A study of the factors influencing outcome after emergency laparotomy for non-traumatic abdominal pathology

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Dedication

To my Mother and best friend, Joan Gibson, for her unfaltering love and support, and to my brother, Mark Witherspoon.

Table of Contents

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Summary

This thesis investigates prognostic factors influencing the outcome and survival of patients undergoing emergency laparotomy (EL) for non-traumatic abdominal pathology. The hypotheses tested were: deprivation adversely influences EL outcome; accuracy of computed tomography (CT) reports vary and relate to anatomical location of pathology and radiologist; sarcopenia as measured by CT criteria is an important prognostic indicator.

Three hundred and thirty-one consecutive patients underwent EL between 1st of January and 31st December 2013 [median age 67 years (18-98), 166 male, 165 female. Thirty day mortality was 16.9% (56/331), 90-day mortality 19.9% (66/331), and overall mortality was 24.5% (81/331). The Welsh Index of Multiple Deprivation (WIMD) was related to 90-day operative mortality (p=0.031), but not 30-day mortality (p=0.061), and lost significance as an independent prognosticator when age and American Society of Anaesthesiology grades were included in regression analysis.

Over an eighteen month time period, a larger group of 361 patients [median age 67 years (18–98); 180 male] underwent CT prior to EL. CT reports were deemed accurate in 318 (88.1%) and inaccurate in 43 (11.9%) cases, which resulted in 5 negative laparotomies in this latter cohort (p<0.0001). Accuracy and strength of agreement varied with anatomical location of the pathology; upper gastrointestinal 75.5%, Kw 0.673 (0.531–0.815; p<0.001); small bowel 89.9%, Kw 0.781 (0.687–0.875, p< 0.001); lower gastrointestinal 90.4%, Kw 0.821 (0.749–0.893; p<0.001). CT examinations reported within working hours had higher strength of agreement [Kw 0.832 (0.768–0.896), p<0.001] than CTs reported out of hours [Kw 0.789 (0.721–0.857), p<0.001], but there was no significant difference in overall accuracy (89.9 vs. 86.0%; p=0.253). Reporter seniority was not associated with improved diagnostic accuracy (p=0.177).

Sarcopenia as defined by Hounsfield Unit Average Calculation (HUAC) was associated with 30-day operative mortality (p=0.010), and 90-day mortality (p=0.004) following EL, but when other variables were considered, no significant association was apparent.

Abbreviations

ACS	American College of Surgeons
ACS NSQIP	The American College of Surgeons/National Surgical Quality Improvement Program
ACPGBI	Association of Coloproctology of Great Britain and Ireland
ASGBI	Association of Surgeons Great Britain and Ireland
ATLS	Adult Trauma and Life Support
BSCP	Bowel Cancer Screening Programme
CRC	Colorectal Cancer Cancer
CSAMM	Cross-Sectional Area of Muscle Mass
CT	Computerised Tomography
DCLC	Department for Government and Local Communities
ERAS	Enhanced Recovery After Surgery
EWGSOP	European Working Group on Sarcopenia in Older People
EWTD	European Working Time Directive
gFOBT	Guiaiac-based Faecal Occult Blood testing
GI	Gastrointestinal
HES	Hospital Episode Statistics
HD	Health Deprivation
HR	Hazard Ratio
HUAC	Hounsfield Unit Average Calculation
IMD	Index of Multiple Deprivation
ISCP	Intercollegiate Surgical Curriculum Programme
ISI	International Sarcopenia Initiative
ITU	Intensive Care Unit
IWGS	The International Working Group on Sarcopenia

LOS	Length of Stay
LSOA	Layer Super Output Areas
LGI	Lower Gastrointestinal
MRCS	Membership of the Royal College of Surgeons of Great Britain and Ireland
NAD	Nil Abnormal Detected
NSQIP	National Surgical Quality Improvement Program
NELA	National Emergency Laparotomy Unit
NHS	National Health Service
NISRA	Northern Ireland Statistics and Research Agency
ONS	Office of National Statistics
OR	Odds Ratio
PMD	Psoas Muscle Density
P-POSSUM	Portsmouth Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity
RCS	Royal College of Surgeons
SMI	Skeletal Muscle Index
SPARCS	Statewide Planning and Research Cooperative System
TPA	Total Psoas Area
TPV	Total Psoas Volume
TPI	Total Psoas Index
UGI	Upper Gastrointestinal
UK	United Kingdom
USA	United States of America
WIMD	Welsh Index of Multiple Deprivation

Chapter 1: Introduction and Review of the Literature

1.1 Definition of Emergency Laparotomy

An emergency laparotomy [laparo- + G. tomē, incision] is a non-elective surgical procedure involving an incision through the abdominal wall when the patient's well-being or life is in jeopardy.

1.2 Anaesthesiology, Antisepsis and Emergency Surgery

1.2.1 The History of Anaesthesiology, Antisepsis and Emergency Surgery

Operations on the abdomen were rare until the beginning of the nineteenth century. Anaesthetic agents were being administered in 1835 onwards but their use was not widely publicised. Humphry Davy (1778-1829) was an English chemist and inventor from Cornwall (Knight 2004). His first experience of chemistry was making fireworks with his sister. Later in his career he combined oxygen and nitrogen and in 1799 he discovered a concentration which was safe and caused euphoria. He wrote first-hand accounts of the anaesthetic action of the gas and of it's effects: ''My emotions were enthusiastic and sublime; and for a minute I walked about the room perfectly regardless of what was said to me. As I recovered my former state of mind, I felt an inclination to communicate the discoveries I had made during the experiment. I endeavoured to recall the ideas, they were feeble and indistinct; one collection of terms, however, presented itself: and with the most intense belief and prophetic manner, I exclaimed … 'Nothing exists but thoughts!—the universe is composed of impressions, ideas, pleasures and pains!' ''(Davy 1799). Although Davy recommended the use of nitrous oxide in minor surgery, the idea was not adopted at that time.

In 1842, an American surgeon and pharmacist Crawford Williamson Long M.D. (1815-1878) administered the first ether anaesthetic for surgery and operated to

remove a tumour from a patient's neck in Georgia (Long 1849, Madden 2004). The patient was James M. Venable and Long subsequently removed a further tumour from him. He observed that diethyl ether had the same physiological effects as Humphry Davy had described for nitrous oxide in 1800 (Madden 2004).

Unaware of Long's use of ether for anaesthesia, an anaesthetist called William Morton performed the first public demonstration of anaesthesia with ether on 16th October 1846 at Massachusetts General Hospital in Boston and he is generally credited with being the first to use ether for anaesthesia (Fenster 2001). The chief of surgery, John Collins Warren removed a portion of a vascular tumour from the jaw of Gilbert Abbott. An observing botanist and physician in the audience, Jacob Bigelow, announced this important discovery to the American Academy of Arts and Sciences on 3rd November 1846 despite Morton's wish to keep the process a secret in the hope of patenting it (Alper 1964, Fenster 2001). Bigelow also wrote to his friend in London describing the experience. Word travelled quickly and on 19th December 1846, ether was administered for procedures in Dumfries and London. Prior to the introduction of anaesthesia, surgery was a last resort to save life and few dared to enter the abdomen. Speed was of the essence and patients were held or strapped down during the extremely painful and terrifying experience.

James Simpson, a Professor of Obstetrics in Edinburgh introduced another inhalational agent, chloroform on 4th November 1847. He is famous, not only for inventing chloroform, but also for designing obstetric forceps which to this day are known as 'Simpson's Forceps'. Dr Simpson used to try several chemicals each evening to see if they had any anaesthetic effect. On the inhalation of chloroform their mood improved then they fell asleep and slept until the following morning (Encyclopaedia Britannica, 2010). He discovered its anaesthetic properties when experimenting with friends and proceeded to administer it to his

patients within the next few days. The side effects were potentially fatal due to cardiac arrhythmias and there was a risk of significant liver failure with its use. Despite this, it was effective and was easier to use than ether so it became popular until the beginning of the 20th century when the permitted control of breathing and the airways in 1910s.

In 1847 Ignaz Semmelweis (1818-1865), a Hungarian obstetrician of German extraction, identified that surgeons hands were a route of spread of puerperal infection and published his work 'The Cause, Concept and Prophylaxis of Childbed Fever' in 1861 (Loudon 2013). When appointed as an assistant in obstetrics in Vienna, he observed that women delivered by physicians and medical students had a much higher rate of post-delivery mortality than women delivered by midwife trainees or midwives (13-18% versus 2%) (Best and Neuhauser 2004). This observation led Semmelweis to hypothesize that the higher rates of infections in women delivered by physicians and medical students were associated with handling cadavers during autopsies prior to delivering babies. He introduced a mandatory hand washing policy and then performed a trial using a chloride of lime solution resulting in a reduction of maternal mortality to 2%, the same as mothers being delivered by midwives (Best and Neuhauser 2004). As a result of the reduction in infection rates, washing the operating instruments improved mortality rates further to 1% (Best and Neuhauser 2004). Unfortunately his theory was discounted by his seniors, who explained the reduction in mortality rates by the new hospital ventilation system based on the theory that disease was spread via miasma (bad air as a result of rotting organic material). Semmelweis felt betrayed and left Vienna to return to Budapest. He published his work in a book entitled 'The Etiology, Concept, and Prophylaxis of Childbed Fever' but it was poorly received by the medical establishment. He was committed to an insane asylum when he

exhibited behaviour consistent with early Alzheimer's disease and died age 47 years as a result of injuries sustained by beatings from the staff (Nuland 2004).

Louis Pasteur's was a French chemist and biologist who proved the germ theory of disease and invented the process of pasteurisation. He was born in 1822 in the Jura region of France. His appointment as the Professor of Chemistry and Dean of the science faculty at the University of Lille required his involvement in solving practical problems experienced by local industries, particularly the manufacture of alcoholic drinks. He demonstrated that bacteria were responsible for souring wine, beer and later milk, by demonstrating that rotting and fermentation of food could occur under anaerobic conditions if micro-organisms were present. Pasteur suggested three methods to eliminate the micro-organisms responsible for gangrene: filtration, exposure to heat, or exposure to chemical solutions. His first test to boil and then cool fluid in order to eliminate microbes was completed in 1862 and the process is now known as pasteurisation (Biography.com Editors, 2015). In 1865, Pasteur proved that microbes were attacking healthy silkworm eggs, which affected the silk industry in Southern France. He saved the industry by advising that disease-free eggs be selected despite no prior experience of the industry (Biography.com Editors, 2015).

Joseph Lister (1827-1912) was a British surgeon born in Essex. His main achievements were in antisepsis whilst working in Glasgow Royal Infirmary. He applied Pasteur's advances in microbiology and promoted the idea of a sterile surgery (Bynum and Bynum 2007). In 1865, Joseph Lister published the paper 'On the Antiseptic Principle in the Practice of Surgery' in 1867 (Lister 1867). He was the first to apply Pasteur's germ theory to clinical practice and advocated the use of carbolic acid (phenol) in aseptic surgical practice and wound care, resulting in a dramatic reduction in surgical mortality. He noticed that application of the carbolic solution onto wounds reduced the incidence of gangrene and

wrote about an eleven year old boy in Glasgow Royal Infirmary who had sustained a compound fracture of the leg and was treated with a piece of lint dipped in carbolic acid solution. The boy did not develop infection and after six weeks his bones had healed.

Considered the founder of modern nursing, Florence Nightingale (1820-1910) was a British social reformer and statistician. She instigated radical changes in hospitals caring for wounded soldiers from the Crimean War and later in military hospitals in India by improving hygiene and modernising nursing care. She was known as 'Lady of the Lamp' due to her habit of rounds at night-time (Selankas, 2009).

Ernst von Bergmann, a Baltic German surgeon was also a pioneer of aseptic surgery as he invented the autoclave in 1880, and the use of heat sterilisation of surgical instruments (Nature 1936).

