1)
Doctor	7.6 (8) [total]
Critical care outreach practitioner	6.7 (7) [total]
Other	9.5 (10) [total]
Assistant Practitioner	2.9 (3)
Rehab support	1.0 (1)
Hyper acute stroke support worker	1.0 (1)
Job not given	4.8 (5)

The demographics of the participants were collected in the survey and are detailed in Table 9. Data collected included the age and gender of the participants, the hospital that they work at, whether they are an agency worker, their years of experience in a hospital setting, and the year that they started using the iPads and CareFlow Vitals in practice. Most commonly respondents were aged 25-34 (38.1%; n=40), followed by the 35-44 age group (28.6%; n=30). The majority of the participants were female (80.0%; n=84) and worked at South Fields Hospital (78.1%; n=82). Further, most frequently respondents were not agency workers (46.7%; n=49), followed by agency workers who also had a permanent contract in place (44.8%; n=47). Most of the respondents had 2-5 years of experience working in a hospital setting (32.4%; n=34), and most started using the iPads and CareFlow Vitals in 2023 (21.0%; n=22).

Table 9 The demographics of survey participants.

Age of participants	**Percent (n)**
18-24	5.7 (6)
25-34	38.1 (40)
35-44	28.6 (30)
45-54	15.2 (16)
55-64	12.4 (13)
65+	0
Gender of participants	**Percent (n)**
Male	19.0 (20)
Female	80.0 (84)
Prefer not to answer	1.0 (1)
Primary Hospital	**Percent (n)**
South Fields Hospital	78.1 (82)
Castle Plains Hospital	21.0 (22)
South Fields Hospital and Castle Plains Hospital	1.0 (1)
Agency worker status	**Percent (n)**
Yes, this is my sole contract	8.6 (9)
Yes, alongside my permanent contract	44.8 (47)
No	46.7 (49)
Years of experience in a hospital setting	**Percent (n)**
0-1	8.6 (9)
2-5	32.4 (34)
6-10	18.1 (19)
11-20	27.6 (29)
21-30	4.8 (5)
31+	8.6 (9)
Year started using the device	**Percent (n)**
2015 or earlier	2.9 (3)
2016	1.9 (2)
2017	1.9 (2)
2018	3.8 (4)
2019	14.3 (15)
2020	14.3 (15)
2021	12.4 (13)
2022	14.3 (15)
2023	21.0 (22)

4.6.3. Covid-19 Adjustments

The design of the observations at the hospital acknowledged the disruption caused by Covid-19 to the normal workflow of the hospital, and the risk to the patients, staff, and me (section 1.2.2). Both South Fields Hospital and Castle Plains Hospital were operating with 'red' wards where Covid-19 positive patients had been admitted, and 'green' wards where there were no Covid-19 cases. The wards that were included in the case studies were limited to the green wards to minimise transmission of the disease. This was decided in conversations with hospital staff at an early stage of research planning. I have also received both doses, and the booster of the Covid-19 vaccination and took lateral flow tests before undertaking an observation of a shift to ensure safety to all staff and patients on the ward. Necessary PPE was also worn. Data collection started in October 2022 and at this point masks were still mandatory in hospitals in Wales. Over the period of data collection, masks were not considered mandatory in hospitals in Wales anymore. I still wore a mask in environments where staff and patients were still wearing them. In some cases I was asked not to wear a mask as some patients were hard of hearing. In the case that Covid-19 restrictions were in place prohibiting access to hospital wards, the interviews were designed to be conducted virtually on Microsoft Teams or Zoom. Observations would not have been able to go ahead. However, this was not the case and all observations were unaffected by the Covid-19 restrictions. Some interviews were still held over Microsoft Teams as home working has become a normal standard for staff who do not need to be present in the hospitals at all times. This made organising interviews with busy staff more convenient for both parties.

4.7. Analysis

Qualitative data gathered from the interviews, open questions from the survey, and field notes from the observations were thematically analysed using the Framework Method (Furber et al., 2010; Gale et al., 2013) to identify recurring behaviours and patterns (Braun and Clarke, 2006). The Framework Method was developed for large-scale policy work in the 1980s and is now being widely used in other areas, including health research. It is a flexible tool that is not aligned with a particular epistemological,

philosophical, or theoretical approach, but it can be used with many qualitative approaches to generate themes (Gale et al., 2013). Analysis proceeded concurrently with data generation which allowed emerging themes and concepts to be reflected upon with subsequent participants (Kendall et al., 2009). The Framework Method was followed using the stages illustrated in Gale et al. (2013):

1. Transcription

Ideally a verbatim transcript is needed for the Framework Method analysis. I transcribed the interview recordings myself which allowed me to become immersed in the rich data. I also typed field notes and free-text comments from the survey into a document and uploaded this to NVivo.

2. Familiarisation with the transcriptions

It is important to read and listen (in the case of the interviews) multiple times to gain familiarity with the data and become fully immersed. At this stage, initial thoughts and impressions were recorded in a research diary.

3. Coding the transcriptions

After becoming familiar with the data (interview transcripts, field notes, free text comments), the process of coding started. The data were carefully read, and a code was given that described the interpretation of important passages. The coding was conducted using NVivo.

4. Developing the analytical framework

After the first few transcripts were coded, an analytical framework was developed and discussed in supervision with the supervisory team.

5. Applying the analytical framework

The working analytical framework was applied to subsequent transcripts using NVivo.

6. Charting data into the matrix

A spreadsheet was used to generate a matrix that summarised the data by category for each transcript, recording important phrases and quotes from the participants. An excerpt of this can be seen in Appendix 11.

7. Interpreting the data

Using the charting matrix, conclusions about the data were identified and interrogated using the different theories illustrated in Chapter 3, and the existing literature presented in Chapter 2.

SPSS was used to support the analysis of the quantitative data collected from the closed questions of the questionnaire, including basic descriptive statistics and the chi-square test of statistical significance. SPSS and Microsoft Excel were also used to present any graphs that illustrated the data.

4.8. Reporting Findings

A common concern, particularly from a positivist perspective, when collecting data using qualitative methods is the lack of rigour, comprehensiveness and credibility when reporting the findings. With this in mind, I actively used the Consolidated Criteria for Reporting Qualitative Research (COREQ) (Tong et al., 2007). COREQ is a 32-item checklist that was developed for explicit and comprehensive reporting of qualitative studies. The checklist covers three domains:

- Domain 1: Research team and reflexivity

This domain highlights the personal characteristics of the research team, and the relationship with participants. Items include naming the author who conducted the qualitative research, their credentials and training (section 1.4).

- Domain 2: Study design

This domain refers to the theoretical framework (Chapter 3), participant selection (section 4.6.1), setting (section 4.4.3.) and data collection (section 4.5). Items included are: the methodological theory (section 4.3), the sample size (section 4.6.2) and method of approach to sampling (section 4.5), the setting of the data collection (section 4.4.3), and stating whether the research used audio or visual recordings (section 4.5.2).

- Domain 3: Analysis and findings

Domain 3 included items related to data analysis (section 4.7) and reporting which include: how many people coded the data, the derivation of themes, the software

used, the inclusion of participant quotations, and the consistency between data and findings (Chapters 5-7).

4.9. Advisory Group Input

A goal from the start of this research was to involve the public alongside medical professionals in the health board in an advisory group. The National Institute for Health and Care Research (2024) defines public involvement in health research as "research being carried out 'with' or by members of the public rather than 'to', 'about' or 'for' them. It is an active partnership between patients, carers and members of the public with researchers that influences and shapes research." Russell et al. (2020) argue that the majority of studies of the impact of public involvement in health research have focused on its impact on the research process, and on the utility and quality of the research. Public involvement is therefore conceptualised through a consequentialist or benefits-based lens as it is a means to an end of achieving better research. Thus, this concept is appealing to researchers. However, this conceptualisation does not do justice to other conceptualisations of public involvement. An alternative conceptualisation is the democratic approach which is concerned with people having more say in agencies, organisations, and institutions which impact upon them and being able to exert more control over their own lives (Beresford, 2002). This approach shifts the attention from the research output to the patients and wider community. It is important to recognise that involving the public in health services research has benefits for both the research and the people involved.

My supervisors and I recruited two public volunteers through the Involving People Network at HCRW. The advisory group also comprised of multiple healthcare professionals at the hospital including the key contact and Chief Investigator at the health board, the Chief Nursing Information Officer who assisted in the observations set-up, and consultants who had an interest in patient flow and the new technology. A particular challenge in including healthcare professionals in the advisory group was finding a convenient time to meet due to low availability because of the nature of their roles in the hospitals. However, meetings were scheduled with plenty of time in advance, and non-attendees of the meetings were fully debriefed via email. The advisory group informed the research by helping to shape participant-facing

materials, give their own insight to the results and conclusions made, and assist in identifying future research opportunities that arise.

In our first meeting in October 2021 the advisory group was introduced to CareFlow and the findings from the review of the literature. They were familiarised with the research questions, proposed methodology, and the role of the advisory group. The advisory group guided me through the layout of the hospital wards and the way that they work. They also voiced concerns about the technology taking away clinical judgement and causing overreliance.

Before applying for research sponsorship at Cardiff University, the research materials were sent to the public volunteers for feedback. This was a helpful process as although one volunteer reported back that the materials were thorough, comprehensive, and easy to understand, there were comments about wording that I had not previously considered. The materials had feedback from a mix of backgrounds that enabled the wording to be accessible to both medical professionals and laypeople (i.e. likely patients) to be reviewed before the pilot phase. This gave me an opportunity to review and improve the materials before sending them for sponsorship review.

After applying for ethical approval through the IRAS process, the advisory group met in March 2022 to discuss the practicalities of conducting the research at South Fields Hospital and Castle Plains Hospital. At this meeting the current state of Covid-19 restrictions were discussed, alongside the ways in which doing research inside the hospital could be more effective. It was rationalised that it would be easy to blend in on the wards due to a high turnover of staff, and wearing a health board badge would make me identifiable. I was also made aware about practical aspects of being on a hospital ward that I needed to prepare for, such as the smells and noises related to being in the hospital.

In February 2023 the group met again to discuss preliminary findings. The advisory group gave their own insights to the findings including voicing their own concerns about doctors not seeing patients in person, whether staff are still receiving training on paper forms, and conflicting findings relating to accountability being improved when CareFlow accounts are being shared in practice.

Just before the end of the data collection period in July 2023 the advisory group met to discuss the findings of the research. The meeting date was set before the official end of the data collection due to the approaching summer break which is a notoriously

busy time for working professionals, the public and their families because of school closures. The findings were presented as the chapters in the thesis are laid out starting with the use of the iPads, the preference for using the iPads compared to pen and paper, and the benefits and disadvantages of using the iPads. Through this process, the group voiced their own opinions and thoughts on the data presented which gave me insights I had not initially realised due to my own perspective being that of a researcher rather than a healthcare professional or layperson. This process therefore helped inform and shape this thesis highlighting the benefit of using PPI in healthcare research.

4.10. Ethics

4.10.1. Ethical Considerations

This study was designed so it would not impose any potential discomfort or distress on the participants involved. Being involved had an element of inconvenience for some participants as being a case study site will incur some time taken to be interviewed and observed by the researcher. Participants were in highly demanding roles, so every effort was made to lessen the demand by coming to the study sites and arranging interviews and observations at a date and time to suit the study participants, even if this required to be outside of my usual working hours to minimise any disruption for the participants.

Participants were not asked any questions of a sensitive nature and questions did not seek any disclosures of personal issues. Participants may have felt reluctant to discuss any barriers that they felt in carrying out their role, or any issues within the dynamics of their team. However, participants were reminded that participation in the interviews was voluntary, confidential, and anonymous. Pseudonyms are used throughout the findings to ensure that participants cannot be identified, along with the hospitals and the health board that they work for. Participants also had the option to decline to answer any questions and could withdraw at any time without reason.

A mobile phone was acquired for the purpose of this study so that potential participants could call me on my non-personal phone.

The study did not involve patients. However, I required access to patient rooms or bedsides to observe the way that the devices were used in practice. Patients were briefed by the nurse who was being observed. They were also given an information sheet (Appendix 6) to read in their own time so they could make a decision about whether they were comfortable about having the researcher approach their room or bedside. Only patients with the capacity to understand and agree or disagree to my presence at their bedside, as was determined by the nurse, were approached. No personal data relating to patients and their health or treatment were recorded or taken outside of the health board. I fully understood that I had a duty to keep all personal disclosed information confidential (Beyleveld, 2011). Furthermore, I held the necessary approvals from the health board to be present during staff-patient interactions.

4.10.1.1. Consent

Informed consent is an important aspect of research which protects both the participant from abuse and harm, while also emphasising the rights of the individual, and the research team from legal consequences (Árnason et al., 2011). Consent was taken at the beginning of observations and interviews, after potential participants had been familiarised with the PIS of both (Appendix 4 and Appendix 8) provided prior to the commencement of the method. The consent form for the observations can be located in Appendix 5, and the consent form for the interviews can be located in Appendix 12. Welsh translations of these were available.

Before any potential participant of the survey were able to answer any questions, they were required to read an information page about the study and then tick a consent box before continuing to the questions which can be seen in Appendix 9. Questions were not mandatory to complete. Responses to the questionnaire were anonymous so once the participant has submitted their answers, they were not able to withdraw from the study and this was made explicit on the information page.

4.10.2. Ethical Approval Process

Due to the presence of patients during the observation phase and the exposure to identifiable, sensitive patient data, an ethics review was sought through an NHS Research Ethics Committee (REC) (via the Proportionate Review system) via the IRAS process. IRAS is a single online system that allows researchers to seek permissions and approvals for health and social care/community care research in the UK. Before this submission, sponsorship from Cardiff University was sought as part of the ethical approval process. Although this process can be time-consuming, the IRAS process was ultimately useful as all the data collection tools were prepared thoroughly in advance and I felt prepared to undertake the research in the hospital setting. After the submission of the IRAS ethics review, it was deemed appropriate that the study would require a Full REC Meeting. The reasoning for this was:

> *"Participants are vulnerable at the time they are approached. Patients will be observed on hospital wards and in their private rooms whilst clinical procedures are undertaken by staff."*

A person is deemed vulnerable if they are susceptible to being harmed, wronged, exploited, mistreated, discriminated against, or taken advantage of in the context of healthcare and research (Ganguli-Mitra and Biller-Andorno, 2011). Although, the patients are not the focus of this study, they were in a vulnerable position when I was present to observe the staff members using the mobile devices. Therefore, it was vital that they were protected from any of these listed susceptibilities. The Full REC Meeting was conducted on 11th April 2022. Both the first supervisor and I were in attendance via Zoom. At the meeting there were 15 others in attendance including the ethics panel and observers. Key questions that were asked were:

- Why was it decided that patients do not need to sign a consent form?
- What exactly will you be observing at the bedside?
- Will you be using video as stated in the interview PIS?
- Will you be using an external transcription service for interview recordings?

I explained that patients did not need to sign a consent form as they were not the focus of the study, although they could ask that I do not observe at their bedside. When I was observing at the bedside, I was solely focusing on the way that the devices were used to input patient observations. I would not be making field notes

about the patient, what is said or anything about their medical condition or treatment. The reference to video recording was a mistake as there was no video recording taking place during any stage of the study. At the time of the meeting, I was intending to use an external Cardiff University approved transcription service for interview recordings. However, this decision changed after ethical approval, and I transcribed the recordings myself which facilitated immersion in the data and enabled me to identify patterns at an earlier stage than had I outsourced this transcription task. A favourable opinion was given on the 21st April 2022. Conditions for Health Research Authority (HRA) to start the study were:

- Amend the interviews PIS (Appendix 8) to make clear that an external transcription service was going to be sourced.
- Amend the consent form for interviews (Appendix 12) to remove reference to video.
- Add a short title and date to the information leaflet.

HRA and HCRW approval was given on the 25th April 2022 to start the study at participating NHS organisations. I was also granted a Letter of Access from the health board to allow access to wards and clinical areas. The health board confirmed capacity and capability to carry out the study on the 10th August 2022 and I was given the 'green light' to start the study on the 19th August 2022. From the date of the creation of the IRAS form, the ethical process up to the green light was 16 months. From the submission for university sponsorship, the process was 9 months. Each stage of the process is summarised in Figure 12.

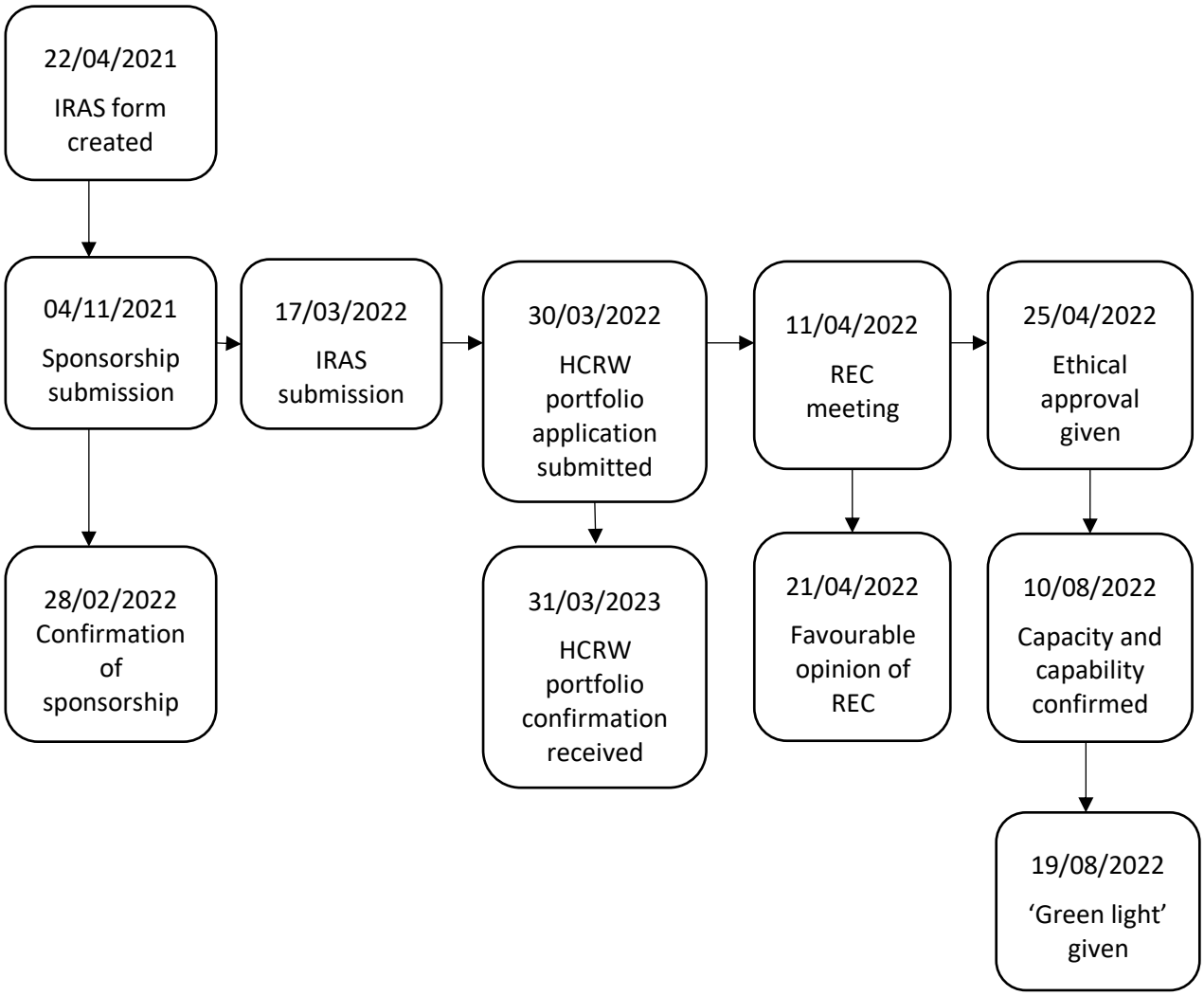

Figure 12 The NHS Ethical Procedure.

4.11. Conclusion

To recap, this is a mixed-methods study with case study and survey designs. There are two hospitals within one health board that formed the case study sites. Methods at the case study sites involved observation and interviews. There were four participant groups: the recorders, the clinical decision makers, the ward organisation decision makers, and the hospital decision makers. Qualitative data were analysed using NVivo software, and the quantitative data were analysed using SPSS. In the next chapter the results will be presented, including the benefits and disadvantages of the iPads with CareFlow Vitals from the perspectives of the people using them.

Chapter 5. The Use of iPads with CareFlow Vitals in Clinical Practice

5.1. Overview

This chapter explores the use of the devices and CareFlow Vitals in clinical practice. The findings reported in this chapter seek to address research questions: 1) How were the mobile devices equipped with CareFlow Vitals implemented in the hospitals in Wales?, 1a) How did the users of the mobile devices perceive the introduction of the technology into the hospitals?, 2) How are mobile devices used to record patient observations?, 2a) Who is using the devices on the hospital ward?, 2b) What processes are being followed when recording patient observations on the mobile devices?, 4) How have mobile devices used to record patient observations at the bedside impacted clinical decision making?, and 4a) At what stage(s) of care planning have mobile devices supported decision making? i.e., immediately, medium/long term.

Firstly, I explore how the devices were initially implemented in practice and the general perceptions of them by the people using them. I then describe the actual use of the iPads and CareFlow Vitals including what they are being used for, where they were being used in the clinical setting, when they were being used, and how the healthcare professionals in the study were using them. I also report on reasons given for why they were being used. The chapter ends with a report of how having the mobile technology in the hospitals affects patient care management before briefly examining how the Covid-19 pandemic affected the use.

5.2. Implementation

The iPads and CareFlow Vitals were firstly introduced to Castle Plains Hospital and another hospital within the health board (Blossom Valley Hospital) as a pilot study. They were introduced to South Fields Hospital in 2020. Therefore, staff had a varied

experience of the implementation of the devices as some were part of this pilot whereas others were not. Typically, ward staff were not involved in the decision making of how they were introduced to the new technology. It was not uncommon for staff to be dubious about the introduction of the iPads and CareFlow Vitals software and were concerned about moving away from the use of pen and paper in their clinical practice. However, training typically accompanied the implementation and staff were assisted to use the devices by other health professionals. Ward manager Caroline explains her experience of the introduction to the mobile technology:

> *"So I was previously working in Blossom Valley Hospital, and so I think they were one of the first hospitals to have them. Um, so yeah, we were sort of just given them to be honest and, you know, given training obviously before we started using them, I think everyone was a little bit dubious to start with because obviously they were a bit scared about getting away from paper. […] Well, I wasn't involved in, you know, rolling it out. We were just obviously given the training and started using them from there." (Caroline, ward manager, South Fields Hospital, interview)*

The survey responses substantiate Caroline's point about the training provided. Table 10 illustrates that the majority of participants received training on both inputting the patient observations into the CareFlow Vitals software on the iPads, and how to use that information to make clinical decisions.

Table 10 The number of participants who received training on how to input information and make clinical decisions on the iPads and CareFlow Vitals.

Training on using the iPads and CareFlow Vitals	**% Yes (n)**	**% No (n)**	**Total n**
To input information	91.2 (83)	8.8 (8)	**91**
To use the information in clinical decisions	80.4 (78)	19.6 (19)	**97**

Figure 13 illustrates that on a scale of 1-10, most participants felt prepared to input information into the iPads and CareFlow Vitals and make clinical decisions using that

information on their first shift (74.8% and 60.7% scoring ≥7, respectively), although a small number of participants still felt a degree of unpreparedness.

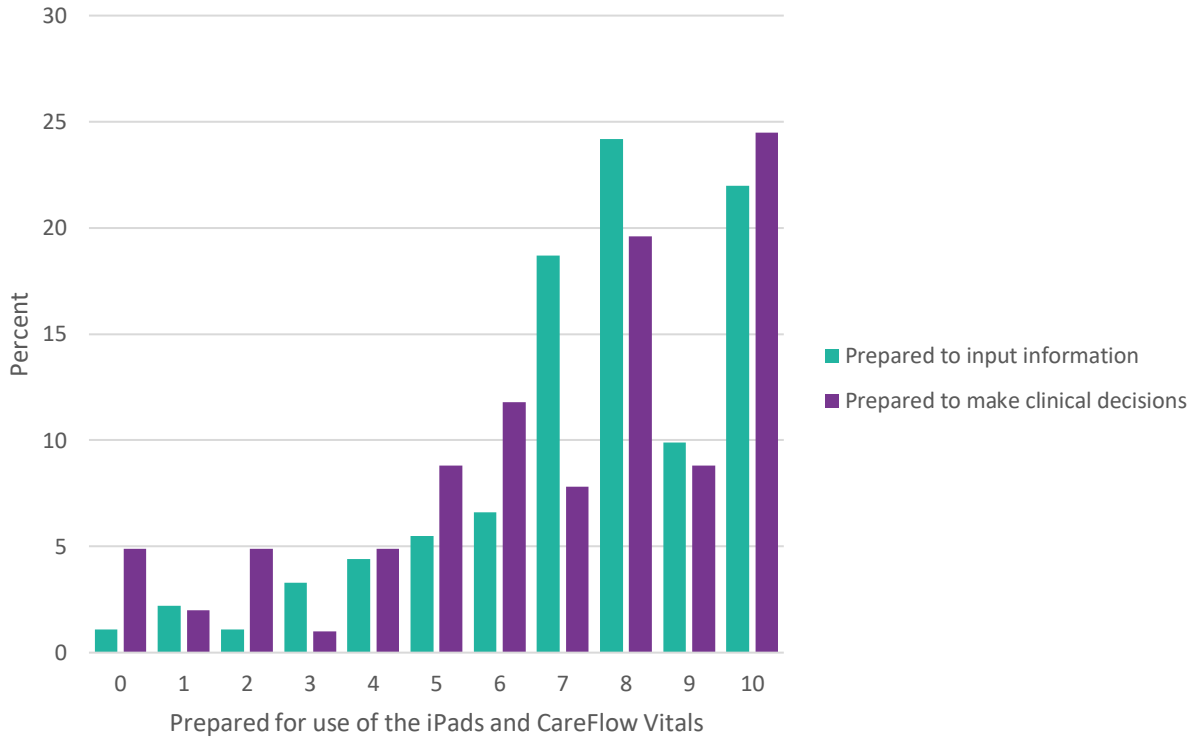

Figure 13 The distribution of responses on a scale of 1-10 of how prepared participants were to input information and make clinical decisions on their first shift with the iPads and CareFlow Vitals.

Participants explained that they felt prepared because of this training. It was quite extensive (two weeks) and was supported by shadowing in the workplace. HCSW Mandy explained:

> *"When I started here as a healthcare [support worker], what they started doing was they gave you two weeks training and you did everything. So we did the iPads and everything, what to do. And then when we came onto the ward then we just shadowed some of the other healthcares, and then we had to go with them watching us to make sure we did it correctly." (Mandy, HCSW, South Fields Hospital, Ward 2, interview)*

However, there were concerns that training was not effective as it was provided too early, and therefore participants were not sure whether they knew how to use the devices and CareFlow Vitals to their full potential.

> *"Training was provided before the system was in use, so it was difficult to actually see how it would work in practice. It therefore took a lot longer to work out how to use them and I still don't know if I am using them to their fullest." (P73, physiotherapist, survey)*

There was also a general sense of anxiety around starting to use the devices as Caroline (ward manager) intimated in her comment above. In addition to anxiety about moving away from paper-based records, it was not known what the reception would be from patients and their families, which the health board tried to negate with informational posters.

> *"I think there was a nervousness that if everyone thought that they'd be […] accused of fiddling on their phones. […] When we went into Castle Plains Hospital and as we expanded across the sites we kind of put warning signs in the lift that, just because nurses and healthcare professionals are fiddling with phones, what look on the ward like phones, they are actually there for healthcare." (Theo, hospital organisational decision maker, interview)*

Although there was this initial reported unease around introducing mobile technology to the hospital sites due to their likeness to personal devices, after time it became part of the accepted practice throughout the health board and patients and families seemingly accept their place in healthcare.

> *"I mean, you know, we were worried that there'd be a kickback from patients and relatives saying look they're fiddling and not doing healthcare. But actually, I think it's now become recognised as part of the bread and butter of how we do it so." (Theo, hospital organisational decision maker, interview)*

This section highlights how implementation took place over a few years as it started as a pilot study at Castle Plains Hospital and Blossom Valley Hospital before being

more widely adopted throughout the other hospital sites in the health board. By the time that South Fields Hospital opened, many staff had become familiar with the iPads and CareFlow Vitals through training and observing others. Most participants had received training which had helped to prepare them in the use of the technology which was becoming increasingly embedded into their routine clinical practice. Although some concerns were expressed about how hospital staff, patients and families would react towards the new technology on the wards, it seems to have become an accepted aspect of modern healthcare.

5.3. The Use of the iPads

This section reports on how the devices were used in practice by healthcare professionals in their patient care. At the time of the survey, of those responding, 88.6% (n=93) used CareFlow Vitals in their clinical practice to record patient observations.

5.3.1. What the Devices are Used For

The iPads are installed with both CareFlow Vitals and WNCR (Welsh Nursing Care Record). WNCR is also available on computers where I observed it being used most frequently. The iPads were predominantly used to access CareFlow Vitals and input the patients' vital signs. During my observations, I only witnessed HCSWs and staff nurses recording the vital signs of their patients using CareFlow Vitals. The interface to the CareFlow Vitals software includes multiple views of the patient list. The staff member using the software can choose which view to use based on their own personal preference. Different views include viewing the patients from high-low EWS, the time to the next observation, alphabetical order and in bed number order. When a patient is selected the member of staff has access to multiple screens containing different vital signs, therefore they do not have to follow a pre-set order when conducting their patient observations. As mentioned in Chapter 1, CareFlow Vitals calculates the EWS immediately which gives the healthcare professional an instant measurement of the clinical risk of the patient. Carly mentioned that this is especially

good for new starters as they don't need to feel confident in their ability to calculate the EWS manually as the device does this for them.

The data from CareFlow Vitals is also used for assisting with making clinical decisions, and 91.3% of the participants reported that they used the software for this purpose. For example, if a patient receives a high EWS, the member of staff is then asked, "does the patient have signs/symptoms of infection?" This then makes the clinician think about sepsis. During one of my observations with Rebecca (HCSW), I saw this screen when a patient scored a 3 on their respiratory rate which was significantly higher from their previous observations. However, Rebecca was not worried about sepsis due to other vital signs remaining normal but used this prompt to report to the nurse to make that clinical decision. It is possible that the respiratory rate was increased due to Rebecca making it known to me that she was counting breaths, and the patient became aware of this and increased their breathing as the respiratory rate returned back to normal after the vital signs were collected.

5.3.2. Where the Devices are Used

During my time on the wards, I observed the use of the iPads with CareFlow Vitals in a range of settings including single-bed rooms, multi-bed rooms, inpatient medical, surgical, and rehab wards, and assessment units with triage facilities. From these observations I did not record a difference in the way the iPad was used in different settings. It was only possible to record one patient's observations at a time regardless of the setting. Often in a multi-bed ward a curtain would be pulled around the patient's bed to ensure privacy. Carly confirmed that the process does not change when inputting the observations in rooms with differing layout:

> *"Researcher: Does the process change depending on if a patient is in a single bed room or in the multi-bed room?*
>
> *Carly: No. All the same." (Carly, HCSW, South Fields Hospital, Ward 4, interview)*

I was assured by Mandy that this was the same on the assessment unit at South Fields Hospital.

> *"No. No, no. They're the same. It's the same on here on [the assessment unit]." (Mandy, HCSW, South Fields Hospital, Ward 2, interview)*

Both South Fields Hospital and Castle Plains Hospital had an assessment unit. The difference of the assessment unit compared to other wards in the hospital is that there is a triage system so patients who present themselves at the unit have their observations initially done before being allocated to a seat or a bed. This process entails the collection of additional information as Jane explained:

> *"Triage is probably the one that's slightly different because then we've triaged this information that's gathered as a one-time thing when they come in as standard. So, when we triage somebody, we get their height and their weight as well, which is not part of the standard observations. And we'll get their BM [capillary blood glucose test] so that glucose is measured, whether they are diabetes, it's diabetes or not so it's just a standard thing that everybody will get when they come in. After that, we would only monitor glucose if diabetes was present." (Jane, HCSW, South Fields Hospital, Ward 2, interview)*

As part of this research, I sought to identify whether having the CareFlow Vitals software on the iPad would influence the user to follow a certain order when doing their rounds. I regularly recorded in my field notes that users would record the observations one patient at a time, as it was not possible to do it another way. This is because observations needed to be submitted together to be saved to the system and staff could not switch between patients when the observations had been started on the system. In most cases, during observational rounds, the user of the device was not influenced by the EWS scores reported via the software (e.g., doing observations in order of high to low EWS) and followed the order of the beds on the ward. As Jane testified:

> *"I can do observations in any order I choose" (Jane, HCSW, South Fields Hospital, Ward 2, interview)*

Mandy explained that she preferred to conduct her observations in the order of the beds on the ward as it reassured her that she had visited all of her allocated patients as she was often diverted into different rooms.

> *"I do, yeah. We tend to do, we have […] 50 to 57. So I always start off at 50 and work my way around. And if I'm 59 to 64, I'll do, I'll just do those, and then just do them in sequence I do. […] You know you've been into them because if you're in and out and going to different people all the time…." (Mandy, HCSW, South Fields Hospital, Ward 2, interview)*

Although Todd usually followed a set bed order, he did also check CareFlow Vitals before starting his observations to identify whether any of his patients were due their observations before any others based on their EWS. He did this because there was always a possibility in the busy hospital environment that he could be interrupted during his rounds, and the patients' needs were at the forefront of his approach to managing the care. Because of this, he undertook the observations of the patients who were due them first to ensure they were within the time prescribed by the EWS. He also modified his approach if the patient was sleeping:

> *"I'll just work my way up and back down the other side. If someone's due closer I'll probably start with them if they're due now in about an hour but my other person isn't due for six hours I'll probably go to the hour one first just to make sure they are done just in case something crops up in the meantime […] If someone is asleep I won't bother with them, if they are due or coming up too I'll wake them, I'll do them. Yeah, it does affect it a little." (Todd, HCSW, South Fields Hospital, Ward 3, interview)*

Ben similarly used the CareFlow Vitals software to determine in which order he would conduct his observations with his patients, but not necessarily when he was doing his rounds. Due to the busy nature of the hospital he would keep close attention to the EWS and when the software indicated that the observations were due. If he had a moment of available time, he would then conduct the observations of patients who were due next. However, if the patients were occupied he would give them a choice to have their observations done now or later.

> *"I was always trying to sort of keep an eye on that early warning score and what the recommendation would be. Whether it was like six, eight, 12 hours and I literally knew it was coming up in the next sort of couple of hours. […] But, if you were free, literally just popping your head in that room and saying, 'do you know what, your obs might be due in two hours, do you mind if I do them now?', kind of thing. […] If they were free because yeah, sometimes it gets busy so and there's people in and out of rooms. Yeah, it would depend on what was going on, obviously, […] like visitors coming in as well. I would say if they want to spend some time with their family or whatever privately, then, you know, you sort of work around that as well." (Ben, HCSW, South Fields Hospital, interview)*

Jane also explained that her order may be affected by the circumstances of the patient as they may not be in their bed when she arrives to do her observations. They may be in a different part of the hospital to receive some other medical treatment or test, or outside of the hospital having a cigarette or perhaps talking on their personal phone.

> *"Sometimes if a patient has gone down for a scan or if they've left to, I don't know, maybe to have a cigarette or something, then it will affect the order of when I'm doing people, because you know I have to come back when they're back, so sometimes they they'll have theirs a little late. But that's based on that personal situation." (Jane, HCSW, South Fields Hospital, Ward 2, interview)*

This section has illustrated that the iPads and CareFlow Vitals product can be used differently to adapt to the nuances of different wards and the preferences of the staff inputting observation data. Most of the healthcare professionals followed the bed order when doing their ward rounds, some did their observations based on the EWS to ensure they were not conducted late, some participants mentioned letting their patients sleep unless their observations were due imminently, and others seemingly let the patient decide when they were ready to have their observations done.

Accommodations also had to be made for workplace demands and patients being away from their beds for medical or personal reasons. In terms of how this is different from before device implementation, it is clear that some participants were using the software to guide them to do their observations to the protocol of the hospitals based on the EWS. This is not a function that was available on the previous paper-based forms.

5.3.3. Why Observations are Conducted

Before the implementation of WNCR, the iPads were only used to record the vital signs of patients using CareFlow Vitals. Therefore, the sole reason to use the iPads and CareFlow Vitals was to conduct patient observations. This section will explore the reasons why a patient may need their vital signs collected according to hospital protocol. During my observations at both South Fields Hospital and Castle Plains Hospital, I recorded multiple different instances in which observations of vital signs needed to be conducted including routine ward rounds, patient falls, and the post-operative patients.

> *"I observe Nicola who is using the iPad to do ward round of patient obs." (South Fields Hospital, Ward 2, field notes)*
>
> *"Sally is doing obs for a patient who requires hourly monitoring as they have a high EWS." (South Fields, Hospital, Ward 1, field notes)*
>
> *"The devices are used when patients come in for triage as a full set of vital signs need to be collected as part of the assessment." (South Fields Hospital, Ward 2, field notes)*
>
> *"Fiona is doing obs on the same patient as before who came out of theatre. They are done as before directly into the device. After an operation the patient has obs due every 30 minutes for two hours, and every hour thereafter." (South Fields Hospital, Ward 4, field notes)*

> *"A patient fell and bumped his head. Obs have to be done again earlier than NEWS says they should be done due to hospital protocol after falls. Obs are inputted directly into the iPad by Lucy." (South Fields Hospital, Ward 1, field notes)*

> *"I observed Edna (HCSW) doing obs on a patient scoring a four to see if paracetamol has helped lower the score. Patient was still scoring a four but vital signs were slowly looking better so Edna concluded that the paracetamol had started working." (Castle Plains Hospital, Ward 1, field notes)*

Little difference was noted between the use of the iPads in the clinical setting compared to the paper-based forms in patient files. No comparison was noted in the field notes.

The main difference is the automation of the EWS score and the prompts to staff that observations are due. Nevertheless, sometimes the healthcare professionals conducted their observations outside of these CareFlow Vitals-dictated times. This could be because a patient is deteriorating, or staff have concern about their condition.