1.2.2 The Founders of Medicine and Emergency Surgery

Hippocrates, the famous physician and teacher of medicine and was known as the 'father of medicine' as he liberated medicine from religion, superstition and magic paving the way for a scientific approach. He was born on the Greek island of Kos around 450 BC and regarded health as a balance of four fluids known as the humours; blood formed in the heart, phlegm formed in the brain, black bile formed in the spleen and yellow bile from the liver (Grammaticos and Diamantis 2008). It is likely that he is describing an acute abdomen when he wrote about 'ileus'; 'In ileus the belly becomes hard, there are no motions, the whole abdomen is painful, there are fever and thirst and sometimes the patient is so tormented that he vomits bile…Medicines are not retained and enemas do not penetrate. It is an acute and dangerous disease' (Grammaticos and

Diamantis 2008). Treatment was poultices to the abdomen, cupping, purgation, bleeding and enemas, which may have done more harm than good.

Before 1809, all attempts at abdominal exploration had resulted in peritonitis and death. Ephraim McDowell (1771–1830) was an American physician and pioneer surgeon who is known as the founding father of abdominal surgery. He was born in Virginia and attended lectures in Medicine at the University of Edinburgh from 1793-1794 and then began his practice as a surgeon (Schachner 1921). He perfected the technique of lithotomy to removal renal calculi but is better known for being the first person to successfully excise an ovarian tumour, without before the advent of anaesthesia or antisepsis, in 1809. McDowell was a Presbyterian and his response to the surgery was recorded in a biography: 'How is that I have been so peculiarly fortunate with my patients of this description?, I know not; for, from all the information I can obtain, there has not one individual survived who has been operated, on elsewhere, for diseased ovaria. I can only say that the blessing of God has rested on my efforts' (Schachner 1921)

1.2.3 The History of Specific Surgical Conditions requiring Emergency Laparotomy

1.2.3.1 Peritonitis

In 1776, William Cullen from Edinburgh coined the term 'peritonitis' for inflammation of the lining membrane of the abdominal cavity and viscera. His view on the management of peritonitis was 'they do not require any remedies besides those of inflammation in general'. Nowadays, it is commonly accepted that most cases of peritonitis require emergency surgery.

1.2.3.2 Splenectomy

Oskar Riegner in Breslau performed the first successful splenectomy in 1893. The 14-year old male patient was found to have a ruptured spleen and 1.5 litres of free intra-peritoneal blood. His post-operative recovery was hampered by development of a gangrenous foot, which required amputation but he survived and left hospital 5 months following his splenectomy. Earlier unsuccessful attempts at preserving life after splenic trauma were reported by Sir Arbuthnot Lane of Guy's Hospital, London in 1892 and by Friedrich Trendelenburg in Leipzig in 1893. A surgeon from Paris, Jules Pean, was demonstrated that an elective splenectomy was compatible with survival when he operated on a girl with a massive splenic cyst in 1867.

1.2.3.3 Intestinal Obstruction

The first attempt to perform a colostomy was in 1776 by Henri Pillore of Rouen. He formed a caecostomy on a patient with an obstructing rectosigmoid lesion who later died due to mercury-induced jejunal necrosis. Piere Fine, a surgeon from Geneva performed the first successful transverse colostomy in 1797 in a 63 year old female with an obstructing sigmoid growth but she died 14 weeks later with ascites. The formation of adhesional small bowel obstruction after abdominal surgery is a recognised complication constituting a significant portion of our emergency work today. The first report of this was in 1872 by Thomas Bryant when he reported a fatal case of bowel obstruction due to a band adhesion following removal of an ovarian cyst in Guy's Hospital.

1.3 Modern Anaesthesiology and Antisepsis

Current emergency surgery-related themes in the Anaesthesia literature include new fasting guidelines for patients undergoing surgery. Early work performed by

Curtis Mendelson (1946) in peripartum women described catastrophic consequences following pulmonary aspiration of particulate matter with poor overall survival (44 patients out of 44,016 survived). For over seven decades, our policy of fasting patients has remained unchanged; 6 hour fast for solids and 2 hour fast for clear liquids. The risk of aspirating gastric contents during anaesthesia is low (1:900-1:10,000) and recommended techniques which attempt to minimise the risk of aspiration, include rapid sequence induction (RSI) with cricoid pressure, and the use of prokinetics, proton pump inhibitors and H_2-receptor antagonists to increase the pH of gastric secretions. A recently published editorial in the British Journal of Anaesthesia summarises the new evidence that is currently challenging these guidelines (Thomas and Engelhardt 2017). The most striking evidence is from the paediatric population, which has been studied by Chauvin and colleagues (2017). Children who had a high pain score in theatre recovery were offered a dilute apple juice drink in preference to a dose of morphine and showed a reduction in the pain scores, less postoperative vomiting, a shorter stay in recovery and lower morphine requirements in the post-operative period (Chauvin et al 2017). Theoretically, by reducing the fasting period for fluids pre-operatively, we could reduce post-operative thirst and improve outcomes. It was noted that several paediatric units in the United Kingdom now allow selected children who are deemed low-risk, a clear fluid drink up to one hour before anaesthesia. More research is required to ascertain whether this can be applied to adult patients requiring emergency laparotomy although certain patients would not be suitable because of their underlying pathology (perforation, bowel obstruction).

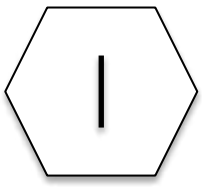
1.4 Emergency Laparotomy

1.4.1 Indications for Emergency Laparotomy

Laparotomy may be exploratory when patients present with acute or unexplained abdominal pain whose symptoms have not been explained by clinical or radiological diagnostic methods. Once the underlying pathology has been determined, the surgeon may perform a biopsy to obtain the diagnosis in cases of uncertainty or execute a therapeutic procedure. The most common indications for laparotomy in the non-traumatic setting are intestinal obstruction or perforation of a viscus. Intestinal obstruction may present with abdominal pain and distension, vomiting and absolute constipation. Abdominal x-rays may show dilated loops of small or large bowel with air-fluid levels. Patients with perforation will have clinical signs of peritonitis and may have a pneumoperitoneum on an erect chest x-ray (75% of cases). The common sites of perforation are the large bowel (due to diverticular disease or malignancy), the duodenum or stomach (due to peptic ulcer disease), or less commonly, the small bowel (due to adhesional obstruction, ischaemia or herniation). Patients with pain and fever may have intra-abdominal sepsis due to a diverticular abscess, appendicitis, perforated viscus or tubo-ovarian abscess.

1.4.2 Types of Incisions used for Emergency Laparotomy and their Advantages/Disadvantages

1.4.2.1 Midline Incision



A laparotomy can be performed through a variety of incisons but the most common one is a midline laparotomy, a vertical incision which follows the relatively bloodless linea alba. The upper midline

incision usually extends form the xiphoid process to the umbilicus and a lower midline incision ends at the pubic symphysis inferiorly. Some pathologies will require a full midline from the xiphoid process to pubic symphysis to allow for wide access to the abdominal cavity. The method of a midline incision is as follows: incise the skin in the midline, through the subcutaneous tissues and along the linea alba. The peritoneum should be picked up between clips and a small nick made to allow gas to enter the abdomen. Insertion of a finger will ensure that there is no bowel adherent to the peritoneum before extending the incision. The standard technique for abdominal closure is 'mass closure' which involved closing all layers of the abdominal wall, excluding the skin. Non-absorbable sutures such as nylon or slow-resorbing sutures such as polydioxanone (PDS) are widely used.

Advantages: This incision gives excellent access and it can be extended if required. There should be minimum blood loss through the avascular linea alba and minimum nerve or muscle damage. This incision can be made and closed quickly (mass closure).

Disadvantages: There is a risk of incisional hernia.

Incisional hernias are a common complication of midline laparotomies and are defined as 'abdominal wall gaps around post-operative scars, perceptible or palpable by clinical examination or imaging' (Korenkov et al. 2001, Muysoms et al. 2009). The reported incidence of incisional hernia following open colorectal surgery ranges from 8.6% to 33% and the rate is higher for emergency laparotomy (Braga et al. 2005, Kuhry et al. 2008).

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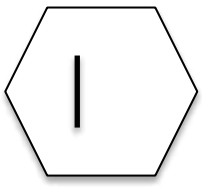


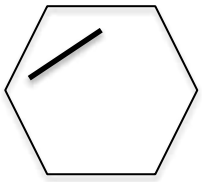
1.4.2.2 Paramedian Incision

A paramedian or original McEvedy's incision is lateral to the

midline which involves incising the skin and the rectus sheath along its lateral margin. Access is gained by pulling the rectus medially.

Advantages: This previously popular incision allows access to lateral structures such as the kidney, adrenals and spleen.

Disadvantages: Very high incisional hernia rate and the incision needs to be closed in layers which takes longer.

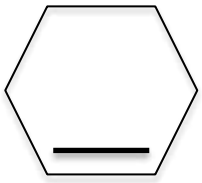


1.4.2.3 Kocher's Incision

This is an oblique incision made in the right upper quadrant of the abdomen, which is classically used for access to the gallbladder and biliary tract but also allows good access to the liver.

Advantages: This incision provides good access to liver and gallbladder and the incision be extended across the midline.

Disadvantages: This incision does not provide access to lower abdomen and takes longer to make and close as it is usually performed in layers.



1.4.2.4 Pfannenstiel Incision

This is a transverse incision just above the pubic symphysis which involves incising the skin and subcutaneous tissues transversally, retracting the rectus muscles laterally and opening the peritoneum either vertically or transversely. It is the incision of choice for Caesarian section and to access the uterus and ovaries.

Advantages: This incision permits urgent access to the gravid uterus and it's location means that it may be hidden in the pubic hair line.

Disadvantages: There is a risk of incisional hernia and also of injury to the bladder if not catheterized during surgery. It gives limited access to the abdominal organs and to the deep pelvic organs in the obese patient.

1.4.3 The 'Hughes Abdominal Repair Trial'

This ongoing 1:1 randomised controlled trial comparing two suture techniques for the closure of the midline abdominal wound following surgery for colorectal cancer was designed in Cardiff (HART 2012). It aims to randomise 800 patients from approximately 20 general surgical units within the United Kingdom. Patients over the age of 18 years undergoing surgery for elective or emergency colorectal cancer are eligible and both open or laparoscopic with >5 cm midline incision procedures are eligible. Patients are randomised intraoperatively to the Hughes Repair or standard mass closure. The Hughes Repair combines a standard mass closure (all layers) with a series of horizontal and two vertical mattress sutures within a single suture and theoretically distributes the load along the incision length as well as across it. The primary outcome measure of the study is the incidence of incisional hernias at 1 year as assessed by clinical examination. The secondary outcomes of the study include quality of life patient-reported outcome measures, cost analysis, incidence of wound dehiscence and C-POSSUM scores. Tertiary outcomes are the incidence of computerized tomography diagnosed incisional herniae at 1 year.

1.5 The Development of Emergency Surgery

1.5.1 Publications from The Royal College of Surgeons and the European Working Time Directive

The Royal College of Surgeons (RCS) of England is a registered charity and professional membership organisation, which supports 20,000 members and aims to advance patients' care. They hold an important role in the development of policy and guidance. In 2001, the Royal College of Surgeons (RCS) of

England produced a report entitled ‘Standards for unscheduled surgical care‘ which aimed to provide guidance to those providing and commissioning emergency care (RCS 2011). They acknowledged that patients requiring emergency surgery are likely to amongst the sickest patients that the NHS looks after and recognized the impact of poorly delivered emergency surgical services; increased cost to the NHS in terms of perioperative complications, unplanned returns to theatre and increased in-patient stay, costs to society because of welfare support and rehabilitation costs and, not least, the costs to the patient and their carers/family because of high morbidity and mortality. This document quoted mortality rates of 25% following emergency general surgery with approximately 14,000 annual admissions to the Intensive Care Unit (ITU) in England incurring costs of £88 million. The RCS recognized that many hospitals did not have adequate access to emergency imaging and theatre because of concerns that these resources would be under-utilized, but this was resulting in avoidable delays with resultant rises in morbidity and mortality. Speedy assessment prioritization and treatment of patients requiring emergency intervention, in addition to adequate access to well-staffed and resourced theatres, was recommended in order to be cost-effective and reduce morbidity and mortality. Cardiac surgery was noted to have good data collection and audit, which led to good results for emergency cardiac surgery with continued improvements in patient outcome. In comparison, the RCS noted that data collection for emergency general surgery was poor leading to difficulties in benchmarking outcome improvements (this report preceded the National Emergency Laparotomy Audit {NELA}).

The European Working Time Directive (EWTD) is a European Union initiative to prevent employers forcing their workforce to work excessively long hours, by reducing the working week to an average of 48 hours. Further regulations relate to break periods and holiday allowance (11 hours rest a day and one day off per

week, a rest break if the shift is longer than 6 hours, 5.6 weeks paid leave each year). The EWTD applies to consultants, career grade staff and junior doctors, and in addition to other staffing issues such as such as sub-specialisation and the introduction of the EWTD, many had concerns that patients often see numerous doctors resulting in poor continuity of care. This may affect the provision of emergency surgical care and the RCS also recognized there were issues with handovers, a fragmented on-call system and reliance on junior doctors to run the on call emergency service. In addition, a reduction in the training time for junior doctors was thought to have to challenges in providing an emergency surgery service due to imbalances in service provision and training to achieve the competencies set out by the Intercollegiate Surgical Curriculum Programme (ISCP). A working group comprising surgical and related specialty experts reported on the standards of care for unscheduled adult and paediatric patients focusing on clinical and managerial leadership, consultant-led practice, multidisciplinary teams, and the prioritization of acutely unwell patients over elective activity. An important standard from the RCS was having clinical governance with a focus on outcomes, audit and regular review. The first standard was regarding the provision of emergency (unscheduled) surgical care and stated that emergency patients should take priority over elective patients and that 24-hour service provision should include access to radiology, access to theatres and critical care, and senior well-trained staff. Trained personnel should assess the patient and early warning scores should be used in conjunction with agreed escalation protocols for the sick patient. The standard stated that the service should be consultant-led and as a minimum, a trainee at least ST3 (post-MRCS and ATLS provider) level should be available to assess an ill patient within 30 minutes and then escalate to the consultant. If the consultant is not on site, they should be contactable by telephone and within 30 minutes travelling time to the hospital. The standard included consultant

surgeon and anaesthetist input in patients who are deemed high risk (predicted mortality >5%) unless adequately experienced senior staff was present. The RCS recommended that all emergency surgical patients should be discussed with a consultant within 12 hours of their admission and seen within 24 hours. Surgeons responsible for the care of emergency patients should be free from elective commitments and separate pathways should exist for emergency and elective patients to avoid delays. Importantly, accurate and full documentation, including the documentation of times of decision-making was included in the standard in addition to the use of regular Morbidity and Mortality meetings and Audit. The RCS set other standards in the document: 'Leadership and Governance', 'Patients and Supporters', 'Education and Training', 'Network and Cooperation', 'Ambulance Services', 'Emergency Department', 'Emergency Theatre', 'Acute Medicine; community/primary care, acute and local hospitals, acute general surgery', Radiology: diagnostic radiology, interventional radiology', 'Pathology; generic, haematology and blood transfusion, biochemistry, microbiology and infection control, histopathology', 'Anaesthesia: pre-operative assessment, peri-operative care, post-operative care', 'Intensive Care', and 'Discharge, ongoing care and rehabilitation', The document also provided standards in 'Paediatric Surgery', 'Trauma and Orthopaedic Surgery' in addition to the 'Provision of the emergency surgical service' standard.

Also in 2011, The Royal College of Surgeons of England/Department of Health released a report entitled 'The Higher Risk General Surgical Patient: towards improved care for a forgotten group' (RCS/DOH 2011). They focused on the issues around emergency surgery and highlighted the fact that the peri-operative pathway for emergency surgery was disjointed, protracted and not always patient centred. The working group made key recommendations for care pathways including diagnostic and monitoring plans, timing of surgery and post-operative placement of patients. They highlighted the need to prompt

recognition and treatment of emergencies and complications by appropriately trained staff, and access to emergency services such as theatre, radiology and critical care.

Emergency surgery standards are not limited to the UK; The American College of Surgeons and the American Geriatric Society have formed ‘best practices’ in the preoperative assessment and optomisation of elderly patients with the aim of mitigating their higher perioperative risk (Chow et al. 2015). They have made recommendations for patients with cognitive impairment, dementia and depression, and have provided guidance on determining decision-making capacity. Recommendations on identifying patients at risk of alcohol and substance abuse, fall risk and risk of post-operative delirium aim to reduce the post-operative morbidity and mortaility. Jointly they also provide information on cardiac and pulmonary evaluation, evaluation of nutritional status, pre-operative testing and on the management of the elderly patient’s medication as they are at risk of polypharmacy. No equivalent practice guidelines specifically aimed at elderly patients currently exist in the United Kingdom.

1.6 The National Emergency Laparotomy Audit (NELA)

The National Emergency Laparotomy Audit (NELA) is part of the National Clinical Audit and Patient Outcomes Programme (NCAPOP) and is funded by the Department of Health (DOH) through the Healthcare Quality Improvement Partnership (HQIP). The latter is an independent organization established in 2008, led by the Academy of Medical Royal Colleges, the Royal College of Nursing and National Voices whose aim is to promote quality in healthcare. The NELA describes and compares inpatient care and outcomes in order to promote quality. The first report published in 2015 highlighted variations in

facilities available at hospitals performing emergency laparotomy and provided data on over 20,000 patients. The second Patient Audit looked at patients undergoing surgery between 12/2014 and 11/2015 and was reported in 2016 (NELA 2016). The audits reported 30-day post-operative mortality of 11.8% in 2015 and 11.1% in 2016, representing a 15% reduction from previous published reports, although this mortality rate varied considerably between patient groups (NELA 2015, NELA 2016). The most recent publication from NELA (2017) is the third patient report including 24,897 patients from all 187 hospitals performing emergency laparotomy across England and Wales from 12/2015 until 11/2016. The mortality data has been independently verified from the Office of National Statistics and the 30-day mortality has reduced to 10.6% (NELA 2017). Key processes of care were identified using published standards and an important one was timely review by a consultant surgeon (within 14 hours of admission), which was in comparison to previous guidelines by the RCS (RCS 2011) of discussion of all emergency patients with a consultant within 12 hours and review within 24 hours. Additional key processes of care included prompt prescription and administration of antibiotics (when clinically indicated), consultant reporting of pre-operative CT scans and access to emergency theatres. Other processes from the NELA were documentation of the risks of surgery, pre-operative consultant surgeon and anaesthetist review and critical care admission for high-risk patients, and elderly medicine specialists input for older patients, were also key processes. These processes give surgical units targets and help them to devise local protocols for emergency patients.

1.7 Risk Prediction In Emergency General Surgery

The contrast between outcomes of patients undergoing emergency versus elective surgery is striking and it may in part be due to the lack of time to plan

and optimize the patient prior to surgery. Risk assessment became a focus in these patients with both the 2011 reports from the RCS recommending that patients' should have their mortality risk assessed and documented prior to intervention and the RCS deemed patients with a predicted hospital mortality of ≥5% as high risk, and those with a predicted mortality of ≥10% should undergo surgery with direct supervision of a consultant surgeon and consultant anaesthetist unless both have satisfied themselves that the delegated member of staff has adequate experience and competency to perform the procedure independently (RCS 2011, RCS/DOH 2011). NELA (2016) specific hospital results for 2014-2015 suggest that the University Hospital of Wales could perform better with regard to pre-operative review by a consultant surgeon and anaesthetist when the risk of death is ≥5%; 48% of patients had a pre-operative consultant review compared to an the national mean of 57%. Presence of a consultant surgeon in theatre when the risk of death is ≥5% was good however – the hospital value was 80% compared to the national mean of 89%. The hospital fared less well on having both a consultant surgeon and consultant anaesthetist present in these patients; this only occurred in 60% of cases compared to the national mean of 74% (NELA 2016).

Critical care post-operatively was considered mandatory for those with predicted mortality of ≥10% and should be considered in those in the high risk group (≥5%). Risk is routinely predicted using the Portsmouth modification of the Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity (P-POSSUM) (Whiteley et al. 1996, Prytherch et al. 1998). The Risk Prediction Application is a piece of software downloaded by a user to a mobile device and is widely used by the Cardiff and Vale University Health Board to calculate the risk of morbidity and mortality for patients undergoing emergency general surgery using the P-POSSUM scoring system (P-POSSUM 2017). NELA have recently released an application to aid risk assessment.

The American College of Surgeons/National Surgical Quality Improvement Program (ACS NSQIP) Surgical Risk Calculator is another tool using multiple variables to estimate the risk of surgery (Cohen 2017). These variables include age, sex, functional status, emergency status, ASA class, steroid use, presences of ascites within 30 days prior to surgery, systemic sepsis within 48 hours prior to surgery, ventilator dependent, disseminated cancer, diabetes, hypertension, congestive cardiac failure within 30 days prior to surgery, dyspnea, smoking history, chronic obstructive pulmonary disease (COPD), use of dialysis, acute renal failure and body mass index (BMI).

Risk assessment for mortality in patients undergoing emergency surgery allows patients, families and surgeons to titrate the intensity and ceiling of care. It may help in making end-of-life decisions in the face of medical futility, or in making decisions to proceed with emergency surgery. Care must be taken when using these risk estimators as they only take certain variables into account and there may be other factors that may increase or decrease the risk of morbidity or mortality.

NELA (2016) have produced specific hospital results spanning 2014-2015 for documentation of risk of death prior to emergency surgery. Results from the University Hospital of Wales suggest that the hospital is performing well – 88% of patients had risk documented compared to the national mean of 64%. Currently, physiological and operative parameters are used in the various risk prediction calculators.

The hypothesis of the thesis is that multiple deprivation and sarcopenia (reduced muscle mass and strength) may influence emergency laparotomy outcome. Multiple deprivation may not be immediately amenable to targeting in the pre-operative emergency setting, but computerised tomography to assess the presence of sarcopenia may be an untapped resource for risk stratification. The

accuracy of computerized tomography reports was deemed an important aspect of emergency care.

1.7.1 Age as a potential Risk Factor

The structure of our society is changing as more people are living longer; life expectancy has been growing steadily for over half a century and currently one in five (12 million people) are pensioners. At present, there are approximately 1.25 million people aged 85 and over, 16,000 aged 100 and over, and there are more people over State Pension age than children (Help the Aged, 2008, ONS 2008). Life expectancy for a man aged 65 is now 86, and by 2050 it will be 91 (ONS 2008). The Office for National Statistics (ONS) predicts that by 2020, people over 50 will comprise almost a third of the workforce and almost half the adult population (ONS 2008). People over the age of 65 are the core users of acute hospital care, account for 60% of all admissions, 65% of bed days and 70% of re-admissions. These statistics undoubtedly have an impact on the provision of health services as we are performing surgery on an older population with more co-morbidities.

1.7.2 Multiple Deprivation as a potential Risk Factor

Indices of Multiple Deprivation (IMD) help to identify and understand small area deprivation and the IMD of Welsh Government (WIMD) encompasses eight types of deprivation (income, employment, health, education, community safety, housing, physical environment, and geographical access to services), each with it's own weighted score, shown in Chapter 2, Table 1 (Welsh Government 2011). Deprivation is one of the many factors which may influence a person's health; physical or socioeconomic factors (air pollution, lack of services and

amenities, climate), and individual factors (genetic make-up, age, sex, ethnicity, disability, health behaviours, occupation, income, housing quality) may all contribute. Health inequalities are considered avoidable differences in health and access to healthcare between populations. 'The Black Report' published in 1980 demonstrated widespread health inequalities and showed that the death rate for men in social class V was twice that for those in social class I (DHSS 1980). Overall, health has substantially improved over the past 150 years and this is reflected in improvements in life expectancy (ONS 2008) but when compared with England, the general health of the population of Wales is significantly poorer with more emergency hospital admissions per capita, and an overall life expectancy one year shorter (ONS, 2016).