During the period of time I was observing practice at South Fields Hospital, WNCR was implemented and installed onto the iPads as well as laptops and the computers at the nurses' stations throughout the hospital. Daniel explained to me that he preferred using the iPads for WNCR as doctors were often using the laptops.

> *"I observed Daniel (HCSW) doing a ward round at 10:50am. He told me that 'they [hospital managers] gave us laptops but doctors tend to use them so I like to flick through with the iPad' [when uploading notes to WCNR after collecting vital signs of patients]." (South Fields Hospital, Ward 4, field notes)*

In this way, the iPads are facilitating the engagement with patient data even when other methods of viewing the data are in use. Daniel is able to use the iPads in this way to support the care of his patients. Further, the iPads have also been useful as a point of reference when transcribing vital signs from CareFlow Vitals to WNCR on the computer.

> *"Lisa then uses the computer to write up the patient notes to WNCR using tablet for reference." (South Fields Hospital, Ward 5, field notes)*

> *"Sadie now puts notes from obs into WNCR on the computer using iPad for reference." (South Fields Hospital, Ward 5, field notes)*

However, WNCR and CareFlow Vitals are not interconnected, and Isla explained to me that this creates more work as the staff have to input notes into both systems, and this might be at different times. It could be suggested that the CareFlow Vitals software is better for recording patient observations than transcribing to WNCR as the time of recording will be more accurate.

> *"What would be good is if CareFlow and WNCR were connected […] when you write the notes in WNCR it's a different time to when you actually did it." (South Fields Hospital, Ward 4, field notes)*

Not every healthcare professional had access to WNCR and I observed one member of staff ask another to input notes to the system when they could not.

> *"Physiotherapist asks student nurse to record that a patient passed a small amount of urine on WNCR as she does not have access to it." (South Fields Hospital, Ward 4, field notes)*

Some staff do not have access to the iPad itself and so will ask members of staff who do to view the patients and their vital signs using their login. This shows that the iPads and CareFlow Vitals software can facilitate engagement between different professional groups. However, it is discussed in Chapter 7 that some members of staff reported that not everyone having access to the iPads was a disadvantage.

> *"They come and ask us. Well, they can't get on them [the iPads], half of them. […]and they always say, 'oh can you?'. They usually ask, 'can you get on the iPad?' I just say 'yes', they'd say' oh can you get up so-and-so's obs and stuff like that for me'. So yeah, it's good." (Mandy, HCSW, South Fields Hospital, Ward 2, interview)*

To summarise, the iPads and CareFlow Vitals product is used in different situations where the patients' vital signs need to be collected such as ward rounds or patient falls. WNCR can also be used in South Fields Hospital to record patient notes using the iPads. There are also reports that not all members of staff have access to the iPads, CareFlow Vitals, and WNCR which makes the transition away from paper-based forms more difficult as there is not a consensus on which system to use. Importantly, the CareFlow Vitals software is only used to record patient vital signs and calculate the EWS so is only used for this purpose. At South Fields Hospital, where WNCR is in use, the iPads can also be used to record patient notes. It is noteworthy however that WNCR can also lead to a repeated inputting of the data which would be an unnecessary task if the two systems could be linked in some way to read data from one to another.

5.3.4. When the Devices are Used

When I first started my observations I thought that the devices would be used often throughout the day. I was struck initially by how little they were actually used, especially before the implementation of WNCR. This is also a reflection on how often patient observations are made as using the device does not seem to have an impact on the frequency of this. Jane explained to me how often they are used in the assessment unit of South Fields Hospital:

> *"We have standard observations, which are every four hours which everybody will get regardless of how well they seem. But if people have more specific needs so they are a bit more unwell generally, they can come down to as little as every half an hour and maybe even more. Sometimes we leave the monitor in their room. So, for example, if people have had surgery post-op for the first two hours, they have their obs taken […] every half an hour for two hours. Then it drops to two hours, then it drops to four hours as long as everything's progressing as it should. But again, you know, at any given time, a patient's observation could be what we call scoring. And if they start to score, which means*

> *their results are not how we'd like them to be, then we just do the observations more regularly and we can repeat them at any time if the nurse isn't happy with those results." (Jane, HCSW, South Fields Hospital, Ward 2, interview)*

In most of the wards that I observed, observations were conducted at about 6am, and then again around 10am, 2pm, 6pm, and 10pm. During night shift patient observations were only taken when the EWS dictates to ensure that patients are only interrupted from their sleep when necessary. Necessary interruptions to sleep could include when a patient has had a fall or needs to be monitored after taking a medication to improve their condition (e.g., paracetamol to reduce a temperature). This highlights examples of where staff are utilising their clinical judgement, not blindly following the CareFlow Vitals timescales. Mandy explained in more detail what is meant by scoring and how they can use medication to lower the EWS of their patients.

> *"Well they like us to do them ten, two and six on the wards. […] We do everybody's like that. But when we do someone's obs, if they score over a three it'll tell you on the iPad, this patient is scoring a three, you need to do their observations in like two hours or something like that. Or if we got someone that has like a high temperature or something, obviously we know ourselves that once our patient's had some paracetamol or something, that the nurse just say to us then that you need to go and can you do their temperature again, see if the paracetamol has worked." (Mandy, HCSW, South Fields Hospital, Ward 2, interview)*

In this example, Mandy indicates how the iPads and CareFlow Vitals are potentially influencing practice in a way that was not available before implementation as healthcare staff are immediately notified of when a patient is "scoring" by the device, and the benefits of being able to bring the score down with medication theoretically a bit quicker.

The exception to the timed observations every four hours (at approximately 6am, 10am, 2pm, 6pm and 10pm) was on Ward 4 in South Fields Hospital. Carly explained

to me that the healthcare professionals monitoring the patient observations on the day shift are only expected to do so at 10am unless the EWS dictates otherwise. The staff on the night shift were then expected to do a ward round at 8pm and 6am.

> *"So we do them at 10 o'clock in the morning and then the night shift then will do them when they come in at eight and they will, they'll do them again at six then. But if they're scoring, we'll do them as and when they say. That is always on the iPad." (Carly, HCSW, South Fields Hospital, Ward 4, interview)*

Carly also stated that doctors had the ability to change the time to the next observation if they wanted their patient to be monitored more or less than the EWS dictated which would be reflected on CareFlow Vitals. This provides an illustration of a team based in different places, working together to provide the most appropriate care to their patients. However, as HCSWs were unable to change the timing of the observations on the software a hierarchy within the team is suggested.

> *"Obviously if they're scoring then through the day it'll prompt, or if the doctors want them done like every four hours they will put it on the iPad so then every four hours it'll come up red so that we know then that we've got to do them." (Carly, HCSW, South Fields Hospital, Ward 4, interview)*

Above, Carly states that "every four hours it'll come up red". This refers to the CareFlow Vitals system having the setting to colour code when observations are due. This is a feature that is not possible to have with the paper-based method of data entry which highlights a value for digitisation of healthcare settings. Todd told me that first the patient will be colour-coded if the observations are due, and then will become red when they are overdue. The ward sister is able to display the overview of observations on a screen on the wall in their office for the ward staff to see. Further, the outreach team are also able to view these patients and contact the staff on the ward to do their observations.

> *So I'll do them about three o'clockish, if they're not due anyway, because on the side it will tell you that they're due, they go yellow first, then red. So there is a warning sign. I think if they go red, if you go into the sister's*

> *office there on the wall, so you see the chart there and they go red, they go elsewhere then to like higher up and that, outreach and stuff like that and they would go flashing to them like they're overdue. You sort of get a little telling off that you haven't done this persons' in enough time, but they were more for the people who were regular, like I leave it if a patient's not, you know due just once today and you haven't done them. But yeah, I usually go by the times anyway on the side. (Todd, HCSW, South Fields Hospital, Ward 3, interview)*

To summarise, the iPads and CareFlow Vitals are not in use very often throughout the hospital wards as they are only used to record patient observations that are usually collected either during ward rounds or because the EWS has dictated. There may be other occasions when they have to be used such as for a new admittance to the ward, a post-operative patient, or a patient fall. There are potential benefits to using the iPads and allocated software such as a visual colour-coded prompt to conduct a patient's observations, and an immediate notification of the patient's EWS and this is discussed more in Chapter 7.

5.3.5. How Observations are Recorded

On my very first observation at Ward 1 in South Fields Hospital I wrote the field note:

> "*Observations were entered directly into the device"*
> *(South Fields Hospital, Ward 1, field notes)*

For the majority of the interactions that I had with participants on the wards that I observed, this was the case. The healthcare professional would pick up the iPad and carry it to the patient's bedside alongside the medical equipment needed to monitor the patients. The staff member would then ask the patient to confirm their name as they scrolled on their patient list to find that name. They would then place the equipment (blood pressure cuff, heart rate monitor etc.) on the patient and transcribe the results into the iPad as they happened. When all of the observations were completed, they could be submitted and the EWS would be calculated. The member of staff would then remove from their pocket a folded A4 piece of paper with a printout

of their patient list and notes and handwrite the EWS and any abnormal or concerning observations next to that patient's name. If the user of the device was very concerned about an aspect of the patient's health, they would report this to the nurse in charge of the patient. This highlights that although the bulk of the task is conducted using the iPads, paper was still being used to make notes that can be put into the staff member's pocket and carried around for the rest of the shift. This was the same at every ward that I observed at both case study hospital sites.

As the iPads were used purely for recording observations before the use of WNCR in South Fields Hospital, paper files were still used at both hospitals. I recorded that healthcare professionals who were not stationed permanently on the wards used the paper files to record their notes.

> *"When doctors/occupational therapists/physios etc. come to visit patients, they take a file, read the notes, go to the patient, write their own notes and put the folder back." (South Fields Hospital, Ward 1, field notes)*

However, this led to some healthcare professionals duplicating their workload, particularly in Castle Plains Hospital where WNCR was not yet implemented. Though, as previously stated, there is still some duplication involved with using WNCR. The participant group 'the recorders' would have to input the vital signs into CareFlow Vitals using the iPad as described earlier, and then have to write those same observations into the patient's paper files that were held at the nurses' station in South Fields Hospital, and the patient's bedside in Castle Plains Hospital.

> *"I observed Moira (HCSW) doing a ward round at 20:05. Moira told me that she has to write up all of the obs into the patients' paper files which 'is repeating yourself but it's how it's done.'" (Castle Plains Hospital, Ward 1, field notes)*

A survey participant spoke about how this was a particular issue in the triage area of the medical assessment unit which is often a space with a high patient turnover and so duplicating work can create longer patient wait times as they wait to see a doctor or nurse. This can create a sense of frustration for patients and healthcare professionals.

> *"I work within the Triage area of Medical Assessment Unit. When triaging a patient sometimes this can be more time consuming trying to input the same data onto the VitalPac as well as our Triage Paperwork. So, we are doubling up on the same work." (P61, HCSW, survey)*

However, having the installation of WNCR at South Fields Hospital did not prevent this problem but rather deferred it to the new system. Instead of transcribing the notes in the patient files directly after inputting the observations into CareFlow Vitals, they are inputted into WNCR using either the iPad or the computer. A survey participant suggested that the different digital systems in use in the health board need to be integrated together to prevent the issue of duplication. That would save time and give the user of these systems more time to do other tasks in their clinical practice.

> *"WNCR and CareFlow and WCP [Welsh Clinical Portal] need to share information to prevent duplication." (P62, ward manager, survey)*

Participants in this study reported that there were occasions that the iPads with CareFlow Vitals were *not* used for recording patient observations, and notes were taken instead on paper. Todd reported that on occasion he would use paper if he could not locate the iPads or they were not connecting to the internet. Rather than wait for an iPad to become available or connect to the system, he felt that it made sense while being with the patient to record the observations on paper and then upload them to the system later.

> *"Generally now, we've gone out and [nurse] said […] 'can you quickly do this lady's observations?'. I was there and I think 'oh I need to quickly write that down' because of waiting, you know, for an iPad to be free to then transfer them […] So sometimes it's not connected. You picked up one and it's not connecting. So you need to go get another one. So you're, you're with the patient at the time. So it's like, I'll go and find it afterwards, but that's the, that's the only time." (Todd, HCSW, South Fields Hospital, Ward 3, interview)*

At Castle Plains Hospital I had a conversation with Isabelle at the computer located in the corridor of the assessment unit, where she explained that sometimes all of the iPads and computers are in use. On one occasion, she reverted to using paper notes because she simply could not wait longer.

> *"She does not like using iPads and computers for documentation. She used an example of when she did a bank shift at South Fields Hospital and she couldn't get on a computer because there was always somebody else using the iPads and computers to document their notes. Eventually it got to midnight and she got out some paper and handwrote her notes by going round each patient one at a time to refresh her memory." (Castle Plains Hospital, Ward 1, field notes)*

In the assessment unit, paper forms can be used when there are a lot of patients coming into triage and the staff do not have time to upload the observations to the iPad and transcribe those notes to the paper file.

> *"Sometimes if patients, if they are coming in quite quickly and we haven't got a receptionist we use paper then because we haven't got time, we haven't had time to upload them onto the iPad. […] So then we have got written sheets and we have got graphs that we fill in." (Mandy, HCSW, South Fields Hospital, Ward 2, interview)*

Another example occurred while I was observing a night shift as a new patient was admitted to the ward from the assessment unit. The patient observations had not yet uploaded to the clinical workstation (CWS) and so the initial observations taken at the point the new patient was admitted to the ward could not be uploaded to CareFlow Vitals. This is because the patient was not on the system yet and so it was not possible to record their observations on the CareFlow Vitals software. Therefore, Ella (HCSW) wrote these observations in note form on paper so that she could later transcribe them into CareFlow Vitals using the iPad.

Overall, the iPads and CareFlow Vitals are most often used to record patient observations by inputting the vital signs directly into the software and immediately calculating the EWS. There are occasions where the iPads are not available for use,

and this leaves the healthcare professionals needing to revert back to using paper-based forms. This can lead to a duplication of work for the ward-based staff which is using time they could be spending tending to their other patient-orientated tasks such as personal care and medication administration. This highlights issues with a dual system which means that the new technology is not able to function seamlessly and results in a loss of benefit for the users in the clinical environment.

5.4. Patient Care Management

Participants spoke about the ways in which the iPads and CareFlow Vitals assisted in their clinical practice. CareFlow Vitals gave the HCSWs a digital view of their allocated patients on the ward. Mandy spoke about how in handover they are given the paper list of all of the patients on the ward. She discussed how this can be a lot of information so she uses the iPad when she first comes onto the ward to understand her patients and their EWS so she can prioritise and plan during her shift.

> *"When you're in handover, they give you the handover for everyone. And then they will say to me or [other HCSW], you're [bed] 60 to 64. […] I like to have a little look on the iPad again […] to see if any of my patients are scoring. I like to know, you know, what's going on with those patients that I'm, that I am responsible for. So it is good like that, you can check because like you think, ooh right, number four, [bed] 51, she's quite poorly, she's scoring a four, so-and-so is scoring a three, the other ones are scoring nothing so they're fine, so I can concentrate on the other ones." (Mandy, HCSW, South Fields Hospital, Ward 2, interview)*

Rose also spoke about how the software enabled her to plan the 12-hour shift on the ward although she was aware that patients can deteriorate (as well as improve) and that the nature of healthcare is unpredictable.

> *"Obviously, if they're not scoring, you know it'll usually say then obs to be redone in 12 hours' time. So you know, you can plan, obviously anything can happen in*

> *that amount of time […] but it will tell you then when it needs to be done next if you haven't got any concerns in the meantime." (Rose, HCSW, South Fields Hospital, Ward 4, interview)*

Having CareFlow Vitals available during patient observations also assisted in immediate care planning. When the EWS was automatically calculated as a five for one patient that Lisa was working with, she was able to make the decision to inform the nurse immediately who could assess the patient without the time taken to manually work out the EWS on paper. Lisa had to inform the nurse verbally as CareFlow Vitals does not send alerts to individual staff members' accounts.

> *"The first patient was scoring a five which was the same from the last obs. Lisa had to report this to the nurse directly. Lisa and the nurse went to assess the patient straight away before moving onto the next patient." (South Fields Hospital, Ward 5, field notes)*

Interestingly, Todd felt that the iPads with CareFlow Vitals assisted in the care planning of the nurses on the ward rather than the HCSWs, especially if they are unable to use a computer because it is already in use, suggesting that Todd was aware of a hierarchy among the healthcare team in the hospital.

> *"Yeah, I think that would be more for the qualified nurses do you know what I mean? […] They've got all the care planning and stuff on there so it'll probably assist them in doing that if they can't get onto the computer." (Todd, HCSW, South Fields Hospital, Ward 3, interview)*

I spoke to a consultant who explained that CareFlow Vitals assisted in his care planning decisions when he was not at the patient's ward by enabling him to see the patient's records, albeit from the computer rather than the iPad. This is because doctors do not have access to the ward-based iPads. They do however have access to the observation data collected and recorded by the staff in those wards. Gerald stated that this was helpful in situations when he only needed to give advice. He would, however, visit a patient if necessary.

> *"So for instance, if I'm, say I'm not on the ward and a colleague contacts me, I can go and have a look at all*

> *of the records myself without necessarily having to go to the patient. […] Clearly, if you need to see the patient, you see the patient. But if it's just for advice and just a recommendation, then it's just so much easier." (Gerald, consultant haematologist, South Fields Hospital, interview)*

Moreover, Ben (HCSW) discussed how having an iPad instantly available on the ward was useful when asking a doctor for help. They could readily be shown the most recently collected patient information via CareFlow Vitals. This indicates that the iPads and CareFlow Vitals software have a usefulness for communication both remotely and in person on the wards.

> *"Sometimes you would have like, you know, literally a doctor on the ward. And, you know, obviously flash up or whatever and you just say, there you go, and show them, show them the iPad and be like, 'can you help us with this?'" (Ben, HCSW, South Fields Hospital, interview)*

The iPads and CareFlow Vitals also facilitated patient care management at ward-level. Caroline spoke about how CareFlow Vitals gives ward managers a view of their whole ward and the patients that are 'NEWSing[7]'. Caroline discussed how this view could guide her towards nurses and patients who may need some extra assistance from her.

> *"I suppose from a nurse in charge [perspective], you can look, you know, look at the whole ward. And see, you know, the patients that are NEWSing. And go to those individual patients, see if the nurses, you know, need any help with those patients." (Caroline, ward manager, South Fields Hospital, interview)*

This view provided by CareFlow Vitals saves time for the ward manager as otherwise they would have to look through the individual file of each of the patients on their ward

[7] A term that the healthcare professionals use in practice to describe patients who have a high EWS and may need more clinical attention.

to know their status. By having this holistic digital view of the patient list, assuming that all observations are on the system rather than paper files, the ward manager can remind their staff to conduct patient observations when they are due.

> *"I'll look then throughout the shift then to see if, you know just to remind staff if, you know, obs are due, and yeah, you can see an overall look of our ward, I suppose from having to go to each individual file to have a look what patients obs are." (Caroline, ward manager, South Fields Hospital, interview)*

Further, Judy explained that the ward manager, as well as doctors, have the ability to amend the patient observations if a patient needs more frequent observations than the EWS suggests. By having the ability to do this in CareFlow Vitals, the healthcare professionals working with the patient can feel more supported that they do not miss these observations.

> *"[Nurse in charge] is able to amend patient observations accordingly dependent upon the care required. For example we have patients on the stroke thrombolysis pathway/ GTN [Glyceryl Trinitrate] protocol, who require more frequent observations. Using the iPad ensures that their observations are not missed." (Judy, ward manager, South Fields Hospital, interview)*

CareFlow Vitals was also useful when patients had been to the hospital previously with low oxygen saturation levels of 89%. It provided that earlier data which then served as a reference point. For most people a normal oxygen level is between 95% and 100% so this level would be concerning. However, 89% can be a normal level for people with certain medical conditions such as COPD. Carly explained this to me using the scenario below.

> *"So if you have a patient that comes back in and you know that their sats[8] is always 89, you haven't got to initially panic because the iPad would have picked that*

[8] Healthcare staff on the wards referred to oxygen saturation levels as sats colloquially,

up before. So when they come back in, it's like 'oh my God, their sats are 89'. 'Oh no, actually, the last time they was in…'. If you look back, the iPad will say." (Carly, HCSW, South Fields Hospital, Ward 4, interview)

In contrast to these findings, a survey respondent spoke about how having the iPads with CareFlow Vitals had not assisted in care planning as they would behave the same in their clinical practice whether they used the iPads or the paper-based forms.

I would react the same way in whatever the results were if observations were done on pen and paper or tablet." (P26, RGN, survey)

Caroline also stated this because if the patient had a high EWS then she would escalate those concerns to the doctor regardless of the medium that she used to record the patient observations.

"You're still going to escalate anything to the doctors really. Yeah, I'd still, you know, I'd still operate the same." (Caroline, ward manager, South Fields Hospital, interview)

This section has shown how staff perceive that the iPads and CareFlow Vitals assist them in their clinical practice by allowing them to use the EWS to plan how to use their time when providing patient care. The devices and software also allow staff at a ward-management level to have a digital view of probably all of the patients (some may not be on the system when first admitted) on the ward, which is more efficient than checking each individual patient file. Further, this digital view allows clinical staff to view their patients' vital signs away from the wards and issue instructions to the ward-based staff to start or amend any treatments without seeing the patient. However, some participants perceived that iPads and CareFlow Vitals had not assisted them in their clinical practice as they are working the same way that they would have with pen and paper.

5.5. Covid-19

Although not one of my research questions, as part of this research I was interested to explore whether Covid-19 affected the use of the iPads and CareFlow Vitals as this was a temperamental time in the healthcare industry, as previously discussed in Chapter 1.

Respondents to the survey were asked whether they perceived that the Covid-19 pandemic affected the use of the devices and CareFlow Vitals; 58.3% of respondents indicated that they were not sure, 37.9% thought there was no change, and 3.9% perceived a change. The respondents who were not sure mostly expanded that this was the case because they were not working at the health board during this time. The four people that did perceive an effect from Covid-19 on the use of the devices included a critical outreach and resuscitation practitioner, an advanced nurse practitioner, a nurse, and an assistant practitioner. One reason given for this was that the acceptable oxygen saturation levels was lowered for some patients due to the nature of the disease but there was no setting to change this on the iPads.

> *"Other acceptable saturation ranges were placed upon patients as per NICE guidance yet there was no setting for this. E.g. >92%" (P1, critical care outreach and resuscitation practitioner, survey)*

Another respondent mentioned that there were not enough devices during this period so there was always paper being used.

> *"Kept separate. Not enough devices, always lots of paper." (P41, registered nurse, survey)*

In summary, only a small number of participants perceived that the Covid-19 pandemic affected the use of the iPads and CareFlow Vitals. Those that did perceive a difference gave reasons which highlights disbenefits such as being unable to lower oxygen saturation ranges due to the nature of the disease, and that they were kept separate because of infection control procedures.

5.6. Conclusion

To conclude, this chapter has explored the use of the iPads and the CareFlow Vitals product in clinical practice. This has included the ways in which the devices and software have assisted in patient care management, though some participants reported not changing their clinical practice since device implementation. It is interesting to note that the devices were not in use constantly as they are only used to record patient observations, although they were being used more often as WNCR is being implemented throughout the health board. However, not all staff members are currently using the iPads and CareFlow Vitals software which reveals something of the difficulty in achieving widespread technology acceptance. These findings also suggest that the technology may be indicating the existence of a hierarchy within the hospital. WNCR will allow the healthcare professionals to record their patient notes digitally and will enable the health board to move towards a paperless environment. However, having dual systems in use has its own issues such as the duplication of work. These findings will be further explored in Chapter 8.

Chapter 6. The Perceived Preference of Using CareFlow Vitals Compared to Paper-Based Forms

6.1. Overview

This chapter explores the staff preferences for using CareFlow Vitals or pen and paper in their clinical practice, and factors that may contribute to this preference. The data here are drawn from the quantitative questions on the survey. The research question that these findings relate to is question three: 3) How did staff respond to the change from pen and paper records to the use of the iPads with CareFlow Vitals?, and 3a) Do the demographic characteristics of the participants affect the preference for iPads and CareFlow Vitals in practice?

In this section I start by exploring how the demographic characteristics of the participants had an influence on the preference in practice before delving into how the characteristics of the devices compare to the traditional paper-based forms. Finally, further insights into training and the benefits and disadvantages of the devices will be gathered for any effect on the preference in practice. In this chapter I will be reporting findings, but not discussing them or exploring potential reasons for them. This discussion will come in Chapter 8.

Overall, as seen in Table 11, CareFlow Vitals was preferred by more of the survey respondents (46.8%) than those preferring pen and paper (37.7%); 15.6% were not sure of their preference.

Table 11 The preference of using CareFlow Vitals compared to pen and paper.

Preferred data-entry method	Percent (n)
Pen and Paper	37.7 (29)
CareFlow Vitals	46.8 (36)
Not Sure	15.6 (12)
Total n	**77**

6.2. Influences on Preference

This section explores whether the expressed preference of the survey respondents for either CareFlow Vitals or paper-based records were related to their demographic characteristics. The demographics explored include personal characteristics, the job-related characteristics, and the organisational characteristics of the case study hospitals.

6.2.1. Personal Characteristics

In this section I examine how personal characteristics of the participants (gender, age, attitude to change) were related to the preference for modes of recording data from patient observations. Table 12 illustrates the distribution of the preference for mode of recording data by gender. It is important to recognise that there was a big disparity in the number of males and females who responded to the survey. There was a slight preference for CareFlow Vitals over pen and paper by both males (50%; 7/14) and females (46.8%; 29/62). Results were non-significant (x^2=1.006, df=2, p=0.605).

Table 12 Preference for mode of recording data from patient observations by gender.

	Preference percent (n)			
Gender	**Pen and Paper**	**CareFlow Vitals**	**Not Sure**	**Total n**
Male	42.9 (6)	50.0 (7)	7.1 (1)	**14**
Female	35.5 (22)	46.8 (29)	17.7 (11)	**62**

Table 13 shows the pattern of responses by age[9]. CareFlow Vitals was preferred by those aged 35-44 (56.5%; 13/23). In contrast, paper-based records were preferred by participants aged 18-34 (42.5%; 14/33). The distribution of preference for participants aged 45-64 was equal for pen and paper and CareFlow Vitals (47.6%; 10/21). Despite apparent differences, the results were non-significant (x^2=5.435, df=4, p=0.245). These differences however do seem surprising as it could have been hypothesised that more younger participants would have preferred the technology due to spending most of their lives living alongside digital innovation. It could be suggested that when the iPads and CareFlow Vitals failed to work effectively due to poor WiFi or system outages, pen and paper was used as a backup implying the manual reports are more reliable and cause less disruption. As the younger participants are more likely to have started working at the health board after the implementation of the iPads and CareFlow Vitals, they may not be aware of the disadvantages of using pen and paper, as the older participants may be.

Table 13 Preference for mode of recording data from patient observations by age.

	Preference percent (n)			
Age group	**Pen and Paper**	**CareFlow Vitals**	**Not Sure**	**Total n**
18-34	42.5 (14)	39.4 (13)	18.2 (6)	33
35-44	21.7 (5)	56.5 (13)	21.7 (5)	23
45-64	47.6 (10)	47.6 (10)	4.8 (1)	21

[9] Age groups were combined in this category to increase the sample size to test for statistical significance. The table with the original age group categories can be found in Appendix 13.

Preference and its relation to attitude towards change was also explored. It is recognised that this is not a demographic variable, but a question was also included in the survey to assess the participant's attitude to change to see whether this would factor into the perceptions of what method of data-entry was preferred in practice. The majority of participants reported that they embraced change, as seen in Table 14. CareFlow Vitals was the most common preference by the group who embraced change (50.9%; 27/53). CareFlow Vitals was also preferred by the group that really disliked change (66.7%; 2/3) but this group was very small. The group that was indifferent to change preferred using paper-based forms (45%; 9/20). Results were not significant (x^2=2.230, df=4, p=0.694).

Table 14 Preference for mode of recording data from patient observations by attitude to change.

	Preference percent (n)			
Attitude to change	**Pen and Paper**	**CareFlow Vitals**	**Not Sure**	**Total n**
I embrace change	34.0 (18)	50.9 (27)	15.1 (8)	53
I am indifferent to change	45.0 (9)	35.0 (7)	20.0 (4)	20
I really dislike change	33.3 (1)	66.7 (2)	0 (0)	3

6.2.2. Job Related Characteristics

In this section I seek to explore how the job-related characteristics of the participants (years of experience, agency worker, occupation) affect the preference of CareFlow Vitals in practice. The majority of participants with 0-1 years of experience were not sure of their preference for collecting patient observations (75%; 3/4), as seen in Table 15. It is relevant to note here that this could potentially be because they will not have used paper-based records unless the CareFlow System was for some reason not working. Participants with 2-5 years of experience were equally split on their preference for pen and paper and CareFlow Vitals (CareFlow preference 47.1%; 8/17). CareFlow Vitals was preferred by the majority of participants with 6-10 years of experience (58.8%; 10/17) and 11-20 years of experience (50%; 13/26). The most

common preference for participants with the most amount of experience at 21+ years was for pen and paper (53.8%; 7/13). The results were statistically significant (x^2=16.203, df=8, p=0.04). This suggests that participants at the later stages of their career preferred using the traditional method of pen and paper, whereas those were midway into their career were more likely to prefer the iPads and CareFlow Vitals. Those with more experience would have had greater historical familiarity with the paper-based forms compared to CareFlow Vitals. Participants who were at the start of their career were more unsure of their preference, perhaps because they had limited experience of either data recording method.

Table 15 Preference for mode of recording data from patient observations by years of experience.

	Preference percent (n)			
Years of experience	**Pen and Paper**	**CareFlow Vitals**	**Not Sure**	**Total n**
0-1	0 (0)	25.0 (1)	75.0 (3)	4
2-5	47.1 (8)	47.1 (8)	5.9 (1)	17
6-10	35.3 (6)	58.8 (10)	5.9 (1)	17
11-20	30.8 (8)	50.0 (13)	19.2 (5)	26
21+	53.8 (7)	30.8 (4)	15.4 (2)	13

Table 16 illustrates the preference in practice by whether the participants had an agency contract, either as their sole contract or shared with a permanent contract. Most participants who did not have an agency contract or had an agency contract alongside their permanent contract preferred using CareFlow Vitals in their clinical practice (53.1%; 17/32, and 44.7%; 17/38, respectively). Most commonly, participants with a sole agency worker contract were not sure of their preference (42.9%; 3/7). Although there were some differences, the patterns of preference were not statistically significant (x^2=5.126, df=4, p=0.275)

Table 16 Preference for mode of recording data from patient observations by agency worker status.

	Preference percent (n)			
Agency worker status	**Pen and Paper**	**CareFlow Vitals**	**Not Sure**	**Total n**
Yes, this is my sole contract	28.6 (2)	28.6 (2)	42.9 (3)	7
Yes, alongside my permanent contract	39.5 (15)	44.7 (17)	15.8 (6)	38
No agency work	37.5 (12)	53.1 (17)	9.4 (3)	32

Staff had the option to disclose their job title when responding to the survey. Table 17 shows the preference of different data-entry methods in relation to job role. CareFlow Vitals was preferred by the majority of nurses (51.5%; 17/33), health care support workers (60%; 12/20), and critical care outreach practitioners (57.1%; 4/7). The nurse category included seven different job titles. Staff nurses overall preferred CareFlow devices (45.5%; 10/22) but this was closely followed by staff nurses who mostly preferred pen and paper (40.9%; 9/22). All of the clinical nurse specialists, advanced nurse practitioners, and critical care nurses who responded to the survey (n=6) preferred using CareFlow Vitals, whereas all of the nurse practitioners and deputy ward sisters responding to the survey (n=3) preferred using pen and paper in their clinical practice. Ward sisters who responded to the survey were equally split in their preference for pen and paper and CareFlow Vitals (50%; 1/2). None of the physiotherapists responding to the survey preferred using CareFlow Vitals in their practice (n=6). Of those responding to the survey, the majority (67.7% (4/6) of physiotherapists, including one clinical specialist physiotherapist, preferred using pen and paper and 33.3% (2/6) were not sure of their preference.

Table 17 Preference for mode of recording data from patient observations by profession.

	Preference percent (n)			
Profession	**Pen and Paper**	**CareFlow Vitals**	**Not Sure**	**Total n**
Nurse	**39.4 (13)**	**51.5 (17)**	**9.1 (3)**	**33 [total]**
Staff nurse	40.9 (9)	45.5 (10)	13.6 (3)	22
Clinical nurse specialist	0 (0)	100 (2)	0 (0)	2
Nurse practitioner	100 (2)	0 (0)	0 (0)	2
Advanced nurse practitioner	0 (0)	100 (2)	0 (0)	2
Critical care nurse	0 (0)	100 (2)	0 (0)	2
Ward sister	50.0 (1)	50.0 (1)	0 (0)	2
Deputy sister	100.0 (1)	0 (0)	0 (0)	1
Health care support worker	**25.0 (5)**	**60.0 (12)**	**15.0 (3)**	**20 [total]**
Critical care outreach practitioner	**28.6 (2)**	**57.1 (4)**	**14.3 (1)**	**7 [total]**
Physiotherapist	**66.7 (4)**	**0 (0)**	**33.3 (2)**	**6 [total]**
Physiotherapist	60.0 (3)	0 (0)	40.0 (2)	5
Clinical specialist physiotherapist	100 (1)	0 (0)	0 (0)	1
Doctor	**33.3 (1)**	**33.3 (1)**	**33.3 (1)**	**3 [total]**
Other	**25.0 (1)**	**25.0 (1)**	**50.0 (2)**	**4 [total]**
Student nurse	0 (0)	0 (0)	100.0 (1)	1
Assistant practitioner	0 (0)	100.0 (1)	0 (0)	1
Rehab support	0 (0)	0 (0)	100.0 (1)	1
Hyper acute stroke support worker	100.0 (1)	0 (0)	0 (0)	1

6.2.3. Organisation Related Characteristics

This section explores whether the organisation where the participants worked was related to their preference for using CareFlow Vitals or pen and paper in clinical practice. There was a variation in the number of responses from each site with a greater number of responses received in South Fields Hospital than from Castle Plains Hospital (n=64 and n=13, respectively), as illustrated in Table 18. Although

fewer than half of the respondents at South Fields Hospital (45.3%; 29/64) preferred the use of CareFlow Vitals in practice, it was the option most commonly selected. The majority of participants at Castle Plains Hospital preferred the use of CareFlow Vitals (53.8%; 7/13). The results were non-significant (x^2=1.615, df=2, p=0.446).

Table 18 Preference for mode of recording data from patient observations by primary hospital.

	Preference percent (n)			
Primary hospital	**Pen and Paper**	**CareFlow Vitals**	**Not Sure**	**Total n**
South Fields Hospital	40.6 (26)	45.3 (29)	14.1 (9)	64
Castle Plains Hospital	23.1 (3)	53.8 (7)	23.1 (3)	13

6.3. Preferences and Views on Method of Data-Entry

This section explores preference of data-entry method and views on usability (see Table 19). Participants were invited to choose which of the methods were optimal in relation to six measures based on the study by Prytherch et al. (2006): which method provided greater accuracy, easier detection of errors, was simpler to use, quicker, more convenient, and easier to use. CareFlow Vitals was perceived as being more accurate (76.9%; 60/78), allowing for easier detection of errors (77.6%; 59/76), and more convenient (51.3%; 39/76). On the other hand, pen and paper was identified as being simpler (58.4%; 45/77), quicker (53.2%; 41/77), and easier to use (59.2%; 45/76).

Table 19 Preference by the different measures of the data-entry method.

	Preference percent (n)		
Measure	**Pen and Paper**	**CareFlow Vitals**	**Total n**
Allows easier detection of errors	22.4 (17)	77.6 (59)	**76**
More accurate	23.1 (18)	76.9 (60)	**78**
More convenient	48.7 (37)	51.3 (39)	**76**
Quicker	53.2 (41)	46.8 (36)	**77**
Simpler	58.4 (45)	41.6 (32)	**77**
Easier to use	59.2 (45)	40.8 (31)	**76**

To explore this further, the sample was separated into groups based on their overall preference (Table 11) to identify what measure each group prioritised. The table which reports these figures can be found in Appendix 14. The findings in this table are explored in the next three figures (14-16).

Figure 14 shows the attitude towards the six measures of data-entry of those who preferred using paper-based forms overall (n=29). The majority in this group identified that pen and paper was easier to use (89.7%), more convenient (86.2%), simpler (79.3%), quicker (79.3%), and more accurate (51.7%). However, more participants in this group did report that CareFlow Vitals allowed easier detection of errors (60.7%).

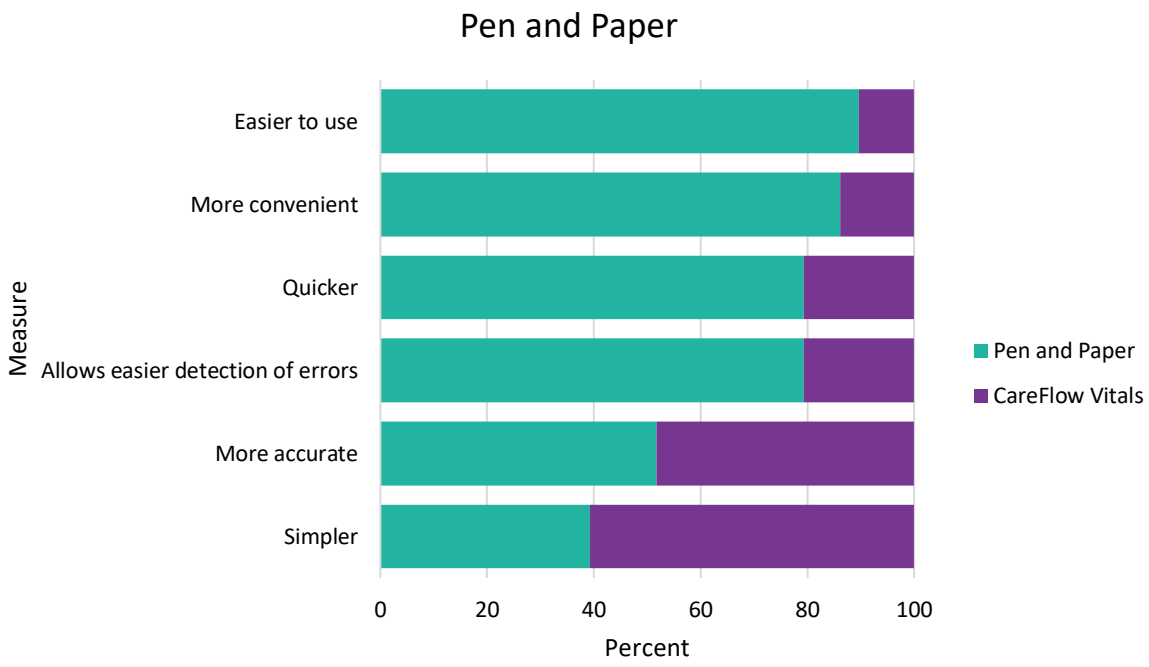

Figure 14 Measures by pen and paper preferred group.