Health Deprivation (HD) constitutes a relative weight of 14% of the IMD and contains four separate indicators: cancer incidence, all-cause death rate, percentage of low-weight live single births (<2.5kg) and limiting long-term illness (WIMD 2011). Using similar methodology, separate indices have been constructed for England, Northern Ireland and Scotland (DCLG 2015, Scottish Government 2012, NISRA 2010) and measure deprivation across key themes of income, employment, education and health (ONS 2015). Other measures of deprivation are used worldwide; Eurostat, the statistical office of the European Union, disseminate severe material deprivation rates for over half of the European Union Member States, and Iceland (Eurostat 2016) and there are several composite measures of deprivation used in the USA [Diez et al. 2001, Winkleby and Cubbin 2003, Krieger et al. 2003, Singh 2003, Messer et al. 2006). Patients in the USA who are from a socially deprived background are 64% more likely to undergo emergency surgery than affluent patients (OR 1.64, C.I 1.50–1.80, p<0.001) (Askari et al. 2015). Disparities in surgical outcomes amongst different races and ethnicities are recognized by The American College of Surgeons and explained, in part, by late presentation of cancer and poor

access to services (ACS 2010). In the 'Global Burden of Disease Study 2013' Newton et al. found marked inequalities between the most deprived and least deprived areas in England (Newton et al. 2015). In 2013, 91.1% of the variance of years of life lost (YLL) for men is explained by deprivation area and only 5.1% by region; for women 78.7% of the variance is explained by deprivation area. The leading risk factors by deprivation level in England are smoking, high body mass index (BMI) and high blood pressure (Newton et al. 2015). Most long-term conditions are more prevalent in adults from lower socioeconomic groups, such as diabetes chronic obstructive pulmonary disease, arthritis and hypertension, and multiple co-morbidities are more common in those from deprived areas (The Kings Fund, 2017). The link between deprivation and medical morbidity is described throughout the literature but less is known about the relationship between multiple deprivation and outcomes for patients who undergo emergency surgery.

1.7.3 Sarcopenia as a potential Risk Factor

Irwin H. Rosenberg first described "sarcopenia" (Greek 'sarx' meaning flesh and 'penia' meaning loss) in 1989 as a progressive and generalized loss of muscle mass and muscle strength with advancing age (Rosenberg 1989). In 2010, The European Working Group on Sarcopenia in Older People (EWGSOP) provided a working definition of sarcopenia as 'a syndrome characterised by progressive and generalised loss of skeletal muscle mass and strength with a risk of adverse outcomes such as physical disability, poor quality of life and death (Cruz-Jentoft 2010). They proposed criteria for diagnosis to include low muscle function; either low strength and/or low physical performance (Cruz-Jentoft 2010). The International Working Group on Sarcopenia (IWGS) also provided a consensus

definition of sarcopenia as ‘age-associated loss of skeletal muscle mass and function’ (Fielding 2011).

In 2013, the International Sarcopenia Initiative (ISI), formed by the EWGSOP, IWGS and other international experts, performed a systematic review of some aspects of sarcopenia (Cruz-Jentoft 2014). They included studies which used the EWGSOP definition of sarcopenia and excluded those that used only muscle mass to define sarcopenia. The review found that the prevalence of sarcopenia in the community was 1–33% across different populations (male and female data combined), with higher prevalence in older or acutely ill individuals are cared for (Cruz-Jentoft 2014). Of note, they reported that sarcopenia is an independent risk factor for adverse outcomes, including difficulties in instrumental and basic activities of daily living (Tanimoto et al. 2012, Bastiaanse et al. 2012, Landi et al. 2012, Landi et al. 2013), osteoporosis, falls, hospital length of stay and re-admission (Gariballa et al. 2013). Pre-operative sarcopenia has been found to be associated with severe post-operative complications in elderly gastric patients undergoing gastrectomy (Fukada et al. 2015) and patients following major hepatectomy with extrahepatic bile duct resection (Otsuji et al. 2015). A recent systematic review found that pre-operative sarcopenia as defined by single-slice CT, is associated with impaired overall survival in gastrointestinal and hepatopancreatobiliary malignancies, and increased postoperative morbidity in patients with colorectal cancer with or without hepatic metastases (Levolger et al. 2015). In patients undergoing hepatic resection for colorectal metastasis, Peng and colleagues found an association between sarcopenia and post-operative complications, length of stay and extended ICU stay but not recurrence-free or overall survival (Peng et al. 2011). In addition, sarcopenia, also predicts survival following pancreatic surgery (Peng et al. 2012).

Levolger and colleagues performed a systematic review of sarcopenia in patients with gastrointestinal and hepatopancreatobiliary malignancies who were operated on (Levolger et al. 2015) . They assessed the impact of CT-diagnosed sarcopenia on short- and long-term outcomes in 13 observational studies involving 2884 patients and adhered the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Studies were included if they reported the prevalence of sarcopenia and at least one outcome (post-operative mortality, complications, length of intensive care stay, length of hospital stay, disease free survival and overall survival). The authors found that sarcopenia was independently associated with reduced overall survival in seven out of ten studies. Hazard ratios were highest for hepatic cancer (HR 3.19) and colorectal hepatic metastases (HR 2.69) and lowest for pancreatic cancer (HR 1.63) and colorectal cancer (HR 1.85). Sarcopenia was independently associated with higher post-operative mortality in colorectal cancer (OR 43.3), more complications (OR 2.22) and severe complications (OR 3.12) in colorectal hepatic mestastases. The authors did not offer an explanation why higher muscle mass was associated with more complications (OR 0.96) in patients with colorectal cancer (Levolger et al. 2015).

Studying 234 patients undergoing elective colorectal surgery, Leiffers et al. reported that sarcopenia predicts postoperative infections, inpatient rehabilitation care and increased length of stay (Leiffers et al. 2012). Infectious complications were seen in 23.1% of those with sarcopenia versus 12.6% in those without sarcopenia (p=0.036) and this difference was more pronounced in patients ≥ 65 years (OR 4.6, 1.5-13.9, p=0.007) (Leiffers et al. 2012).

Reisinger et al. (2015) used cross-sectional area of muscle mass (CSAMM) at L3 with a cut-off of 38.5cm^2 for females and 52.4cm^2 for males, and they also investigated sarcopenia in patients undergoing elective colorectal surgery reporting that it is associated with hospital mortality but not anastomotic leakage

or sepsis. In this study, hospital mortality was 8.8% in patients with sarcopenia versus 0.6% in those without sarcopenia (OR 43.3, 2.74 to 685, p=0.007) (Reisinger et al. 2015). This research underscores the importance of understanding the true prevalence of sarcopenia and effective preventative strategies.

1.8 The use of Radiology in Emergency Surgery and the Accuracy of Emergency Radiology Reports

Patients with abdominal pain commonly present to the emergency department and their underlying pathology is wide-ranging. Abdominopelvic computerized tomography (CT) is an important imaging modality in these patients and is considered highly accurate in the assessment of the acute abdomen. The increase in utilization in the acutely unwell surgical patient had resulted in increased demands on the radiology service and several different reporting systems are currently in use. The emergency reporting may be performed by on-site registrars with subsequent review by a consultant on or off-site, by on-site consultants or by consultant radiologists who may or may not have trained and be based in the UK with no direct affiliation to the imaging hospital.

The Royal College of Radiology (RCR), a registered charity, produces standards to guide radiologists and others involved in the delivery of radiology services. Their aim is to define good care and advance radiology practice. In 2016, the RCR produced ‘Standards for providing seven-day acute care diagnostic radiology service’. Some of the standards relevant to emergency general surgery related to timely access to a radiologist when their skill is likely to aid diagnosis, a support network of secretarial and clerical staff to facilitate communication between radiologists and the referring clinician, well defined

telephone communication systems, in addition to systems to support teleradiologists when outsourcing reporting for acutely ill patients.

Radiologists have to report imaging under conditions of uncertainty and error may be made. When these images are re-read, sometimes with the benefit of additional information, discrepancies may be detected in the original interpretation. The RCR recognize that reviewing and learning from discrepancies and adverse events can minimize potential harm and enhance patients' safety. Another important standards document produced from the RCR is 'Standards for Learning from Discrepancies Meetings' (RCR 2014). Based on the finding that the potential of peer review feedback, shared learning, and improved team working was underutilized, they recommended that radiologist peer feedback should occur in daily practice and that there should be evidence of a quality assurance radiology reporting programme in all services. The RCR recommended that peer feedback should be carried our through a number of processes with multidisciplinary team meetings using a structured framework. Discrepancy meeting and clinical audit should also be regular practice and an aim to implement systematic review of 5% of reports by 2018. The RCR state that peer feedback should be fair, objective, confidential and relevant to the practice of the department, and the quality assurance programme would have the aim of improving quality and patient safety. Prior to the most recent audit in the literature by Howlett et al. (2016) radiological discrepancy rates of 3-30% have been reported and were explained by case-mix, selection bias, and inter- and intra-observer variability.

The RCR performed a national, UK-wide audit of acute non-traumatic abdominopelvic CT reporting in surgical and non-surgical patients to assess minor and major discrepancy rates for provisional and addendum reports. One hundred and eighty-eight radiology departments were invited to submit data on 25 consecutive surgical and non-surgical patients from 2013 (Howlett et al.

2017). The non-traumatic surgical patients had out-of-hours (6pm-8am) weekdays or anytime at the weekend and subsequently had laparotomy. The non-surgical patients had CTs but did not have laparotomy although patients who underwent other procedures such as stents, percutaneous drainage and laparoscopy were included. A CT auditor who evaluated provisional and addendum reports was a substantive consultant with experience in reporting abdominal CT and was blinded to the original report content and identity. The RCR defined a major discrepancy as a change, or potential change in the diagnosis or treatment as a result of the addendum or CT auditor and were coded as the following:

- False positive: Provisional report diagnosis positive findings, CT auditor reported negative findings.
- False negative: Provisional report negative diagnosis, positive findings on CT auditor review.
- Misdiagnosis: incorrect provisional diagnosis.
- Indeterminate report: Inappropriately wide range of diagnoses, most of which may be correct but with no attempt by the reporting radiologist to triage the findings.

A minor discrepancy was defined as minor issues unlikely to cause harm or change management.

The authors examined almost 5,000 patients from acute hospitals across the UK and approximately half of these patients went on to have a laparotomy. There was a 58% response rate from 109 participating radiology departments. The main results of the audit was a discrepancy rate of 4%(204 CTs) of provisional reports and these discrepancies were more common in surgical than non-surgical patients. There were discrepancies in 6% of surgical patients between their reports and their surgical findings; more than 2/3 were false negatives or

misdiagnoses. In 1.5% of surgical patients (n=36) and 0.6% of non-surgical patients (n=15), the discrepancies were deemed to have caused harm as a result of delays in diagnosis or unnecessary intervention. The authors reported an overall risk of major discrepancy in surgical patients as 9.4%, dropping to 2.7% with the addition of the addendum. The authors highlighted some important, but perhaps not unsurprising, results regarding the reporting of CTs; the most accurate reports with the lowest risk of potentially harmful error. Registrars (of unknown grade) were 1.6 times more likely to have discrepancies in their report and off-site reporters were 3.3 times more likely than onsite consultants (Howlett et al. 2017).

NELA (2016) have produced specific hospital results for 2014-2016 for CTs scans reported by a consultant before surgery and the University Hospital of Wales' results suggest that the hospital could perform well if some improvements were made; 56% of scans were reported by a consultant radiologist compared to the national mean of 72%.

High standards of practice will only be maintained by learning from experience and discrepancies as part of a continuing learning process. Because of the importance of accurate reporting of CT images in critically ill patients, this will be an important aspect of this thesis.

1.9 The Future of Emergency Surgery Training in Wales

The Wales Deanery produced a Position Statement on the 'Reconfiguration of training in Emergency General Surgery' in 2015. They recognized that emergency general surgery is currently delivered by consultant general surgeons, many of whom have a specialist elective interest. In 2015, 45% of general surgeons had a Colorectal interest and 22% had an Upper Gastrointestinal interest. Now that surgical training is shorter and more

specialised, the experience of newly appointed consultant surgeons is now less than their predecessors, which is thought to have led to fewer new consultants feeling confident in their role on the consultant emergency rota. The Wales Deanery recognised that two types of general surgery consultants were emerging; the Emergency General Surgeon and the Colorectal/Upper Gastrointestinal Surgeon. The former has a specialist interest in Emergency General Surgery and is likely to become a leader in the management and delivery of this service. Their training has included colorectal and upper gastrointestinal specialities but their job plan focuses on emergency care. The latter type of surgeons is one who has a declared interest in colorectal or upper gastrointestinal surgery but is proficient at managing the majority of emergency and trauma surgery. They require mentoring in both their specialist interest and also in complex emergency and trauma work.

1.10 Other Emergency Laparotomy Research

Information regarding emergency laparotomy prognostic indicators is thin and relevant research infrequently reported. The mortality rate for emergency bowel surgery remains some five times greater than in high-risk elective surgery, and the reasons are multifactorial. Poor outcomes following emergency laparotomy are not limited to the UK; a large retrospective analysis of 37,553 patients in the USA showed a similarly high mortality rate of 14% These results were derived from a database form 2005-2009 as part of The American College of Surgeons National Surgical Quality Improvement Program (Al-Temimi et al. 2012). Al-Temimi and colleagues created Logistic regression models for 30-day mortality after emergency laparotomy and found that the variables most significantly associated with mortality were the American Society of Anesthesiologists grade, functional status, sepsis, and age. A smaller population-based cohort study of 2,904 patients across 6 capitol regions over 2 years (2009-2010) in Denmark

and had primary outcome of 30-day mortality (Vester-Andersen et al. 2014). They reported a mortality rate of 18.5% although their study included patients undergoing laparoscopy in addition to laparotomy so their cohort differed to this study. Vester-Andersen and colleagues (2014) analysed the post-operative destination patients and found that 84.2% of patients were treated on a 'standard ward', with a 30-day mortality of 14.3%. After a median stay of 2 days (inter-quartile range 1-6 days) 4.8% of patients were transferred to the intensive care unit (ICU). They then compared outcomes of those who went directly to the 'standard ward' with those who deteriorated and had to be transferred to ICU, and those who went directly to ICU from theatre. Patients who were transferred from the ward to ICU were independently more likely to die within 30 days (OR 5.45, C.I 3.48-8.56). Patients who went directly to ICU were more likely to die than those who went to the ward (OR 3.27 (95% CI: 2.45-4.36) (Vester-Anderson et al. 2014). This data is robust as it is collected from the Danish Anaesthesia Database (DAD), involving all patients undergoing anaesthesia nationwide. It was founded in 2004 as part of Danish Clinical Registries and involves patients from public and private anesthesia clinics, single-centers and multi-hospital corporations across Denmark. This study is interesting as it highlights the need to appropriate allocate high-risk patients post-operatively and the importance of early recognition of the sick ward patient. NELA (2016) have produced specific hospital results for 2014-2015 for patients being admitted to critical care post-operatively when the risk of death ≥10%; in the University Hospital of Wales only 72% of these high risk patients go directly to critical care compared to the national average of 85%.

1.11 Aims and Hypotheses of Thesis

The Aims of this Thesis are:

(1) To explore the history of antisepsis, anaesthesiology and emergency general surgery

(2) To investigate the development of emergency general surgery and current topical issues

(3) To assess the prognostic significance of multiple deprivation on emergency laparotomy outcome

(4) To assess the diagnostic accuracy of emergency computerised tomography in adults with non-traumatic abdominal pain

(5) To investigate the relationship between computerised tomography-defined sarcopenia and emergency laparotomy outcome

The Hypotheses of this Thesis are:

(1) Multiple deprivation is associated with poor outcomes following emergency laparotomy

(2) Computerised tomography-defined sarcopenia is associated with poor outcomes following emergency laparotomy

(3) Computerised tomography accuracy may be suboptimal in the emergency setting

Chapter 2: Prognostic influence of Multiple Deprivation on Emergency Laparotomy Outcome

2.1 Abstract

Objective: Deprivation is a complex concept and is not synonymous with poverty. Recent work has highlighted poor outcomes following emergency laparotomy compared with high risk elective surgery. The aim of this study was to assess the prognostic influence of multiple deprivation on emergency laparotomy outcome.

Method: 331 consecutive adult patients (median age 67 years (18-98), 166M,165F) undergoing emergency laparotomy in one calendar year in a tertiary University hospital were studied. Patients were categorised according to age and American Society of Anaesthesiologists (ASA) system. Deprivation scores and ranks were derived from patients' postcodes, using the Welsh Index of Multiple Deprivation (IMD) 2011 and the ranks were divided into quintiles. The primary outcome measure was 30-day mortality and secondary outcomes were 90-day mortality, length of stay (LOS) and survival.

Results: 30-day and 90-day mortality rates were 16.9% and19.9% respectively. Median length of stay was 15 days (1 – 457) after exclusion of deceased patients, and unplanned hospital re-admission occurred in 47 patients (47/260, 18.1%). Median follow-up was 10.1 months (2.1 – 15.9 months). On univariable analysis, variables related to 30-day mortality were age ($p=0.004$) and ASA ($p<0.001$). Variables associated with 90-day mortality were age ($p=0.001$), ASA ($p<0.001$), and IMD quintile ($p=0.031$) On multivariable analysis, ASA is associated with 30-day mortality ($p<0.001$); age is of borderline significance ($p=0.051$). Overall, variables related to 90-day mortality are age ($p=0.003$) and ASA ($p<0.001$), IMD is no longer significant ($p=0.053$).

Conclusion: There is no association between deprivation and 30-day mortality. Multiple deprivation is related to 90-day mortality but not when age and ASA are

taken into account. Further research is required to evaluate the effect of deprivation on long-term survival.

2.2 Introduction to Emergency Laparotomy in the United Kingdom

Emergency laparotomy accounts for over 30,000 operations annually in 191 units in England and Wales, half of the general surgery workload, and up to 90% of all surgical deaths (ASGBI, 2012). Patients requiring emergency surgery are among the sickest treated by the National Health Service (NHS), and several reports from the Association of Surgeons Great Britain and Ireland (ASGBI), the Royal College of Surgeons England (RCS), and the National Confidential Enquiry into Perioperative Deaths (NCEPOD), have focused on these poor outcomes and an urgent need to reconfigure services to develop specialist centers employing dedicated care protocols (ASGBI 2012, RCSEng 2011, RCSEng/DOH 2011, NCEPOD 2011).

2.3 Materials and Methods

2.3.1 Data collection

Between 1st January 2013 and 31st December 2013, 331 consecutive adult patients underwent emergency laparotomy (access to the abdominal/pelvic cavity within 24 hours of decision to operate) at the University Hospital of Wales, Cardiff. Patient details and results were obtained from the Welsh Clinical Portal online information, theatre operating records and hospital management systems.

2.3.1 Patient Categorisation

Patients were grouped into categories according to their age (<50, 50-59, 60-69, 70-79, ≥ 80 years). Patients were graded according to the American Society of

Anaesthesiologists (ASA) system, and to better equalise the numbers of patients in the ASA groups, ASA grades 1 and 2, and grades 4 and 5 were combined. Table 2 shows the list of procedures found at emergency laparotomy. The data was not powered for stratification of diagnoses so further analysis was not performed. Data was collected on the length of hospital stay (LOS), unplanned 30-day hospital re-admission rate and survival. Patients undergoing primary vascular procedures or procedures for diseases of the appendix and biliary tree were excluded.

2.3.2 Deprivation Scores

Deprivation scores and ranks were derived from patients' postcodes, using the Welsh Index of Multiple Deprivation (IMD) 2011, as determined by the National Assembly for Wales (WIMD, 2011). The most deprived geographical Lower-Layer Super Output Areas (LSOA) is ranked 1 and the least deprived ranked 1,896. To allow sub-group analysis, the deprivation ranks for IMD and HD were sub-classified into quintiles ; the most deprived quintile (LSOA 1-379) was labelled quintile 1 and the least deprived (LSOA 1,517-1,896), quintile 5. Investigation of correlation between IMD and HD quintiles showed a strong positive correlation (Spearman's rho 0.897), so to avoid multi-collinearity, IMD was chosen to take forward into the model.

2.3.3 Outcome Measures

The primary outcome measure was 30-day mortality and secondary outcomes were 90-day mortality, length of stay (LOS), survival and unplanned readmission. The setting was a tertiary University Hospital serving a population of 0.47 million.

2.4 Statistical analysis

Statistical analyses appropriate for non-parametric data (Mann-Whitney U and Kruskal-Wallis) were used, and correlation determined by means of Spearman's rho. Pearson's chi-squared values for calculated to distinguish between groupings for each variable individually. Binary logistic regression was used to identify variables significantly associated with outcome. A survival analysis was conducted through Cox proportional hazard regression models to assess the association between prognostic variables and survival with and without adjustment for potential confounding factors. Multivariable analysis was performed to allow for confounding factors. Variables with a $p<0.05$ were considered statistically significant independent predictors of outcome. Data analysis was carried out using the Statistical Package for the Social Sciences version 23 (SPSS, Chicago, Illinois, USA). Missing data was excluded from analyses but is reported (Table 2).

2.5 Results

2.5.1 Demographics

Three hundred and thirty-one patients underwent emergency laparotomy between 1st of January 2013 and 31st December 2013. The median age of the patients was 67 years (range 18-98), with 166 males and 165 females. The 30-day mortality rate was 16.9% (56/331 patients), 90-day mortality rate was 19.9% (66/331) and overall mortality with median follow-up 10.1 months (range 2.1 – 15.9 months) was 24.5% (81/331). At the time of data analysis, 67 of the 81 deceased patients died during their primary admission (82.7%). The median length of stay was 15 days (range 1 – 457) and unplanned hospital re-admission within 30 days of discharge occurred in 47 patients (47/260, 18.1%).

Fourteen patients died following discharge from hospital although 5 of these patients were following re-admission within 30 days of discharge. ASA data for 5 patients was not documented at the time of surgery and IMD data was missing for 9 patients due to their postcodes not being assigned to an LSOA by the Welsh Government or because they were from outside Wales; these patients were excluded from analysis but the data is presented in table 3.

Mortality at 30 days and 90 days are shown related to age by decade (Table 2a), by gender (Table 3b), by ASA groups (Table 3c) and by IMD quintile (Table 3d)

Analysis of the non-parametric Spearman's rank correlation coefficients (Table 4) shows ASA is significantly correlated with age groups (Spearman's rho 0.281, $p<0.001$) but this was not sufficient to recommend ASA to be excluded from the model. Furthermore, it was considered an important proxy of co-morbidities at the time of laparotomy. Gender correlated with age groups (Spearman's rho -0.137, $p=0.013$), there were greater than twice as many females in the older age groups (48F vs. 22M, Table 3a). The correlation coefficients of the other explanatory variables suggest that relationships between the variables exist, in particular between age and the other variables (gender, IMD quintile) however according to Cohen's correlation effect size measure they are medium size at most, so all of the variables were taken forward into the model.

2.5.2 Univariable Analysis

2.5.2.1 Variables related to 30-day Mortality

Initial analyses was performed to assess the relationship between the variables (Pearson chi-squared, Table 3) and based on these results and clinical judgement (age being an important factor), we proceeded to univariable

analysis. The variables potentially associated with 30-day and 90-day mortality are shown in Tables 5 and 6.

On univariable binary logistic regression analysis (Table 5), variables related to 30-day mortality were age (p=0.004) and ASA (p<0.001), IMD quintile was close to significance (p=0.061) and gender was not (p=0.575). Further examination of the data found that, relative to age <50, age ≥80 (OR 6.214, C.I 1.998 - 19.331, p=0.002) and age 70-79 (OR 4.296, C.I 1.351 - 13.659, p=0.014) were significantly related to 30-day mortality. Relative to ASA grades 1 or 2, ASA 4 or 5 (OR 19.000, C.I 7.430 – 48.588, p<0.001) and ASA 3 (OR 3.393, C.I 1.314 – 8.763, p<0.001) were also associated with 30-day mortality. Relative to the least deprived quintile, the IMD quintile associated with 30-day mortality was the second most deprived (OR 4.111, C.I 1.510 - 11.190, p=0.006).