Figure 15 displays the attitudes towards the six measures of data-entry from the group of participants who preferred CareFlow Vitals (n=36). The majority in this group reported that CareFlow Vitals was more accurate (97.2%), allowed easier detection of errors (88.6%), was more convenient (79.4%), quicker (71.4%), easier to use (70.6%) and simpler (62.9%).

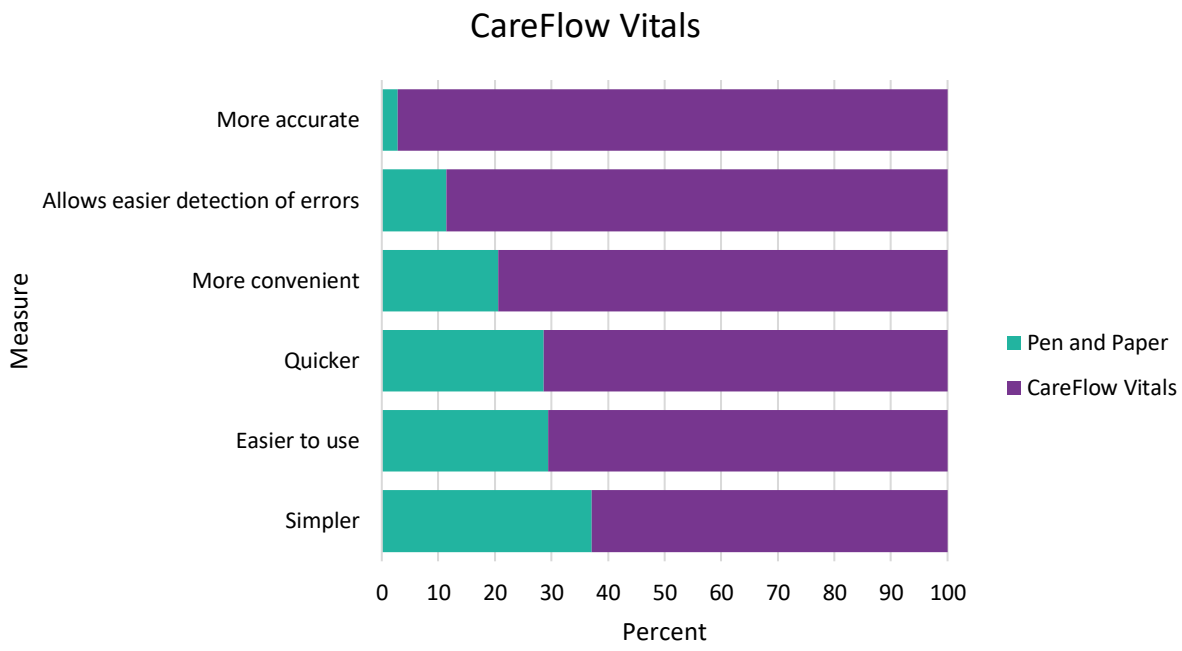

Figure 15 Measures by CareFlow Vitals preferred group.

Figure 16 shows the perspective from the group of participants who were not sure of their preference for the method of data-entry (n=12). The majority of the respondents in this group identified that CareFlow Vitals was more accurate (83.3%), allowed for easier detection of errors (83.3%), and was more convenient (66.7%). The majority of the participants also reported that pen and paper was simpler (66.7%), easier to use (66.7%), and quicker (58.3%).

It is interesting to note that all groups identified that CareFlow Vitals allowed for easier detection of errors. Despite the *pen and paper* group and the *not sure* group reporting that pen and paper were simpler, quicker, and easier to use, the *CareFlow Vitals* group rated the software superior in every measure.

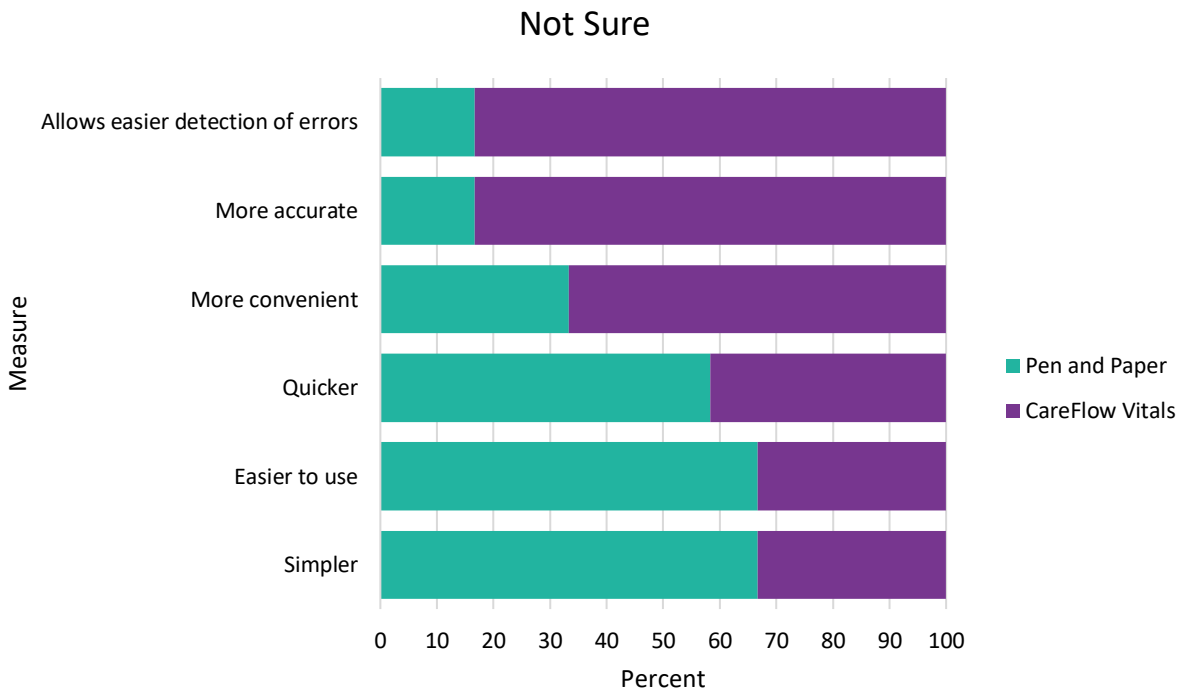

Figure 16 Measures by the participant group who were not sure of their preference.

6.4. Further Insights

This section further delves into the reasons why healthcare professionals at the two hospitals may prefer either CareFlow Vitals or pen and paper. These reasons include whether training was received to input information onto the iPads with CareFlow Vitals, and make clinical decisions based on the information provided, and whether staff members experienced benefits, problems and disadvantages as discussed in Chapter 7.

6.4.1. Receiving Training

Presented in this section is data which enables some exploration of whether receiving training to input information on the iPad and CareFlow Vitals, and to use that collected information to inform clinical decisions, is linked to preference for data-entry method.

Figure 17 demonstrates how receiving training to input information onto the iPads with CareFlow Vitals (n=83) seems to relate to the preference that clinical staff have for the medium of recording data. Over half of the participants (54.0%) who received training preferred using CareFlow Vitals, 34.9% preferred using paper-based forms, and 11.1% were not sure of their preference. Exactly 50.0% of those who did not receive training were not sure, with 25.0% of participants preferring either pen and paper and CareFlow Vitals, respectively. Results however were non-significant (x^2=4.947, df=2, p=0.084).

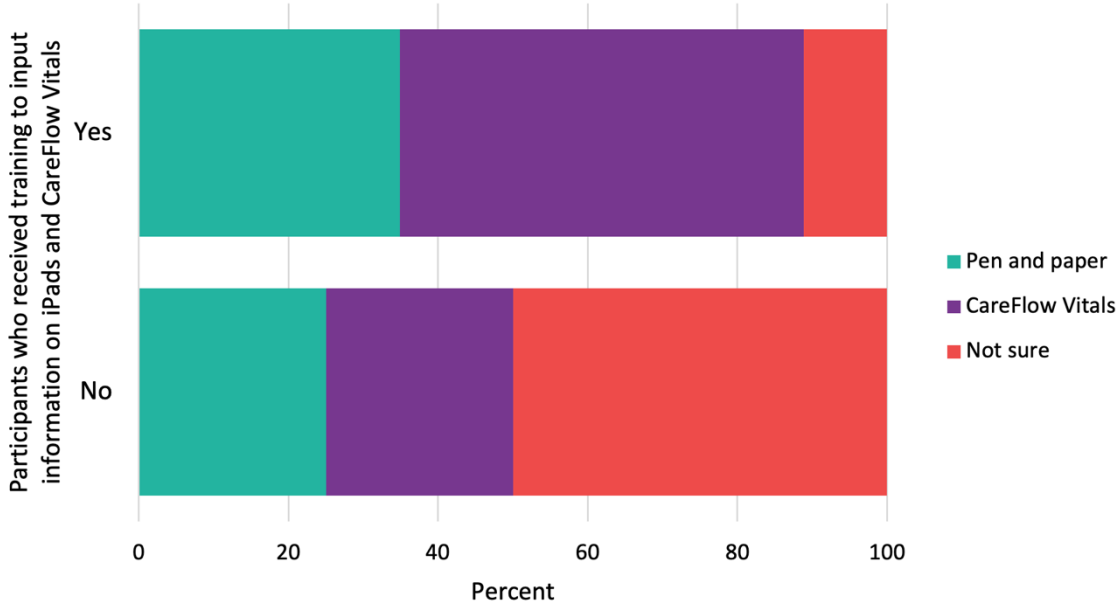

Figure 17 Preference by participants who received training to input information using CareFlow Vitals.

It is demonstrated in Figure 18 how receiving training to use the information collected from CareFlow Vitals to make clinical decisions affects the participants' preference of data-entry method in practice. The majority of participants (57.1%) who did not receive training (n=19) preferred using pen and paper whereas 21.4% were either unsure or preferred using CareFlow Vitals in their practice, respectively. Of those that did receive training (n=78), the majority (50.9%) of respondents preferred using CareFlow Vitals, 33.3% preferred using pen and paper, and 15.8% were not sure. Despite these differences, the results were non-significant (x^2=4.050, df=2, p=0.132).

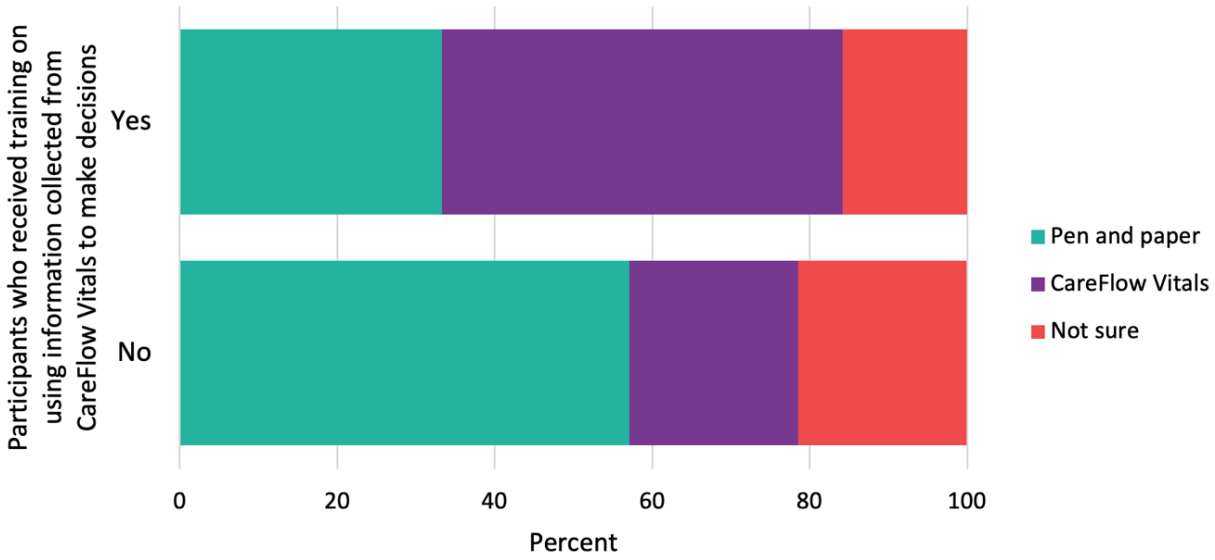

Figure 18 Preference by participants who received training to use data collected using CareFlow Vitals to make clinical decisions.

6.4.2. Benefits and Disadvantages

This section presents data which will give an insight into whether experiencing benefits and disadvantages when using the iPads and CareFlow Vitals in clinical practice has an influence on the preference in practice.

Figure 19 explores whether experiencing benefits when using the CareFlow Vitals software[10] suggested an influence on the preference of data-entry method in clinical practice. Although 54.5% of participants who saw benefits (n=76) preferred to use CareFlow Vitals in their practice, 27.3% preferred using pen and paper, and 18.2% were not sure. Of those who did not see any benefits, the majority (66.7%) preferred using the paper-based forms, and 33.3% preferred CareFlow Vitals. Some participants stated that they were not sure whether they perceived any benefits in using the devices and the software. About two-thirds (64.7%) of this group preferred

[10] The benefits and disadvantages of using the iPads and CareFlow Vitals is further explored in Chapter 7.

using pen and paper, 23.5% preferred CareFlow Vitals, and 11.8% were not sure of their preference. Results were not significant (x^2=9.225, df=4, p=0.056).

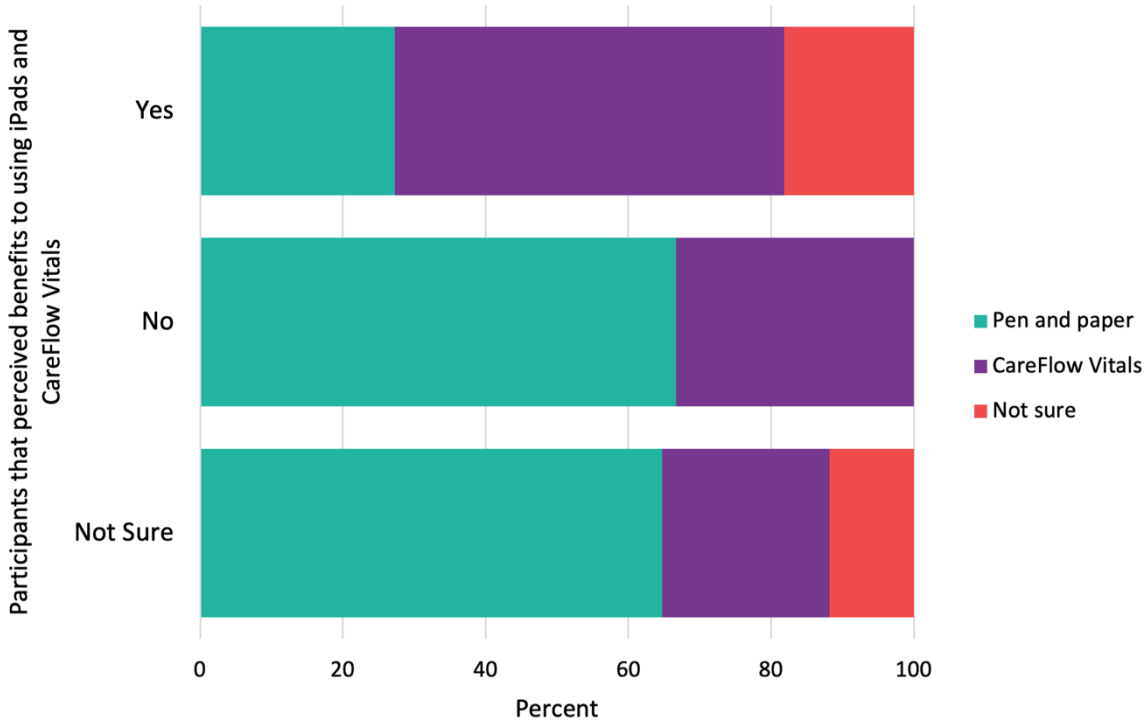

Figure 19 Preference by participants that perceived benefits to using iPads and CareFlow Vitals.

Experiencing problems and technical issues with the iPads and CareFlow Vitals may have had an influence on whether staff members preferred using them in their clinical practice. The pattern of responses is explored in Figure 20. The majority of respondents (63.6%) who had not experienced problems and technical issues preferred the use of devices and CareFlow Vitals. In comparison, most (46.5%) of the professionals who had experienced problems and technical issues preferred using pen and paper. Results were statistically significant (x^2=6.269, df=2, p=0.044). This suggests that experiencing problems or technical issues with the new technology will influence the acceptability of the device over the traditional method.

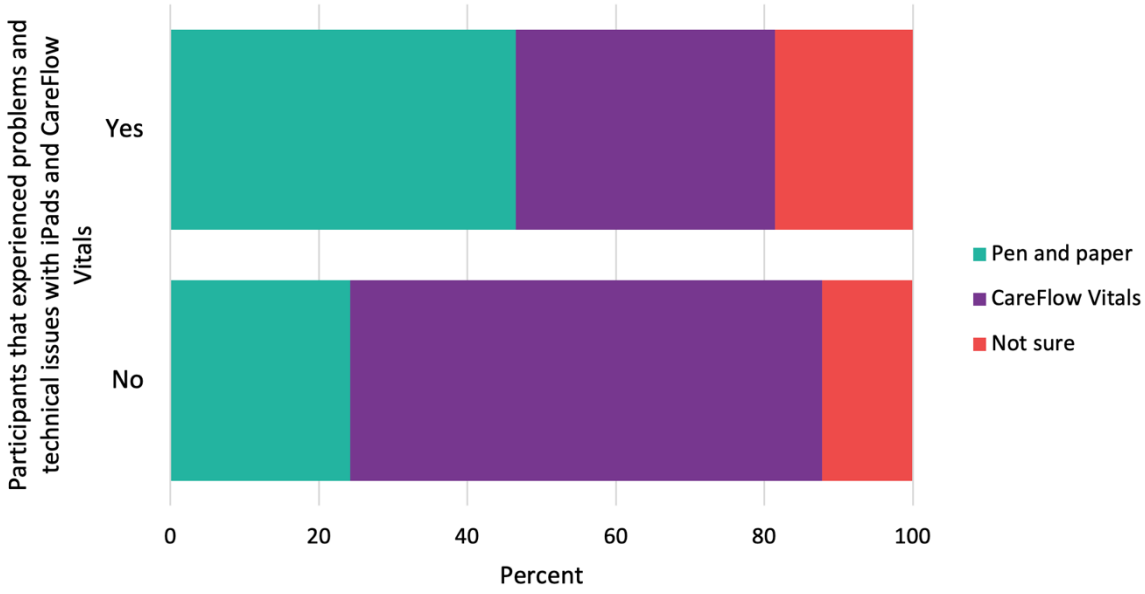

Figure 20 Preference by participants that experienced problems and disadvantages when using the iPads and CareFlow Vitals

Figure 21 shows a similar pattern with participants who had experienced other disadvantages with the iPads and CareFlow Vitals. The majority of participants (61.5%) who had not perceived any other disadvantages preferred using the devices and CareFlow Vitals. Accordingly, most (45.5%) of the respondents who did experience other disadvantages preferred the paper forms. Of participants who were unsure whether they had experienced other disadvantages, 46.7% preferred pen and paper. Results were not statistically significant (x^2=7.158, df=4, p=0.128).

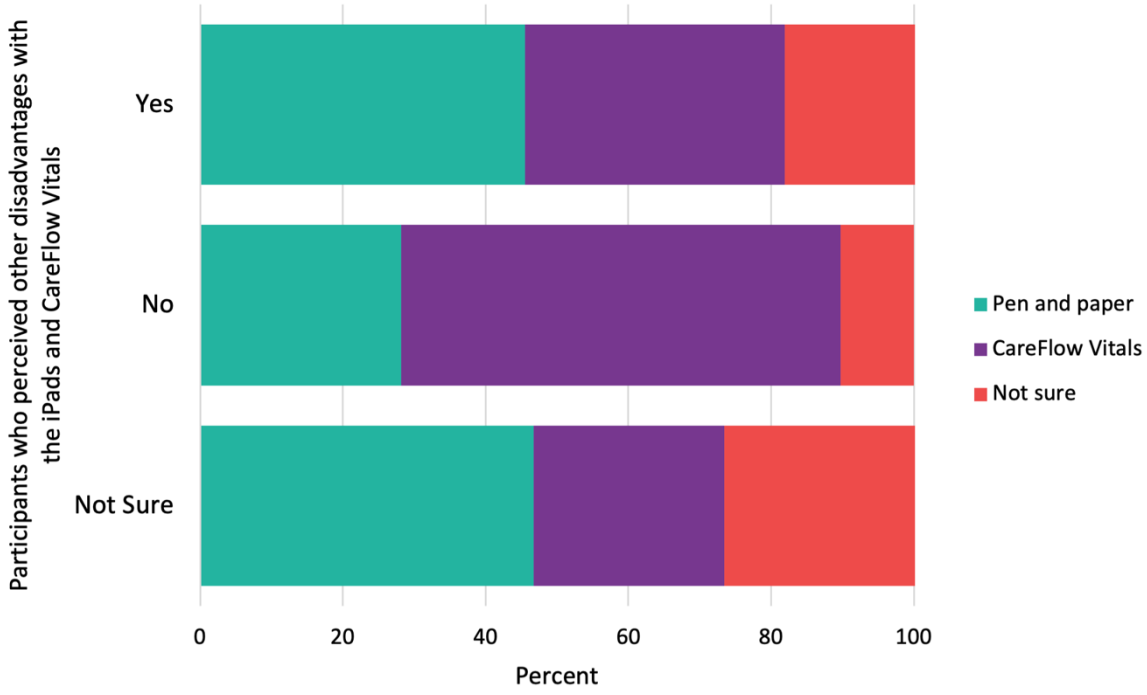

Figure 21 Preference by participants that perceived other disadvantages when using the iPads and CareFlow Vitals.

Overall, this section has illustrated the tendency that participants who received training to input information using the devices and CareFlow Vitals and to use it to inform clinical decisions showed a preference for CareFlow Vitals, alongside participants who experienced benefits when using the iPads. Participants who experienced problems, technical issues and other disadvantages when using CareFlow Vitals during work disclosed a preference for using paper-based forms.

6.5. Conclusion

To conclude, although most (but fewer than half) of the survey respondents indicated a preference for using CareFlow Vitals in clinical practice, the picture was mixed with there still being considerable numbers expressing preference for pen and paper amongst some groups, despite receiving training and experiencing benefits to using the iPads and CareFlow Vitals software. It is expected that experiencing problems with the iPads and CareFlow Vitals would have an impact on the reception of the

devices. However, it was surprising that the younger age group had a preference for using pen and paper compared to the mobile technology. The findings in this section will be further examined and discussed in Chapter 8.

Chapter 7. The Perceived Benefits and Disadvantages of Using CareFlow Vitals in Secondary Care

7.1. Overview

The data collected from surveys, observations and interviews reveal participants reported benefits and disadvantages to the use of iPads with CareFlow Vitals in the hospital wards. This chapter begins with an overview of data collected from the survey. This is followed by further detail about the perceived benefits and disadvantages as derived from the analysis of data from observations and interviews. This chapter aims to address the following research questions: 2d) what are the attitudes of staff towards mobile devices equipped with CareFlow Vitals?, 4) how have mobile devices used to record patient observations at the bedside impacted clinical decision making?, and 4b) what has been useful or not useful about the mobile devices and software when supporting clinical decision making? This chapter builds on the findings reported in Chapter 5 to engage with how the uses and functions of the iPads and CareFlow Vitals software can benefit or disadvantage the users of them.

Participants were invited to provide their general views on the use of CareFlow Vitals on the hospital wards. From the survey data it can be seen that the majority (74.5%) of respondents reported that they had seen benefits to using CareFlow Vitals installed on iPads. Of the other participants, only 3.9% could not see any benefits to using CareFlow Vitals whereas 21.6% were not sure. Despite this, over half (53.8%) of the participants reported experiencing problems and technical issues with the technology, with 46.2% reporting that they did not experience such problems. If participants disclosed that they had experienced problems and technical issues (n=63), they were asked on a scale of 1-10 how they perceived the ease of resolve of these problems. The score varied, although there is a peak at 5 with 30.2% (n=19) of respondents as is illustrated in Figure 22. Some of these participants (n=14) had their problems

resolved relatively easily (8-10 on the scale) whereas others (n=8) had a difficult time resolving the problems (0-2 on the scale).

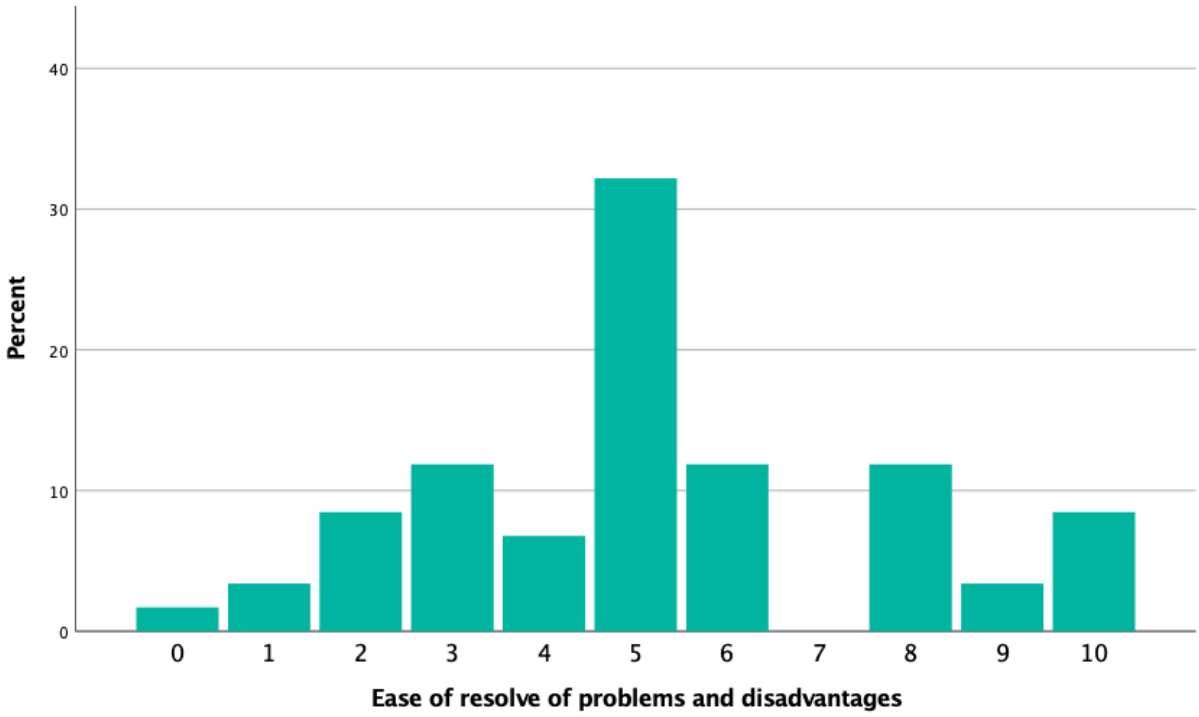

Figure 22 A chart to show the ease of resolve of problems and technical issues on a scale of 1-10.

Further, 26% of participants reported other disadvantages with the iPads and CareFlow Vitals other than technical problems. However, 57.7% of participants did not report any other disadvantages related to using CareFlow Vitals on the iPads, and 16.3% were not sure. Thus, the survey responses highlight that although most of the participants reported advantages to using CareFlow Vitals in their practice, there remained a relatively high proportion of members of staff who experienced problems and technical issues, although for a small group these were easily resolved. This sets the broad context for what follows in the next section.

7.2. Safer Patient Care

Some participants reported that CareFlow Vitals on the wards made it safer for patients. Carly stated that she preferred the devices over paper-based records for this reason:

> *"I think it's safer, the devices are. Because it tells you what they're scoring on, when they need to be rechecked. You know, if you come in and you do them and they're a three and you don't know that they've got to be done in an hour, at least the iPad will say obs due now, in one hour's time. So, you know, I think it is much safer for patients." (Carly, HCSW, South Fields Hospital, Ward 4, interview)*

As discussed in Chapter 5, when recording vital signs, staff members (primarily HCSWs and nurses) would input the relevant vital signs into the iPads and the software would automatically calculate the EWS and inform the user of when the next observation was due. Above, Carly explained that she believes this system makes it safer for patients as the software prompts the user to do the observations at a certain time so reducing the risk that they might be overlooked or forgotten due to the busy nature of working on a hospital ward with many conflicting assigned tasks to do. This section will delve deeper into the potential of the technology to improve patient safety on the wards due to the automatic EWS calculation, the indication of when the observations are due, and a reminder to ask important clinical questions.

7.2.1. Automatic EWS Calculation

HCSW Carly explained that the thing she liked the most about the software was that it calculated the EWS automatically and she did not have to worry whether she had done so correctly, as she would have before implementation.

> *"I like that they score for you. That's the biggest thing for me. So that everybody, you know, you haven't got*

> *to panic or, have I scored it right?." (Carly, HCSW, South Fields Hospital, Ward 4, interview)*

During my observations I saw that the software requires the user to input each vital sign, not necessarily in order, to calculate the EWS. Because of this, the staff member is required to ask each question. Mandy explained that one of the reasons she prefers CareFlow Vitals to the pen-and-paper method to recording patient observations was that it reminds you to ask all of the questions.

> *"They do remind you of the questions that you should be asking because even if you have your charts, it's only got blood pressure and all on there. But we need to know if they've passed urine, it reminds you if they've got a catheter, if they're on oxygen. Obviously you can see, but sometimes because it's always there, you don't ask the questions and things like that and if they've vomited or if they've passed urine. Sometimes if you haven't got those prompts and you try to get everybody done, you could forget to ask those little questions really*." (*Mandy, HCSW, South Fields Hospital, Ward 2, interview)*

As Mandy implies, on a busy ward such as the assessment unit, some questions may be overlooked. Having the CareFlow Vitals software on the device ensures that healthcare staff are prompted to ask all questions before the EWS can be calculated. CareFlow Vitals also has the potential to assist and reassure staff members who do not know how to do the EWS calculation due to the automatic computation and tell them what to do next.

> *"Alerts less qualified staff of what to do if a patient is scoring on NEWS [national early warning score]." (P3, clinical nurse specialist, survey)*

However, there were concerns about the reliance on CareFlow Vitals to calculate the EWS. Participants reported that staff were becoming deskilled as they were only required to input the vital signs into the system and no longer had to calculate the EWS themselves. Arguably, the automatic calculation means that they do not have to understand the information. A concern was that this could lead to staff no longer being able to recognise deterioration or think critically about the clinical assessment.

> *"Staff are not required to understand the information they are inputting so lose the skill of thinking critically, it deskills staff so they are unable to assess patients or pick up if a patient is deteriorating." (P6, hyper acute stroke support worker, survey)*
>
> *"I feel like they have taken away the 'think for yourself' process." (P48, nurse practitioner, survey)*
>
> *"It has autotomised recording vital signs and has distanced the RN [registered nurse] from objective clinical assessment." (P62, ward manager, survey)*

Therefore, if staff are potentially no longer able to assess deterioration as quickly as they once were, the patients are no safer in the hospital as they were before the implementation of the iPads and CareFlow Vitals software.

7.2.2. Indicates when next Observations are Due

As well as calculating the EWS, it can be seen in Chapter 5 that the CareFlow Vitals software on the iPads dictates the time to the next observation based on the EWS. Despite this, staff can still ignore it and some members of staff can change the time interval between observations if they deem it necessary. Participants expressed that this feature was a benefit to them as some patients may require clinical observations outside of the regular ward rounds.

> *"Todd likes the CareFlow system as it keeps track of when he has to do his obs compared to having to find this information in different paper files." (South Fields Hospital, Ward 3, field notes)*
>
> *"Jane explains that the iPad is nice because she doesn't have to remember when obs are due because they can 'be all over the place'." (South Fields Hospital, Ward 2, field notes)*

As explained earlier in Chapter 5, it is a feature of the system to colour-code patients when their EWS is high, or their observations are overdue. This flagging system was

an efficient means of highlighting when observations were due, and participants viewed this as a benefit to their clinical practice.

> *"Before you would have to go back through all the paper file whereas now, they flag up red. If they're six and above on the NEWS or they can be flagged up as orange, and if their obs are overdue they'd be red. So there's a timing on each patient for their next set of obs." (Annie, HCSW, South Fields Hospital, Ward 3, interview)*

Having this information available to them on iPads helped some participants to prioritise their work. For example, if they could see that one patient had an EWS of six and another had an EWS of zero, they would ensure that they do the observations of the patient with the EWS of six before the other.

> *"If it gets really busy, you know you don't go to do them [observations] all the time, you just keep an eye. It'll tell you who's is due. So I do those first before I do the other patients then. (…) It helps you to prioritise, yeah. Because it puts the ones who need it the most at the top in a proper list, so it's good." (Mandy, HCSW, South Fields Hospital, Ward 2, interview)*

There were however barriers to ensuring that the observations were done to the time the CareFlow Vitals software indicated. For example, it was reported frequently that it was perceived that there were not enough iPads per ward, or that the iPad was not immediately available as they were either in use by another member of staff or they were misplaced somewhere in the ward.

> *"Violet (HCSW) told me that 'we only have four iPads and two don't work' – this was in reference to the whole ward and not just in the team where we were based." (South Fields Hospital, Ward 3, field notes)*

> *"iPad was not immediately available so the HCSW went to grab one for Uma (nurse) as they are communal use in the teams as opposed to each team member having their own device." (South Fields Hospital, Ward 1, field notes)*

> *"Sometimes we haven't always got enough [iPads] to go around. And then you've got to wait. Then sometimes if it's, if it's busy, if we haven't got enough, we usually do, but they'd go walkabout and then they do reappear. So that is a bit of a pain sometimes if you've got to like wait for someone else to finish their obs and you want to do yours." (Mandy, HCSW, South Fields Hospital, Ward 2, interview)*

As Mandy stated, if there are not enough devices on the ward, observations will be delayed. However, prior to device implementation there was only one file per patient. Introducing mobile technology has not created this problem but has transferred it elsewhere.

Another explanation for late observations could be because the staff who record the observations are not taking notice of when the observations are due on CareFlow Vitals, despite there being clear coloured visual prompts.

> *Despite the visual prompts for concern, staff do not take notice of them." (P19, critical care outreach practitioner, survey)*

This could be because staff are only alerted to observations being due if they are using the iPad; it would be easy to go a while without looking at the iPads due to the busy nature of a hospital ward.

Some participants also reported that observations were not done as often or as timely as they were previously conducted before the implementation of the devices, which negates the benefit of the iPads and CareFlow Vitals indicating when the next observations should be scheduled.

> *"It seems we are not conducting obs as often." (P90, RN, survey)*

> *"The timeline of obs are not recorded as they should be. For example if the NEWS score is high and the recommendation is 30-minute observations - these are not done to time. Whereas I think if we went back to calculating the score it would trigger staff to see when they should be done next." (P48, nurse practitioner, survey)*

The nurse practitioner above stated that this could be because staff are no longer calculating the EWS themselves which would alert them to plan when their next observation should be. Instead, because the software calculates the EWS they may take insufficient notice of the time to the next observation as they are not actively involved in the calculation process.

A participant that I observed in practice suggested that a prompt acting as a safeguarding measure would be useful in situations where she needed to inform the nurse in charge of her patients if there were any concerns. As it is now, if the ward is busy and Maria has many patients; she could become distracted and not inform the nurse.

> *"Maria (HCSW) would prefer that a safeguarding measure was in place like at her previous hospital. As it is now she could forget to tell the nurse something if she is seeing many patients but with a safeguarding measure she would be forced to stop during rounds and inform the nurse of the problem." (South Fields Hospital, Ward 1, field notes)*

In this scenario, a simple push notification (an alert generated by the application when it is not open) may be valuable to remind HCSWs like Maria to update the nurse about any concerning patients.

A different explanation for why staff may not be acting on the prompts given by CareFlow Vitals at the end of an observation could be that they are simply ignoring them.

> *"Serena (HCSW) told me during a night shift observation that It's really easy to ignore the last screen and just click accept to the recommendations given." (Castle Plains Hospital, Ward 1, field notes)*

> *"Must scroll past escalation message to confirm set of observations. This message cannot be accessed easily again to review if you have done everything needed." (P80, critical care outreach practitioner, survey)*

The action of ticking a box on the last screen does not mean that the information provided has actually been read, especially when there are other pressing duties to attend to.

7.2.3. Potential to Notice Deterioration Sooner

Healthcare staff are able to see a history of EWS and vital sign observations on CareFlow Vitals, and participants reported this was a benefit so they could see patterns and trends, and potential deterioration.

> *"I like that you can go into the patient's file, and you can look at all of their other obs so you can see patterns and trends. That's nice. Obviously, if somebody is deteriorating it's important to know or if somebody is improving, that is important to know as well. And yeah, it's just one point of view when you can see it all in one place." (Jane, HCSW, South Fields Hospital, Ward 2, interview)*

I recorded field notes from an interaction with Jane on the medical assessment unit at South Fields Hospital where I was guided through the different sections of the software.

> *"Jane showed me a patient on the iPad whose EWS was high- you can compare to earlier readings to see the trend e.g. this patient was scoring higher this time compared to 0/1 on the earlier obs showing a decrease in wellness which needs to be reported directly to the nurses. Jane explained that EWS 4 was a concern for this patient as they had scored low beforehand and the device is clearly showing a deterioration between consecutive observation rounds. It also has the option to show this on a line graph as would've been previously plotted on the paper charts, and with this you can clearly see the EWS of patients over time." (South Fields Hospital, Ward 2, field notes)*

From this conversation with Jane, she made it clear that showing a graph of EWSs over time helped staff make decisions about the care that they provide for their patients as they can illicit any patterns or trends from the data. Previously, staff would have plotted the EWS on a paper chart, but the software does this for them. This

ensures that as long as the observations of vital signs have been inputted correctly, there will be no error in the plot.