2.5.2.2 Variables related to 90-day Mortality

Variables associated with 90-day mortality were age (p=0.001), ASA (p<0.001), IMD quintile (p=0.031) but not gender (p=0.179). Using the same reference groups, age ≥ 80 (OR 6.333, C.I 2.246 - 17.859, p<0.001), age 70-79 (OR 4.247, C.I 1.479 - 12.198, p=0.007), ASA 4&5 (OR 18.512, C.I 6.770 – 50.618, p<0.001), ASA 3 (OR 3.172, C.I 1.125 – 8.947, p=0.029), the most deprived and second most deprived IMD quintiles (OR 2.297, C.I 1.047 - 5.038, p=0.038 and OR 4.171, C.I 1.582 - 10.998, p=0.004 respectively) were associated with 90-day mortality {Table 5}.

2.5.3 Multivariable Analysis

2.5.3.1 Variables related to 30-day Mortality

Table 6 shows the final model of binary logistic regression with all variables included, and 30-day and 90-day mortality as outcomes. When each of the

variables is adjusted for, there are minor changes when compared with the unadjusted results. Overall, the variable associated with 30-day mortality is ASA (p<0.001); age is of borderline significance (p=0.051), gender is not (p=0.818) nor is IMD quintile (p=0.186). Using the same reference groups, age ≥80 years is significantly related to 30-day mortality (OR 3.479, C.I 0.951-12.731, p=0.019) and age 70-79 years nearly reaches significance (OR 2.683, C.I 0.737-9.763, p=0.058). ASA grades 4 or 5 (OR 13.652, C.I 4.699-39.662, p<0.001), and the second most deprived IMD quintile (OR 3.711, C.I 1.130-13.198, p=0.031) are associated with 30-day mortality. The most deprived IMD quintile nearly reaches significance (OR 2.340, C.I 0.887-6.173, p=0.086). Females are less likely than males to die within 30-days or 90-days of emergency laparotomy (OR 0.919, C.I 0.449-1.883, p=0.818, OR 0.670, C.I 0.333-1.345, p=0.259 respectively).

2.5.3.2 Variables related to 90-day Mortality

Overall, variables related to 90-day mortality are age (p=0.003) and ASA (p<0.001), IMD is close to significance (p=0.053) and gender is not related (0.259). With regard to the reference groups, age over 80 years and age 70-79 years (OR 13.646, C.I 2.484-74.960, p=0.003, OR 6.699, C.I 1.277-35.151, p=0.025 respectively), ASA grades 4 or 5 (OR 14.311, C.I 5.205-39.347, p<0.001), the most and second most deprived quintiles (OR 3.218, C.I 1.254-8.259, p=0.015, OR 3.768, C.I 1.169-12.147, p=0.026, respectively).

2.5.4 Length of Stay

At the point of analysis, patients who died in hospital and 4 in-patients were censored. The median length of stay for all patients was 15 days (1-457). Age is related to LOS (p=0.031); patients aged >80 years spend twice in long in

hospital than those <50 years (median 20 vs.10 days, Table 3a). Males and females have similar LOS (median 14 vs. 15 days, p=0.551, Table 3b). Higher ASA grades are associated with a longer LOS; median LOS is 19 days for patients with ASA grades 4 or 5, and 11 days for patients with ASA grades 1 or 2 (p<0.001, Table 3c). Patients in the most deprived IMD quintile have median LOS is 17 days compared to 12 days for those in the least deprived IMD quintile, although this finding is not significant (p=0.614, Table 3d).

2.5.5 Survival

A Cox proportional hazard regression survival analysis was performed. The cumulative overall survival is shown in Figure 1. Gender, age groups, ASA groups and IMD quintiles were added to the model both individually and altogether and survival plots are shown in Figures 2-9. Tables 7 and 8 show minimal change in the results before and after adjustment with the most and 2nd most deprived quintiles showing a significant hazard ratio (HR 2.375, C.I 1.197–4.712, p=0.013; HR 3.663, C.I 1.629–8.239, p=0.002, most and 2nd most deprived respectively) with the least deprived quintile being the reference category.

2.6 Discussion

This is the first study to examine the relationship between deprivation and emergency laparotomy outcome, and the principal findings were that 30-day mortality and 90-mortaltiy were relatively high (16.9%, 19.9% respectively), and mortality was related to deprivation, advanced age, and higher ASA grades, but not gender. Despite the strong positive statistically significant correlation

between age and ASA grade, they remain independent prognostic variables. Patients with ASA grades 4 or 5, remain significantly more likely to experience 30-day (44.6% vs. 4.2%, p<0.001) and 90-day mortality (50% vs. 5%, p<0.001) than those with ASA grades 1 or 2 although the size of the effect is reduced once ASA is adjusted for the other variables. Patients with ASA grade 3 also have more favourable outcomes than those with ASA grades 4 or 5; 30-day mortality of 12.1% vs. 4.2% and 90-day mortality of 15.2% vs. 5%. It is expected that patients with higher ASA grades at the time of emergency laparotomy will have worse outcomes, but this study highlights that the difference in mortality between patients with ASA grades 1 or 2, and grades 4 or 5, is ten-fold and that most of the operative deaths occur in the first 30 days. Consideration of these high mortality rates may help clinicians to make decisions regarding patient selection, assist in the consent process and guide post-operative care decisions, and should be used in conjunction with other risk assessment tools such as P-POSSUM or the NELA risk calculator, to individualise patients' risk assessment. The frailty index (FI) was introduced more than a decade ago by Dr K Rockwood and Dr A Mitnitski in Canada and is a useful tool for assessing the health status of individuals and for risk prediction of adverse health outcomes (Rockwood et al. 2008). It is constructed as the proportion of age-related deficits accumulated by an individual; the deficits include diseases, signs, symptoms, laboratory abnormalities, or functional or cognitive impairments. The more deficits an individual has, the higher their fragility index and the more at risk they are to adverse outcomes.

The magnitude of the effect of age in 30-day and 90-day mortality was stark. Comparing the extremes of the age groups (<50 years vs ≥80 years), we saw a five-fold (6.5% vs 30%) difference for 30-day mortality and four-fold difference for 90-day mortality (8.1% to 35.7%). The effect of age on 30-day and 90-day mortality seems to begin to become significant over the age of 70 years.

Original work by the UK Emergency Laparotomy Network (ELN, 1,853 patients) reported an unadjusted OM rate of 14.9%, rising to 24.4% for patients aged over the age of 80 years (Barrow et al. 2013). Other studies have shown that operative mortality increases exponentially with age (Turrentine et al. 2006) and especially so after emergency colorectal surgery. Lidsky and colleagues (2012) again reported mortality rates in the elderly undergoing emergency surgery for diverticulitis nearly 10-fold higher in older patients. They used data on 2,264 patients collected by the American College of Surgeons National Surgical Quality Improvement Program 2005–2009 for all patients undergoing emergency surgery for diverticulitis and used multivariable logistic regression to determine the association between age and post-operative morbidity and mortality after adjustment for peri-operative variables. They reported data on 1,267 patients who were nonelderly (< 65 years), 648 elderly (65-79 years) and 349 super-elderly (>85 years) and found that, among those patients >65 years, being super-elderly was a significant predictor of mortality after adjustment for post-operative complications (Lidsky 2012). In an older, smaller study of 107 patients, Cook et al. found that 44% of patients over the age of 65 years die before leaving hospital however their study included patients undergoing laparotomy for repair of abdominal aortic aneurysm, and this may have led to higher mortality rates due to the high risk nature of the procedure (Cook and Day 1998). Louis et al. (2009) also reported that emergency surgery on the intestinal tract is associated with significant morbidity and mortality in octogenarians with a mortality rate of 32% for emergency colorectal surgery. Madsen et al. studied octogenarians in a Danish population and showed a 39% mortality rate for this cohort (Madsen 1993). Ford et al. performed a more recent study in the UK and found an emergency surgery mortality rate of 42% for this age group (Ford et al. 2007). Not all studies have reported poor outcomes for elderly patients. Arenal et al. studied 710 patients aged 70 years

or older who underwent emergency surgery for intra-abdominal disorders (Arenal and Bengoechea-Beeby 2003). Mortality was predicted by ASA grade (perioperative risk), delay in surgical treatment and conditions that permit only palliative surgery. Increasing age did not affect mortality, morbidity or length of hospital stay.

The relationship between multiple deprivation and mortality on the univariable analysis is interesting; when compared to the least deprived quintile, the second most deprived quintile is more significantly related to mortality than the most deprived quintile, but this may be due to sample size. The difference in mortality between the least and most deprived quintiles is only seen at 90 days (Table 5). The increase in 30-day mortality from 10.8% for the least derived quintile to 18.8% for the most deprived quintile did not reach statistical significance (p=0.086) on the multivariable analysis (Table 6). The effect on 90-day mortality was more pronounced; 23.9% for the most deprived quintile vs.12% for the least deprived quintile (p=0.015), suggesting that multiple deprivation may be more influential on late mortality and only when other factors are accounted for. The 2nd most deprived quintile significantly differs from the least deprived quintile, the confidence intervals are heavily skewed suggesting that, with increased numbers, this result would become statistically significant.

Gender is not a significant predictive factor for 30-day and 90-day mortality but it is closer to reaching significance at 90 days suggesting that gender may have a greater influence on mortality as time goes on. Patients residing in deprived geographical areas were more likely to have longer durations of hospital stay although this was not significant (median 17 vs. 12 days, p=0.614). The effect of IMD on survival is largely independent of age, gender and ASA.

There are several potential limitations to this study. Deprivation exists in a number of forms and such multimodal complexity makes quantification challenging. Important discrepancies in outcome and duration of survival

between patients from different socio-economic backgrounds were identified, but no explanation emerged as to why this should be so. This study used deprivation scores measured at the area level, i.e. each individual was given a score based on the degree of deprivation of their local community. The use of such area-based deprivation scores, as opposed to individual-based scores, calculated on individuals' incomes or occupations, does introduce potential bias, given that it is unlikely that all residents of a specific postcode will have the attributes of that community, but WIMD is the only validated tool for the assessment of deprivation within Wales. There is a clear distinction between poverty (insufficient financial resources) and deprivation (insufficient multiple resources, including financial). Survival was calculated using all-cause mortality and this is of particular relevance when considering deprivation, as patients from more deprived areas have a higher proportion of many chronic diseases, and their mortality is therefore higher than that of patients from more socio-economically advantaged areas. This latter point is, however, controversial as it has previously been reported that disease-specific mortality provides the most accurate measure of survival, when no information regarding comorbidity is available (Morgan et al. 2007). This was a comparative study, and the definition and analysis of subgroups within a study may lead to bias, while comparisons of groups may prove to be not statistically significant simply because the study has insufficient power to demonstrate real differences. The use of quintiles (as opposed to quartiles or deciles) was arbitrary, and it is not clear from the results presented here whether there is an analogue correlation between deprivation and outcome, or whether the effect is binary, with a critical level of deprivation above which adverse outcomes become more likely. WIMD 2011 has now been replaced with WIMD 2014, following the discovery of an error in the income indicator data relating to exclusion of tax credit data (WIMD 2011). Relatively few of the LSOAs move between WIMD deciles (less than 5%) and no LSOAs

move by more than one decile, so the net effect is considered likely to be negligible (WIMD 2014).

The strengths of the study are that prospectively collected data for unselected consecutive patients from a well-defined geographical area were used, a significant proportion of whom reside in areas shown to be amongst the most deprived in the United Kingdom. Access to the IMDs for over 99.9% of all the patients adds further strength. The prognostic data are especially robust, with all patients followed up for at least 12 months or until death.

Cofounding factors such as travelling distances to hospital were considered. To ascertain whether the travelling distances, which patients had to make to obtain emergency surgical care could be analysed, the Social Justice Statistics Department within Knowledge and Analytical Services of the Welsh Government was contacted. Unfortunately this data is not currently captured and they advised that 'access to services' is unlike the other seven domains of the IMD (which can be considered independently) and should be considered as a contributory factor that can compound other types of deprivation.

The 2011 version of WIMD was used in this study. An updated index was published in 2014 and a consultation process was held to disseminate the proposals for the new domains and indicators and was open to all individuals and organisations. One of the questions posed was 'What are your views on the selected calculation of travel times method?'. Specifically, travel distances to 'Accident and Emergency Hospitals' was discussed but because the services were deemed to have more infrequent use, be less local than other healthcare services, and involve free hospital transport and ambulances, the Welsh Government decided not to include this data in the Domains and Indicators of the WIMD 2014.

The Welsh Ambulance Service was contacted to obtain information on their transport times and call out details according to postcode. Their data is

collected according to Middle Layer SOAs, which in contrast to the Lower Layer SOAs used in the WIMD which have a mean population size of 1,500, the Middle Layer SOAs have a mean size of 7,200. It was therefore not possible to perform statistical analysis of deprivation using distance to hospital as a possible confounding factor.

Comparison of the maps in figures 10 and 11 shows that the patients who have furthest to travel i.e. those coming from West Vale of Glamorgan reside in areas which are least deprived. Despite the difficulties in accessing enough information to perform statistical analysis, it is unlikely that distance to hospital is not related to the effect of deprivation on emergency laparotomy outcomes within the Cardiff and Vale catchment areas.

Two large studies have shown that hospital variation may be responsible for high mortality rates in the elderly (Ingraham et al. 2011, Sheetz et al. 2013). This highlights the importance of early recognition and effective management of major complications in elderly populations thereby avoiding failure-to rescue. In the United Kingdom, the Department of Health produced the 2001 National Service Framework (NSF) for older people recognised that care of the elderly in hospital is complex (standard 4) (DOH 2001). It recommended that older patients should be supervised by a specialist team, and a consultant in old age medicine or rehabilitation should be involved in their care. The NCEPOD report 'An Age Old Problem. A review of the care received by elderly patients undergoing surgery' found that less that one quarter of surgical patients were reviewed by a medical specialist for the elderly before discharge (NCEPOD 2011). The routine implementation of this recommendation has scope to improve outcomes in the co-morbid elderly population in South Wales and but has not yet been accomplished in this institution.

2.7 Conclusion

The Acheson report in 1998 (DOH 1998) highlighted the need for global action to address the deep-seated inequalities in our health, and despite multiple UK Government interventions, the health gap between societies most and least deprived has failed to narrow, resulting in the introduction of further specific NHS targets (DOH 2009, DOH 2007, DOH 2003). As prognosis for patients requiring emergency laparotomy remains poor, the potential benefit from understanding and addressing reversible factors is substantial. Emergency General Surgery, poorly resourced for too long, has fallen significantly behind contemporary best specialty surgery related practice. The NELA report in 2016 combined data for years 1 and 2 of the audit reporting 30-day mortality figures of 11.4% and 90-day mortality of 15.6% (NELA 2016). They found that the 30-day mortality decreased by 0.6% in year 2 suggesting an overall improvement in patient outcomes. It is likely that the recent interest in emergency general surgery, dissemination of the NELA data, the introduction of emergency pathways, and focused training programmes for junior doctors, will continue to improve outcomes; our current 30-day mortality has reduced to 13.3%.

Table 1. Indices of Multiple Deprivation (IMD) of Welsh Government (WIMD) and their relative weight (Welsh Government, 2011)

Domain	Weight
Income	23.5%
Employment	23.5%
Health	14%
Education	14%
Access to Services	10%
Community Safety	5%
Physical Environment	5%
Housing	5%

Table 2. Procedures performed at Emergency Laparotomy

Procedure	Number of Cases (% total)
Proximal small bowel resection	46 (13.9)
Distal large bowel resection	62 (18.7)
Right hemicolectomy	28 (8.5)
Total colectomy	11 (3.3)
Defunctioning procedure	18 (5.4)
Palliative bypass	4 (1.2)
Repair of perforated UGI tract	21 (6.3)
Splenectomy	4 (1.2)
Incisional hernia repair	16 (4.8)
Parastomal hernia repair	6 (1.8)
Other hernia repair	4 (1.2)
Adhesionolysis	31 (9.4)
Post-operative complication procedure	15 (4.5)
Other	65 (19.6)

Table 3a. Demographics of patients in different Age groups who underwent Emergency Laparotom
other variables (gender, American Society of Anaesthesiology (ASA) groups and Index of Multiple Deprivat
90-day mortality and median length of stay (LOS). Statistical analysis results are shown as p values. [N=n

		Age (years)		
Variables	**p value**	**<50**	**50-59**	**60-69**
	Pearson Chi-squared			
M:F	p=0.002	34M:28F	26M:23F	45M:34F
ASA	p<0.001	N=61, m=1	N=48, m=1	N=78, m=1
Grades 1&2		41/61 (67.2%)	18/48 (37.5%)	25/78 (32.1%)
Grade 3		14/61 (23%)	22/48 (45.8%)	31/78 (39.7%)
Grades 4&5		6/61 (9.8%)	8/48 (16.7%)	22/78 (28.2%)
IMD Quintile	p=0.367	N=59, m=3	N=46, m=3	N=77, m=2
1 (most deprived)		26/59 (44.1%)	18/46 (39.1%)	32/77 (41.6%)
2		7/59 (11.9%)	6/46 (13.0%)	2/77 (0.1%)
3		8/59 (13.6%)	4/46 (8.7%)	14/77 (18.2%)
4		6/59 (10.2%)	6/46 (13.0%)	10/77 (13.0%)
5 (least deprived)		12/59 (20.3%)	12/46 (26.1%)	19/77 (24.7%)
30-day mortality	p<0.002	4/62 (6.5%)	6/49 (12.2%)	9/79 (11.4%)
90-day mortality	p<0.001	5/62 (8.1%)	7/49 (14.1%)	10/79 (12.7%)
	Kruskal-Wallis			
Median LOS in days (range)	0.031	10 (2-457)	15 (2-426)	13 (2-237)

Age (years)	p=0.016	N=166, m=0	N=165, m=0
<50		34/166 (20.5%)	28/165 (17.0%)
50-59		26/166 (15.7%)	23/165 (13.9%)
60-69		45/166 (26.5%)	34/165 (20.6%)
70-79		38/166 (22.9%)	32/165 (19.4%)
≥80		23/166 (13.9%)	48/165 (29.1%)
ASA	p=0.989	N=163, m=3	N=163, m=2
Grades 1&2		64/163 (39.3%)	56/163 (34.4%)
Grade 3		57/163 (35%)	75/163 (46%)
Grades 4&5		42/163 (25.8%)	32/163 (19.6%)
IMD Quintile	p=0.162	N=159, m=7	N=163, m=2
1 (most deprived)		63/159 (39.6%)	54/163 (33.1%)
2		19/159 (11.9%)	14/163 (8.6%)
3		21/159 (13.2%)	24/163 (14.7%)
4		17/159 (10.7%)	27/163 (16.6%)
5 (least deprived)		39/159 (24.5%)	44/163 (27.0%)
30-day mortality	p=0.576	38/166 (22.9%)	26/165 (15.8%)
90-day mortality	p=0.179	38/166 (22.9%)	28/165 (17%)
	Mann-Whitney U		
Median LOS in days (range)	0.551	14 (1-457)	15 (1-237)

Table 3c. Demographics of patients in different American Society of Anaesthesiology (ASA) groups who underwent Emergency Laparotomy. Also shown is the relationship with other variables (gender, age groups, Index of Multiple Deprivation {IMD} quintiles), 30-day mortality, 90-day mortality and median length of stay (LOS). Statistical analysis results are shown as p values. [N=non-missing data, m=missing data, (%)]

		ASA Groups				
	p value	**Grades 1&2**	**Grade 3**	**Grades 4&5**	**Missing Data (m)**	**Non-missing Data**
	Pearson Chi squared					
Gender	p=0.989	64M:56F	57M:75F	42M:32F	3M:2F	155M:143F
Age (years)	p<0.001	N=120, m=0	N=132, m=0	N=74, m=0	N=5	N=326
<50		41/120 (34.2%)	14/132 (10.6%)	6/74 (8.1%)	1/5 (20%)	61/326 (18.7%)
50-59		18/120 (15%)	22/132 (16.7%)	8/74 (10.8%)	1/5 (20%)	48/326 (14.7%)
60-69		25/120 (20.8%)	31/132 (23.5%)	22/74 (29.7%)	1/5 (20%)	78/326 (23.9%)
70-79		23/120 (19.2%)	32/132 (24.2%)	15/74 (20.3%)	0	70/326 (21.5%)
≥80		13/120 (10.8%)	33/132 (25%)	23/74 (31.1%)	2/5 (40%)	69/326 (21.2%)
IMD Quintile	p=0.231	N=117, m=3	N=128, m=4	N=72,m=2	N=5	N=326
IMD1 (most deprived)		41/117 935%)	48/128 (37.5%)	26/72 (36.1%)	2/5 (40%)	115/326 (35.3%)
IMD2		71/117 (6%)	15/128 (37.5%)	11/72 (15.3%)	0	97/326 (29.8%)
IMD3		16/117 (13.7%)	18/128 (14.1%)	10/72 (13.9%)	1/5 (20%)	44/326 (13.5%)
IMD4		19/117 (16.2%)	15/128 (11.7%)	10/72 (13.9%)	0	44/326 (13.5%)
IMD5 (least deprived)		34/117 (29.1%)	32/128 925%)	15/72 (20.8%)	2/5 (40%)	81/326 (24.8%)
30-day mortality	p<0.001	5/120 (4.2%)	16/132 (12.1%)	33/74 (44.6%)	2/5 (40%)	56/331 (16.9%)
90-day mortality	p<0.001	6/120 (5%)	20/132 (15.2%)	37/74 (50%)	3/5 (60%)	66/331 (19.9%)
	Kruskal-Wallis					

Median LOS in days (range)	<0.001	11 (1-224)	20 (3-457)	19 (1-237)	3 (1-15)	15 (1-426)

Table 3d. Demographics of patients in different Index of Multiple Deprivation (IMD) quintiles who underwent Emergency Laparotomy.

Also shown is the relationship between other variables (gender, age groups, American Society of Anaesthesiology (ASA) groups, 30-day mortality, 90-day mortality and length of stay (LOS). Statistical analysis results are shown as p values. [N=non-missing data, m=missing data, (%)]

		IMD Quintiles						
	p value	**1 (most deprived)**	**2**	**3**	**4**	**5 (least deprived)**	**Missing Data**	**Non-missing Data**
	Pearson Chi-squared							
Gender	p=0.162	63M:54F	19M:14F	21M:24F	17M:27F	39M:44F	7M:2F	159M:163F
Age (years)	p=0.020	N=117, m=0	N=33, m=0	N=45, m=0	N=44, m=0	N=83, m=0	N=9	N=322
<50		26/117 (22.2%)	7/33 (21.2%)	8/45 (17.8%)	6/44 (13.6%)	12/83 (14.4%)	3/9 (33.3%)	59/322 (18.3%)
50-59		18/117 (15.4%)	6/33 (18.2%)	4/45 (8.9%)	6/44 (13.6%)	12/83 (14.4%)	3/9 (33.3%)	46/322 (14.3%)
60-69		32/117 (27.4%)	2/33 (6.1%)	14/45 (13.1%)	10/44 (22.7%)	19/83 (22.9%)	2/9 (22.2%)	77/322 (23.9%)
70-79		23/117 (19.7%)	11/33 (33.3%)	7/45 (15.6%)	11/44 (25%)	17/83 (20.5%)	1/9 (11.1%)	69/322 (21.4%)
≥80		18/117 (15.4%)	7/33 (21.2%)	12/45 (26.7%)	11/44 (25%)	23/83 (27.8%)	0/9 (0%)	71/322 (22.1%)
ASA	p=0.231	N=115, m=2	N=33, m=0	N=44, m=1	N=44, m=0	N=81, m=2	N=9	N=322
Grades 1&2		41/115 (35.7%)	7/33 (21.2%)	16/44 (36.4%)	19/44 (43.2%)	34/81 (42%)	3/9 (33.3%)	117/322 (36.3%)
Grade 3		48/115 (41.7%)	15/33 (45.5%	18/44 (40.9%)	15/44 (34.1%)	32/81 (39.5%)	4/9 (44.4%)	128/322 (39.8%)
Grades 4&5		26/115 (22.6%)	11/33 (33.3%)	10/44 (22.7%)	10/44 (22.7%)	15/81 (18.5%)	2/9 (22.2%)	72/322 (22.4%)
30-day mortality	p=0.073	22/117 (18.8%)	11/33 (33.3%)	6/45 (13.3%)	6/44 (13.6%)	9/83 (10.8%)	2/9 (22.2%)	54/322 (16.8%)

90-day mortality	p=0.014	28/117 (23.9%)	12/33 (36.4%)	8/45 (17.8%)	6/44 (13.6%)	10/83 (12%)	2/9 (22.2%)	64/322 (19.9%)
	Kruskal-Wallis							
Median LOS in days (range)	0.614	17 (1-457)	16 (1-68)	13 (4-215)	17.5 (3-233)	12 (1-237)	31 (5-219)	14 (1-457)

Age Groups	Correlation coefficient		1	0.282 (p<0.001)	0.130 (p=0.020)
ASA Groups	Correlation coefficient			1	-0.067 (p=0.231)
IMD Quintile	Correlation coefficient				1

Table 5. Univariable binary logistic regression analysis of variables (age groups, gender, American Society of Anaesthesiology {ASA} groups and Index of Multiple Deprivation {IMD} quintiles) related to 30-day Mortality and 90-day Mortality for patients undergoing Emergency Laparotomy.