Gerald also explained that as a consultant he was potentially able to detect deterioration sooner by noticing any concerning changes using the data collected by the CareFlow Vitals software.

> *"And I would say you could probably pick things up a bit earlier. You know, if there's a change in one's observations, probably a bit sooner." (Gerald, consultant haematologist, South Fields Hospital, interview)*

This highlights that although the data are used differently by different healthcare professionals during the patient's healthcare journey, CareFlow Vitals is seen to be beneficial by a range of professions within the hospitals. Hayley explained that she loved the devices despite having a preference for pen and paper due to being "old school" because they can assist newer members of staff who may not be experienced enough yet to know when a patient is deteriorating.

> *"While observing Betty conduct patient observations on her ward round she stated that 'I love them [the iPads and CareFlow Vitals]. They alert you when you should be worried. I am old school so I do love pen and paper but everyone is different, and you've got apprentices and they might not know yet when they should be worried about a patient but this [CareFlow Vitals] alerts them'." (Castle Plains Hospital, Ward 3, field notes)*

By being able to easily view patterns and trends in the data from using the CareFlow Vitals software, it was conveyed that this made it easier to track the potential deterioration of patients and detect any problems with them sooner. Once any problems with the patients have been identified, these concerns could be addressed.

> *"Concerns raised on a set of obs have to be acted upon and monitored to protocol." (P27, RGN, survey)*

Protocol in this sense could mean that the devices ensure that observations are monitored to the correct time. For example, patients may have to be monitored every half an hour if their EWS is high (> seven) or every 12 hours if their EWS is zero.

During an observation, Tanya stated that she saw a benefit in the devices in that you "know a lot sooner than you would've" when a patient is presenting well but the device detects that something may not be quite right due to their vital sign observations. Annie also highlighted this and explained why this was a benefit compared to when the hospital was using paper files.

> *"If there is a patient for concern, we can then just act upon them more quickly instead of flicking through paper constantly because it's all there flagging up red." (Annie, HCSW, South Fields Hospital, Ward 3, interview)*

Carly expanded upon this benefit using an example of a patient who may potentially have sepsis. Sepsis can be identified earlier if clinicians recognise the elevated vital signs and EWS as an indicator:

> *"So when you do the, the first set of obs, if their temperature is high and their heart rate is high, you know you're looking at Sepsis there so you can contact the doctor straightaway and say my patient is scoring a six. They'll come down then and get the right antibiotics and IV fluids. So it potentially stops that patient deteriorating. So if they come in, their obs are fine, even though they're unwell you know it's not any septic, anything septic going on." (Carly, HCSW, South Fields Hospital, Ward 4, interview)*

While based at the nurses' station outside of a multi-bed room, I had a conversation with a nurse and two student nurses about a patient they had concerns about due to their high EWS. Penny, the nurse, liked the fact that CareFlow Vitals prompted the user to think about sepsis. This could lead to earlier detection of infection, which ultimately leads to faster treatment decisions and extra monitoring as in the scenario below.

> *"I had a conversation with Penny, Ola, and Nora about CareFlow Vitals at the nurses' station. They have a very sick patient who is scoring a 9 on NEWS and was scoring a 10 one hour ago. To score a 10 you would have to be scoring 3 in 3 different domains. Penny says*

she likes that it asks the question "do you think this person has sepsis?" when they're scoring high. This patient is now on hourly obs even though it is a night shift." (South Fields Hospital, Ward 3, field notes)

Although detecting patterns of change and noticing deterioration was seen as a benefit of the iPads and CareFlow Vitals, some participants reported the opposite effect and found it more difficult to identify patterns of change and deterioration.

"I find it is not as easy to identify patterns of change and therefore identify when patients need escalation and why." (P18, nurse, survey)

"More difficult to detect trends of a declining patient, very much a tick box exercise now." (P87, staff nurse, survey)

This highlights that people respond differently to different ways of working and what some users of technology may find useful in practice, others may not.

Further, if the system becomes unavailable (see section 7.7) healthcare staff cannot see the previously recorded observations so cannot detect any patterns and trends until the system is back online.

"System has been down on several occasions whereby all staff have had no access to CareFlow, we normally revert to paper during such times but obviously no one can access previous observations when the whole system is down. This has happened, albeit not many times, but it has happened and has proven to be a bit of a nightmare especially with acutely ill patients." (P17, HCSW, survey)

A nurse who answered the survey was also concerned that the information provided on the device may be seen as more valuable than a qualified nurse's clinical judgement which may cause them to be overruled by the technology.

"Overall, the system has many benefits but should be viewed as a recording device only... but should be as flexible as possible not to hinder or overrule a qualified

nurse's clinical judgement." (P69, registered nurse, survey)

The survey respondent makes the point that the software is a recording device. It is designed to only have the vital signs inputted into it and automatically calculate the EWS. It does give a suggestion for the next steps, but it should be noted that the technology cannot see the patient as a healthcare professional can do in person.

There were also concerns that protocol was not being adhered to in contrast to the benefit described earlier in this section. There was a report that the deteriorating patient policy is contradicted by the settings on the CareFlow Vitals software and staff were unable to change this.

> *"CareFlow defaults NEWS <3 to 12 hour observations despite if the patient is within 48 hours of admission or procedure. This contradicts the deteriorating patient policy. Many staff on wards cannot change this default." (P80, critical care outreach practitioner, survey)*

A further policy concern from staff was with regard to the oxygen saturation levels of patients. As discussed in Chapter 5 some patients naturally have a lower oxygen saturation level between 88-92% rather than >95%. This could be because of a chronic health condition such as COPD or cystic fibrosis. A disadvantage related to this was that staff reported that patients' EWS might be over inflated if the lower oxygen saturation level was their normal. They were unable to change the oxygen saturation parameters on the device to reflect this.

> *"Of those on CREWS [Chronic Respiratory Early Warning Score], a saturation of 88% scores even though it is normal for them." (P1, critical care outreach and resuscitation practitioner, survey)*

There was also a similar problem with patients who were on oxygen at home which was reflected in one of my field notes below.

> *"Ronald (agency nurse) explained to me that there is a problem with scoring when patients are on oxygen. If a patient is on oxygen, they automatically score an EWS of two unless they have oxygen when they are at home but there is no way to record this, e.g., a patient today scored a four because they were on oxygen. However,*

they were on oxygen 24/7 at home so they should have scored a two." (Castle Plains Hospital, Ward 5, field notes)

In summary, there are instances of the software not aligning with the organisational policy and ways of working (being unable to change the oxygen saturation parameters, devices being unavailable, concerns about the technology replacing clinical judgement), despite participants having seen clinical benefits with the iPads and CareFlow Vitals including potentially noticing a deterioration of a patient sooner due to automated calculated EWSs and a visual way to see patterns and trends in the collected vital signs data.

7.3. Time Management

As earlier identified in section 7.2.1, a reported benefit to the participants was that the CareFlow Vitals software installed on the iPads automatically calculated the EWS. Some participants elaborated that this feature was also a benefit because it saved time as a consequence.

"Before I would have had to work it [EWS calculation] out on paper. […] It saves time instead of when short staffed you can whizz around and it's already documented" (Tanya, HCSW, South Fields Hospital, Ward 1, field notes)

As healthcare staff are saving time by not manually calculating the EWS or transferring the documentation to the paper files (at South Fields Hospital), they have more time to do their other tasks. For example, HCSWs help patients with their personal care as well as to conduct other clinical duties such as blood sugar monitoring or weight measurements.

"In some ways it has freed up time because you're not just doing it for the sake of doing it, you know. […] So it has freed up that time because I've got more time to do something." (Todd, HCSW, South Fields Hospital, Ward 3, interview)

One survey participant perceived that they had more time available because they were not doing observations as often due to the device guiding them when to do them, rather than regularly doing the observations outside of protocol. This is an unexpected comment as it could be anticipated that observations might have increased with the CareFlow Vitals software given that the time to next observation is scheduled automatically.

> *"More free time as we are not conducting obs as often" (P90, RN, survey)*

Having the iPads and CareFlow Vitals software available also sped up the way staff were working as they no longer had to look through paper files to find the information that they needed. This process would involve first finding the right folder in a pile of multiple patients' folders and then finding the right form in a file filled with paper.

> *"The problem with paper is the paper could be filed anywhere, so it does speed things up." (Gerald, consultant haematologist, South Fields Hospital, interview)*

Further, participants also expressed how they benefitted from the devices because they no longer had to share a paper file with multiple clinicians. This meant that participants did not have to search for the paper files that may have been in use, they just had to log on to CareFlow Vitals on the iPads.

> *"Because like I said, you've got to chase the notes all the time to write them in, you know, and the doctors got their notes and they're [the patient] gone to theatre and then they've gone somewhere else, and then by the time you get to write their notes they've gone to a different ward and it looks like I haven't done nothing with them all day, you know? So yeah, they are good for recording. And you know, and from my point of view, I've always been taught if you don't write it down and you don't record it, you haven't done it." (Mandy, HCSW, South Fields Hospital, Ward 2, interview)*

HCSW Edna spoke about how these benefits can lead to swifter follow up actions which can have potentially huge and lifesaving outcomes. Edna included an example

which illustrated how she was able to collect the vital signs of a patient quickly using the device and immediately inform her nurse in charge.

> *"Edna likes that she saves time when a patient is really poorly because it calculates the EWS automatically and so she can involve the nurse or doctor faster. She illustrated this with a patient she had last week who asked her to help him go to the toilet. As HCSWs are often first point of care she noticed that this patient was not acting his usual self so she did a set of observations after he had used the toilet and the patient was scoring a nine so she was able to tell the nurse immediately." (Castle Plains Hospital, Ward 1, field notes)*

Despite these potentially lifesaving consequences, some participants reported that the iPads and CareFlow Vitals were more time consuming to use. One participant explained this was because staff have to locate the devices, log on and change the ward setting before even getting around to the clinical task.

> *"Time consuming to access information due to locating devices and logging on / changing ward settings." (P11, physiotherapist, survey)*

Other participants were concerned that the system required them to conduct their observations more frequently than the NEWS protocol dictated leading them to disturb the patient more than they needed to which conflicts with the notion previously reported in this chapter that the devices led to less frequent patient observations.

> *"Unnecessary disturbance of patient." (P97, staff nurse, survey)*

> *"Can lead to excessive observation being taken." (P23, job title not given, survey)*

The participant above did not expand on why they felt that the CareFlow Vitals software led to increased observations being taken but we could speculate that the iPads nudges the staff member to do the observations according to policy, whereas previously observations could be missed without potential consequence unless paper records were manually reviewed for timings (although it is important to note that there could be sound clinical reasons not to do the observations on occasion). If healthcare professionals are spending too much of their time conducting their patient

observations, they have less time available to do their other clinical tasks on the ward which could negatively affects their patients' care.

There were further concerns that in an emergency situation the iPads would not be conducive to the immediacy needed by the clinicians involved in the patient's care. Caroline explained that this is because if there is a deteriorating patient in front of you, it is harder to input information into the system compared to quickly writing down the required information. Ella also described how simply logging in to the device can waste valuable time when a patient is in need of immediate care.

> *"I suppose initially at the start it was more, you know, the unknown wasn't it, you didn't know how the system was going to work. It is still I suppose when you have a deteriorating patient in front of you. And it's you know, more of an emergency, it's harder to input something that traumatically like it is to grab the CPR chart and quickly write the obs in. You know, they're asking you lots of questions as you go through. And so sometimes I find that there's probably a delay inputting the obs in the iPads and someone's just scribbling them on a piece of paper somewhere before they can input them." (Caroline, ward manager, South Fields Hospital, interview)*

> *"Ella (HCSW) stated that 'if a patient is in cardiac arrest you have to fumble for the iPads and log in' which slows down the response." (South Fields Hospital, Ward 4, field notes)*

This section perfectly highlights the juxtaposition of responses from participants. Although there were reports that the technology was saving time for the members of staff using them, others reported that they were time consuming to use. This was because the user had to locate the iPad, log in and change the ward settings before using the device for the intended purpose. Further, in an emergency situation, valuable minutes are being used finding the iPad and logging in and this is not ideal for safe patient care.

7.4. Access to Data

During the data collection period, the WNCR was implemented, which fully digitalised patient notes and therefore theoretically removed the need for paper files. As already discussed in Chapter 5, paper files are still being used mainly in Castle Plains Hospital. However, they are still present in South Fields Hospital despite the need having been removed. The important aspect of CareFlow Vitals and WNCR is that every user has access to all patient notes and vital sign observations. A range of healthcare professionals spoke about how this was a benefit in their clinical practice. HCSWs in particular spoke about how having the data readily accessible to all members of staff who are registered with CareFlow Vitals and WNCR has helped with sharing information about patients in their care.

> *"It's in your hand, but it's in anybody's hands who needs that information. The doctor, the nurse, another NA [Nursing Assistant] (…), like if I'm with the patient and I'm busy doing one thing another NA can access the same information and she doesn't have to ask me everything. I've only got to update on, you know, the personal things and what happened that day (….) I couldn't imagine it any other way because it's, it's one viewpoint isn't it? And we can all look at the same information from our own individual iPads, and we've got access to it from, you know, just from the same site." (Jane, HCSW, South Fields Hospital, Ward 2, interview)*

This benefits how the MDT can work together to produce the most effective care for their patients. HCSWs could be reassured that doctors and the critical care team were monitoring patients with high EWSs in their care remotely which could not previously be done with paper-based forms.

> *"It has helped a lot because if you have got an ill patient and they can then see what they're scoring on. It's even down onto the computers or the doctors can see, critical care can, they've got access so they could be upstairs and they would know then if there's a patient*

scoring down here and they'll come down as well and see." (Annie, HCSW, South Fields Hospital, Ward 3, interview)

Doctors, and other clinical decision makers, do not have to step onto the ward anymore or visit the patient's bedside to see the vital sign observations. They do not even have to be at the same hospital. This benefits both doctors and their patients as patients receive timely care, and doctors have more time available to conduct other duties due to less travelling around the hospital site. Gerald spoke about how he used CareFlow Vitals multiple times a day to remotely monitor his patients in more than one hospital within the health board. When he was on call this was particularly helpful as he could be based at home and make clinical decisions about the patients at the hospitals using the information provided through the software. Gerald explained that this use of the iPads with CareFlow Vitals was a benefit as it avoided him hassling people to find information about his patients.

"So I work as a haematology consultant in [health board] And we do ward rounds, reviews of patients, inpatients, but we also do on-calls so we are able to access patients records essentially remotely and because it doesn't matter where you are even now I am working from home today I can see how a patient has been doing overnight and that is really really helpful and beneficial so that you are not hassling people so I use it multiple times throughout the day." (Gerald, consultant haematologist, South Fields Hospital, interview)

Critical care outreach practitioners use CareFlow Vitals to routinely monitor patients in the hospital with a high EWS. The software allows them to do this without leaving their office. They can then visit a patient with information they have already received prior without having initially been approached by staff on the ward, streamlining the process.

"At present, Outreach routinely checks the entire hospitals need for all those scoring over 6 on NEWS. CareFlow [gives] us a global view of the hospital from our office." (P1, critical care outreach and resuscitation practitioner, survey)

> *"I can see the observation trends before I go to a ward and review a patient." (P19, critical care outreach practitioner, survey)*

Doctors can use the data collected on CareFlow Vitals to make referrals easier for both them and the service they are referring the patient to, as they can both look at the computer at the same time at real-time observations.

> *"Sometimes we have to refer patients to intensive care, so often that those conversations could be quite difficult. So having that with then the person that we're making a referral to on the other side of the telephone, they can see all of the observations. So it just, it just makes it more, more straightforward, and more streamlined." (Gerald, consultant haematologist, South Fields Hospital, interview)*

This can lead to faster treatment for the patient (as mentioned in section 7.3 as being potentially lifesaving for the patient), and less frustration for the clinicians involved in their care. The iPads and CareFlow Vitals can also be useful during ward rounds. Gerald explained that before the implementation of these devices, staff would have to keep searching for each patient file as they discussed each one. Instead, the healthcare professionals can remain in the same room as all of the patients and their observations are in one place on the iPads.

> *"We always have a catch up after a ward round or in the afternoon and we tend to go through their thoughts and their observations and just make some plans from that perspective. So it's nice that you don't necessarily have to keep on going up and down, getting people's, you know, like folders with all of their observations. And you can do it all together. So that happens pretty much on a, on a daily occurrence. For my practice, anyway, because it's all about spotting subtleties and trends in, in abnormalities and what impact they have and what, what changes we have to put in place." (Gerald, consultant haematologist, South Fields Hospital, interview)*

The iPads can also potentially assist HCSWs to show doctors relevant information when they are on the ward. Doctors do not carry iPads and I was able to see and record in my field notes an exchange where this happened.

> *"Doctors came in during one patient's observations and Rose (HCSW) was able to pass the iPad to them to show them the vital signs and EWS immediately." (South Fields Hospital, Ward 4, field notes)*

When used in this way, the iPads therefore became a tool for the team to interact with each other about their patients without searching through the paper file which may not be to hand.

As previously mentioned, the iPads themselves cannot be accessed by all staff, particularly medical staff. To work around this problem, medical staff used the login information of other members of the team to view patient data. However, a consultant told me that although he did not have access to the iPads themselves, he was still able to access his patients' records via the laptops or computers on the ward.

> *"We don't have access to the iPads because you have to have a special login. I think only people who can input the data use it. But there's laptops and computers on the wards that we can access all of these records and also because it's on CWS you can access them from anywhere really." (Gerald, consultant haematologist, South Fields Hospital, interview)*

A ward manager reported that although medical staff can use CWS to access patient information, they cannot see every measure from this.

> *"When recording a stool motion, the Bristol stool chart is used to record the type of motion. This information isn't displayed in CWS where the medics view this. Also medical teams don't have access to the iPads therefore are using login of other staff." (P62, ward manager, survey)*

This has influenced some members of staff to prefer the paper patient files as all staff have access which makes providing care as a team easier, which goes against what other participants previously reported as a benefit.

> *"While conducting observations on a high scoring (EWS 7) patient, Betty (HCSW) told me 'I like the paper file as people who can't log into the iPads can see the notes easily'." (Castle Plains Hospital, Ward 3, field notes)*

Moreover, there were concerns that the iPads and CareFlow Vitals were not fit for purpose in all wards, particularly the Intensive Therapy Unit (ITU) which is where the patients who need the most care are admitted. Gerald spoke about how they do not use the system in ITU and continue to use paper-based forms.

> *"I think, for instance, there was a patient I was dealing with yesterday. They've gone to intensive care and they don't use it, but that's there. Even if you can't see their records because they're, the intensive care records are, you know, massive sheets of paper. So yeah, but that's just one particular department who's not used it. It's not necessarily a flaw on the system." (Gerald, consultant haematologist, South Fields Hospital, interview)*

Gerald did not see this as a flaw of CareFlow Vitals software as it was an organisational decision not to use the devices for recording observations in ITU, though this may change with time. A survey respondent also shared this sentiment as theoretically there is no reason the devices cannot be used in ITU:.

> *"In theory, accessible to clinicians from anywhere; in practice, on ITU, this isn't utilised as it's for wardable patients who need little oversight." (P83, registered nurse, survey)*

However, another participant was not sure whether there would be any benefit to the care of patients on ITU if the system was available (P87, staff nurse, survey). One conclusion then is that there has not been full implementation of the devices and CareFlow Vitals and there is some inconsistency in the way healthcare professionals are working across departments within the hospitals.

Some participants were also concerned that patients would receive less contact time with doctors as they can access the CareFlow system remotely, allowing them to make clinical decisions without visiting the patient in person.

> *“Well, I think the reason people didn't like it and I can kind of see it is if you imagine a doctor doing their ward rounds or whatever, they wouldn’t have to necessarily step on the ward ever because they'd be in somewhere else on an iPad going ‘fine, fine, fine, fine’, you know? ‘Yeah, I'm not going to see any patients this week or today’ or whatever. So I think that is what people didn't like the way it may go.” (Ben, HCSW, South Fields Hospital, interview)*

> *“Todd (HCSW) feels that the patients may be getting less time with their doctor. He explained that even if the patient is fine and the doctor is not concerned, the patient can feel a lot more reassured hearing that from the doctor.” (South Fields Hospital, Ward 3, field notes)*

Todd felt that although it may be unnecessary for a clinician to see a patient in-person, that patient would miss that sense of reassurance. However, it was reported earlier that clinicians found having the remote access was a benefit in their clinical practice so it seems there needs to be a balance for the interest of both medical professionals and their patients.

7.5. Accountability

Participants spoke about how the software ensures that the observations that they have conducted are timestamped and therefore they can prove they have done their duties despite them not having recorded it in the paper files.

> *“So because you’ve got that device in your hand and you take it around with you, you can record it, you know all your obs that you've done. So I prefer that from my point of interest. Well, yeah. Even if you haven't got*

time to write in the notes[11], it's still on there, on that iPad in black and white to prove that you've done it, you know? So that's what I like about it as well." (Mandy, HCSW, South Fields Hospital, Ward 2, interview)

"The iPad will just store it, the time is stamped, it's in." (Jane, HCSW, South Fields Hospital, Ward 2, interview)

Carly spoke about how she felt more accountable due to a feature on the software that requires her to confirm that she has read the next steps given after inputting the vital signs. After accepting that responsibility, she knows that she has to act on what the software advised. Further, she reported that CareFlow Vitals made other staff members more accountable.

"Yeah, it gives you next steps at the end and then you've got to click to say that you've read them. So everybody is aware. So if I'd done it, then I click there, then I take responsibility then because I've read what it said. Now, you know, you got to act on it. With paper, you sign your name, you can close the book and just put it to one side. […] I'm much more accountable, yeah. (…) And I think because, yeah, because you can say, look I've told you now that they're scoring six now for the last three times. This is what the iPad is saying. This is what you need to do." (Carly, HCSW, South Fields Hospital, Ward 4, interview)

A senior nurse also mentioned that CareFlow Vitals ensures that healthcare staff on the wards are kept accountable for observations being conducted according to the policy of the health board.

"It allows for greater accountability of the observations and that they are being done as per policy." (P76, senior nurse/ANP, survey)

[11] Although clinical notes are now recorded digitally, some wards still required staff to record observations in the paper files. This is further discussed in Chapter 5.

However, disadvantages were reported that reduced the sense of accountability that others reported. For example, on a number of occasions during data collection, participants expressed that they had been logged out of the system or completely removed from the system. Mandy and Carly both experienced this and did not have a reason for why this occurred.

> *"When I first used it, they said it didn't recognise my name. […] the ward sister, she just raised that. She emailed someone and they sorted it out so it was done quite quickly really." (Mandy, HCSW, South Fields Hospital, Ward 2, interview)*

> *"About four months in, it totally wiped me off the system. So then I had to ring them, and then they had to put me back on. They couldn't find my name or nothing. I don't know what happened then, but it stopped me doing the observations then. […] It took about three days, but it did get resolved. […] So I would write [the observations] on pen and paper and give them to the nurse to put in who would come around with me but obviously we can't use each other's names. So either they would come round with me and we do them together or they would do them." (Carly, HCSW, South Fields Hospital, Ward 2, interview)*

Carly expressed that a nurse could upload her observations that she had written on paper in this instance. However, this would be uploaded in the nurse's name rather than Carly's which raises a question about who is responsible for that data? Another participant who had this experience explained that they were technically on the system, but their name had been inputted incorrectly so they could not find themselves in the system.

> *"Initially I couldn't find myself for a long time because my surname was my first name, and my first name was my surname or something." (Ben, HCSW, South Fields Hospital, interview)*

Although these seem like teething issues occurring at the beginning of implementation and the use of the iPads, I observed this happening to a number of

staff when I was onsite at the hospitals, in a time period over three years after the initial pilot and implementation of the devices and CareFlow Vitals.

> *"Rebecca (HCSW) is logged out of iPad but she says this is the first time this has ever happened." (Castle Plains Hospital, Ward 1, field notes)*

> *"Ella (HCSW) cannot find her login on iPad so has to use Isla's. She expresses that 'I'm not coming up' [on system]." (South Fields Hospital, Ward 4, field notes)*

This last field note highlights the consequences of the healthcare professionals not being able to access the system. To gather the observations and record them into the CWS, Ella had to use Isla's login, and this has its own problems, as highlighted above by Carly. To further expand, if there was a problem with the way the observations had been recorded and there was an adverse event, it would be recorded that Isla conducted observations rather than Ella. Ella's other option would be to use the paper-based forms which are not in frequent use in South Fields Hospital and would not allow clinicians working elsewhere to view the live observations which was seen as a benefit in section 7.4. This problem emphasises that technology can be unreliable, and staff have to revert back to using paper-based forms when the iPads and CareFlow Vitals cannot be used. This issue also does not affect all staff at the same time which means that documentation ends up being recorded on different media at the same ward. This could have knock-on consequences for the access and display of data if some are on paper and some are in the CareFlow Vitals software.

Furthermore, temporary staff including agency and students do not have their own account for CareFlow Vitals. Sally, a nurse in Ward 1 of South Fields Hospital, explained that the consequences of this are that either these staff will have to record patient observations using pen and paper, or use somebody else's account. My account of this during an observation is below.

> *"Only permanent staff get login for CareFlow Vitals. Agency and students do not have access. They can get a temporary login but this doesn't tend to happen. In these cases temporary staff will either have to use pen and paper or use somebody else's login- this technically should not be done as records are under the*

wrong name but they don't know another way to do this." (South Fields Hospital, Ward 1, field notes)

Carly explained that this feature is what she dislikes most about CareFlow Vitals because of the potential for consequences for her if the temporary staff member fails to do the patient observations or does not act upon the actions that CareFlow Vitals sets.

> *"They're like, 'ah can you sign in? And then I'll use it'. But I don't like doing that because if they don't do what the iPad says at the end then that comes back on you." (Carly, HCSW, South Fields Hospital, Ward 4, field notes)*

In my field notes I recorded that Daphne, a Nurse on Ward 4 at South Fields Hospitals, explained that she has the authority to create a temporary account for staff but she was reluctant to do so because these staff members may not have had training on CareFlow Vitals. Caroline also had this worry as the ward manager.

> *"I think the main problem was that, and sort of still is probably now, the nurse bank don't train the bank staff, and so we do get bank staff that haven't got pin numbers still and they've been on the bank a few years. You know we can give them access but it's if they've had that initial training. I'm guessing they haven't had the training if they've not got a pin number." (Caroline, ward manager, South Fields Hospital, interview)*

This also creates a problem for the agency staff who cannot see the previous observations of their patients and have to rely on other permanent staff members at the hospital. With agency staff becoming more in demand, this is creating a problem on the wards.

> *"Agency nurses are unable to see any of their patients' previous obs, and often rely on using other staff members passcodes to access this system so they can check their patients. This then causes the issue of who is recording the obs and who is responsible for escalating any concerns." (P69, registered nurse, survey)*

This disadvantage creates both a problem for temporary staff, including students, and permanent staff on the wards and it is unclear who might be responsible for the failure to escalate patient care as more than one person could be using one login.

7.6. Ease of Use

A common perception towards the devices and CareFlow Vitals was that they were simple, straightforward, and easy to use for a range of healthcare professionals.

> *"It's quite self-explanatory so it's quite simple so I like that." (Daniel, HCSW, South Fields Hospital, Ward 4, interview)*

> *"It was really straightforward. […] For what we want to see, a quick snapshot of patient trends and observations, it's, it's invaluable and really straightforward." (Gerald, consultant haematologist, South Fields Hospital, interview)*

Ben explained that he found it very difficult to input incorrect patient observations data because the software would prompt you to check if it detected a likely incorrect value.

> *"For me, it was just very simple to use. I couldn't really go wrong. So it's very difficult to get it wrong. And yeah, like, the warnings you get on there as well as like if you put a wrong value in like it'll check because […] if you take a heart rate or whatever and put it in resps rate and be like, oh yeah, no they're not breathing 90 times a minute and it knew that you cocked that up." (Ben, HCSW, South Fields Hospital, interview)*

By reducing the likelihood of human error in this way, the user of the device can feel reassured when conducting their clinical duties. When conducting the observations using paper-based forms there was no safeguard against incorrect values or EWS calculations. In this way, use of the devices could be seen as contributing to improved patient safety (section 7.2).

Healthcare professionals also identified that the iPads were easier to transport and carry than the paper files.

> *"But they are easy just to hand, to carry around, you know you don't have to hunt the book down for the patient when you can just grab an iPad literally." (Daniel, HCSW, South Fields Hospital, Ward 4, interview)*

Moreover, it was identified that the iPads and CareFlow Vitals were more efficient and clearer than the paper-based forms.

> *"Efficiency and clarity, often paper formats were messy and NEWS scores were not always totalled accurately." (Judy, ward manager, South Fields Hospital, interview).*

There was also a view that the information on the devices was easier to read than the notes available in the paper files.

> *"I think the data [are] easier to access and read for all users." (P57, nurse, survey)*

Although the nurse above mentions that all users have access to the software, it has already been discussed in Chapter 5 that this is not the case and some users do not that have their own personal account. Staff on the wards often mentioned that handwriting was difficult to decipher in the paper files and having the iPads and CareFlow Vitals resolved this problem, even more so when WNCR was installed at South Fields Hospital.

On the other hand, some participants did not find the iPads and CareFlow Vitals easy to use. During an observation with Violet, she explained that sometimes the iPads stopped working and were difficult to interact with.

> *"Violet (HCSW) stated that 'sometimes they don't scroll'– the tablet crashes and they can't use the touch screen at all until it starts working again. When this happens Violet has to use the computers to upload her notes but this is often difficult as all staff use the computers and there can often be a wait before being*

able to use them." (South Fields Hospital, Ward 3, field notes)

This disadvantage explained by Violet also highlights another issue. When the iPads are not working, more staff need to use the computers on the ward which does not have many. Having the iPads available ensures that HCSWs and nurses are able to record their patient observations, and notes if WNCR is available. This frees up the computers for staff who do not have access to the iPads. When the iPads or the system do not work it does make the clinical duties harder for the people who are using them.

"*When they go down, it's hard work if they don't work or if they're not charged. It can be hard work then." (Annie, HCSW, South Fields Hospital, Ward 3, interview)*

In contrast to the results reported earlier in this section, some participants did not find the iPads and CareFlow Vitals user friendly due to not being as clear to read or easy to access.

"I also do not think they are very user friendly. […] Information not easily accessible or readable." (P23, job not given, survey)

"It's not very easy to read the numbers when viewing on CWS." (P76, senior nurse/ANP, survey)

"I don't think that the overall summary of obs is clear enough to see at a glance." (P84, nurse, survey)

This highlights the complexity of implementing the iPads and CareFlow Vitals into the hospitals as some professionals found them agreeable and easier to use, whereas others preferred the previous ways of working and found them more difficult to use.

7.7. Use of Paper

A less commonly identified, but nonetheless an important benefit was the value to the environment by the health board heading in the direction of being paperless, due to the implementation of mobile technology,

> *"The iPads have helped with the wards digital profile, to move away from paper formats." (Judy, ward manager, South Fields Hospital, interview)*

> *"The other thing I would say is that I am a paperless fan. Obviously we had the Welsh Nursing Record come in as well […] so all care notes would be electronic then as well, and people hate that. But it made a huge difference for me, that's the way we kind of need to go in my view. It is the 21st century. If you don't know how to use these things, learn, but yeah, I just thought it was where it was going to go." (Ben, HCSW, South Fields Hospital, interview)*

As Ben stated, being paperless may not necessarily be a popular decision, but it was important to some of the participants who were conscious of the environmental costs of using mass amounts of paper. Besides this, going paperless can be financially beneficial as well as reduce the risk of losing confidential patient information (see section 2.3.6.4).

However, there were times when healthcare staff had to revert back to the use of the paper-based forms. One example is a disadvantage that was described by many of the interview and observation participants. Particularly at the beginning of implementation, the system or the WiFi crashed and was unavailable. When the system goes down, staff have to revert to the paper forms that were in use before the implementation of the iPads and CareFlow Vitals.

> *"We did encounter problems where iPads were offline and we had to revert to paper copies. The CareFlow team assisted, and Site Management advised to revert to paper copies." (Judy, ward manager, South Fields Hospital, interview)*

This has been reported to have improved over time since South Fields Hospital opened.

> *"They have worked really hard on the WiFi here and it's only gone down about three times since South Fields Hospital have opened in two years." (Annie, HCSW, South Fields Hospital, Ward 3, interview)*

A number of respondents to the survey reported that they were unable to input all measures into CareFlow Vitals as it was not available to them. For these measures they have to use paper-based forms so staff end up using both the devices and paper-based forms so patient information is not all in one place.

> *"You cannot put in the 3-minute results in a lying to standing BP [blood pressure] measurement." (P71, physiotherapist, survey)*

> *"Fluid balance not available on CareFlow so end up using pen and paper anyway." (P77, critical care nurse, survey)*

This highlights that although the intention is there to work towards a paperless environment, there is still more to do to ensure paper is never needed at the hospital wards within the health board. This involves integrating all measures into the software and ensuring that system and WiFi issues are minimised.

7.8. Duplication of Work

It was earlier reported in Chapter 5 that a consequence of implementing the iPads with CareFlow Vitals into secondary care settings was a duplication in the workload of hospital staff. This section reports on how disadvantages caused by using the iPads and CareFlow Vitals contribute to staff members duplicating their workload. For example, it was expressed that observations sometimes do not upload, and staff have to repeat their observations.

> *"Tanya (HCSW) stated that the 'only error encountered is sometimes it refreshes and you lose all your obs'. This does not happen often but it is the only problem that Tanya has encountered." (South Fields Hospital, Ward 1, field notes)*

> *"Bianca (HCSW) told me that the 'only problem I've had is that it doesn't save the obs I've put in half the time. This morning we had to do two sets of obs three times because nobody could remember what it said'." (South Fields Hospital, Ward 5, field notes)*

> *"Observations not saving despite being completed so end up repeating observations more than once when this happens." (P77, critical care nurse, survey)*

When this happens, the workload of the staff member recording the observations is increased due to having repeat what they have previously done. This takes them away from their other tasks on the ward. Further, there were reports that there was a delay in the patients being added to the system which was a problem when protocol dictates that observations must be done immediately on new admissions to the ward. There was also a problem with the patients being 'stuck in the system' after discharge and remaining on the patient list.

> *"At the beginning yeah, there was quite a lot of issues. Patients not being added, or when patients left or got discharged, they would still be on the VitalPac." (Annie, HCSW, South Fields Hospital, Ward 3, interview)*

> *"Takes a while for new patients to be added, and old patients to be removed- some are 'stuck' in the system permanently admitted to the ward." (P2, HCSW, survey)*

Annie recognised that this was an issue in the early days of implementation so could be classified as a teething issue associated with the introduction of new technology into a large organisation. However, this led to another issue where healthcare professionals found it difficult to locate their patients on the system when they needed to record the observations.

> *"Sometimes that's a problem, sometimes they move rooms and it's not updated." (Cerys, student nurse, Castle Plains Hospital, Ward 4, field notes)*

> *"Hard to locate the patient when a bed has not been selected." (P29, HCSW, survey)*

If the healthcare professionals are unable to record their patients on the CareFlow system using the iPads they have little choice but to revert to using the paper-based forms to ensure they conduct and record their observations as policy dictates. This resulted in duplication of workload once the patient is on the system and the observation data can be inputted, but this will have the incorrect timestamp and not reflect the time that the observations were conducted.

7.9. Low Battery

A frequent observation from the participants was that the iPads were often running low on battery. However, this was not a problem with the devices themselves but rather a problem because staff were not putting them on charge when not in use.

> *"If I come on shift and there's like six percent and I picked up the last iPad because everyone picks them up with the most, check how much charge is in there. And you obviously want it to last you the shift, so you, you pick them up. But if you were the last one, you might not have much charge. So, then you know, I've got into little, little habits like this. We've sat down so I've put it on charge straight away, and when it's busy, they're obviously being used a lot and the battery can go down, so that's probably the only thing. (…) If everybody charged it up a little bit more then we'd be fine." (Jane, HCSW, South Fields Hospital, Ward 2, interview)*

Throughout my field notes, I recorded many times that the devices were left out and not on charge. There was only one ward (Castle Plains Hospitals, Ward 2) where I witnessed the devices being placed into the docking station.

> *"Two iPads are left on the desk not plugged into a charger." (South Fields Hospital, Ward 5, field notes)*
>
> *"iPad is out, not being charged or in use next to patient files." (Castle Plains Hospital, Ward 1, field notes)*
>
> *"I have seen three iPads left out on the side not on charge." (Castle Plains Hospital, Ward 1, field notes)*

This however could be a teething issue and staff may improve the habit of putting the iPads on charge as it becomes more difficult to conduct their clinical duties due to the low battery. Another perspective on the devices running low on battery could be because the iPads are getting older and are naturally running out of charge quicker than they used to.

> *"An iPad doesn't last long. They've probably been with us now for about five years. […] When it first happened, they were speedy, quick, and some of them are slowing down now because of that age thing, you know, they're not holding their battery either, so that's another thing. You get, you get charged up, within like half a day, it's dead. Before they lasted a couple of days, you know?" (Todd, HCSW, South Fields Hospital, Ward 3, interview)*

If Todd is correct and the age of the iPads are affecting the length of battery time, it does raise a question about how often the iPads should be replaced with a newer model.

To summarise, if staff are picking up the iPads at 6% and 1% battery level, they have the choice to put the device on charge and delay observations, or record patient observations on paper and upload to CareFlow Vitals later. Alternatively, they could try to rush their observations to get them done before the device is out of charge. This introduces potential for error and less safe care for patients.

7.10. Conclusion

To conclude, this chapter builds on the findings reported in Chapter 5 by expanding on how the uses and functionalities of the CareFlow Vitals software have created perceived benefits and disadvantages for healthcare professionals in secondary care. Some of these results seem contradictory. What one participant may report as a benefit, was reported as a disadvantage by another participant. For example, some reported that patterns and trends were easier to detect on CareFlow Vitals, and others that patterns and trends were more difficult to detect on CareFlow Vitals. Additionally, some of these disadvantages seem more like temporary issues expected at the beginning of an implementation period, whereas other disadvantages will have a longer-term impact on the device users and the way that they work. A good example of this is the issue surrounding WiFi. Participants acknowledged that the poor WiFi was associated with the opening of South Fields Hospital and has since improved, whereas the lack of access to a CareFlow Vitals account for all healthcare professionals continues to cause longer-term issues and results in accountability

concerns and increased use of paper. However, it is indicated that the benefits reported in the study are lost if there are technical issues causing the healthcare professionals to revert back to using paper-based forms. These points will be further discussed in Chapter 8.

Chapter 8. Discussion

8.1. Overview

In the previous chapters the results of the research were presented. In Chapter 5 it was reported that most staff members received training on how to input information using the devices during implementation. There were concerns about the perceptions of patients and families when healthcare professionals were using the devices (staff using their personal mobile phones, being distracted), but management staff members at the health board mitigated this with informational posters throughout hospitals. This seemed to be a successful venture as I did not record any complaints from patients during my observations at the South Fields Hospital and Castle Plains Hospital. It was observed that in most situations the iPads and CareFlow Vitals were used to record patient observations at the bedside, with the occasional use of pen and paper if there was a system or WiFi outage, or the patient had not been added to the system on admission. The devices were used in a similar way throughout the observed wards, except where there was a triage system in place. In these wards the devices were used more regularly as there was a higher patient turnover. iPad use tended to be limited to recording patient observations during ward rounds approximately at 6 am, 10 am, 2 pm, 6 pm and 10 pm, plus when patients were first admitted, when a patient had an operation, or a patient had a fall. This did not seem to change over time as usage of the devices was designed to replace the paper-based record forms that were used previously.

Some healthcare professionals perceived the iPads as a great patient management tool as they could immediately see the patients on their ward in one list and plan their shift accordingly. Patients' vital signs could also be viewed away from the ward limiting the need for clinicians to travel throughout the health board if not necessary. Doctors could gauge from the vital signs available to them on CWS whether it was essential to visit a patient. They could also be contacted by staff on the wards if there were any concerns that they may need to be present for. Others perceived that the iPads and CareFlow Vitals did not change the way in which they managed their patient care as they would have worked the same with pen and paper. It was reported that the Covid-19 pandemic did not disrupt the implementation of the devices

equipped with the CareFlow Vitals software, which could be seen as surprising as the Covid-19 pandemic deeply affected healthcare services as illustrated in Chapter 1.

In Chapter 6 it was illustrated that CareFlow Vitals was the most preferred method of data-entry amongst the survey participants, but not by a majority as a proportion were unsure of their preference. The years of experience demographic variable and preference for using CareFlow Vitals in clinical practice revealed a statistically significant difference. This finding showed that participants with less than one year of experience were not sure of their preference for data-entry method, participants with 2-5 years or 21+ years of experience preferred using pen and paper, and participants with 6-20 years of experience preferred using CareFlow Vitals. It was unexpected that the group with fewer years of experience (<5) did not prefer using CareFlow Vitals as they started working either during or after the implementation. This was a surprising outcome as this group of participants would have had little or no experience of the alternative paper-based forms as they would have started their career at a similar time to the implementation of the technology into the hospitals. In terms of role, CareFlow Vitals was largely preferred by general nurses, HCSWs and critical care outreach practitioners; physiotherapists and nurse practitioners preferred using the traditional pen and paper method. This finding will be discussed in this chapter. CareFlow Vitals was seen to be superior compared to pen and paper in convenience, accuracy, and allowing easier detection of errors. In contrast, pen and paper was seen as superior in terms of being easier to use, simpler, and quicker. Most of the participants who received training to input information and make clinical decisions using the information provided on the iPads preferred using CareFlow Vitals. Moreover, participants who perceived benefits from using CareFlow Vitals, and did not experience problems, technical issues or other disadvantages, also preferred using the iPads over paper-based records.

In Chapter 7 it was highlighted that the majority of the participants in the survey had perceived benefits but also experienced problems and technical issues when using the iPads with CareFlow Vitals in their clinical practice. Benefits included providing safer patient care by calculating the EWS automatically and reducing human error, potentially identifying deterioration in patients sooner, saving the time of hospital staff when documenting vital signs and freeing up time to do other clinical tasks, and allowing remote access to patient information meaning that on occasion clinicians could avoid an in-person presence on the hospital ward when on-call. Disadvantages included promoting an over-reliance on the software, system/WiFi failure causing staff

to revert back to paper-based materials, low battery because not all staff charge the devices when they are not in use, staff without logins, and reduced patient contact time with doctors because of decisions being made remotely.

In this chapter I discuss these findings in more depth and their relation to the theoretical framework and relevant literature.

8.2. Innovation Diffusion Theory

IDT was introduced in Chapter 3. In this section I endeavour to apply IDT to the findings of this research and discuss this. Diffusion in the IDT is about an innovation being communicated through certain channels over time among the members of a social system. There is an innovation-decision period which is the length of time that is required for an individual or organisation to pass through five stages: knowledge, persuasion, decision, implementation, and confirmation (Rogers, 2003). There are a set of prior conditions before decision makers choose to introduce a new innovation as shown in Figure 7. In terms of this research, it has been noted that before the introduction of the iPads with CareFlow Vitals, previous practice was to record patient observations on paper-based forms. There was a felt need from the decision makers at the health board that recording patient observations could be improved by using digital technology and there was evidence for this in previous research (Chapter 2). The first three stages– knowledge, persuasion and decision- were conducted by the hospital decision makers before the start of this doctoral research. The implementation stage was initiated with a pilot study before wider introduction. The confirmation stage is where this research specifically lies as the organisation has sought evaluation of the innovation in practice. That said, I discuss each stage in turn and apply them to this research. My discussion of stages 1-4 of the IDT are necessarily speculative as this research was started during Stage 5.

8.2.1 Stage 1: Knowledge

Prior to my study of staff perceptions of the use of CareFlow Vitals on the wards, management decision makers at the health board would necessarily have had to seek

information about the innovation to gain an understanding of how it may work in clinical practice. As shown in Chapter 2 there are many products that serve the function of recording patient observations and automatically calculate the EWS. The individuals making these decisions will tend to expose themselves to ideas that are in accordance with their interests, needs, and existing attitudes (Rogers, 2003).The decision would have been made to pursue this particular innovation based on the needs and attitudes of the hospital decision makers at the health board in relation to the knowledge they had gained from information seeking activities which are likely to have included discussions with product vendors, others using the systems and the wider literature.

8.2.2. Stage 2: Persuasion

During the persuasion stage, the decision makers form a favourable or unfavourable attitude towards the innovation that they have gained knowledge about. At this time, they seek further information on the characteristics of this innovation.

The IDT describes five different attributes (relative advantage, compatibility, complexity, trialability, and observability) that can contribute to the different rates of innovation adoption during the persuasion stage. As mentioned, the first attribute is relative advantage. Relative advantage can be measured in economic terms, social prestige factors, convenience, and satisfaction. The National Institute for Health and Care Excellence (2020) states that in economic terms installing an automated EWS system is unlikely to save money because it typically does not reduce the number of staff in practice. That said, it could release nursing resources such as reduced paper charts which will indirectly save money. However, relative advantage is not measured using objective terms, but is measured by the individual's subjective opinion that the new system is better than the predecessor. According to IDT, the greater the relative advantage, the faster the rate of adoption. In this research I have shown that healthcare staff were divided in their opinion of the iPads and CareFlow Vitals and their potential advantage over the traditional paper-based forms. Some members of staff were very enthusiastic in explaining the benefits of the new technology. Others did not like the new technology at all and could only speak about the disadvantages compared to using pen and paper. Therefore, relative advantage is very mixed in this sample.

The next attribute is compatibility which is the degree to which the innovation is perceived as being consistent with the existing values, needs and experiences of potential adopters. Hospital organisations are described as being a “dynamic cultural mosaic made up of multiple complex, and overlapping subgroups with variably shared assumptions, values, beliefs, and behaviours” (Mannion and Davies, 2018) but the main goal for any healthcare professional is to provide the best care for the patient. Looking at the iPads with CareFlow Vitals through a patient-centred lens portrays a system that is safer for patients as deterioration in condition (as indicated by the monitoring of vital signs) is easier to detect due to the automatic calculation of the EWS. The software also allows the user to reflect on previously collected vital signs and EWS to see a display in change over time which can allow a clinician to detect subtle changes that could indicate a decline in health. However, just as there are clinical benefits in this way, there are some disadvantages for patients including less contact time with clinicians due to the ability to remotely monitor vital signs, and a perception that observations are conducted unnecessarily frequently.

The third attribute is complexity. Complexity is the degree to which the new technology is perceived as difficult to use and understand. Throughout this study, participants spoke about how the new innovation was not difficult to learn and that the device was self-explanatory to use. Users were also provided with training and staff were able to ask other users questions about the devices on the wards if they had any questions. Overall, participants did not find the devices complex to use despite other disadvantages.

The fourth attribute is trialability which is the degree to which an innovation can be experimented with on a limited basis before adoption; this would include use of a pilot study. The health board piloted the innovation at Castle Plains Hospital and Blossom Valley Hospital. This led to a business case being accepted in 2019 to extend the implementation to every hospital in the health board.

The final attribute is observability. This attribute is about the degree to which the results of adopting the innovation are visible to others. The rate of adoption will be faster in an organisation where the results of the innovation are easier for others to see. Although I was not present during the pilot study implementation, the decision makers may have seen visible results during this period to influence their decision, as is noted in the next section.

8.2.3. Stage 3: Decision

At the decision stage, the hospital decision makers had to determine whether to adopt or reject the iPads with CareFlow Vitals. The decision to implement the innovation can be described as an authority-innovation decision as the choice to adopt or reject the devices and software was made by relatively few individuals in the system. Individuals with authority are those who possess power, high social status, or technical expertise (Rogers, 2003). One way to test the idea of adoption is to trial the innovation on a small scale. The hospital decision makers chose this option and implemented the iPads into two hospitals- Castle Plains Hospital and Blossom Valley Hospital. Innovations that can be trialled in this way are more often adopted than those that are not (Rogers, 2003).

8.2.4. Stage 4: Implementation

The implementation stage usually occurs directly after the decision stage and this is where the innovation is put to widespread use. The iPads with CareFlow Vitals were implemented in all hospitals throughout the health board after the pilot trial. WNCR was also implemented in South Fields Hospital as a separate pilot to the CareFlow Vitals implementation and there were plans to introduce this software in all of the hospitals alongside. This research did show that for a truly paperless environment, both CareFlow Vitals and WNCR needed to be implemented together to address the issue of notetaking on paper forms. When this new practice is considered a regularised aspect of ongoing operations, the innovation-decision process is considered to be terminated unless the decision makers seek confirmation (section 8.2.5.). At the time of my observations, the iPads with CareFlow Vitals were definitely an institutional norm as they were used regularly to record patient observations due to them being mandatory to use. Participants did highlight some disadvantages, but there was no indication of going back to the original method of recording patient observations on paper-based forms.

8.2.5. Stage 5: Confirmation

The confirmation stage occurs when the decision-making unit seeks reinforcement of the innovation they have introduced. It is possible that decision makers will choose to discontinue an innovation if they are aware of performance dissatisfaction, or another innovation that can supersede the original adopted idea (Rogers, 2003). As part of this evaluation, this research sought to collect the perceptions of the staff inside the hospitals who were using the innovation in practice. Overall, as stated previously, the reception of the iPads and CareFlow Vitals has been mixed. It is observable that the members of staff do not find the technology difficult to use, and that there are benefits for different professional groups. However, it is noteworthy that a part of this social system did not prefer using CareFlow Vitals. All physiotherapists in this sample did not prefer the use of the new innovation and this could impact the overall rate of adoption in the whole system. Of course, it is important to highlight a limitation of this research: the number of this group of participants was small and so caution is needed in interpreting these results. What can be said is that in this group it was not observed that there were sufficient benefits to using the devices and CareFlow Vitals.

Although healthcare professionals reported experiencing both benefits and disadvantages in their clinical practice, a greater proportion preferred the new technology than the conditions of practice prior to implementation. This could indicate that with some adjustments to the overall infrastructure regarding the mobile technology (e.g., allowing temporary staff to have passwords, setting protocols for recharging the devices, and making the iPads and CareFlow Vitals accessible in every ward), acceptance could improve, and more staff would prefer to use the devices rather than the traditional paper-based forms used before implementation.

8.2.6. Reflections on the Innovation Diffusion Theory

The IDT is a useful and widely regarded tool when evaluating the implementation of an innovation in an organisation. By using this theory, I have been able to illustrate the diffusion process of the iPads and CareFlow Vitals into the health board from the pilot study at Castle Plains Hospital and Blossom Valley Hospital (for which I am unaware of the results) before the main implementation period throughout the rest of

the hospitals in the health board including South Fields Hospital. The stages of diffusion are clear, and the data can be interpreted to provide reasoning for progression at each stage.

However, it is difficult to apply this theory retrospectively as I was not present for the first four stages of the diffusion process and therefore the data was applied necessarily speculatively. Ideally, the research would have followed the journey of acceptance from first knowledge to widespread implementation. This was not possible given the timing and duration of this doctoral research.

8.3. Unified Theory of Acceptance and Use of Technology Model

In this section I apply the UTAUT model to my findings. This model is discussed in depth in Chapter 3. The UTAUT model is a combination of the strongest influence of factors from previous theories of technology acceptance, including the IDT. Four constructs (performance expectancy, effort expectancy, social influence, and facilitating conditions) act as direct determinants of usage behaviour and user acceptance. Gender, age, experience, and voluntariness of use act as key moderating variables in the model. These variables together influence the behavioural intention and use behaviour of the new technology. First, I will apply the direct determinants of the model to the healthcare professionals who use the iPads and CareFlow Vitals to input the vital signs of the patient and immediately calculate the EWS (e.g., HCSWs and nurses). After this I will apply the model to the members of staff who use the data collected from the devices to make clinical decisions. (e.g., nurses, clinicians, ward managers). I will then apply the moderating variables of the model to the data collected to explain the strongest effects before delving into the behavioural intention and use behaviour.

8.3.1. Using the Devices to Input Information

In this section I discuss the acceptance and use of the technology from the perspective of the participants who used the iPads and CareFlow Vitals to input the

vital signs of patients and calculate the EWS by going through the first three direct determinants of the UTAUT model in turn. In my observations I only observed HCSWs and nurses input information into the iPads and software.

Performance expectancy is defined as "the degree to which an individual believes that using the system will help him or her to attain gains in job performance" (Venkatesh et al., 2003, p.447). As reported in Chapter 5, the iPads with CareFlow Vitals were seen by the individuals in this study to be more accurate and allow for easier detection of errors. The recorders participant group also spoke about how they could use the devices to plan how and when they would conduct their competing workload. For example, at the beginning of the shift they could look at their patient list and their patients' corresponding EWS. They could then ensure they repeated patient observations when the EWS indicated and do other tasks (e.g., personal care, serve meals, conduct other patient tests such as blood sugar observations) when there was available time.

Effort expectancy is about the ease of using the new system in practice. CareFlow Vitals was described as being more convenient for healthcare professionals. However, overall the paper-based forms were seen to be easier to use. The devices and software were reported to be time-consuming to use due to the requirement to locate the devices, sign into the software, and then locate the patient on the system before starting their patient observations. Part of the reason for being more time consuming for the data inputters (the recorders) was because of the duplication of work. When WNCR was unavailable (which was still the case in Castle Plains Hospital during my data collection period), the recorders had to input the patient observations into the CareFlow Vitals software before scribing the same information into the paper-based patient files. After WNCR was implemented, patient vital signs were inputted into the devices and software before being transferred manually into WNCR using either the iPads or computers. Therefore, no matter whether WNCR has been introduced into the hospital, there is still an element of duplication because the CareFlow Vitals software does not 'talk' to the WNCR system and does not include a section to transcribe patient notes outside of collecting the vital signs of the patient.

Social influence is described as "the degree to which an individual perceives that important others believe he or she should use the new system" (Venkatesh et al., 2003, p.451). As the implementation of the iPads and CareFlow Vitals was mandatory it could be perceived by the users of the devices that the hospital decision makers in management (important others) believed that the healthcare professionals in the

health board should use the new system. Overall, the recorders (those inputting the observation data, e.g., HCSWs and nurses) preferred the use of the devices and software in their clinical practice because of the benefits they perceived such as a reminder to conduct the next observations, and a recommendation of the next steps in the patient care journey. Such benefits were seen as means of improving patient care and safety. Using the devices also was seen to streamline the workflow of the ward-based professionals which could facilitate a sense of community and acceptance around the new technology.

8.3.2. Using the Data to Make Clinical Decisions

In this section I apply the first three direct determinants of the UTAUT model in turn to the clinical decision makers (e.g., nurses, doctors, physiotherapists, and critical outreach practitioners) and ward organisational decision makers (e.g., ward managers/sisters). In my observations I did not see this group of participants use the iPads and CareFlow Vitals on the wards, but interviews and open questions in the survey illicit that this group did use the data to make clinical and organisational decisions about patients.

In terms of performance expectancy, different professional groups described different gains in job performance due to having the data available from the CareFlow Vitals software on the CWS. Doctors spoke about how accuracy and error reduction can make a significant difference in patient care by allowing an easier detection of deterioration (Chapter 7) as doctors could access the vital signs information of patients remotely which enabled them to make clinical decisions without visiting the patients. If vital signs were indicating a serious condition such as sepsis, treatment could be started earlier which potentially improved the outcomes of patients. Ward managers also felt that the data collected from the CareFlow Vitals software improved their job performance as they were able to see all of the patients on the ward on one screen and make organisational decisions based on this, rather than having to go through each individual file.

As mentioned in the previous section, effort expectancy is about the ease of using the new technology. The participants who used the devices to make clinical decision did not have the same issue regarding the duplication of work. However, these participants did not often use the iPads (doctors especially did not have a login for

them) but instead accessed the data collected from CareFlow Vitals on the CWS from computers either on the wards, in offices, or remotely at home. This is especially beneficial for staff who may be on 24-hour call shifts. They can be present from home by using the vital signs information to make decisions about their patients because of this new technology.

On the whole, nurses and clinical care outreach practitioners preferred using the data from CareFlow Vitals (as opposed to using the iPads to record observations) in their clinical practice, rather than paper-based records. However, no physiotherapists in the sample preferred the use of CareFlow Vitals in their clinical practice (although the sample was small). There was no one common reason for this finding. Physiotherapists spoke about difficulties accessing the information during critical events, technical issues such as being locked out or being low on battery and having difficulties switching between wards and patient lists on the iPads. These differences between different clinical professions may contribute to the mixed preference of the sample as a whole.

8.3.3. Facilitating Conditions

Facilitating conditions are defined as "the degree to which an individual believes that an organisations and technical infrastructure exists to support the use of the system" (Venkatesh et al., 2003, p.453). All groups of participants identified the same conditions inside the organisation that either supported or hindered the implementation of the new technology. The majority of the participants confirmed that they had received training to input the information into the iPads and CareFlow Vitals and use that information to make clinical decisions in their practice. The majority of participants experienced benefits to using the mobile technology. However, most of the participants also experienced problems and technical issues including system/WiFi failure, not working in all departments, and all staff not having to access to the iPads or CareFlow Vitals highlighting that the infrastructure of the organisation is not fully supportive of the technology. In contrast to this, my data showed that most technical issues were resolved relatively quickly showing that the organisation is active in resolving issues related to the devices and software to ensure they keep working on the hospital wards. Another condition that was not facilitating to the device users was a failure to adhere to a rigorous protocol around the recharging of the

iPads. This caused the devices to run out of battery which prevented participants from using them, or forced them to use paper-based forms, to record their patient observations. The implication of this was more work for staff members on the ward due to the duplication of information, and a disconnect between paper notes and the records on the CareFlow Vitals system.

8.3.4. Moderating Variables of UTAUT

Gender, age, and experience of the participants are seen as key moderators in the UTAUT model. The UTAUT model states gender is a moderating variable in performance expectancy (as men tend to be more task-oriented than women), effort expectancy (with the effect being stronger for women than men), and social influence (as research shows women are more sensitive to the opinion of others). In this study I reported that there was a slight preference for CareFlow Vitals for both males and females, but the picture was largely a mixed one with no clear pattern.

Research has demonstrated that age is a moderating variable for performance expectancy (as younger workers place more importance on extrinsic rewards), effort expectancy (the effect being stronger for older workers), social influence (as older workers are more likely to place increased importance on the influence of their peers) and facilitating conditions (the effect being stronger for older workers). There was some difference between age groups in this study but the results were non-significant and largely mixed. These non-significant mixed results highlight the varied acceptance of the devices and software, but, unlike in other research, the age variable did not seem to contribute to the overall picture. By way of explanation, it could be speculated that technology in general is becoming a more accepted part of society from all age groups. It is observable that most people have a mobile smartphone and know how to use it. Therefore, compared to studies from two decades previous where technology was novel in some settings, this research has taken place at a period of time when people have become accustomed to it. This result could also be linked to the experience level discussed next, on the assumption that in general more experienced members of staff will be older, and less experienced members of staff will be younger in most cases.

Further, research shows that experience is a moderating variable for effort expectancy (with workers at the early stages of experience having a stronger effect),

social influence (the effect declining with increased experience) and facilitating conditions (the effect being stronger with increasing experience). There was a significant result in the experience of the healthcare professionals and their preference towards using CareFlow Vitals in clinical practice, suggesting this variable may have a contribution towards the acceptance of the technology. Staff with 6-20 years of experience had a preference towards the technology whereas those with more experience (21+ years) had a preference towards pen and paper. Participants with the least amount of experience (0-5 years) were more unsure.

The term voluntariness is used to describe whether the new technology being introduced throughout the organisation is something that staff can decide whether or not they use. The technology in focus in this research was mandatory for healthcare professionals to use. During the research I reported that pen and paper was being used, although it was not a routine option and was only used in specific circumstances (e.g., where WNCR was not available, the system or WiFi went down, or the patient was no longer on the system). Therefore, there is a strong influence from this towards the acceptance of the use of the technology as the users could not themselves choose whether or not to learn how to use the iPads and CareFlow Vitals. Training was provided and paper-based forms phased out during the implementation of WNCR so the organisation assisted the healthcare users while mandating the technology.

8.3.5. Behavioural Intention and Use Behaviour

Behavioural intention refers to the motivational factors that influence a given behaviour. The stronger the intention to perform the behaviour, the more likely the behaviour will be performed. This behavioural intention is informed by each segment of the UTAUT model explained previous to this except for the facilitating conditions segment. Many recorders of the patient vital signs information felt that they had a high degree of performance expectancy as they attained gains in their job performance by being able to plan their patient care management using the devices. CareFlow Vitals also calculated the EWS automatically allowing a more accurate detection of deterioration for the users who make clinical decisions using the data. With regard to effort expectancy, the paper-based forms were perceived as easier to use for the data inputters which lessens the behavioural intention of the users. However, clinical

decision makers perceived the CareFlow Vitals software as easier than using multiple patient files in their clinical practice, although this data was available on the CWS on computers rather than on the iPads on the hospital wards. Social influence may have had an effect on behavioural intention as there were clear indications that some professional groups preferred using the devices (HCSWs, nurses, critical outreach practitioners) whereas others did not (physiotherapists).

Behavioural intention and facilitating conditions directly inform the use behaviour which is a continued commitment towards using the devices. Despite there being some factors that would not have informed the motivational behaviours to use the devices, I have reported a continued commitment towards healthcare professionals using the iPads and CareFlow Vitals in their clinical practice through observations and interviews. Although there were still some disadvantages when using the devices, participants were observed to use the iPads to input patient vital signs and conduct their clinical duties. Clinicians and ward managers also highlighted in interviews that they used the data from the CWS to make clinical and organisational decisions.

8.3.6. Reflections on the Unified Theory of Acceptance and Use of Technology Model

The UTAUT model was a useful theory to use alongside IDT as it builds on the foundations of the diffusion process to assess the acceptance of the technology post-implementation. It was also much easier to apply the data that I had collected throughout the study as it did not require speculation of the time before the study started. Additionally, it allowed me to delve into different facets of the organisation to try and explain why there was a mixed response to the iPads and CareFlow Vitals.

On the other hand, it was difficult to run the theory for all professional groups at the same time, hence the reason for separating the section into participants who inputted the vital signs into CareFlow Vitals (the recorders), and the participants who used the data to make clinical decisions. It was however valuable to use this theory to gather a nuanced view of the new technology being used in clinical practice by exploring the performance expectancy, effort expectancy, social influence, facilitating conditions and the moderating variables gender, age, experience, and voluntariness of use.

8.4. Reflections on the Wider Literature

This study joins a worldwide growing body of research evaluating mobile technology being used in patient-facing settings. Akin to this study, the most recent research has particularly been evaluating the use of Android and Apple devices and associated software. Previous studies have evaluated the impact of software used to record and display up-to-date vital signs monitoring and automatic EWS calculation (Hope et al., 2019; Lang et al., 2019; Downey et al., 2018; Gale-Grant and Quist., 2018; Wong et al., 2018; Sefton et al., 2017; Wong et al., 2017; Schmidt et al., 2015; Hands et al., 2013; Prytherch et al., 2006). However, this study adds novel insights to this research arising from use of observation-based methods, the inclusion of a range of professional groups throughout the hospitals, and being on the ground at the time a new, associated technology (WNCR) was being implemented in real time. The study also employed interview and survey methods which added evidence to the findings collected during observations at the two hospitals.

Similarly to Hands et al. (2013) I identified a difference in the way that observations were collected during day and night shifts. This was largely because hospital protocol dictated that ward rounds were to be conducted on most wards every four hours during a day shift at around 10am, 2pm, and 6pm. Observations would be conducted more frequently if the EWS indicated that. At night, vital signs were monitored during ward rounds at about 10pm and 6am. Vital signs were not collected between these hours to allow patients to have a restful sleep. However, if patients had a high EWS, their vital signs were still monitored in line with the deteriorating patient policy. Some participants identified that some patients were monitored unnecessarily frequently due to a high EWS caused by an existing chronic condition such as COPD. Hope et al. (2019) reported that this was a reason staff may not have complied with hospital vital signs monitoring policy which is a finding confirmed by this study.

Most of the related literature recounted benefits and disadvantages to using the novel technology in secondary care settings. At a broad level, this research also identified similar mixed findings of benefits and disadvantages as might be expected in a study of use of a new recording system where initial ‘teething’ issues are experienced in the early stages, and in settings where users have differing baseline opinions of technologies. Participants in this study perceived an increase in patient safety further

confirming this as a central benefit to introducing this technology to hospitals (Burkoski et al., 2019; Motulsky et al., 2017; Wager et al., 2010; Downey et al., 2018).

The iPads with CareFlow Vitals were perceived as being more accurate in clinical practice, a finding consistent with the literature (Prytherch et al., 2006; Sefton et al., 2017; Jones et al., 2011; Lang et al., 2019; Wager et al., 2010; Wong et al., 2018). Accuracy was improved due to the automation of the calculation of the EWS. In the survey of this study which was based on Prytherch et al. (2006)**,** CareFlow Vitals was also perceived as being more convenient, and allowing for easier detection of errors. However, pen and paper was perceived as being easier to use, simpler and quicker. In the original study of 21 nurses, the technology VitalPAC was perceived as also being more accurate, more convenient and allowing for easier detection of errors. In contrast, VitalPAC was also perceived as being simpler and quicker. CareFlow Vitals was formally known as VitalPAC so this study adds to the findings by Prytherch et al. (2006). It is interesting to notice that participants were more divided in their preference for CareFlow Vitals 17 years after the former study as it might be expected that staff would have become more accustomed to new technologies in 2023 compared to 2006. It is noteworthy that in this research there was a larger sample including different professions which may have contributed to this difference. The contrasting findings from this study demonstrate the value of further research, extending numbers and types of participants and revealing variation. It is pertinent to ask the question why is it taking so long for this technology to be more widely accepted across healthcare professional groups, and what can be done to move the sector forward towards a fully digital healthcare system?

This study has added to the growing evidence that mobile technology in secondary care settings can assist healthcare professionals to make decisions in clinical practice (Wu et al., 2013; Hill et al., 2019; Nuss et al., 2014). Participants in this research found that this was because they had instant access to the automated EWS score so they were able to make decisions immediately about the next stage of care planning. As in the study by Nuss et al. (2014) participants spoke about how having the EWS available assists them to explore why the patient may be unwell. For example, a high EWS signalling specifically a high temperature and fast heartbeat made staff on the hospital wards think about sepsis perhaps earlier than they would have before device implementation. It is interesting to note that I reported relatively little use of the data collected from the iPads and CareFlow Vitals to inform medium to longer term decisions. Clinical decision makers and ward organisational decision makers

appreciated having access to the EWS of patients on the ward but did not change the way that they worked compared to when they had paper patient files. Arguably, the technology is not being used to its full potential, but participants were not aware of what this potential entails. There is scope to expand the training available to staff beyond the initial induction to the iPads and CareFlow Vitals. Alternatively, there may be an argument that the participants were indeed using the software to full potential, and instead the decision makers at the health board might be encouraged to consider installing other CareFlow modules to fully utilise the technology in the secondary care setting.

Participants in this study did not report any particular change to the way that they communicated with other members of the MDT. Rather, they reported that the iPads and CareFlow Vitals served as a tool in their clinical practice and they would have behaved the same way without them. CareFlow Vitals does not offer a communication setting although there is a CareFlow module named CareFlow Connect designed to do this. During my observations I did not see this module in use. There was a different communication technology on the wards called Vocera which is a pendant that is worn around the neck that can be used to call other professionals in the hospital. I observed this being used frequently in both South Fields Hospital and Castle Plains Hospital so why would professionals use the iPads to connect when they already have a different technology in use for this purpose? Perhaps acceptance and use of the CareFlow product would be more uniform if there were not competing technologies being used at the same time in the same organisation. Participants did however appreciate that all staff had access to the CWS so could see real-time patient observations. This is in contrast to other studies that reported improved interprofessional relationships arising from use of the new technology in clinical practice (Dewane et al., 2019; Valle et al., 2017). Dewane et al. (2019) specifically reported improved interprofessional relationships between physicians and nurses. I did not report this finding, and this could be because the iPads and the CareFlow Vitals software were not built-in with features such as email, texting, and voice call capabilities which Valle et al. (2017) purported to have the potential to enhance communication in the healthcare setting. If anything, one of the main reported benefits to physicians was being able to work remotely which removes the need to be on the ward with the patients, as well as the nursing staff. It could be argued that physicians should be required to also use the iPads for homogenous use throughout the health board but is it necessary when their job duties do not include recording patient observations? Physicians theoretically only need to use the iPads to study the data

collected about their patients to monitor patterns and trends, and this can be done via the computer as is the current practice. However, the multiple technologies at play seem to create a disconnect within the interprofessional team.

Previous studies also reported increased patient contact time because of the use of the devices in practice (Crowson et al., 2016; Lang et al., 2019). This finding aligns in part with my research which showed that device use could save time which might then be used in more patient-facing activities. However, in contrast, participants in this study reported a decrease in direct patient contact time specifically by doctors as they were able to work remotely because the vital signs were available on the CWS. This created more time for them to spend doing other tasks or visiting patients who were seriously unwell. Hence, doctors could use the instant access to this data collected by the CareFlow Vitals software on iPads as a means to improve their overall performance as clinicians. Healthcare professionals did feel more reassured about their patients when they had this remote instant access which is a benefit that has been reported previously (Lang et al., 2019; Holleran et al., 2003). It is arguable however that although this is a benefit for clinicians, that it is not an advantage for patients who may feel they want or need to speak directly to a doctor involved in their care. It is important for physicians to balance the pressures of their demanding workload and CareFlow Vitals is a useful tool for this, but patients may be experiencing a difficult and daunting time in hospital and a way to feel reassured is to speak to the person responsible for their care. Despite having remote access to the patient information, which may be a personal benefit to their work as doctors, clinicians need to be mindful of the implications for the people they are caring for.

A concern about the devices that also arose in the literature was the lack of internet access (Youm and Wiechmann, 2015)**.** Many participants in this research spoke about this being an issue, particularly towards the beginning of implementation. It was reported that this had improved as a matter of priority. This is an important disadvantage to recognise and improve as without internet access, vital signs cannot be collected using the iPads and CareFlow Vitals and therefore paper forms are then utilised. Use of the devices is therefore obsolete on occasions when the internet is down.

Another disadvantage of using the iPads and CareFlow Vitals that had been reported in the literature was that staff were worried that patients would not perceive the use of the devices in a positive light (Burkoski et al., 2019). The hospital decision makers at the health board in this study anticipated this reaction and focused on

disseminating patient-facing educational materials throughout the hospitals to advertise the imminent implementation of the iPads. This may have contributed to there being no reports in this study of a negative opinion of the mobile devices from patients and their families. Alternatively, it could also be an example of progress over time in terms of public perceptions of mobile technology. For example, mobile technology (particularly smartphones) is used frequently for many purposes and the general public are aware of this. People typically can use their smartphone to search the internet, count their steps, make calculations, and take photographs so there is an awareness that mobile technology is not only used for recreational purposes such as social media and gaming. However, this research did not specifically ask patients their opinions of staff use of iPads. There could also be an argument that patient responses could be different towards handheld tablets of various size compared to smartphones, though this is out of the scope of this current study.

There were a number of disadvantages that were reported in this research that were not previously highlighted in other studies. Importantly, a prevalent disadvantage was the frequency in which the iPads had a low battery level. This however was not because of a fault with the devices themselves, rather a failure to implement a clear policy on device use and recharging, and the mechanisms to support that. Some staff were aware of this issue and would collect iPads to put them on charge, but if all available iPads had low battery charge then vital signs could not be recorded digitally. There could be actions that the decision makers at the health board could take to encourage the use of regular charging. For example, more docking stations at convenient locations, more support from ward organisational decision makers, clear protocols and advertisement in staff spaces. If the situation is not improved it could have serious healthcare implications and represents an immediate loss of all of the advantages reported in this research. For example, clinicians who are relying on remote access to data may have to come to the hospital to see patients which defeats the time-saving benefits of the devices and software. Moreover, professionals on the hospital wards would have to calculate the EWS themselves based on the vital signs collected manually on paper-based forms which introduces greater likelihood of human error and thus loss of the enhanced accuracy benefit of the iPads and CareFlow Vitals package.

A novel finding that was not previously reported in the literature was the sharing of personal accounts for both the iPads and the CareFlow Vitals software, as not all staff had access to them. This has important implications for accountability for both the

staff participating in this action, and the wider health board if something adverse were to happen. There is the potential for entering vital signs wrongly into the software potentially leading to the software calculating an incorrect EWS. This could lead to a potential serious adverse event for a patient, therefore reducing the benefit of improved patient safety. Arguably, this is the most important benefit in healthcare as the safety of the patient is paramount and decisions can be the difference between life and death in the most serious of situations. If this were to happen, the temporary staff member would have been the person to have conducted and recorded the patient observations, but these would have been ascribed to the staff member owning the password. It cannot be proven that the owner of the password did not record the vital signs of the patient, so are they responsible for the consequences of the serious adverse event? Ultimately, does the responsibility actually lie with the hospital decision makers themselves for not giving access to the temporary staff members? It is difficult to create a seamless digital environment if all members of the organisation do not have access to the system. Password sharing is a means to an end to a difficult problem on the wards of the hospitals, but it does open up a liability issue.

8.5. CareFlow Vitals as a Medical Tool

Some participants in this study spoke about how CareFlow Vitals did not affect the way that they worked as they perceived that CareFlow Vitals was simply a tool that replaced paper. They did not behave any differently during their clinical practice, just transferred the output from paper to the mobile technology. The only difference was that they did not calculate the EWS themselves. Although there were reported clinical benefits to digitalising the recording of patient observations, these participants did not perceive any difference which allows us to ask the question whether this investment from the hospital decision makers was worth the cost and time. For this amount of investment in a product, it would be desired that there are clear differences and benefits identified to using it. Can the costs be justified by the benefits? Or does it matter that some staff members at the health board do not see any additional benefits if there is overall confidence that the iPads and CareFlow Vitals do have benefits such as being more accurate and allowing for easier detection of errors?

It was surprising to note that most participants did not identify that the mobile technology affected the way that they communicated with the MDT as mobile

technology in most scenarios would provide this benefit. For example, the population is more connected to their social circle because they can instantly connect to them using their mobile device. However, the iPads with CareFlow Vitals do not have this capacity and hospital staff are contacted by other professionals in the hospital by the same means they were prior to implementation. There is potential for the CareFlow Vitals to enhance communications within the MDT by using them in meetings where all members of staff should have access to the software (although it has been discussed that this is not always the case) rather than each member of staff having a printout of all the notes.

8.6. Hierarchy and Control

It was suggested in Chapter 5 that the iPads and CareFlow Vitals software could be encouraging a hierarchy within the secondary care setting. Studies have shown that hierarchies are perceived to exist with junior doctors feeling intimidated and humiliated by senior staff despite feeling respect for the hierarchical structure (Crowe et al., 2017), nurses being perceived as subservient to clinicians in some healthcare systems (Green et al., 2017), and when NHS staff reported being bullied, it was most likely by a manager (Quine, 1999).

In this study, it was reported that the CareFlow Vitals software was not available to every member of staff, including agency staff and student nurses. Agency staff and student nurses would have to seek other people's passwords to use the software. The members of staff that could be perceived higher up the hierarchal structure as these members then had the power to either agree or disagree to this request. This removes the agency that the temporary members of staff have to conduct their work as they require a permanent member of staff to give them their approval to use the system. Further, only doctors and ward managers conveyed that they were able to change the time to the next observations on the CareFlow Vitals system. HCSWs and nurses, who primarily use the iPads, were unable to do this themselves. Therefore, they relied on the members of staff who could be perceived as more senior to do this for them, reinforcing a hierarchical structure. Without the ability to modify time to next observation, the staff member is in effect controlled to do the observations when the software or the senior member of the team dictates. This limits their clinical decision

making role despite being the member of staff who is closest to the patient on the ward.

8.7. The Interface Between CareFlow Vitals and WNCR

An interesting aspect about being physically on the wards was observing a new innovation being implemented in real time. At the start of the data collection period, CareFlow Vitals was already in the confirmation stage as mentioned previously in this chapter. However, WNCR was another innovation that was not initially a focus of this study but was raised regularly throughout data collection. WNCR was being piloted in South Fields Hospital. This small-scale trial highlighted that this innovation was in the implementation stage of diffusion (section 8.2.4.). Therefore, there were differences in South Fields Hospital and Castle Plains Hospital due to WNCR being available in one and not the other. In South Fields Hospital, paper was not frequently used as patient notes were manually re-entered to WNCR whereas paper files were in regular use in Castle Plains Hospital. At South Fields Hospital, iPads equipped with both CareFlow Vitals and WNCR were used more often than in Castle Plains Hospital, where iPads and CareFlow Vitals were only used during patient observations. This implies that it is possible that healthcare staff are not using the mobile technology to its full potential because its full potential might require more than just the one software. Hence, WNCR is not an alternative software to use that may supersede CareFlow Vitals, but a complementary software that can enhance the user experience. It would be valuable to conduct a similar study to this when WNCR is wholly implemented to identify any changes to the acceptance rate of the mobile technology in clinical practice.

8.8. Further Reflections

As mentioned in previous chapters, CareFlow Vitals was previously known as VitalPAC. The new title of the software insinuates that the technology is designed to assist with patient care and patient flow. However, the interface of the software is structured to align more with the patient flow aspect of the name. The healthcare

professionals have to collect vital signs from the patient when the device dictates. This information is quantitative and objective in nature, and the output is an EWS that reflects the potential deterioration of the patient. This EWS helps staff to plan their schedule throughout their shift. It also allows ward managers to engage in an overview of their ward and manage the staff and patients accordingly. Nevertheless, healthcare professionals have more tasks than inputting this information into the software and monitoring the patients' vital signs. These important tasks revolve around the care of the patient, such as giving medication, cleaning the patients' bedspace, moving the patient, and talking to and comforting patients. The CareFlow Vitals software is not designed to assist with these tasks which reminds us that healthcare cannot be completely replaced with technology. It has to work in unison with the tasks that can only be conducted with the human touch.

As society continues to become more digitally integrated, self-tracking has become more popular as people strive to reflect and improve upon their own health metrics through monitoring, measuring and recording data by using technology such as fitness trackers. Digital devices are therefore changing the way that people view their own bodies, relying on the real visually represented data rather than the way that they feel (Lupton, 2016). The devices and software in this study illustrate that this is a phenomenon not exclusive to the individual, but also the healthcare industry. The data collected through the CareFlow Vitals software is detailed over time to measure potential deterioration. One could argue that there is a danger of depersonalising the patient if they are just seen as the numbers on the screen, disregarding the 'feel' that the patients have of their own body. This reinforces the message that the healthcare professionals must continue to use their own professional judgement alongside the technology to deliver best practice for their patients.

8.9. Conclusion

This study adds to the growing evidence of increased use of mobile technologies in clinical practice. The theory of innovation diffusion has been applied to the findings from this research. As the research was conducted in the confirmation stage, IDT was viewed as a means of providing insight into the new innovation for hospital decision makers. It is necessary however to recognise the importance of the previous four stages before this point to understand why the decision was made to implement the

novel mobile technology in the first place. The iPads and CareFlow Vitals were seen to address a need that decision makers at the hospital had identified, and it successfully passed through the first four IDT stages, but potential value still remains untapped due to the need for the complementary WNCR to become more widespread and available to reduce the need for paper resources. The UTAUT model provides a framework to understand the reasoning why a technology may or may not be accepted. In this case, it assisted in deciphering why the technology received a mixed reception by the healthcare staff using it. This is because some professional groups (HCSWs, nurses, critical care outreach practitioners) experienced a degree of performance expectancy, effort expectancy and social influence from using the devices and CareFlow Vitals. However, other professional groups, particularly physiotherapists, did not experience this. Further, there is the remaining question of whether this investment was worth it by hospital decision makers due to the perception that CareFlow Vitals is another technological tool that just replaces a traditional paper-based format that requires another software (WNCR) to create a fully digital environment. The next chapter will include my conclusions as well as consider implications, limitations, and insight for future research.

Chapter 9. Conclusion

9.1. Overview

By conducting a mixed methods study, including observations in the hospital setting, I have shown how implementing a new mobile technology to record patient observations in hospitals can impact clinical practice and secondary care management. In this chapter I conclude the thesis by broadly reviewing the research questions in the context of the strengths and limitations of this research. I identify the implications of the key findings and raise areas for further research.

9.2. Strengths and Limitations

Although this study was focused on the implementation of iPads and CareFlow Vitals, the research also collected evidence on the implementation of WNCR in real time. A strength of this study is also the observational aspect. I spent a significant amount of time in both of the case study hospitals watching how the devices were used in practice and becoming immersed in the intricacies of working in a busy hospital ward in the current climate of staff shortages and dismay in working practices post the Covid-19 pandemic (Chapter 1). The research also collected further in-depth qualitative research from interviews which built upon the observed practices. The survey allowed for further reach of professionals not often on the hospital wards during observations, such as some allied health professionals, resulting in a more holistic view of the new technology from a range of professionals with varying levels of experience. A further strength of the study was the use of two theories (IDT and UTAUT) to assess both the diffusion of the mobile technology, and the acceptance.

The generalisability of these results could be limited due to size of the sample of participants. In qualitative research it is difficult to collect data from a large number of participants, especially as a sole researcher under the timeframe of a PhD research study. Observational data are rich but time-consuming to collect and analyse. Only

two hospitals from one health board were used as case study sites due to these limitations.

Further, the sample size of the survey was small as it was difficult to advertise the study to the staff in the two hospitals. The sample size increased significantly once important gatekeepers were identified but this took a large period of time (about eight months) to do so as an outside researcher. I was unable to access email lists of potential participants, so I was reliant on the goodwill of members of the health board. This limitation made it difficult to undertake more sophisticated statistical testing. For the formal interviews I was also only able to recruit participants from South Fields Hospital and was only able to informally interview participants at Castle Plains Hospital.

Nonetheless, this study provides rich insight into staff use of mobile technology to collect patient observations in clinical practice and their perceptions of its value, across multiple professional groups at two hospitals in Wales.

9.3. Addressing the Research Questions

In this section I review the research questions posed in this thesis which aimed primarily to assess the impact of mobile technology on clinical practice and care management. The research questions are concerned with the implementation of the devices (RQ1), how the devices are used in practice (RQ2), the change from pen and paper materials to CareFlow Vitals (RQ3), and the impact on clinical decision making (RQ4). Each research question also contained a series of sub-questions that will guide the commentary in this section.

9.3.1. Research Question 1: How were the Mobile Devices Equipped with CareFlow Vitals Implemented in the Hospitals in Wales?

This question can be approached by looking at the IDT. The innovation was perceived by the decision-making unit at the health board to fulfil a need. Digitalisation of healthcare is a priority in Wales (Welsh Government, 2021b), and this health board was trialling the automated patient observation software before potential wider

implementation. The mobile devices were firstly introduced to Castle Plains Hospital and Blossom Valley hospital before being introduced to the remaining hospitals in the health board, including South Fields Hospital. It was anticipated that patients and families may react negatively to staff using iPads on the hospital wards, but I did not observe any negativity. Ward organisational decision makers (e.g., ward managers) indicated that they were not part of the decision-making process to implement the iPads and CareFlow Vitals. However, participants indicated that they were prepared for the impending change to the way that they worked.

Most of the participants in this study iterated that they had received training to use the new mobile technology with CareFlow Vitals before they used it for the first time on the wards. The training was given to staff prior to the implementation of the devices and logins were only given after completion of the training. The participants spoke about how this training was thorough and how they could attend until they felt confident. Staff could also rely on their co-workers to help them with the iPads and software if they were unsure during a shift. However, there was an indication that training was not available for all members of staff. Doctors spoke about how they did not have training to use the iPads, but they did not use them on wards. Agency staff were also not provided with training which caused an issue as they could not be given logins for the devices which meant they could not conduct patient observations using CareFlow Vitals or they had to use a permanent member of staff's login.

9.3.2. Research Question 2: How are Mobile Devices used to Record Patient Observations?

Throughout my observational time at the two hospitals in the health board, I only observed HCSWs and nurses using the iPads with CareFlow Vitals in clinical practice.

All of those observed using the iPads with CareFlow Vitals inputted patient observations directly into the software when the patient was on the system. Occasionally, a patient was not uploaded to the system in time for the initial observations, and so the member of staff would write the observations on paper ready to upload to the CareFlow Vitals system when ready despite the time of the observations taken being different. However, before the implementation of WNCR in South Fields Hospital, this information was routinely transcribed into the patients' paper files essentially duplicating the work of the device user and this was still evident

in Castle Plains Hospital where WNCR was not yet available. After WNCR implementation, the iPads with CareFlow Vitals installed could then also be used to record patients notes, as well as the observations.

9.3.3. Research Question 3: How did Staff Respond to the Change from Pen and Paper Records to the use of the iPads with CareFlow Vitals?

Overall, the reception towards the iPads and CareFlow Vitals was mixed. Some healthcare professionals fully embraced and accepted the digital transformation whereas others were not receptive to the change and preferred working with the paper forms. It was reported that some professional groups (nurses, HCSWs, critical care outreach practitioners) preferred using the mobile devices and software in practice whereas other groups such as physiotherapists preferred the use of pen and paper. Further, it was suggested that the experience of healthcare professionals may have an influence on the acceptance of the new technology in secondary care settings.

There was evidence that the experience of healthcare professionals had a significant effect on whether the participants preferred the use of CareFlow Vitals compared to pen and paper records. In particular, those with the smallest amount of experience, and those with the largest amount of experience preferred the use of pen and paper whereas those who were midway into their career preferred the use of CareFlow Vitals in their clinical practice. Other demographic results were non-significant but gave insight nonetheless into which participant groups preferred the use of the iPads and CareFlow Vitals. For example, both males and females had a slight preference for the mobile technology, and those aged 35-44 also shared this preference.

9.3.4. Research Question 4: How have Mobile Devices used to Record Patient Observations at the Bedside Impacted Clinical Decision Making?

In most cases healthcare professionals who participated in the study explained that they used the CareFlow Vitals software available on the iPads to plan when they would conduct patient observations outside of the usual ward round times

(approximately every four hours at 6am, 10am, 2pm, 6pm, and 10pm) as they could view the EWS of the patient and the time their next observations were due. The software enables the user to see an overall view of this information rather than the healthcare professional having to look in multiple patient files. Immediately after conducting a patient's observations, the user of the device is given an instantaneous EWS calculation with prompts about the next steps in the patient care journey. This can be beneficial in instances where a patient is potentially deteriorating as it saves the clinician time in working out the EWS manually, as well as improving the accuracy by removing most of the human error (possible remaining human error is in incorrect inputting of the vital signs data).

Ward organisational decision makers also relayed that they were able to see each patient on the wards' vital signs in one place which saved them time that they previously used to look through each patient file. Clinical decision makers were also able to access the vital signs remotely which meant that they did not have to visit their patients at their bedside unless necessary to make diagnosis and treatment decisions. This also meant that when they were on call they did not have to be present at the hospital, and instead could work from home as long as they had access to the CWS. However, hospital management decision makers stated that they did not use the data collected from the CareFlow Vitals software to make wider decisions at the hospitals. Most participants also reported that the CareFlow Vitals software did not change the way that they interacted with the wider multi-disciplinary team as they did not use the mobile devices to communicate. Hence, the healthcare professionals interacted as they did before the implementation of the devices and software into the health board.

Participants in the study perceived that there were both benefits and disadvantages to using the iPads installed with the CareFlow Vitals in their clinical practice and patient care management. There were perceived benefits such as improved patient safety, potentially identifying deterioration sooner leading to faster treatment decisions, saving the time of clinicians allowing them to do other clinical tasks, and creating a paperless digital environment (where WNCR was implemented alongside CareFlow Vitals).

Disadvantages were reported with the device use (system/WiFi failure, low battery, problems logging in, more time consuming than paper-based records, and inability to override protocols), and device and software access (temporary staff do not have a login, iPads not available to all staff, they are not available to use in all departments

such as intensive care). There were also concerns that patients had reduced contact time with doctors due to the ability to access vital signs remotely. Using the UTAUT model it can be seen that disadvantages related to device use and access can affect the use and acceptance by hindering the performance expectancy and effort expectancy (Chapter 8).

9.4. Implications

Although the reported preference for the iPads with CareFlow Vitals has not been as high as that reported for other similar products in earlier research (Prytherch et al., 2006), participants that were observed did not actively dislike or avoid using the product that was made mandatory to them on behalf of a small group of decision makers at the health board. It was identified that there were benefits to clinical practice when using the iPads with CareFlow Vitals such as timesaving, the ability to work remotely, and increased patient safety. However, disadvantages were also reported that may need addressing by hospital decision makers to improve. Benefits to clinical practice are important when introducing an innovation, but they are negated through non-use due to highlighted disadvantages.

An important and novel finding in this study is the sharing of devices which have already been logged into between temporary and permanent staff. This was a work-around for temporary staff who did not have their own logins for the CareFlow Vitals software. This is not a sustainable practice during a period of staff shortages as agency workers are a prominent feature on the hospital wards. Although these members of staff are employed on a temporary contract, they can return to the same hospital frequently so it would make sense to give them permanent access within the temporary timeframe of their contract. Decision makers at the health board may want to reflect on whether this is because of a hierarchical practice so permanent staff can maintain some control on the wards.

During the research project it was determined that the full potential of the mobile devices and the CareFlow Vitals software was not being realised. This is because participant group 4 (the hospital decision makers) reported that they were not using the data collected from the software to make hospital organisational decisions. Potentially the CareFlow Vitals software could be used to see the layout of wards and empty beds, reflect on ward activity after incidents, and review and create training

materials based on previous observational insights. However, to make these decisions and expand the utility of the software requires direction from hospital leaders. At the time of the study, a business-as-usual approach was taken meaning that past practice was reflected in the implementation of the devices. This suggests some resistance from the top of the hospital structure to use the new technology. Further, WNCR was being implemented into the health board during the research study. It has been recognised that the WNCR is a complementary system to the CareFlow Vitals software and therefore neither can be fully utilised until WNCR is available in all hospitals within the health board.

This research did not look at the benefits to patients of having the iPads and CareFlow Vitals implemented throughout the health board. Therefore, there is the potential for big data research which could establish whether the implementation of iPads with CareFlow Vitals have had an effect on the length of stay, mortality of patients, and patient flow. If possible, data could be collected for the years previous to the implementation of the software and compared with clinical aspects since the implementation to gather whether there are any quantitative aspects to patient care (e.g., LOS, mortality, serious adverse events) that have been negatively or positively affected by the new technology being available.

To further explore the benefits to patients, their views could also be sought. This could be done by conducting a qualitative study involving interviews or focus groups with patients who have been exposed to the iPads during their time in hospital.

It would also be worth exploring whether the implementation of WNCR has impacted the preference and acceptance rate of the iPads with CareFlow Vitals as it becomes more widely integrated within the health board. Such investigation could adopt a study design similar to this research and include the mixed methods of observations, interviews, and survey. Depending on the size of the research team, more hospital sites could be included to gather more data. As WNCR is planned to be introduced to other health boards in Wales, it could also be worth conducting the study at these health boards to understand how WNCR interfaces with the technology available as CareFlow Vitals is not as widespread.

9.5. Summary

In conclusion, this study has explored the research questions from the perspective of multiple health professional groups using mixed methods within a case study design. The thesis provides valuable insight into the implementation of a new mobile technology with software designed to collect patient observations and provide automated EWS calculation, and the impacts of this on clinical practice and patient care management in secondary care using the IDT and UTAUT.

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APPENDICES

Appendix 1. Mixed Methods Appraisal Tool (MMAT), version 2018

Category of study designs	**Methodological quality criteria**	**Responses**			
		Yes	No	Can't tell	Comments
Screening questions (for all types)	S1. Are there clear research questions?				
	S2. Do the collected data allow to address the research questions?				
	Further appraisal may not be feasible or appropriate when the answer is 'No' or 'Can't tell' to one or both screening questions.				
1. Qualitative	1.1. Is the qualitative approach appropriate to answer the research question?				
	1.2. Are the qualitative data collection methods adequate to address the research question?				
	1.3 Are the findings adequately derived from the data?				
	1.4. Is the interpretation of results sufficiently substantiated by data?				
	1.5. Is there coherence between qualitative data sources, collection, analysis and interpretation?				
2. Quantitative randomized controlled trials	2.1. Is randomization appropriately performed?				
	2.2. Are the groups comparable at baseline?				
	2.3. Are there complete outcome data?				
	2.4. Are outcome assessors blinded to the intervention provided?				
	2.5 Did the participants adhere to the assigned intervention?				
3. Quantitative non-randomized	3.1. Are the participants representative of the target population?				
	3.2. Are measurements appropriate regarding both the outcome and intervention (or exposure)?				
	3.3. Are there complete outcome data?				
	3.4. Are the confounders accounted for in the design and analysis?				
	3.5. During the study period, is the intervention administered (or exposure occurred) as intended?				
4. Quantitative descriptive	4.1. Is the sampling strategy relevant to address the research question?				
	4.2. Is the sample representative of the target population?				
	4.3. Are the measurements appropriate?				
	4.4. Is the risk of nonresponse bias low?				
	4.5. Is the statistical analysis appropriate to answer the research question?				
5. Mixed methods	5.1. Is there an adequate rationale for using a mixed methods design to address the research question?				
	5.2. Are the different components of the study effectively integrated to answer the research question?				
	5.3. Are the outputs of the integration of qualitative and quantitative components adequately interpreted?				
	5.4. Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?				
	5.5. Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?				

Appendix 2. Synthesis of High Relevance Primary Research Studies

Table 20 Synthesis table for high relevance primary research studies.

Study	Aim	Study design	Setting	Participants (and device type, software)	What was 'measured'?	Key Findings
EHRLER, F., TUOR, C., TROMPIER, R., BERGER, A., RAMUSI, M., REY, R. & SIEBERT, J. N. 2022. Effectiveness of a mobile app in reducing therapeutic turnaround time and facilitating communication between caregivers in a pediatric emergency department: a randomized controlled pilot trial. *Journal of Personalized Medicine,* 12.	To study the impact of the PIMPmyHospital app in a real paediatric emergency department (PED) during the overload period related to the Covid-19 pandemic.	Prospective single-centre non-blind, two-arm, randomised controlled pilot trial. Two methods were evaluated for considering laboratory results and finding a colleague to aim for joint action during standardised semi-simulated scenarios of everyday life in a PED. Time-to-goal completion was measured using a stopwatch. Participants took a survey at the beginning of the study to collect demographic characteristics.	Switzerland	Five postgraduate residents pursuing a <6-year residency in paediatrics and five registered nurses from the PED. Apple iPhone X. "Patients In My Pocket in my Hospital" app (PIMPmyHospital)	The elapsed time (in minutes) in each allocation group from the availability of the new laboratory results on either the mobile app or the institutional computerised patient data system to their consideration by the participant on the allocated medium. The elapsed time (in minutes) from the moment the participant was informed by the mobile app or a statement given by a study investigator that a nurse required assistance to perform a technical procedure up to the point in time in which the participant reached the nurse.	The median time to review laboratory results once available was significantly reduced from 23 minutes to one minute with the use of the app. The median time to find a colleague was reduced almost significantly from 24 minutes to one minute with the use of the app.
AL HARRASI, A., AL MBEIHSI, L.	To explore the perception and	Cross-sectional survey.	Oman	175 residents and 91 trainers (senior	Point of contact (POC) device perception,	The most frequently used applications for point of care

Study	Aim	Study design	Setting	Participants (and device type, software)	What was 'measured'?	Key Findings
M., AL RAWAHI, A. & AL SHAFAEE, M. 2021. Perception and usage of point of care devices: a cross-sectional study targeting residents and trainers in Oman. *Oman Medical Journal,* 36, 1-6.	usage of mobile handheld devices among Oman Medical Specialty Board (OMSB) residents and trainers.			consultants, senior specialists, consultants, specialists, and associate professors) in five major programs within the OMSB. Participant's own devices.	usage, trend, and perceived barriers.	devices used by residents were accessing the internet for medical purposes, checking their emails, and drug references. Other applications included taking pictures related to clinical practice, reading e-books, using medical calculators, accessing data books, and research purposes. The most frequently used applications for point of care devices used by trainers were checking their email, accessing the internet, and taking pictures related to clinical practice. Other applications included drug references, reading medical journals, and using medical calculators. Point of care devices were used before, during and after patient encounters. The point of care devices were perceived to shorten the patient's length of stay. Most residents believed that the point of care devices influenced clinical decision making by helping them to determine diagnoses and avoid ordering unnecessary tests. Factors that limited the use of the devices for

Study	Aim	Study design	Setting	Participants (and device type, software)	What was 'measured'?	Key Findings
						residents included a lack of training, limited time, the small size of the screen of the device, the lack of applications for their devices, other resources were more helpful, and a lack of comfort with the technology.
JACOB, C., SANCHEZ-VAZQUEZ, A. & IVORY, C. 2020a. Factors impacting clinicians' adoption of a clinical photo documentation app and its implications for clinical workflows and quality of care: qualitative case study. *JMIR MHEALTH AND UHEALTH,* 8.	To understand the social, organisational, and technical factors affecting clinicians' adoption of a clinical photo documentation mHealth app and its implications for clinical workflows and quality of care.	Qualitative case study. In-depth semi-structured interviews.	Switzerland and Germany	Nine clinicians, five medical informatics experts, four imito AG team members. imitoCam app.	Utility and limitations of the app. Most useful features, added value, and features to add. Technical and social factors impacting user adoption. Organisational and policy factors impacting user adoption.	The app was described as easy to use. Photo and wound documentation were the most used features, followed by electronic medical record integration. Saving time and increased efficacy added value for most of the participants. Participants also reported an improvement in patient safety and quality of care as well as data security and validation. Limitations included the absence of a patient interface, lack of offline functionality, the app can only be used inside the hospital, and the use of quick response (QR) codes can be cumbersome.
KIM, S., KU, S., KIM, T., CHA, W. C. & JUNG, K. Y. 2020. Effective use of mobile electronic medical records by medical interns in real clinical	To determine the association between interns' clinical task completion time interval and the frequency of mEMR usage.	Mixed methods study. Collect the log data from the mEMR server and intern clinical task time-series data.	South Korea	84 interns regularly performed tasks during the study period. 15 interns responded to the survey.	The comparison of the time interval to complete the intern tasks. The time the task was requested to the task completion check time.	The frequent mobile electronic medical record user group took a shorter time to complete the requested tasks compared to less-frequent users. The medical intern task completion time had a significant inverse relationship with individual frequency of mobile electronic

Study	Aim	Study design	Setting	Participants (and device type, software)	What was 'measured'?	Key Findings
settings: mixed methods study. *JMIR mHealth and uHealth,* 8, e23622-.		Survey. Interviews.		Device not specified. mDARWIN (mEMR system)	The correlation between the frequency of mEMR usage and the median time of interval of interval to complete the intern's tasks individually. System usability,	medical record usage. Using the mobile electronic medical record once reduced the task completion time by approximately 16 seconds. Locations where the mobile electronic medical record was used included: in areas without a computer such as operating rooms and the cafeteria, while walking, and outside of the hospital.
BURKOSKI, V., YOON, J., HUTCHINSON, D., FERNANDES, K., SOLOMAN, S., COLLINS, B. E. & JARRETT, S. R. 2019. Smartphone technology: enabling prioritization of patient needs and enhancing the nurse-patient relationship. *Nursing Leadership,* 32, 29-40.	To examine the potential of smartphone technology to improve nursing workflows and enhance the nurse-patient relationship at Humber River Hospital (HRH).	Qualitative exploratory study. In-depth semi-structured interviews with open-ended questions. Interviews lasted between 20 and 40 minutes. Interviews were recorded and transcribed. Transcripts were analysed and subjected to a content analysis.	Canada Humber River Hospital-large community acute care hospital	12 nurses who predominantly provide direct care to inpatients and have at least 6 months of experience working at HRH. 66.7% of participants were female, age ranged from 20s to 40s and the average number of years of experience at HRH was 3.11 years. Institutional smartphones were used.	Nurses' perceptions of hospital smartphone technology within clinical settings.	Many of the nurses perceived significant improvement in efficiency over traditional systems. Most of the participants found that a smartphone was essential because of the physical size of the hospital. Nurses found that they could prioritise smartphone alarms that presented a safety risk to patients. Overhead noise was reduced using smartphone alarms. Patient safety was increased as calls could be delegated to a secondary nurse if unanswered. Nurses also found they were able to develop a one-to-one relationship with patients because of the smartphones.

Study	Aim	Study design	Setting	Participants (and device type, software)	What was 'measured'?	Key Findings
						Disadvantages of the smartphones were: poor call quality, interference, patients not knowing how to use the phone, stress from receiving multiple notifications and poor perceptions from patients and families.
HILL, J. R., NUSS, M. A., CERVERO, R. M., GAINES, J. K., MIDDENDORF, B. & MISHRA, S. D. 2019. Using mobile technology to support physician and student learning as part of patient care. *Journal of Interactive Learning Research,* 30, 27-44.	To understand how mobile technology supports supervising doctors' and medical students' learning and professional practice.	Case study design. Questionnaires in the beginning and the end of each year. Interviews at several stages of the study. One observation of the supervising doctors and students was completed each week.	United States of America	9 supervising doctors and 77 students total (2 classes over 2 years). 3rd generation iPad pre-loaded with relevant apps.	How mobile technology supports faculty preceptors in learning the practice of academic teaching. How mobile technology supports medical students in learning the practice of internal medicine. How mobile technology supports faculty preceptors in clinical decision making.	All of the supervising doctors indicated that the time that they spent using the iPad in the care of patients and teaching students increased over time, and most agreed that their expertise in using the iPad increased over time. The same trend was seen with students. There were certain situations that were not conducive to iPad use e.g., when full coverage with a gown and mask was required. Some students also felt that taking the iPad on rounds was not ideal or necessary. iPads made it easier to facilitate interactions at the bedside with patients and students. Retrieval of information, reports and test results were facilitated with ease. 67% of the supervising doctors indicated that they use the iPad to support clinical decision making. However, the

Study	Aim	Study design	Setting	Participants (and device type, software)	What was 'measured'?	Key Findings
						mobile network did not always run at top efficiency due to overload.
HOPE, J., GRIFFITHS, P., SCHMIDT, P. E., RECIO-SAUCEDO, A. & SMITH, G. B. 2019. Impact of using data from electronic protocols in nursing performance management: a qualitative interview study. *Journal of Nursing Management,* 27, 1682-1690.	To explore the impact of using electronic data in performance management to improve nursing compliance with a care protocol.	Qualitative interpretative study using semi-structured interviews administered either face-to-face or by telephone.	United Kingdom	13 registered nurses, 2 student nurse/support workers and 2 support workers. Mobile handheld devices installed with the VitalPAC software.	Patient characteristics, care needs and ward specialty. Role responsibilities. Views of the ward's protocol compliance. Barriers to complying with the protocol. Impact of other ward routines. Attitude to complying with the protocol at night. Ward consequences following protocol non-compliance. Views of protocol requirements. Impact (if any) of ward performance targets aimed at increasing compliance with the protocol.	Participants described competing demands, which could interfere with their ability to take scheduled observations when they were due. They described missing scheduled observations to respond to rapid patient deterioration. Patients with chronic conditions such as COPD, asthma and high blood pressure had chronically abnormal vital sign values that contributed to an elevated EWS value. This created an observation schedule perceived by many participants as inappropriately frequent. Medical "outliers" (patients moved to a different specialty area to create bed space on another ward) could also have their vital signs missed at night. This suggested that even when overall ward compliance was high, certain groups may be disproportionately affected by non-compliance. During night shifts, observations of people with dementia could be delayed or missed for non-clinical reasons such as

Study	Aim	Study design	Setting	Participants (and device type, software)	What was 'measured'?	Key Findings
						challenging behaviour or disrupting other patients' sleep. Pressure from ward managers to maintain and improve ward performance meant that some participants would carry out observations even when this conflicted with their clinical judgement and was unpopular with patients. Due to the inability to report reasons for omissions, participants described feeling penalised when prioritising care of rapidly deteriorating patients and would sometimes use a loophole to avoid having an omission recorded. This highlighted the existence of invisible non-compliance. Some participants described benefits of external reminders such as having their attention focused on doing observations during a busy period. Some nurses used the EWS to explore the reasons why a patient was unwell, using clinical judgement to decide on the next step.
LANG, A., SIMMONDS, M., PINCHIN, J., SHARPLES, S., DUNN, L.,	To identify improvement and deterioration in workplace efficiency and	Pre- and post-deployment via direct observations.	United Kingdom	16 nurses and 7 doctors were observed pre-deployment.	Time spent on tasks for nurses and doctors. Perceptions of the deployment process,	Nurses spent less time interacting with notes and talking on the phone than they did before implementation. Nurses also spent more time

Study	Aim	Study design	Setting	Participants (and device type, software)	What was 'measured'?	Key Findings
CLARKE, S., BENNETT, O., WOOD, S. & SWINSCOE, C. 2019. The impact of an electronic patient bedside observation and handover system on clinical practice: mixed-methods evaluation. *Jmir Medical Informatics,* 7.	quality of care resulting from the large-scale imposition of new technology.	Interviews and focus groups collected qualitative data. Longitudinal analysis of unplanned critical care admission. Review of early warning score (EWS)-related incidents on eObs wards.		18 nurses and 47 doctors were observed post-deployment. 40 participants were interviewed. iPhones and iPads were deployed with eObs installed.	eObs and mobile devices.	at the nurses' station than in the office. There was also a decrease in rapid task switching. Doctors were also observed interacting with paper notes or desktop PCs less. They also spent less time in the office and more time at the nurses' office. Patient contact time more than doubled. The accessibility of information on the mobile devices appears to have streamlined staff discussions to facilitate remote decision making. Nurses had a largely positive response because of the added value in the form of reassurance of patient health state owing to real-time eObs information and awareness of ward capacity. Nurses began to see the device as a tool for workload management and awareness of team capacity. There was also value as a means of communication for use with patients and relatives. Medical staff could use the device to check-up on patients when they were off duty and had physically left the ward. There was a perceived lack of

Study	Aim	Study design	Setting	Participants (and device type, software)	What was 'measured'?	Key Findings
						engagement by senior medical personnel. There was an association with an approximate 10% reduction in total unplanned admission to critical care. This equated to a saving of £250k per quarter since deployment. There was also an association with an approximate 50% reduction in reported EWS policy-related patient safety incidents in eObs wards. Adherence with EWS policy has also improved.
CHASE, T. J. G., JULIUS, A., CHANDAN, J. S., POWELL, E., HALL, C. S., PHILLIPS, B. L., BURNETT, R., GILL, D. & FERNANDO, B. 2018. Mobile learning in medicine: an evaluation of attitudes and behaviours of medical students. *BMC Medical Education,* 18.	To evaluate the impact of mobile learning (mLearning) devices provided to support placement-based learning by gathering feedback from a large group of students, over a long observational period, in a naturalistic setting.	A survey questionnaire was completed in the first induction session and students were encouraged to complete the follow-up version of the questionnaire after a six-week clinical placement with the iPads.	United Kingdom	275 medical students completed the pre-intervention questionnaire and 217 completed the post-intervention questionnaire. Apple iPad minis (2013 model).	Perceived advantages and disadvantages of using the iPads. Efficiency of work. The attitudes of the students, as well as the perceived reaction of surrounding clinicians and patients towards the use of the devices in the clinical setting. Students' perceived impacts of mLearning devices to learning in clinical settings. Whether mLearning devices have an impact	The average number of hours spent using the device was reported as approximately two hours per day. Overall time spent studying during the week increased with an average reported increase of 3.1h/week. The most useful time and place identified to use the iPads was in the student hub; least useful time and place was clerking on the ward. Rather than as a support for clinical learning, students were mainly using the device in informal and private settings. Suggested explanations for this included poor internet access in clinical areas, and how students use mobile devices for learning

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					on the reported length or efficiency of students studying hours.	generally. Whilst 80% of students reported internet access as a significant limiting factor in the early part of the study, once WiFi access was expanded, this figure decreased to 56.5%. Advantages included: speed of information access, administration, multimedia learning and up-to-date resources, size and portability of the iPad mini device and free access to core textbooks as e-books. 67% of students felt that the mobile learning device made the hours they spent working more efficient. Perceptions of disadvantages were reduced by device use. The largest decrease included those relating to negative perceptions by patients or relatives and clinicians. Some students felt that the devices were overloaded or slow.
DOWNEY, C. L., BROWN, J. M., JAYNE, D. G. & RANDELL, R. 2018. Patient attitudes towards remote continuous vital signs monitoring on	To discover what patients think of monitoring in hospital, with a particular emphasis on intermittent early warning scores versus remote	Semi-structured interviews with patients participating in a randomised controlled study evaluating the SensiumVitals on two surgical wards at a	United Kingdom	12 surgical inpatients. SensiumVitals remote continuous monitoring device (the "patch"). The data from the patch is transmitted	Data collection was iterative, and themes were gathered from the interviewees' responses.	Six main themes were identified: 1) importance of nursing contact- patients were keen to emphasise their appreciation of face-to-face nursing contact, and their concerns that remote monitoring might replace this.

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general surgery wards: an interview study. *International Journal of Medical Informatics,* 114, 52-56.	continuous monitoring, in order to inform future implementations of continuous monitoring technology.	single large teaching hospital in England.		wirelessly every two minutes to a mobile device carried by the nurse.		Observation rounds provided much needed social interaction and relief of boredom. 2) nighttime burden- participants mentioned their irritation at being woken up for observation rounds. Participants wondered if continuous remote monitoring could replace manual observations overnight. However, other things in the hospitals such as noisy neighbours and bleeping machines also kept them from sleep. 3) comfort- patients found the patch so comfortable that they forgot they were wearing it. One patient found the patch uncomfortable whilst two had concerns about the practicalities of wearing the patch. 4) sense of security- patients felt safer wearing the continuous monitoring device. Some mentioned that the patches would help certain people more than others, if they needed more monitoring and attention.

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						5) staffing concerns- the patch was seen as a positive thing as nursing staff were described as too busy and on their feet all the time so they appreciated that the patch freed up nurses' time. 6) trust of technology- a number of patients expressed reservations about the reliability of the technology and one patient expressed concerns about data security. Others were worried about system failure. The most common reason for mistrusting the technology was the lack of feedback, especially if no notifications were sent by the device.
GALE-GRANT, O. & QUIST, H. 2018. Electronic recording of vital signs for mental health inpatients. *British Journal of Mental Health Nursing,* 7, 64-69.	To assess the feasibility of transitioning from paper-based charts to a new purpose designed electronic reporting system, and, as a secondary outcome, to assess the acceptability of this change to staff and patients.	Data collected from a 22-bed male adult acute inpatient unit and a 10-bed male psychiatric intensive care unit located at two different hospital sites was collected over 10 months. Surveys from both staff members and service users was returned via paper forms.	United Kingdom	Clinical staff and patients on the selected wards MioCare A200 Handheld Tablet with Live Obs software.	Feasibility and acceptability of the electronic monitoring system to staff and patients. Nursing compliance.	Clinical staff participants indicated satisfaction with the new system. However, 50% reported that the system was cumbersome to use. 53% of patients preferred the new system. There were no significant differences observed between the two wards in the study in terms of uptake of the new system.

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WONG, D. C. W., KNIGHT, J., BIRKS, J., TARASSENKO, L. & WATKINSON, P. J. 2018. Impact of electronic versus paper vital sign observations on length of stay in trauma patients: stepped-wedge, cluster randomized controlled trial. *JMIR Med Inform,* 6, e10221.	To prospectively assess whether the deployment of the VitalPAC eObs system compared with the paper-based system, changed patients' length of stay.	Randomised stepped-wedge interventional study in 2 adult inpatient wards of the trauma unit. Nursing staff measured vital signs using spot-check monitors and documented the result on paper and manually calculated the EWS. Nurses then did the same with the VitalPAC intervention.	United Kingdom John Radcliffe Hospital, Oxford University Hospitals National Health Service Trust	1199 patients. VitalPAC eObs system on handheld device.	Age, sex, ethnicity of patient, American Society of Anaesthesiologists score, reason for admissions and admission method. Initial ward and zone on the trauma unit. Date and time of admission into the ward. Date, time and clinician-recorded EWS for the first vital sign observations recorded on the trauma unit. Total number of vital sign observations on the unit recorded electronically and on paper. Fit to discharge data. Actual hospital discharge date and time. In-hospital mortality. 30-day mortality following ward admission.	1232 episodes were recorded: 628 on paper, 604 using eObs. 873 were fully consistent with the randomised intervention. There were 37 deaths in the hospital, 21 in paper and 16 in eObs. A significantly greater proportion of patient episodes contained an EWS ≥3 using the eObs system than paper. The median time between observations for those without a delayed discharge was 7.1 hours in the paper arm and 7.0 on the eObs arm. There was no difference in escalation time or length of stay. Longer time to discharge was associated with greater age but there was no difference with the treatment arm. Per-protocol in-hospital time to mortality analysis suggested a mortality benefit in favour of eObs but this was not sustained at 30 days.

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					Unplanned admission to the ICU or a cardiac arrest for each episode.	
MOTULSKY, A., JENNA, W., CORDEAU, J.-P., POMALAZA, J., BARKUN, J., TAMBLYN, R. & WONG, J. 2017. Using mobile devices for inpatient rounding and handoffs: an innovative application developed and rapidly adopted by clinicians in a pediatric hospital. *Journal of the American Medical Informatics Association,* 24, e69-e78.	To describe the usage patterns and user experiences of a novel application that allows mobile devices to be used for rounding and handoffs in an academic tertiary health care centre.	Audit of all The FLOW entries. All clinicians who had used the app were sent an invitation to complete a questionnaire.	Canada McGill University Health Centre	127 clinicians responded to the questionnaire. Clinicians' own devices with the V-Sign app installed with the module The FLOW (flows being informal documentation not attached to the EMR). Users were categorised in to 2 groups: continued users and episodic users.	Usage patterns of The FLOW. Perception of The FLOW.	The FLOW was used in three different ICUs but all general medical units had stopped using it. Nearly three-quarters of the participants used the app frequently. Male users were less likely to be comprehensive with their flows than females. Most users preferred accessing The FLOW via computer than smartphone. The FLOW was perceived as having improved patient care and patient safety.
SEFTON, G., LANE, S., KILLEN, R., BLACK, S., LYON, M., AMPAH, P., SPROULE, C., LOREN-GOSLING, D., RICHARDS, C.,	To explore how an electronic physiological surveillance system (EPSS) compares with traditional paper-based documentation of	Mixed methods prospective study. Participants were given five vignettes to record data from and calculate the PEWS.	United Kingdom	23 staff including RNs, student nurses, healthcare assistants and medical students working on the ward where pilot testing of the EPSS was being	The user acceptability of using both methods. Accuracy of data recording. Accuracy of calculation of age-specific PEWS.	The accuracy of vital sign documentation for the electronic physiological surveillance system was higher at 98.5% compared with the pen and paper method of 85.6%. Paper-based documentation provided 21 to 25 potential opportunities for

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SPINTY, J., HOLLOWAY, C., DAVIES, C., WILSON, A., CHEAN, C. S., CARTER, B. & CARROL, E. D. 2017. Accuracy and efficiency of recording pediatric early warning scores using an electronic physiological surveillance system compared with traditional paper-based documentation. *CIN: Computers, Informatics, Nursing,* 35, 228-236.	vital signs, clinical observations and calculating PEWS.	Participants were randomised to either start with the paper-based traditional method or using the handheld device with the VitalPac software. Participants then completed the exercise with the other method. Web-based survey was used to assess the user acceptability of using both methods.		conducted took part in the controlled exercise. 29 staff members completed the online survey. iPod Touch 4th gen with VitalPac Pediatric, System C Healthcare Ltd.	Time taken to document vital signs, clinical observations and PEWS (efficiency).	error whereas the electronic physiological surveillance system provided 14 to 16 potential opportunities for error. The accuracy of PEWS calculation using electronic physiological surveillance system documentation was 94.6% compared to 55.7% for the paper-based method. Time taken to record vital signs and clinical observation and calculate PEWS was faster using the electronic physiological surveillance system documentation at 68 seconds compared to 98 seconds for the paper-based method. 93% of survey respondents had prior experience with Apple hardware. 55% preferred data entry using the electronic physiological surveillance system but 25% remained undecided.
WONG, D., BONNICI, T., KNIGHT, J., GERRY, S., TURTON, J. & WATKINSON, P. 2017. A ward-based time study of paper and	To determine whether introduction of an eObs system alters the time required to record a complete set of vital sign observations.	Before-and-after observational study. Time-motion methods were used to measure how much time was spent taking and documenting patients' vital signs.	United Kingdom Oxford University Hospital's NHS Trust.	Care support workers, student nurses, nurses and senior nurses. Tablet mounted on a roll-stand alongside the vital sign monitor with	Ward-level data e.g., staff levels, staff seniority, ward speciality. The difference in task completion time.	A total of 606 sets of vital sign recordings were observed during the study period. The majority of staff observed were band 5 nurses. The geometric mean task completion time was lower using eObs. The overall

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electronic documentation for recording vital sign observations. *Journal of the American Medical Informatics Association,* 24, 717-721.		Observations were Monday to Friday between 9am and 5pm. Observations were undertaken over 2 5-week periods, 1 before and after implementation of SEND.		the SEND app installed	The time needed to take a set of vital signs and compute an EWS. The differences in times to complete the View Chart and Take Vital Signs subtasks pre- and post-intervention.	treatment effect ratio was 0.70, equivalent to a 30% reduction in time for the eObs system compared to the paper system. Of the two subtasks, View Chart and Take Vital Signs, the greatest time savings were in the latter.
CROWSON, M., KAHMKE, R., RYAN, M. & SCHER, R. 2016. Utility of daily mobile tablet use for residents on an otolaryngology head & neck surgery inpatient service. *Journal of Medical Systems,* 40, 1-5.	1) To investigate the effects of mobile tablet technology in conjunction with the EHR on resident clinical productivity in an inpatient surgical setting. 2) To evaluate perceived educational benefit and potential economic benefits of the use of mobile tablet technology in place of traditional paper 'patient list' formats.	Prospective cohort study There was a 2-week pre-intervention period before the implementation of the iPads and a 2-week study period with the iPads in use.	United States of America Duke University inpatient service	13 Otolaryngology inpatient residents. iPads with the Epic EHR platform accessed through a Citrix Receiver software were used. The iPads could be used to place orders, look up clinical data, and facilitate education and patient data handoff transfers.	Number of pieces of paper pertaining to daily rounds printed and utilised. Time from start of rounds to complete order entry after rounds. Number of times that the team or individual residents needed to either exit or interrupt rounds in order to answer clinical question pertinent to the rounds. Percent of patients discharged before 11am (of those patients whom were intended to be discharged that day).	During the pre-intervention period, 607 pieces of paper were used. After the iPads were issued, no paper was used. The duration of formal rounds was significantly shorter after intervention. The iPads would prevent an estimated 15,782 potential instances confidential information could be compromised by using paper lists. Residents felt a tablet facilitated more detailed and faster transfer of information and improved ease of documentation in the medical record. 70% of the residents felt that the tablets helped them spend more time with patients. 80% of the residents felt that the tablets improved morale.

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ALEXANDER, S. M., NERMINATHAN, A., HARRISON, A., PHELPS, M. & SCOTT, K. M. 2015. Prejudices and perceptions: patient acceptance of mobile technology use in health care. *Internal Medicine Journal,* 45, 1179-1181.	To evaluate the perceptions and potential endorsements of both student and qualified health professionals' use of mobile devices at the patient bedside.	Survey	Australia Adult and paediatric teaching hospital	70 patients and carers Smartphone (no elaboration)	Had the health professional used a mobile device during the consultation Had the health professional asked permission to use the device What the patient thought the health professional was doing How the patient and carer felt about the device use Whether the patient and carer thought the device use was useful for health care Patients and carers own use of health-related software apps	The main reported reasons for using the mobile devices were taking calls, information search-related and communication.54% of patients and carers reported that doctors used mobile devices while they were with them. Patients reported that doctors used a mobile device to answer phone calls, photograph a medical condition, look up information about medication or to use an app. 36% thought that doctors were using the devices for work-related purposes. 4% perceived that nursing staff were using mobile devices to send text messages socially. Two patients reported that doctors discussed other patients within hearing of patients or carers. Half the patients and carers were tolerant of doctors using mobile devices and justified it as a 'way of life these days'. Mobile devices enabled doctors to look up something related to patient care, discuss the condition with another doctor, discuss the condition with the patient/carer if they called from home or use

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						diagrams on the device to explain the condition to the patient/carer. 73% of patients and carers said they did not mind doctors using mobile devices if it was for patient care. A third of patients and carers did not like doctors using mobile devices at the bedside and thought it was not beneficial to patient care. There were concerns that mobile devices could distract health professionals or interrupt their train of thought.
BULLOCK, A., DIMOND, R., WEBB, K., LOVATT, J., HARDYMAN, W. & STACEY, M. 2015. How a mobile app supports the learning and practice of newly qualified doctors in the UK: an intervention study. *BMC Medical Education,* 15.	To examine how smartphones are used in relation to other types of resources available in the workplace and report changes in their use over time.	Baseline survey when participants were newly in their post. Exit survey at the end of data collection phase. The relationship between variables at baseline and exit were explored.	United Kingdom	125 F1 trainee doctors. Participant's own devices. iDoc app (Dr Companion software) which included five key medical textbooks.	Frequency of use. Type of device. Usefulness of app. Variation in use. The effects of the intervention.	Just over half of the participants reported using the app daily. There was a significant decrease of the use of hard-copy textbooks and journals, use of electronic textbooks and journals accessed by a PC, lecture notes, and the internet as a workplace resource. Over time, the percentage of participants who would feel comfortable using a device containing textbooks in front of patients significantly increased. There was an increase in participants who would feel comfortable using a mobile device containing

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						textbooks in front of senior medical staff.
SCHMIDT, P. E., MEREDITH, P., PRYTHERCH, D. R., WATSON, D., WATSON, V., KILLEN, R. M., GREENGROSS, P., MOHAMMED, M. A. & SMITH, G. B. 2015. Impact of introducing an electronic physiological surveillance system on hospital mortality. *BMJ Qual Saf,* 24, 10-20.	To determine whether introducing an electronic physiological surveillance system (EPSS) specifically designed to improve the collection and clinical use of vital signs data, reduced hospital mortality.	Crude monthly and annual mortality rates were calculated. The mortality data was used in two ways: Method 1: Multi-year trend analysis. Monthly admissions data were seasonally adjusted to derive a seasonally adjusted mortality rate (SA-MR) at each hospital. Method 2: Analysis of deaths occurring in each speciality. The seasonally adjusted deaths for Medicine, Surgery and T&O were analysed using a cumulative sum control method.	United Kingdom Queen Alexandra Hospital (QAH) and University Hospital Coventry (UHC)	Mortality of patients was studied. VitalPac was available on handheld devices. Vital signs charts were viewable on wireless PC tablets and desktop PCs at QAH, but only on desktop PCs on wards at UHC.	Measure of EPSS implementation. Hospital mortality.	During implementation of the electronic physiological surveillance system across Queen Alexandra Hospital crude mortality fell from 7.75% at baseline to 6.42% after implementation, with an estimated 397 fewer deaths. At University Hospital Coventry, crude mortality fell from 7.57% at baseline to 6.15%, with an estimated 372 fewer deaths. Seasonally adjusted mortality rate fell markedly and remained low in both hospitals within a short time of electronic physiological surveillance being implemented for the whole hospital journey. In all three specialities at Queen Alexandra Hospital, increasing use of the electronic physiological surveillance system across the hospital was associated with decreasing cumulative total of excess deaths. At University Hospital Coventry for medicine, the mortality plateaued following the first use of the electronic

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						physiological surveillance system but did not begin to fall until the electronic physiological surveillance system was also implemented in the emergency admissions unit. The reduction was delayed in the trauma and orthopaedic wards.
YOUM, J. & WIECHMANN, W. 2015. Medical student use of the iPad in the clerkship curriculum. *The Clinical Teacher,* 12, 378-383.	To describe the outcomes of a year-long iPad integration into clerkships and aims to contribute to the research on the use, perceptions, and potential of mobile technology integration to support clinical learning.	Students were asked to complete a pre- and post-survey before and after their third-year clerkship.	United States of America	Third-year medical students who were in the first cohort to receive iPads during their first year of medical school. 85 students completed the pre-survey, and 49 students completed the post-survey at the end of the year.	Use of the recommended apps during the third year. Activities performed on the iPad during the clerkships. Perceptions on use of the iPad in the clinical setting. Benefits and challenges of using the iPad.	Students began their clerkships with positive perceptions of the iPad as a clinical tool. Students felt that the iPad would make a positive impact on their learning and allow them to be more efficient during their rotations. Sunrise Mobile MD II, an app to access EMRs, and iAnnotate, a PDF annotation tool, were the most frequently used apps during a rotation. There was infrequent use of most other apps. Activities most frequently reported on the iPad were: reading or writing emails, searching clinical information online, and studying for exams. The most frequent benefits were: access to EMRs during rounds, the ability to study during downtime and quick or 'on the go' access to information. The top challenge was a lack of Wi-Fi internet access.

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NUSS, M. A., HILL, J. R., CERVERO, R. M., GAINES, J. K. & MIDDENDORF, B. F. 2014. Real-time use of the iPad by third-year medical students for clinical decision support and learning: a mixed methods study. *J Community Hosp Intern Med Perspect,* 4.	To further understand medicinal students' use of the iPad during their Internal Medicine clerkships. Specifically: 1) In what ways did the students use mobile technology for learning and clinical decision support? 2) What apps did the students use in the care of patients? 3) Did the amount of time spent and the students' expertise in using mobile technology grow over time?	Year-long mixed methods study. 1) Beginning and end-of year questionnaires. 2) iPad usage logs. 3) Weekly rounding observations. 4) Weekly semi-structured medical student interviews.	United States of America	37 third-year medical students. 3rd generation iPad with 64GB of storage pre-loaded with relevant apps. Students were free to purchase their own apps also.	Students' past and present use of mobile technology and Apple computers. Experience with the iPad. Types and amount of time used on medical resources and apps on the iPad in the care of patients.	The students reported using the iPad at all stages of patient care. Two primary uses were obtaining real-time patient data via the EHR and finding additional information for clinical decision support. Various medical knowledge resources were used including library resources and a multitude of iPad apps. Students also indicated using the iPad for personal learning and productivity throughout the day. The iPad was used for email, note taking and word processing. 71% reported that the amount of time they spent using the iPad for clinical decision support grew over time. Those who did not use their iPad often reported insights in to why, such as the size and weight of the iPad and the use of other electronic devices. 75% reported that their expertise also grew over time. The most frequent apps used were: Epocrates, PDFExpert, Micromedex, DynaMed, First Consult, DrawMD, USMLE World Q Bank and VisualDx.
ALBRECHT, U. V., BEHRENDS,	To discuss the experiences	10 clinical wards were provided with	Germany	39 nursing staff answered the	iPad usage within the project.	76% had "rarely or never" used xprompt during the study. 71%

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M., SCHMEER, R., MATTHIES, H. K. & VON JAN, U. 2013. Usage of multilingual mobile translation applications in clinical settings. *JMIR mHealth and uHealth,* 1.	gained from a study carried out at the Hannover Medical School regarding the use of a mobile translation application in hospital wards.	an iPad containing a copy of the xprompt app. A paper survey was distributed after six weeks of using xprompt. Five nurses were interviewed.		xprompt questions on the survey. iPads "xprompt-multilingual assistance" app	General iPad usage. Availability of the devices during the project. The experienced usability of the device. Relevance of the iPad related to work. Expectations of working with the iPad in the future. General attitude towards the usefulness of translation apps. Usability aspects of xprompt. The experience of the usage of xprompt in communication with patients and colleagues.	stated that the iPad was always available when desired. Mobile translation tools were seen to be helpful for daily communication with foreign-language patients although xprompt received neutral ratings. xprompt was seen to be easy to use and participants did not have to spend much time familiarising themselves with it. It was primarily used with patients. 90% rated the usability positively and 33% assumed the iPad as relevant for their daily work. When attempting to provide information about delicate procedures the members of the nursing staff often indicated that they had avoided using xprompt. Older patients had problems using the devices, and older members of the nursing staff were more cautious and sceptical about their use. Some patients were unable to use the devices due to visual impairment or analphabetism. At times, the desired language was not available on xprompt. xprompt was sometimes not

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						used as one device per ward was not sufficient. Only head nurses were trained, and so other members of the nursing staff did not understand how to use the devices. Other barriers to use involved the iPad being locked away and a high workload.
DRAYTON, K. 2013. How mobile technology can improve healthcare. *Nursing Times,* 109, 16-18.	To understand the requirements of mobile working for health professionals and to identify whether it could increase productivity and efficiency.	The devices were implemented into the study sites. The study sites were asked to collect data from staff using a standard baseline assessment tool. The health professionals provided comments from patients or other staff members about the impact of deploying the technology, the difficulties encountered and the benefits of using the devices.	United Kingdom	764 health professionals. Panasonic Toughbook	Standard baseline assessment areas: Contacts: the number and duration of patient/service user contacts in each day over the assessment period. Journeys: the number and duration of all journeys made on each day over the assessment period. Referrals and admissions: the total number of referrals and admissions made (if any) during the assessment period. No access visits: the number of times in a day that a clinician was	Benefits: Participants reported an improved work/life balance. They also suggested being able to complete work in a timely fashion, improvements in the quality and timeliness of clinical data recording, the ability to view and share data between the clinical services involved in an individual patient's care and being able to avoid duplication. Journeys and travels time decreased and time spent with patients increased, as well as clinicians being able to increase their capacity to see new patient. There was a reduction in no-access visits, and financial savings. Patients reported feeling more confident about their care and health professionals reported being more satisfied as they could fulfil their role more effectively.

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					unable to gain access to a patient. Instances in which access to the mobile device helped prevent admissions, referrals and no-access visits. When information was duplicated in different systems. Positive and negative comments about the technology.	Difficulties: maintaining the early benefits and being able to resource the project beyond the deployment period. The study did not reveal any cultural barriers to technology.
FURNESS, N. D., BRADFORD, O. J. & PATERSON, M. P. 2013. Tablets in trauma: using mobile computing platforms to improve patient understanding and experience. *Orthopedics,* 36, 205-8.	To assess patient-reported outcomes to confirm whether a desire existed to view radiographs after admission for trauma management: to determine whether this was perceived by patients to benefit their experience with, understanding of, and involvement in decision making regarding their injury and the proposed	Patients in the preintervention cohort completed a questionnaire after being examined by the on-call orthopaedic consultant. Patients in the postintervention cohort were given the opportunity to view their radiographs as part of the consultant post-take trauma ward round. These patients were given the same	United Kingdom	Two cohorts of 50 patients who were admitted to a district general hospital trauma unit after sustaining a traumatic injury requiring radiographic evaluation via radiographs, CT or MRI. Motion C5t Tablet PC.	Patient satisfaction with, understanding of, and involvement in the explanation of their injury and proposed management plan. Whether patients perceived that having the opportunity to view their radiographs as part of the consultation would have affected the variables stated above. Age, sex and type of injury sustained.	Participants in the post-intervention cohort reported a significant improvement in perceived involvement in decisions made about their care and treatment. An improvement was shown in the number of patients reporting being given the right amount of information about their condition or treatment. 46/50 patients reported seeing their images on the post-take ward-round, one patient was not shown the images, and three patients declined to view the images. 45 patients reported that seeing their images helped them

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	management plan: and if so, to quantify any improvement in these parameters after viewing the radiographs.	questionnaire after the post-take round.				understand what the consultant had told them. 35 reported that an explanation of their injury would not have been as effective if they had not been shown their images, three were not sure, and eight reported that it would have been as effective. 44 reported that seeing their images had a positive effect on their overall experience of their hospital treatment, two were unsure.
HANDS, C., REID, E., MEREDITH, P., SMITH, G. B., PRYTHERCH, D. R., SCHMIDT, P. E. & FEATHERSTONE, P. I. 2013. Patterns in the recording of vital signs and early warning scores: compliance with a clinical escalation protocol. *BMJ Qual Saf,* 22, 719-26.	To use the hospital's large vital signs database to study the pattern of the recording of vital signs observations throughout the day and examine its relationship with the monitoring frequency component of the clinical escalation protocol that forms part of the hospital's track and trigger system.	The pattern of vital signs and VitalPac Early Warning Score (ViEWS) data were collected from admission to all adult inpatient areas (except high care areas) and compared.	United Kingdom Portsmouth Hospitals NHS Trust (PHT)	Staff at PHT who recorded vital signs observations with a personal digital device equipped with VitalPac.	Hourly and daily patterns of vital sign and ViEWS value documentation. Numbers of vital signs in the periods 08:00-11:59 and 20:00-23:59 with subsequent vital signs recorded in the following 6 hours. The time to next observation (TTNO) for vital signs recorded in the periods 08:00-11:59 and 20:00-23:59.	950,043 complete observation sets were recorded during the study period. The pattern of vital signs recording was variable throughout the 24h period. Only 12.81% of vital signs were measured during the period 23:00-05:59. There was an increase in the percentage of vital signs collected each hour between 10:00-17:59. There were two peaks of recording activity at 06:00-06:59 and 21:00-21:59. The pattern of observations was identical each day of the week. Lower ViEWS values (0-6) were more likely to have time to next observation values closer to that expected than higher ViEWS values (≥7).

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						Those with a higher ViEWS score were more likely to have their vital signs measured through the night. Adherence to the hospital vital signs monitoring protocol was always greater during the daytime period, irrespective of ViEWS value.
WU, J., WALDRON, J., HOOD, S., KAHNAMELLI, A., KHAN, M., BARNETT, J., FRENCH, J., SLAGER, S., MELHEM, S. & SHABESTARI, O. 2013. The introduction and evaluation of mobile devices to improve access to patient records: a catalyst for innovation and collaboration at BCCA. *Studies in Health Technology and Informatics,* 183, 232-237.	To determine if providing a mobile device with access to the EHR, clinical reference applications and administrative tools improved care delivery and clinicians' experience.	Phase 1: One-group before and after (12 weeks) implementation of iPads surveys. Informal interviews were also conducted before and after. Phase 2: One-group before and after (12 weeks) implementation of iPads surveys. 12 semi-structured interviews were also conducted during the project.	Canada BC Cancer Agency	Phase 1: 34 radiation oncologists. iPads were distributed. Phase 2: 25 radiation oncologists and 25 medical oncologists.	Adoptability, effectiveness and costs. Privacy and security requirements.	Clinicians reported a reduction in the number of interruptions during patient visits and a reduction in the need for printing. Most of the respondents believed that the iPad improved their workflow and enhanced clinical decision-making. The response time, security and reliability of the iPad were reported to be acceptable.

Study	Aim	Study design	Setting	Participants (and device type, software)	What was 'measured'?	Key Findings
DAVIES, B. S., RAFIQUE, J., VINCENT, T. R., FAIRCLOUGH, J., PACKER, M. H., VINCENT, R. & HAQ, I. 2012. Mobile Medical Education (MoMEd) - how mobile information resources contribute to learning for undergraduate clinical students - a mixed methods study. *BMC MEDICAL EDUCATION,* 12.	How the medical students used the technology, how it enabled them to learn, and what theoretical underpinnings supported the learning.	Prospective observational study. Four focus groups. Pre- and post-surveys. Students were required to regularly synchronise their device which monitored usage.	United Kingdom	387 medical students. Hewlett Packard iPAQ 114 Classic handheld PDA loaded with DrCompanion software.	Where and when the devices were used. What resources were used the most. What prevented use. What encouraged use. How did the mobile devices help students learn. What was required of the students and the establishment to make the most of the tool. Students' personal experiences with the devices.	Initial perceptions of personal digital assistant use were the benefits of instant access and portability of the device. Disadvantages were perceived as loss or theft of the device, the development of dependency on the device, and concerns that it may appear disrespectful. In the post-study survey, 47% of respondents used their personal digital assistant at least once a week mostly from the clinical setting and at home. 24% had not used their personal digital assistant because they did not want to carry another device, learning preference, and concerns around theft and loss. 98% wanted the initiative to continue either with the school providing DrCompanion resources with or without a personal digital assistant or smartphone. Students tended to use the device mostly between patients or scheduled teaching activities and less commonly during teaching sessions. Using it 'on the go' was a common statement.

Study	Aim	Study design	Setting	Participants (and device type, software)	What was 'measured'?	Key Findings
						Ways in which learning was enabled included: timely access to key facts, consolidation of knowledge through repetition, a supplement rather than a replacement, and making use of wasted time. Barriers that inhibited the learning opportunity included: interrupting the experience, negative experiences with patients and staff, dislike of technology, practical issues, and an extra device to carry. A change in attitude, behaviour, and approach was required for the personal digital assistant to become an optimal tool.
HORNG, S., GOSS, F. R., CHEN, R. S., NATHANSON, L. A., HORNG, S., GOSS, F. R., CHEN, R. S. & NATHANSON, L. A. 2012. Prospective pilot study of a tablet computer in an Emergency Department. *International Journal of Medical*	To determine the effect of physician tablet use in the Emergency Department.	Combined quantitative and qualitative study design. Usage data of EDIS was analysed. Survey before and after study.	United States of America	13 physicians Tablet computer	The time spent using the Emergency Department Information System (EDIS) at a computer workstation per shift. The number of EDIS logins at a computer workstation per shift. Perception of physicians using tablets.	Each physician used a tablet for a median of three shifts. Clinician use of a tablet when working in the emergency department was associated with a 38-minute decrease in time spent per shift using the EDIS at a computer workstation. The number of logins was associated with a 5-login decrease per shift. Physicians found the tablet to be clinically useful and easy to carry around. Physicians held these beliefs before using a tablet. Physicians found the

Study	Aim	Study design	Setting	Participants (and device type, software)	What was 'measured'?	Key Findings
Informatics, 81, 314-319.						tablet easy to get started with. 46% of physicians felt that tablet use decreased the number of logins at a computer workstation. 31% felt that tablet use was associated with more time at the bedside. 69% were afraid of losing the tablet and 62% were afraid of dropping it.
JONES, S., MULLALLY, M., INGLEBY, S., BUIST, M., BAILEY, M. & EDDLESTON, J. M. 2011. Bedside electronic capture of clinical observations and automated clinical alerts to improve compliance with an early warning score protocol. *Crit Care Resusc,* 13, 83-8.	To determine whether automated clinical alerts increase compliance with the CMFT EWS protocol and improve outcomes of patients with acute critical conditions.	Historically controlled study of the Patientrack intervention. Phase 1: baseline data capture. Phase 2: Implementation of the electronic observation capture and EWS calculation. Phase 3: electronic observation capture with automated electronic alerts. Data was collected from the Patientrack system and EMR to be analysed.	United Kingdom Central Manchester University Hospitals National Health Service Foundation Trust (CMFT)	705 patients at the baseline phase and 776 patients during the alert phase. Nurses entered in bedside observations using a PDA. Alert response system to doctors is Patientrack.	The primary outcome measure was length of stay. Secondary outcome measures were compliance with the EWS protocol, cardiac arrest incidence, critical care utilisation and hospital mortality.	Significant reduction in the length of stay of patients recruited during the alert phase (9.7 days v 6.9 days). 81% of EWSs were calculated correctly during the baseline phase. There was no difference between the baseline and alert phase time interval to recheck an EWS 3, 4 or 5. Both the baseline and alert phase groups continued to have non-compliance of 9% and 10%. The documentation of a clinical response to a patient with an EWS 3, 4 or 5 increased from 29% at baseline to 78% in the alert phase. The documentation of a clinical response of a patient with an EWS >5 increased from 67% to 96%. The other secondary

Study	Aim	Study design	Setting	Participants (and device type, software)	What was 'measured'?	Key Findings
						outcomes did not meet statistical significance.
WAGER, K. A., SCHAFFNER, M. J., FOULOIS, B., SWANSON KAZLEY, A., PARKER, C. & WALO, H. 2010. Comparison of the quality and timeliness of vital signs data using three different data-entry devices. *Comput Inform Nurs,* 28, 205-12.	To measure the accuracy and timeliness of vital signs data before and after the implementation of a clinical documentation system using four different data-entry devices: 1) a paper medical record system, 2) a clinical documentation system with a computer on wheels workstations, 3) a clinical documentation system with a tablet PC affixed to the vital signs monitor and 4) a clinical documentation system with direct feed from the vital signs monitor to the tablet PC.	Observational study.	United States of America Medical University of South Carolina	Patient care technicians (PCTs) working during observations. Two types of tablet PCs (Motion Computing LE1600 and the C5).	Errors in recording vital signs: transcription and omission. Time taken to record observations.	270 instances of vital signs were made during the 3 stages (stage 4 had not yet been implemented). In phase 1, the observers found that the patient care technicians typically handwrote the vital signs into the patient's paper medical record at the point of care. In phase 2, patient care technicians were most often observed handwriting the patient vital signs and then transcribing them into the clinical documentation system using the computer on wheels outside of the room. It was not uncommon for the patient care technicians to continue their rounds when the workstation was busy and enter the data later. In phase 3 patient care technicians would enter the vital signs directly into the tablet PC. During phase 2 physicians were frustrated when vital signs were not in the patient's record at the time of their rounds. Concerns were made

Study	Aim	Study design	Setting	Participants (and device type, software)	What was 'measured'?	Key Findings
						about patient care to the senior leadership team. There was a 16.8% error rate in Stage 1, 15.2% in Stage 2 and 5.6% in Stage 3. Of the total 31 documentation errors, 90.3% (28) were transcription errors.
LEE, T. 2006. Nursing administrators' experiences in managing PDA use for inpatient units. *CIN: Computers, Informatics, Nursing,* 24, 280-287.	To explore how implementing a technology application (PDA) affected nurse managers' perceptions of daily unit management.	In-depth interviews	Taiwan	16 nurse managers. PDAs.	Nurse manager's perceptions of the day-to-day experiences of PDA use in their units.	Using PDAs was supposed to replace paperwork but because of the limitations of the system, paper records were still kept. Without wireless transmission, doctors refused to enter medical orders in the PDAs, which was one of the rationales for implementation. Not all nurses found that using the PDA was easy to learn. Super-users were assigned to help less computer-skilled nurses. One nurse manager preferred using the PDAs when doctors were not around as they would say they were outdated and question the use of them. Doctors would access the nurse's PDAs for personal use. Some nurse managers had ambivalent feelings about implementing the PDAs which

Study	Aim	Study design	Setting	Participants (and device type, software)	What was 'measured'?	Key Findings
						created stress and conflicts. Strategies used by the hospital to increase the usage frequency of PDAs added to their stress. Wireless transmission was desired by nurse managers due to management concerns such as only being able to see patient observations from 24 hours ago. The system was criticised for poor content design.
PRYTHERCH, D. R., SMITH, G. B., SCHMIDT, P., FEATHERSTONE, P. I., STEWART, K., KNIGHT, D. & HIGGINS, B. 2006. Calculating early warning scores--a classroom comparison of pen and paper and hand-held computer methods. *Resuscitation,* 70, 173-8.	To compare the speed and accuracy of charting the weighted value attributed to each vital sign, and of calculating an EWS, using the traditional pen and paper method with that using the PDA (VitalPac).	Participants were asked to entry and chart 5 different fictitious physiological vital signs datasets. Each dataset was presented to the participant on a separate sheet of paper in a quiet room. Participants were randomly allocated to first complete the pen and paper method group, or the VitalPac PDA method group. Each participant was asked to rate their preference for	United Kingdom Medical Assessment Unit of Portsmouth Hospitals NHS Trust	21 nurses. PDA installed with VitalPac.	The time taken for the participant to complete the processing of each dataset was recorded. Pen and paper=tPP, VitalPac=tVP. For each vital signs dataset, the completeness of charting and the accuracy of each weighted value and the calculated EWS. Participants' preferences (accuracy, easier detection of errors, simplicity, speed, convenience).	168 datasets were available for analysis (84 VitalPac and 84 pen and paper). Errors occurred in 7.3% of individual weighted value entries using the pen and paper method; 6.7% were recording errors and 0.6% were omissions. In total 28.6% of EWSs were incorrect which generated 14.3% incorrect clinical actions. Errors occurred in 2.4% of individual raw physiological entries made using the VitalPac method. No data items were omitted, and no participant made more than 1 error. In total 9.5% of EWSs contained errors which would

Study	Aim	Study design	Setting	Participants (and device type, software)	What was 'measured'?	Key Findings
		pen/paper or VitalPac methods using a 5-point Likert scale. A value above 3 indicated a preference for VitalPac.				have generated 4.8% incorrect clinical actions. For each question of the survey the participants showed a preference for the VitalPac.
HOLLERAN, K., PAPPAS, J., LOU, H., RUBALCABA, P., LEE, R., CLAY, S., CUTONE, J., FLAMMINI, S., KUPERMAN, G. & MIDDLETON, B. 2003. Mobile technology in a clinical setting. *AMIA ... Annual Symposium proceedings / AMIA Symposium. AMIA Symposium*, 863.	To evaluate the technology.	Six-month pilot study where physicians were asked to use the devices in clinical practice. Follow-up survey.	United States of America	21 physicians (20 responded to survey) PDA (Palm VII), an app that allowed users to view patient lab results, radiology and transcribed reports.	Usability, performance, and feasibility.	Most respondents stated that the ability to access real time patient data anytime, anywhere, was extremely helpful. The majority of participants used the handheld while off campus. Lab results were the most favoured lab patient result available. System usage was low, averaging 11-20 accesses for clinical data and 21-30 for the phone directory per user in the six months. There was difficulty in reading the data was due to the small form factor and font size. The system was too slow. Signal strength was also an issue for users. Many participants stated that when it was used, it was highly effective. The reassurance of being able to access clinical data when away from a computer received a high mark. More than half felt as

Study	Aim	Study design	Setting	Participants (and device type, software)	What was ‘measured’?	Key Findings
						though this was a worthy addition to their clinical toolkit and sought to have continued access to the system.

Appendix 3. Synthesis of High Relevance Reviews

Table 21 Synthesis table for high relevance reviews.

Study	Aim	Setting	Device studied	Number of studies identified	Key Findings
WILSON, C. B., SLADE, C., WONG, W. Y. A. & PEACOCK, A. 2020. Health care students experience of using digital technology in patient care: a scoping review of the literature. *NURSE EDUCATION TODAY,* 95.	To collate and interrogate current scholarly literature that informs the preparation process for nursing and midwifery students to undertake clinical placements and to ultimately work in digital healthcare environments.	United Kingdom	Four studies considered the use of digital health systems already in practice (EHRs and computerised prescribing system), one study explored the use of mobile technology such as tablet computers and PDAs.	n=7	A barrier of using mobile technology was the students' own discomfort in using technology. Concerns were raised about functionality, portability, and potential loss of the devices. This concern reduced over time. Students were concerned that staff may perceive that they are on their phones for personal reasons during placements or that supervisors may perceive the student as lacking knowledge or making the patient feel uncomfortable. Students felt the personal digital assistant provided them with more confidence and they felt part of the team due to having the same patient information provided on the personal digital assistants. Nursing students found that using the personal digital assistant was easier to access accurate information. The personal digital assistants were also beneficial in providing information for patients and/or their relatives. Medical students placed value in using personal digital assistants for learning but rarely used devices with patients. They

Study	Aim	Setting	Device studied	Number of studies identified	Key Findings
					believed the use of technology would harm the relationship with the patient.
JACOB, C., SANCHEZ-VAZQUEZ, A. & IVORY, C. 2020b. Social, organizational, and technological factors impacting clinicians' adoption of mobile health tools: systematic literature review. *JMIR MHEALTH AND UHEALTH,* 8.	To systematically explore relevant published literature to synthesise the current understanding of the factors impacting clinicians' adoption of mHealth tools, not only from a technological perspective but also from social and organisational perspectives.	United Kingdom	Smart devices.	n=171	Technological issues included connectivity, reliability, technical support, and technical difficulties in general. Several studies raised concerns relating to compatibility, interoperability issues, EHR integration, and competition with existing programmes. Training was the most central workflow related theme followed by workflow fit, time and cost efficiencies, collaboration and coordination, technical skills and experience, the impact on role and responsibilities, and the extent of leadership support. The most prevalent patient-related subtheme was quality and efficiency of patient care followed by the quality and ease of communications. Other central themes included policy and regulations relating to privacy, cultural and social factors, and monetary factors.
DEWANE, M., WALDMAN, R. & WALDMAN, S. 2019. Cell phone etiquette in the clinical arena: a professionalism imperative for healthcare. *Current Problems in Pediatric &*	Does not specify.	United States of America	Mobile phones.	Does not specify.	Physicians and nursing staff perceived an improvement in interprofessional communication. Other benefits include more efficient communication, and improved availability of supervising faculty and residents to trainees. Unintended consequences of mobile phones in the clinical setting included increased interruptions and distractions, decreased face to face interactions, loss

Study	Aim	Setting	Device studied	Number of studies identified	Key Findings
Adolescent Health Care, 49, 79-83.					of autonomy, and concerns about professionalism and inappropriate use. Further concerns included issues of privacy and confidentiality, microbial transmission, maintenance of personal/professional boundaries, and prioritisation of patient care.
MARTIN, G., KHAJURIA, A., ARORA, S., KING, D., ASHRAFIAN, H. & DARZI, A. 2019. The impact of mobile technology on teamwork and communication in hospitals: a systematic review. *Journal of the American Medical Informatics Association,* 26, 339-355.	To evaluate the current quality and breadth of evidence for the impact of mobile technologies on communication and teamwork within hospitals.	United Kingdom	Mobile technology (handheld devices that facilitated two-way communication or data transfer which directly impacts patient care)	n=38	The introduction of mobile devices led to improvements in workflow, efficiency, and the quality of communication. There was significant streamlining of clinical workflows and improvements in the quality of clinical discussion, improvements in handover and patient care, and faster response times. The use of mobile devices had a positive impact on accessibility, interprofessional interactions, and the involvement of senior decision makers in clinical care. Doctors frequently felt that they were interrupted with low-value and unnecessary information. The physical limitations of mobile devices were commonly reported such as small screen size, poor battery life, the requirement to enter a password on a regular basis, and unreliable connectivity. Mobile devices were reported to be regarded as less effective than face-to-face communication for complex patient care issues. Mobile devices were also seen to be more convenient, less intrusive, more efficient, and less intimidating than traditional methods of communication.

Study	Aim	Setting	Device studied	Number of studies identified	Key Findings
					The use of mobile phones was seen to be promoting an unprofessional image and appearing rude or impersonal in front of patients. A number of studies identified the potential risk to security and confidentiality of patient information, but staff favoured efficiency and mobility over security.
VALLE, J., GODBY, T., PAUL III, D. P., SMITH, H. & COUSTASSE, A. 2017. Use of smartphones for clinical and medical education. *Health Care Manager,* 36, 293-300.	To examine the effects of smartphones in a clinical setting and for medical education, to determine the overall impact of smartphone use in the healthcare field.	United States of America	Smartphones	n=48	The review identified benefits and disadvantages to using smartphones in the clinical setting. Benefits: Convenience of mobility: smartphones are seen as a “learn anywhere resource” and medical students have been increasingly relying on them as a “pocket brain” for fast and easy access to information that they require. Enhanced communication: smartphone apps have enhanced communication through features such as email, voice, and texting capabilities. Enhanced quality of care: smartphones have been used to aid in diagnosis, prognosis, and treatment of medical conditions in clinical settings. References are provided to staged systems which can be accessed quickly to inform decision making. Smartphones also provide quick and easy access to clinical data of hospitalised patients. Disadvantages:

Study	Aim	Setting	Device studied	Number of studies identified	Key Findings
					Distractions and interruptions: having mobile devices at work has generated a threat of mixing personal and business apps. The Agency for Healthcare Research & Quality highlighted the case of a resident harming a patient because they became distracted while using a smartphone. On average there are 4.6 interruptions per hour for residents. Confidentiality and privacy: email, text messaging, and images/photos taken with smartphones are often poorly protected methods of communication. There is also a potential for theft.
AUNGST, T. D. & BELLIVEAU, P. 2015. Leveraging mobile smart devices to improve interprofessional communications in inpatient practice setting: a literature review. *Journal of Interprofessional Care,* 29, 570-578.	To describe primary literature that reports on the experiences with communication between healthcare professionals via mobile smart devices in inpatient clinical practice settings.	United States of America	Mobile smart devices	n=16	Most participants agreed that personal digital assistants usage enhanced the efficacy of communication between team members. The use of the device also allowed them to provide faster, more efficient care to patients. Smartphones were reported as easy to use, improved the quality and speed of communication between team members, and increased awareness of activity in the trauma bay. Participants perceived an improved connectedness with team members and other clinical services and professions. Trainees felt greater degrees of support for situations in which they were less confident. Smartphone email communication reduced staff frustration, improved team coordination, patient care and patient safety, and allowed for faster care of patients. Residents felt as though

Study	Aim	Setting	Device studied	Number of studies identified	Key Findings
					their efficiency was improved by not needing to stay near a landline phone for return calls. Email communications via smartphones added a barrier when issues had to be resolved by multiple back-and-forth communications. Nurses in particular felt that smartphones reduced the need for face-to-face discussion which hindered the development of interprofessional relationships. The volume of interruptions increased substantially because of smartphone communications. This led to reports of concerns over professionalism when at the bedside with patients. Distractions can also cause clinicians to miss vital information about patients during attending rounds. Attending physician team members perceived that the increased connectedness decreased autonomy and independent decision making of the trainees which increased reports of micromanagement. The overall consequence of being more connected is a medical team which is more globally connected but less locally present.
CARTWRIGHT, A. L. & SPINA, S. P. 2014. Smartphones in clinical pharmacy practice: is it evidence-based?	To review the available literature pertaining to the use of smartphones and other mobile technology by clinical pharmacists.	Canada	Smartphones	n=6 (one literature review and five primary research articles)	There is evidence to support the beneficial effects of handheld computer technology in healthcare, but the majority of the literature pertains to personal digital assistants and their use by physicians.

Study	Aim	Setting	Device studied	Number of studies identified	Key Findings
HEALTH POLICY AND TECHNOLOGY, 3, 85-89.					There is a lack of evidence regarding the association of smartphone use by clinical pharmacists and the effects on objective outcomes performed before and after implementation of the devices. Prospective studies assessing the utility of smartphones are urgently needed to support the continued use of smartphones by pharmacists as an evidence-based practice.
DIVALL, P., CAMOSSO-STEFINOVIC, J. & BAKER, R. 2013. The use of personal digital assistants in clinical decision making by health care professionals: a systematic review. *Health Informatics Journal,* 19, 16-28.	To identify and assess available evidence on whether PDA use in the clinical setting, compared with usual practice, improves professional practice in terms of processes and outcomes of care.	United Kingdom	PDAs	n=7	Three distinct themes to the studies were identified: those investigating diagnosis using a clinical decision support system (CDSS) as a primary outcome measure (diagnosis), those investigating the appropriateness of the treatment using CDSS (treatment), and those investigating personal digital assistants for the accuracy of record keeping (record keeping). Diagnosis: the personal digital assistant group identified more diagnoses than the control; the intervention increased diagnostic accuracy. Treatment: the use of CDSS loaded onto a personal digital assistant improved treatment decisions, improved knowledge and understanding. Unsafe prescribing was significantly reduced in the personal digital assistant group, a significant difference in favour of the personal digital assistant for antimicrobial prescribing levels.

Study	Aim	Setting	Device studied	Number of studies identified	Key Findings
					Record keeping: more patient information was documented in the personal digital assistant use groups than in the control groups and the devices were easier to use. Statistically significant differences were found in completion of patient and the number of documented diagnoses using a personal digital assistant.
MICKAN, S., TILSON, J. K., ATHERTON, H., ROBERTS, N. W. & HENEGHAN, C. 2013. Evidence of effectiveness of health care professionals using handheld computers: a scoping review of systematic reviews. *Journal of Medical Internet Research,* 15, e212-e212.	To scope the evidence of effectiveness across all aspects of healthcare practice by reviewing systematic reviews, to identify documented positive outcomes.	United Kingdom	Handheld computers	n=5 (systematic reviews)	Physicians, pharmacists, and medical students were the most common populations studied. Handheld computers improved patient documentation through more complete records with fewer documentation errors with improved ease and efficiency of documentation. More accurate diagnostic coding and more frequent documentation of side effects were reported. A key benefit was improved decision making using handheld and patient management systems. Nurses reported that using a patient management system on a personal digital assistant made nursing care more consistent with patient preferences and improved patients' preference achievement. Handheld computers demonstrated effectiveness for support healthcare professionals' information seeking needs. Handheld computers can enhance efficiency and improve patterns of work. Physicians who utilised personal digital assistants reported improved efficiency of their daily

Study	Aim	Setting	Device studied	Number of studies identified	Key Findings
					rounds through spending less time accessing, retrieving, and recording data.
PRGOMET, M., GEORGIOU, A. & WESTBROOK, J. I. 2009. The impact of mobile handheld technology on hospital physicians' work practices and patient care: a systematic review. *JOURNAL OF THE AMERICAN MEDICAL INFORMATICS ASSOCIATION,* 16, 792-801.	To undertake a systematic review of evidence for the impact of mobile handheld technology on hospital physicians' work practices and patient care.	Australia	Mobile handheld technology	n=13	All the studies identified the handheld computers as personal digital assistants. Personal digital assistant use led to faster treatment. When using a personal digital assistant, response times were lower, and failures to respond occurred less often than with a pager. When using a personal digital assistant for decision support, a significant decrease of antibiotics occurred. The average patient length of stay also decreased significantly. Introduction of handheld computers significantly increased the average rate of electronic prescribing. Documentation via the personal digital assistant recorded significantly more diagnoses per patient compared with paper documentation. However, the rate of false or redundant codes were higher with the handheld computers. The majority of studies documented technical difficulties including failed transmissions, battery issues, synchronisation problems, hospital network failure, and device breakdown.
LINDQUIST, A. M., JOHANSSON, P. E., PETERSSON, G. I., SAVEMAN, B. I. & NILSSON,	To obtain an overview of existing research on the use of PDAs among personnel and students in healthcare.	Sweden	PDAs	n=48	Students agreed that the personal digital assistant enhanced their learning. Physicians made fewer unsafe treatment decisions by using the personal digital assistant. Nursing care was made more consistent with patient preferences. The

Study	Aim	Setting	Device studied	Number of studies identified	Key Findings
G. C. 2008. The use of the personal digital assistant (PDA) among personnel and students in health care: a review. *JOURNAL OF MEDICAL INTERNET RESEARCH,* 10.					personal digital assistant was seen to be generally helpful and convenient for checking medical orders and retrieving results of recent clinical tests at the bedside. Participants reported that they learned about new medical developments sooner than they otherwise would have. The personal digital assistant was seen as a timesaving device since it made it immediately possible to find information. Using a personal digital assistant can also reduce the number of medical errors. Patient confidentiality when using a personal digital assistant was of no concern compared to when using other technologies and physicians had no concern about using the personal digital assistant in front of a patient. Older nurses and physicians were seen as a barrier to personal digital assistant acceptance due to the technology being a challenge, but personal digital assistant use was accepted when it solved practical issues and was easy to use compared to paperwork. The personal digital assistant was not believed to decrease paperwork or improve patient health outcomes. Physicians who had previously used a personal digital assistant but stopped using it reported reasons like complex and confusing software applications, lack of support, not being useful in practice, cost, and the inconvenience of carrying it.

Study	Aim	Setting	Device studied	Number of studies identified	Key Findings
					Physicians found the personal digital assistant to be ineffective during night shift or emergency situations. Several technical problems were described, but after guided practice, explanations, and time many of the problems were solved.
BAUMGART, D. C. 2005. Personal digital assistants in health care: experienced clinicians in the palm of your hand? *Lancet,* 366, 1210-1222.	To provide an overview of current PDA technologies and applications relevant to medical education and clinical practice, a guide to medical software, safety and security, a personal perspective, current limitations, and a future outlook.	Germany	PDAs	Does not specify.	Personal digital assistant usage increased the number of patient encounters and recorded diagnoses, helped improve history-taking skills, and improved overall computer literacy. Improved perceived usefulness of personal digital assistants was associated with supportive faculty attitudes, good knowledge of evidence-based medicine, and enhanced computer literacy skills. Personal digital assistants could simplify data collection and assess doctor and programme performance. Junior doctors could use the personal digital assistant to keep track of their clinical tasks, keep in touch with patients, and access commercial medical references. Personal digital assistants could also reduce bulky drug reference books and help with the selection and comparison of drugs, identification of dosing schedules, and dose adjustment when drug excretion is impaired. Most patients felt comfortable with their physician using a personal digital assistant. Perceived drawbacks included: not being able to be tailored to residents' needs, the small and bulky size, becoming too dependent on one source of information,

Study	Aim	Setting	Device studied	Number of studies identified	Key Findings
					and being too easy to lose or break. Users were more likely to believe that personal digital assistants could reduce medical error, but often complained about memory capacity. The median time of the assessment period during the patient encounter with the personal digital assistant was longer than with paper. However, the median total encounter time was significantly shorter with the personal digital assistant.

Appendix 4. Participant Information Sheet (Observations)

Participant Information Sheet (observations)

Research Project Title
Using mobile technology to record patient observations: impact on care management and clinical practice.

Invitation
You are being invited to take part in this research project. Before you decide to do so, it is important you understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether you wish to take part. Thank you for reading this.

What is the project's purpose?
The research project aims to investigate the impact of the use of mobile devices and the associated software on patient care management and clinical practice in hospitals in Wales. The research in particular will focus on CareFlow which has been introduced to hospitals by the Aneurin Bevan University Health Board.

Why have I been chosen?
You have been chosen to take part as you work in the selected case study wards in this hospital (which is one of two hospitals in the study), and you have knowledge and experience working with the CareFlow system on the hospital's devices. If you agree to participate, you will be one of a number of staff members in the hospital whose use of CareFlow during their work will be observed.

Do I have to take part?
It is up to you to decide whether to take part. If you do decide to take part, you will be able to keep a copy of this information sheet. You can still withdraw from having field notes made about your work at any time before the end of the observation. You do not have to give a reason.

What will happen to me if I take part?
You will be asked to conduct your work as normal as Shannon Costello observes and take notes. As an observer in the clinical setting, Shannon will adhere to the Health Board requirements in relation to confidentiality and infection control measures.

What do I have to do?
Please conduct your shift as you normally would. There are no other commitments or restrictions associated with participating. You may choose to take part in a semi-structured interview to gather more information about your views on the CareFlow system and iPads in the hospital setting. This would be conducted at your preferred time and place in the hospital either during the observation period, or at an agreed future date. Shannon will not collect any data relating to patients during the observations. Patients will first be asked if they are willing to allow Shannon to be present while you are administering routine care and treatment. Observations will not take place without the permission of the patient.

What are the possible disadvantages and risks of taking part?
Participating in the research is not anticipated to cause you any disadvantages or discomfort. The observation will be conducted as unobtrusively as possible.

What are the possible benefits of taking part?
Whilst there are no immediate benefits for those people participating in the project, it is hoped that this work will have a beneficial impact on how mobile technology is used in direct patient care in Wales. Results can be shared with participants on request in order to inform their professional work.

Will my taking part in this project be kept confidential?
All the information that we collect about you during the research will be kept strictly confidential. You, or the organisation that you work for, will not be identifiable in any ensuing reports or publications. No individual (staff or patient) will be named or identifiable.

What will happen to the results of the research project?
Results of the research will inform the PhD thesis of the researcher. The hope is also to publish the results from the research in academic journals and presented at academic conferences. You will not be identified in any report or publication, nor will any patients. Your hospital and ward will also remain anonymous in any report, publication or presentation. If you wish to be given a copy of any reports resulting from the research, please ask us.

Who is organising and funding the research?
Funding for this research has been granted by Health and Care Research Wales. The project is a partnership involving the Aneurin Bevan University Health Board. The Sponsor is Cardiff University.

Will I be recorded and how will the recorded media be used?
You will not be recorded in any way other than the researcher taking notes on what they observe.

How will we use information about you?
We will need to use information from you for this research project.
This information will include your: name; initials; contact details; job title and place of work.
People will use this information to do the research or to check your records to make sure that the research is being done properly.
People who do not need to know who you are will not be able to see your name or contact details. Your data will have a code number instead.
We will keep all information about you safe and secure.
Once we have finished the study, we will keep some of the data so we can check the results.
We will write our reports in a way that no-one can work out that you took part in the study.

What are your choices about how your information is used?

- You can stop being part of the study at any time, without giving a reason, but we will keep information about you that we already have.
- We need to manage your records in specific ways for the research to be reliable. This means that we won't be able to let you see or change the data we hold about you.
- If you agree to take part in this study, you will have the option to take part in future research using your data saved from this study.

Where can you find out more about how your information is used?
You can find out more about how Cardiff University uses your information:

- by asking Shannon Costello (PhD student), or Shannon's supervisors (contact details can be found at the end of this Information Sheet);
- by viewing the Cardiff University Data Protection policy: https://www.cardiff.ac.uk/public-information/policies-and-procedures/data-protection
- by contacting the University's Data Protection Officer by email: inforequest@cardiff.ac.uk or in writing to: Compliance and Risk, University Secretary's Office, Cardiff University, McKenzie House, 30-36 Newport Road, Cardiff CF24 0DE.

Who has ethically reviewed the project?
This project has been reviewed and given a favourable ethics opinion by an independent NHS Research Ethics Committee **[**North West- Greater Manchester Central Research Ethics Committee].
It has also been approved by Aneurin Bevan University Health Board Research and Development office.

Contacts for further information
Researcher: Shannon Costello, School of Social Sciences, Cardiff University, UK.
Email: costellosk@cardiff.ac.uk

Supervisors:
Professor Alison Bullock, School of Social Sciences, Cardiff University, UK.
Email: bullockad@cardiff.ac.uk

Dr Liam Turner, School of Computer Science and Informatics, Cardiff University, UK.
Email: turnerl9@cardiff.ac.uk

Thank you for considering taking part in this research.

Appendix 5. Consent Form (Observations)

Participant Observation Consent Form

Title of research project: Using mobile technology to record patient observations: impact on care management and clinical practice.

	Please initial box
I confirm that I have read the information sheet dated February 2022 for the above research project.	
I confirm that I have understood the information sheet dated February 2022 for the above research project and that I have had the opportunity to ask questions and that these have been answered satisfactorily.	
I understand that my participation is voluntary, and I am free to withdraw at any time without giving a reason and without any adverse consequences.	
I understand who will have access to personal information provided, how the data will be stored and what will happen to the data at the end of the research project.	
I understand that anonymised excerpts and/or verbatim quotes from my ***interactions*** with patients may be used as part of the research publication.	
I understand how the findings and results of the research project will be written up and published.	
I agree to take part in this research project.	

Name of participant (print)	Date	Signature

Name of person taking consent (print)	Date	Signature

Role of person taking consent (print)

Thank you for participating in our research.

Appendix 6. Patient Information Sheet

Research Project Title
Using mobile technology to record patient observations: impact on care management and clinical practice.

Information for patients
My name is Shannon Costello and I am a PhD student at Cardiff University. I am conducting a research project called: Using mobile technology to record patient observations: impact on care management and clinical practice.
I am conducting the project with NHS staff working on the ward that you are staying on. The project does not involve patients, but I may be present during some of your interactions with staff.

What is the project about?
The research project aims to look at the use of mobile devices and software in the NHS and how it used to manage patient care and clinical practice in hospitals in Wales. The project is looking at the use of software called CareFlow which is used by staff in hospitals within the Aneurin Bevan University Health Board.

What do I need to do?
You do not need to do anything, and you will continue to receive care and treatment as would normally be provided. It's important for you to know that if you do not want me to be present during your interactions with staff, then please let me or the member of staff treating you know. You can also speak with the Ward Sister.

Important information for you to know
It is important to be aware that some Aneurin Bevan UHB staff responsible for providing your care may be participating in the study. As a patient, <u>you are not being invited to participate in the project.</u> However, I may be present while staff are caring for you and making decisions about your care and treatment. Some important things for you to be aware of:

- You have the right not to permit me to be present during your interactions with staff on the ward;
- I will not be audio, or video-recording you or the staff on the ward;
- I may take notes while I'm observing the interaction between you and the member of staff, but these notes will not include any personal details about you (like your name, date of birth, contact details or anything relating to your health);
- All information leaving the ward will be fully anonymised and treated in strictest confidence;
- The study will not impact on your care and treatment.

Who has approved this project?
This project has been reviewed and given a favourable ethics opinion by an independent NHS Research Ethics Committee [North West- Greater Manchester Central Research Ethics Committee].
It has also been approved by Aneurin Bevan University Health Board Research and Development office. The study Sponsor is Cardiff University.

Contacts for further information
Researcher: Shannon Costello, School of Social Sciences, Cardiff University, UK.
Email: costellosk@cardiff.ac.uk

Supervisors:
Professor Alison Bullock, School of Social Sciences, Cardiff University, UK.
Email: bullockad@cardiff.ac.uk

Dr Liam Turner, School of Computer Science and Informatics, Cardiff University, UK.
Email: turnerl9@cardiff.ac.uk

What if I have a concern about the project?
Please feel free to speak to me if you have any questions. If you would prefer to speak to someone independent of the study, then you can talk to the Ward Sister at any time.

Appendix 7. Participant Leaflet

WHAT?

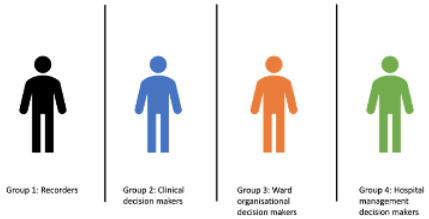
The research project aims to investigate the impact of the use of mobile devices and the associated software on patient care management and clinical practice in hospitals in Wales. The research in particular will focus on CareFlow which has been introduced to hospitals by the Aneurin Bevan University Health Board.

Funding for this research has been granted by Health and Care Research Wales. The project is a partnership involving Cardiff University and the Aneurin Bevan University Health Board.

WHO?

We are approaching a range of people who use the CareFlow software for different purposes- those who input data, those who use it to inform clinical decisions about individual patient care, and those who use it to inform decisions about healthcare management at ward or hospital level.

You have been approached to take part as you work in the selected case study wards in this hospital (which is one of two hospitals in the study), and you have knowledge and experience of working with the CareFlow system on the hospital's devices.



HOW?

You will be asked to complete a semi-structured interview which we estimate will take between 10 and 30 minutes of your time. Interviews will be conducted on a one-to-one basis with Shannon Costello, and in person if covid restrictions allow. If restrictions do not allow, interviews will be conducted remotely via Microsoft Teams.

The interview you will take part in will be audio recorded and transcribed. The audio recording made during this research will be used only for analysis and for illustration in publication and conference presentations.

Using mobile technology to record patient observations: impact on care management and clinical practice.

Cardiff University / Prifysgol Caerdydd
Ymchwil Iechyd a Gofal Cymru – Health and Care Research Wales
GIG Cymru NHS Wales – Bwrdd Iechyd Prifysgol Aneurin Bevan University Health Board

Thank you for considering taking part in this research.

It is hoped that this work will have a beneficial impact on how mobile technology is used in direct patient care in Wales.

WHAT NEXT?

If you are interested in taking part in this research, or if you have any further enquiries, please do not hesitate to contact Shannon who can tell you more about the study at:

Email: costellosk@cardiff.ac.uk
Mobile: 07543303510

It is up to you to decide whether to take part. You can withdraw at any time. You do not have to give a reason.

Results of the research will inform the PhD thesis of the researcher (Shannon Costello). The hope is also to publish the results from the research in academic journals and present findings at academic conferences. **You will not be identified** in any report or publication, nor will any patients. Your hospital and ward will also remain anonymous in any report, publication, or presentation.

This project has received ethical approval from an NHS Research Ethics Committee [North West- Greater Manchester Central Research Ethics Committe]

IRAS ID: 299883

GIG Cymru NHS Wales – Bwrdd Iechyd Prifysgol Aneurin Bevan University Health Board
Ymchwil Iechyd a Gofal Cymru – Health and Care Research Wales
Cardiff University / Prifysgol Caerdydd

Appendix 8. Participant Information Sheet (Interviews)

Participant Information Sheet (interviews)

Research Project Title
Using mobile technology to record patient observations: impact on care management and clinical practice.

Invitation
You are being invited to take part in this research project. Before you decide to do so, it is important you understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether you wish to take part. Thank you for reading this.

What is the project's purpose?
The research project aims to investigate the impact of the use of mobile devices and the associated software on patient care management and clinical practice in hospitals in Wales. The research in particular will focus on CareFlow which has been introduced to hospitals by the Aneurin Bevan University Health Board.

Why have I been chosen?
You have been chosen to take part as you work in the selected case study wards in this hospital (which is one of two hospitals in the study) and you have knowledge and experience working with the CareFlow system on the hospital's devices. We are approaching a range of people who use the CareFlow software for different purposes- those who input data, those who use it to inform clinical decisions about individual patient care, and those who use it to inform decisions about healthcare management at ward or hospital level.

Do I have to take part?
It is up to you to decide whether to take part. If you do decide to take part, you will be able to keep a copy of this information sheet and you should indicate your agreement on the consent form. You can still withdraw at any time before the study has been completed (estimated September 2023). You do not have to give a reason. However, the anonymous information you have provided to the point of withdrawal may still be included in the analysis.

What will happen to me if I take part?
You will be asked to complete a semi-structured interview which we estimate will take between 10 and 30 minutes of your time. Interviews will be conducted on a one-to-one basis with Shannon Costello, and in person if covid restrictions allow. If restrictions do not allow, interviews will be conducted remotely via Microsoft Teams. Interviews will be conducted at your preferred time and place inside of the hospital.

What do I have to do?
Please respond to the questions which are asked by the researcher. There are no right or wrong answers. Aside from taking up some of your working day, there are no other commitments or restrictions associated with participating.

What are the possible disadvantages and risks of taking part?
Participating in the research is not anticipated to cause you any disadvantages or discomfort.

What are the possible benefits of taking part?
Whilst there are not immediate benefits for those people participating in the project, it is hoped that this work will have a beneficial impact on how mobile technology is used in direct patient care in Wales. Results can be shared with participants on request in order to inform their professional work.

Will my taking part in this project be kept confidential?
All the information that we collect about you during the research will be kept strictly confidential. You, or the organisation that you work for, will not be identifiable in any ensuing reports or publications.

What will happen to the results of the research project?
Results of the research will inform the PhD thesis of the researcher. The hope is also to publish the results from the research in academic journals and presented at academic conferences. You will not be identified in any report or publication, nor will any patients. Your hospital and ward will also remain anonymous in any report, publication or presentation. If you wish to be given a copy of any reports resulting from the research, please ask us.

Who is organising and funding the research?
Funding for this research has been granted by Health and Care Research Wales. The project is a partnership involving the Aneurin Bevan University Health Board. The project Sponsor is Cardiff University.

Will I be recorded and how will the recorded media be used?
The interview you will take part in will be audio recorded. The audio files will be sent to an external transcription service approved by Cardiff University. Only the researcher and her academic supervisor Alison Bullock will have access to the transcripts. The audio recording made during this research will be used only for analysis and for illustration in publication and conference presentations. No other use will be made of

the data without your written permission, and no one outside the project will be allowed access to the original recordings.

How will we use information about you?
We will need to use information from you for this research project.
This information will include your: name; initials; contact details; job title and place of work.
People will use this information to do the research or to check your records to make sure that the research is being done properly.
People who do not need to know who you are will not be able to see your name or contact details. Your data will have a code number instead.
We will keep all information about you safe and secure.
Once we have finished the study, we will keep some of the data so we can check the results.
We will write our reports in a way that no-one can work out that you took part in the study.

What are your choices about how your information is used?

- You can stop being part of the study at any time, without giving a reason, but we will keep information about you that we already have.
- We need to manage your records in specific ways for the research to be reliable. This means that we won't be able to let you see or change the data we hold about you.
- If you agree to take part in this study, you will have the option to take part in future research using your data saved from this study.

Where can you find out more about how your information is used?
You can find out more about how Cardiff University uses your information:

- by asking Shannon Costello (PhD student), or Shannon's supervisors (contact details can be found at the end of this Information Sheet);
- by viewing the Cardiff University Data Protection policy: https://www.cardiff.ac.uk/public-information/policies-and-procedures/data-protection
- by contacting the University's Data Protection Officer by email: inforequest@cardiff.ac.uk or in writing to: Compliance and Risk, University Secretary's Office, Cardiff University, McKenzie House, 30-36 Newport Road, Cardiff CF24 0DE.

Who has ethically reviewed the project?
This project has been ethically reviewed and given a favourable ethics opinion by an independent NHS Research Ethics Committee [North West- Greater Manchester Central Research Ethics Committee].
It has also been approved by Aneurin Bevan University Health Board Research and Development office.

Contacts for further information
Shannon Costello, School of Social Sciences, Cardiff University, UK.
Email: costellosk@cardiff.ac.uk

Supervisors:
Professor Alison Bullock, School of Social Sciences, Cardiff University, UK.
Email: bullockad@cardiff.ac.uk

Dr Liam Turner, School of Computer Science and Informatics, Cardiff University, UK.
Email: turnerl9@cardiff.ac.uk

Thank you for considering taking part in this research.

Appendix 9. Survey

Survey

Research Project Title
Using mobile technology to record patient observations: impact on care management and clinical practice.

You are being invited to take part in this research project which aims to investigate the impact of the use of mobile devices and the associated software on patient care management and clinical practice in hospitals in Wales. The particular focus is CareFlow Vitals which has been introduced to hospitals in the Aneurin Bevan University Health Board.

The survey is being distributed to staff working in two hospitals in the Aneurin Bevan University Health Board. We estimate that it will take 10 minutes to complete. All questions are optional. All responses are anonymous: no individual will be identifiable. The last question will ask whether you will want to take part in an interview related to this survey. If you are interested, a contact email address will be required.

It is hoped that the results will have a beneficial impact on how mobile technology is used in direct patient care in Wales. Results will be widely shared with participants and may be used to inform their professional work.

Results of the research will inform the PhD thesis of Shannon Costello. Results from the research could be potentially published. A summary of findings will be available on the CUREMeDE website in due course. This website can be found at: https://www.cardiff.ac.uk/curemede.

Funding for this research has been granted by Health and Care Research Wales. The project is a partnership involving the Aneurin Bevan University Health Board.

This project has been ethically approved by the Integrated Research Application System (IRAS).

Contact for further information
Shannon Costello, School of Social Sciences, Cardiff University, UK.
Email: costellosk@cardiff.ac.uk

I consent to take part in this survey. I understand that my data will be held securely. I understand that when this information is no longer required, official university procedure will be followed to dispose of my data.

I give consent freely []
I do not give consent freely []

PART 1: SCREENING QUESTIONS

1. Do you currently use the CareFlow Vitals product in your practice to record patient observations?

Yes []
No []

-Q2-3 not available to those who answer "No" to Q1-

2. In which year did you start using the device?

2015 or earlier []
2016 []
2017 []
2018 []
2019 []
2020 []
2021 []
2022 []
2023 []

3. Did you receive training on how to input information into the CareFlow Vitals software on the devices?

Yes []
No []

4. Do you currently use the information collected through the CareFlow Vitals product to aid your clinical decision making?

Yes []
No []

-Q4 not available to those who answer "No" to Q3-

5. Did you receive training on how to use the information recorded in the CareFlow Vitals software on the devices?

Yes []
No []

6. What hospital do you primarily work for within the Aneurin Bevan health board?

The Grange University Hospital []
Ysbyty Ystrad Fawr []
Neither []

-IF ANSWERED NO TO Q1 OR Q4 OR NEITHER TO Q6 DO NOT CONTINUE-

PART 2: DEMOGRAPHIC CHARACTERISTICS

7. What is your age?

18-24 []
25-34 []
35-44 []
45-54 []
55-64 []
65+ []

8. What is your gender?

Male []
Female []
Non-binary []
Other []
Prefer not to answer []

9. What is your job title?

……

10. How many years of experience do you have working in a hospital setting?

0-1 []
2-5 []
6-10 []
11-20 []
21-30 []
31+ []

11. Are you an agency/bank worker?

Yes, this is my sole contract []
Yes, alongside my permanent contract []
No []

12. Did you work for the ABUHB before the implementation of the devices and CareFlow Vitals software?

Yes []
No []

PART 3: QUESTIONS

13. How often do you use CareFlow Vitals to input information?

Inputting information is a routine part of my everyday work []
Inputting information is something I do on a weekly basis []
Inputting information is something I do on a monthly basis []
Inputting information is something I do occasionally []
I never use the CareFlow Vitals software to input information []

-Q14 not available to those who answer "I never use the CareFlow Vitals software to input information" on Q13-

14. How prepared did you feel to use the CareFlow Vitals software to input information at the beginning of your first shift with the devices? (0= not at all, 10= completely)

0 1 2 3 4 5 6 7 8 9 10 N/A

14. How often do you use CareFlow Vitals to aid decision making on patient care?

Daily []
Weekly []
Monthly []
Occasionally []
Never []

-Q15 not available to those who answer "Never" to Q14-

15. At the beginning of your first shift with the devices, how prepared did you feel to use information from the CareFlow Vitals software to inform immediate clinical decisions? (0= not at all, 10= completely)

0 1 2 3 4 5 6 7 8 9 10 N/A

16. Have there been any benefits to using the devices with CareFlow Vitals?

Yes []
No[]
Not sure []

-17. Please expand further on your answer.

18. Have you experienced any problems, including technical issues, with the devices and CareFlow Vitals software?

Yes []
No []

-19. If yes, what problems have you experienced?

-20. How easily were any problems with the devices and software resolved? (0= very difficult to resolve, 5= neither difficult nor easy, 10= very easily resolved)

0 1 2 3 4 5 6 7 8 9 10 N/A

21. Have you experienced any other disadvantages with the devices and CareFlow Vitals software?

Yes []
No []
Not sure []

-22. If yes, what disadvantages have you experienced?

23. Did the Covid-19 pandemic affect the way the devices and CareFlow Vitals were used?

Yes []
No []
Not sure []

-24. Please expand on your answer.

PART 4: COMPARISON QUESTIONS WITH PREVIOUS METHOD

(Only applicable to people who have used both pen and paper method and CareFlow Vitals method- based on Prytherch et al., 2006)

-WILL ONLY BE AVAILABLE TO THOSE WHO ANSWERED YES TO Q12-

25. Would you describe yourself as someone who generally welcomes and embraces change, someone who really does not like change, or someone who is generally indifferent to change?

I embrace change []
I am indifferent to change []
I really dislike change []

Please state whether you believe the pen and paper method or the CareFlow Vitals method to collecting vital signs information is:

26. More accurate
    Pen and paper []
    CareFlow Vitals []
27. Allows easier detection of errors
    Pen and paper []
    CareFlow Vitals []

28. Simpler
    Pen and paper []
    CareFlow Vitals []

29. Quicker
    Pen and paper []
    CareFlow Vitals []

30. More convenient
    Pen and paper []
    CareFlow Vitals []

31. Easier to use
    Pen and paper []
    CareFlow Vitals []

32. Would you like to go back to the pen and paper method?
    Yes []
    No []
    Not sure []

33. To what extent do you think the use of the CareFlow Vitals software on mobile devices has made a difference to patient care management?
    A very great positive difference/it has made things much better []
    Some positive difference/it has made things better []
    No notable difference []
    Some negative difference/it has made things worse []
    A very great negative difference/it has made things much worse []
    Not applicable/I have no point of comparison/did not work before the implementation of devices []

    -34. Please give a reason for your answer.

PART 5: ANY OTHER COMMENTS

35. Do you have any other comments about the use of the devices and CareFlow Vitals in the clinical setting?

PART 6: INTERVIEW

36. Have you been interviewed by Shannon Costello about the mobile devices and CareFlow Vitals software.

Yes []
No []

-37. If no, would you like to be interviewed in the future to provide a more in-depth perspective of your use of the devices and CareFlow Vitals?

Yes []
No []

-38. If yes, please leave your email address to be contacted further.
In the analysis of the questionnaire responses, this information will not be linked to your answers to earlier questions. If you prefer, you can email the researcher directly at costellosk@cardiff.ac.uk

Thank you for taking part in this survey.

Appendix 10. Interview Schedules

Interview schedule: the recorders

1. How do you use the devices in the process of recording patient observations?

   Prompt: Are there times when you use pen and paper to record patient observations? If yes, please describe when and why you might use pen and paper.

2. How were you prepared for using the device and the CareFlow software?

   2.1. Describe any training you received on how to use the device.

   2.2. Who provided the training?

   2.3. Where was the training provided?

   2.4. When was the training provided?

3. Did you encounter any initial issues or problems with the devices and software?

   3.1. Were these issues or problems resolved?

   Prompt: How so? By whom?

4. Think about being on the ward. How do you decide when to do patient observations?

   Prompt: Are you guided to do patient observations based on their EWS?

   Prompt: How does shift change-over affect the timings of patient observations?

   Prompt: How does the layout of the beds on the ward affect the sequence of patient observations?

   4.1. Does the process change depending on the time of day?

   Prompt: How often are patient observations conducted at night?

   4.2. Does the process change depending on if the patient is in a single-bed room or multi-bed room that is shared with other patients?

5. Has having the device changed the way that you work compared to when you didn't have the devices available?

   Prompt: Do you have any examples that illustrate this change?

6. How have the devices and CareFlow assisted in immediate care planning?

6.1. How about care planning in the medium and longer term?

7. From your perspective, has having the devices and CareFlow software affected the way that you interact with the multi-disciplinary team?

   7.1. How so?

8. What have you liked about using the devices and CareFlow?

   8.1. What have you not liked about using the devices and CareFlow?

   8.2. Ultimately would you say you prefer the devices or pen and paper for recording patient observations?

      8.2.1. Why?

Interview schedule: the clinical decision makers

1. How were you prepared for the device implementation?

   1.1. Describe any training you received on how to use the device.

   1.2. Who provided the training?

   1.3. Where was the training provided?

   1.4. When was the training provided?

2. Did you encounter any initial issues or problems with the devices and software?

   2.1. Were these issues or problems resolved?

   Prompt: How so? By whom?

3. Has having the device changed the way that you work compared to when you didn't have the devices available?

   Prompt: Do you have any examples that illustrate this change?

4. How has having access to patient observational data at the bedside changed the way that you make clinical decisions?

   Prompt: Do you have any examples?

5. Have the devices and CareFlow software been useful when making immediate clinical decisions and care planning?

   5.1. How so?

   5.2. How about care planning in the medium and longer term?

6. Have there been times when the devices and software were not useful when making clinical decisions?

   6.1. How?

7. From your perspective, has having the devices and CareFlow software affected the way that you interact with the multi-disciplinary team?

   7.1. How so?

8. What have you liked about using the devices and CareFlow?

8.1. What have you not liked about using the devices and CareFlow

Interview schedule: the ward organisational decision makers

1. How involved were you in the distribution of the iPads among the staff that you have responsibility for on the ward?
2. How did the staff that you manage respond to the rollout of the iPads and CareFlow?
3. Did you encounter any initial issues or problems with the devices and software?

   3.1. Were these issues or problems resolved?

   Prompt: How so? By whom?

4. How have the iPads and CareFlow assisted in immediate care planning?

   4.1. How about care planning in the medium and longer term?

5. How has having immediate access to the patient observational data affected the way that you manage the ward and team?

   Prompt: Do you have any examples that illustrate this change?

6. From your perspective, has having the iPads and CareFlow software affected the way that you interact with the multi-disciplinary team?

   6.1. How so?

7. What have you liked about using the devices and CareFlow?

   7.1. What have you not liked about using the devices and CareFlow?

Interview schedule: the hospital management decision makers

1. What was your involvement in the decision making to incorporate the iPads with CareFlow into the hospital?
2. What was the general reception of the iPads and the CareFlow software?
3. How were the iPads distributed throughout the hospital?

   3.1. Was there any training provided?
4. How have the iPads and CareFlow assisted in immediate care planning?

   4.1. How about care planning in the medium and longer term?
5. From your perspective, has having the iPads and CareFlow software affected the way that you interact with the multi-disciplinary team?

   5.1. How so?
6. Has having immediate access to the patient observational data affected the way that the wider hospital is managed?

   Prompt: Do you have any examples that illustrate this change?
7. What have you liked about using the devices and CareFlow?

   7.1. What have you not liked about using the devices and CareFlow?

Appendix 11. An Excerpt of the Survey Charting Matrix

	AG : Reminds to ask questions	AI : Saves time	AJ : Tells you next steps	AK : Tells you when obs due	AM : Whole team has access to central system	
41 : P40					Easier access for all to see.	
42 : P41			No lost paperwork- records exactly when next observations should be taken. Also advises what to look for if scoring.	No lost paperwork- records exactly when next observations should be taken		
43 : P42			Who to contact, how often to repeat observation.	how often to repeat observation.		
44 : P43		Fast & effective way to see NEWS & their position in the ward.				

Appendix 12. Consent Form (Interviews)

Interview Consent Form

Title of research project: Using mobile technology to record patient observations: impact on care management and clinical practice.

	Please initial box
I confirm that I have read the information sheet dated April 2022 for the above research project.	
I confirm that I have understood the information sheet dated April 2022 for the above research project and that I have had the opportunity to ask questions and that these have been answered satisfactorily.	
I understand that my participation is voluntary, and I am free to withdraw at any time without giving a reason and without any adverse consequences.	
I understand who will have access to personal information provided, how the data will be stored and what will happen to the data at the end of the research project.	
I consent to being audio recorded for the purposes of the research project and I understand how it will be used in the research.	
I understand that anonymised excerpts and/or verbatim quotes from my interview may be used as part of the research publication.	
I understand how the findings and results of the research project will be written up and published.	
I agree to take part in this research project.	

Name of participant (print)	Date	Signature

Name of person taking consent (print)	Date	Signature

Role of person taking consent (print)

Thank you for participating in our research.

Appendix 13. The Preference in Practice by Age Group with Non-Combined Groups

Table 22 Preference by age group with non-combined groups.

	Preference in practice percent (n)			
Age group	**Pen and Paper**	**CareFlow Vitals**	**Not Sure**	**Total n**
18-24	75.0 (3)	0 (0)	25.0 (1)	4
25-34	37.9 (11)	44.8 (13)	17.2 (5)	29
35-44	21.7 (5)	56.5 (13)	21.7 (5)	23
45-54	66.7 (6)	22.2 (2)	11.1 (1)	9
55-64	33.3 (4)	66.7 (8)	0 (0)	12

Appendix 14. The Measures of Data-Entry Method and Preference in Practice

Table 23 Preference in practice groups and their view on the measures of data-entry method.

	Measures of data-entry method percent											
	More accurate		**Allows easier detection of errors**		**Simpler**		**Quicker**		**More convenient**		**Easier to use**	
Preference in practice	**Pen and Paper**	**CareFlow Vitals**	**Pen and Paper**	**CareFlow Vitals**	**Pen and Paper**	**CareFlow Vitals**	**Pen and Paper**	**CareFlow Vitals**	**Pen and Paper**	**CareFlow Vitals**	**Pen and Paper**	**CareFlow Vitals**
Pen and paper	51.7	48.3	39.3	60.7	79.3	20.7	79.3	20.7	86.2	13.8	89.7	10.3
CareFlow Vitals	2.8	97.2	11.4	88.6	37.1	62.9	28.6	71.4	20.6	79.4	29.4	70.6
Not sure	16.7	83.3	16.7	83.3	66.7	33.3	58.3	41.7	33.3	66.7	66.7	33.3