	30 day mortality			**90 day mortality**		
Age	Overall p=0.004			Overall p=0.001		
	OR	**95% C.I**	**p value**	**OR**	**95% C.I**	**p value**
≥80	6.214	1.998 - 19.331	0.002	6.333	2.246 - 17.859	<0.001
70-79	4.296	1.351 - 13.659	0.014	4.247	1.479 - 12.198	0.007
60-69	1.864	0.546 - 6.366	0.320	1.652	0.534 - 5.111	0.384
50-59	2.023	0.538 - 7.613	0.297	1.900	0.564 - 6.403	0.300
<50 (REF)						
Gender	Overall p=0.575			Overall p=0.179		
Female	0.848	0.477 - 1.508	0.575	0.688	0.399 - 1.187	0.179
Male (REF)						
ASA	Overall p<0.001			Overall p<0.001		
ASA 4&5	19.000	7.430 – 48.588	<0.001	18.512	6.770 – 50.618	<0.001
ASA 3	3.393	1.314 – 8.763	0.012	3.172	1.125 – 8.947	0.029

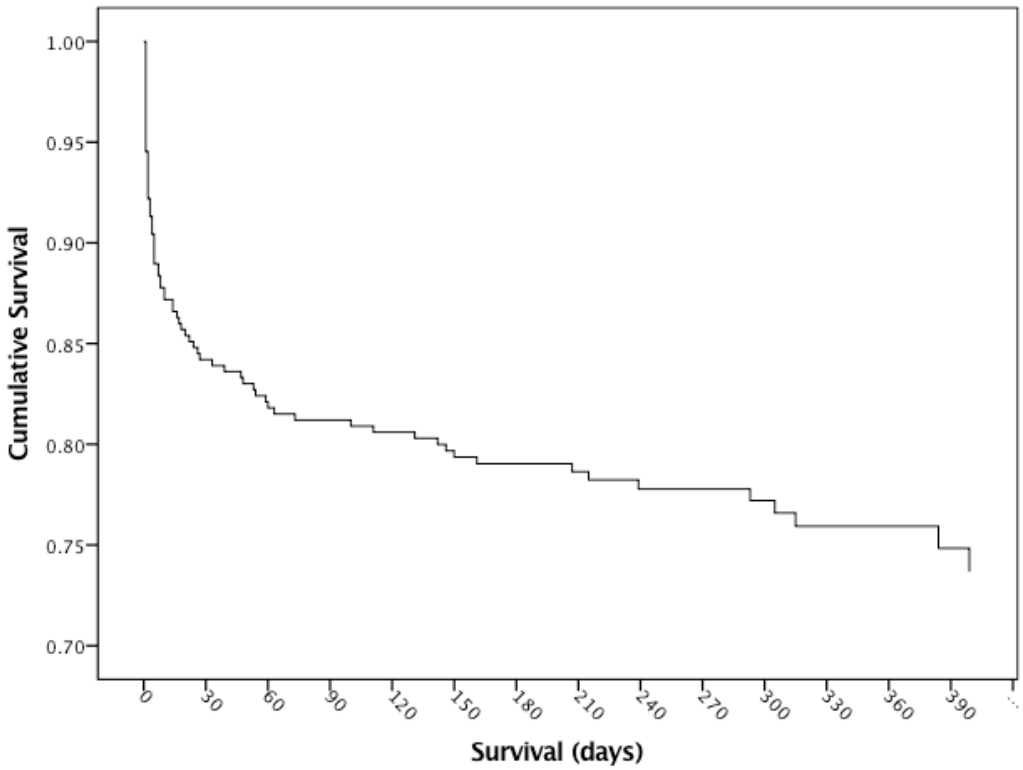
ASA 1&2 (REF)						
IMD Quintile	Overall p=0.061			Overall p=0.031		
1 (most deprived)	1.904	0.828 - 4.380	0.130	2.297	1.047 - 5.038	0.038
2	4.111	1.510 - 11.190	0.006	4.171	1.582 - 10.998	0.004
3	1.265	0.420 - 3.813	0.676	1.578	0.575 - 4.335	0.376
4	1.298	0.430 - 3.918	0.643	1.153	0.389 - 3.413	0.789
5 (least deprived, REF)						

Table 6. Multivariable binary logistic regression analysis (adjusted) of variables (age groups, gender, American Society of Anaesthesiology {ASA} groups and Index of Multiple Deprivation quintiles) related to 30-day Mortality and 90-day Mortality for patients undergoing Emergency Laparotomy.

	30 day mortality			**90 day mortality**		
Age	Overall p=0.051			Overall p=0.003		
	OR	**95% C.I**	**p value**	**OR**	**95% C.I**	**p value**
≥80	3.479	0.951 - 12.731	0.060	13.646	2.484 - 74.960	<0.001
70-79	2.683	0.737 - 9.763	0.134	6.699	1.277 - 35.151	0.025
60-69	1.066	0.272 - 4.174	0.927	1.477	0.251 - 8.694	0.666
50-59	0.924	0.192 - 4.448	0.922	2.664	0.421 - 16.862	0.298
<50 (REF)						
Gender	Overall p=0.818			Overall p=0.259		
Female	0.919	0.449 - 1.883	0.818	0.670	0.333 - 1.345	0.259
Male (REF)						
ASA	Overall p<0.001			Overall p<0.001		
Grades 4&5	13.652	4.699 - 39.662	<0.001	14.311	5.205 - 39.347	<0.001
Grade 3	2.146	0.716 - 6.428	0.173	2.243	0.815 - 6.173	0.118

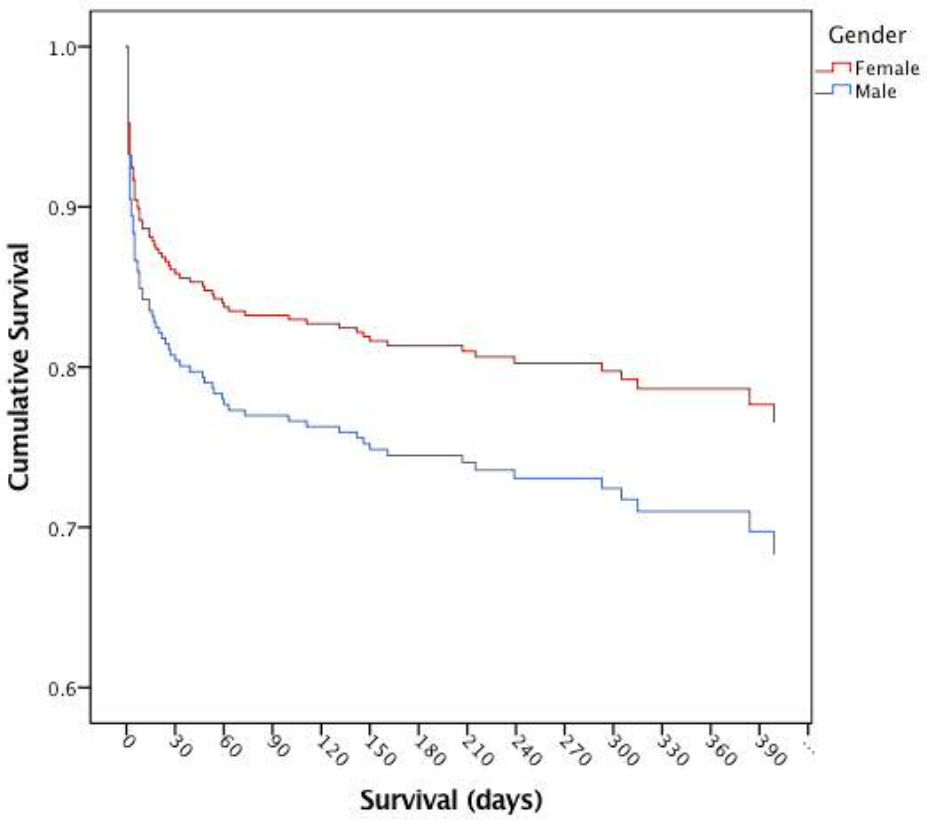
Grades 1&2 (REF)						
IMD Quintile	Overall p=0.186			Overall p=0.053		
1 (most deprived)	2.340	0.887 - 6.173	0.086	3.218	1.254 - 8.259	0.015
2	3.711	1.130 - 13.189	0.031	3.768	1.169 - 12.147	0.026
3	1.347	0.386 - 4.698	0.640	1.487	0.442 - 4.998	0.521
4	1.287	0.364 - 4.513	0.699	1.144	0.326 - 4.001	0.833
5 (least deprived, REF)						

Figure 1. Survival Plot for all patients following Emergency Laparotomy



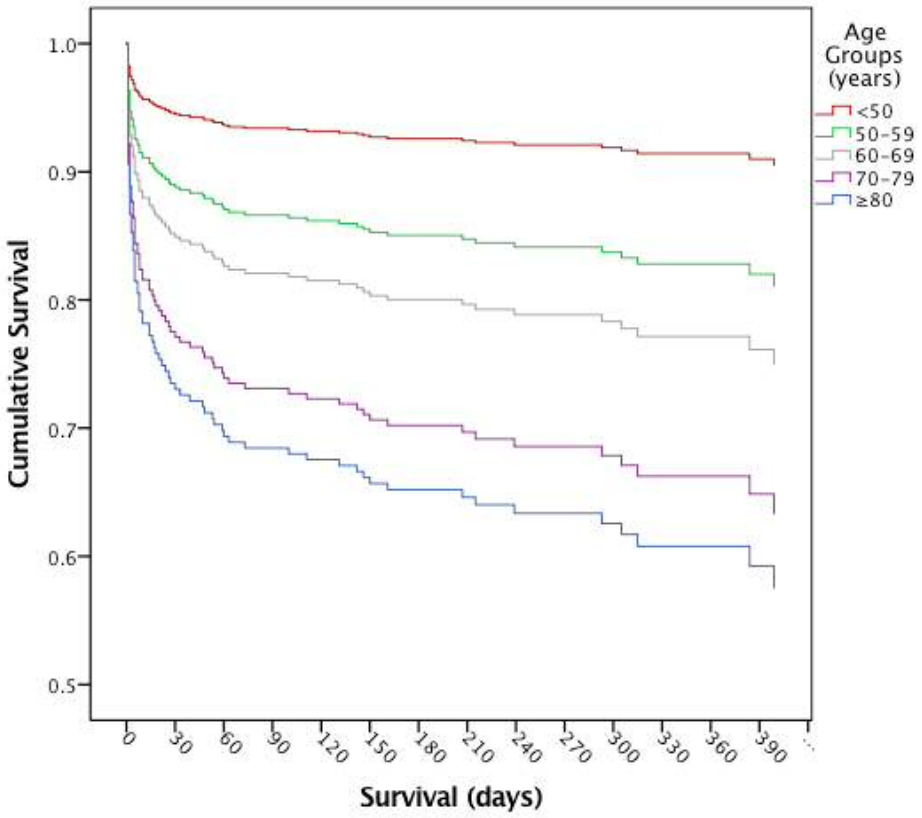
Time (days)	30	60	90	120	180	240	300
No. at risk	275	267	265	263	218	168	130

Figure 2. Survival Plot for Males and Females following Emergency Laparotomy



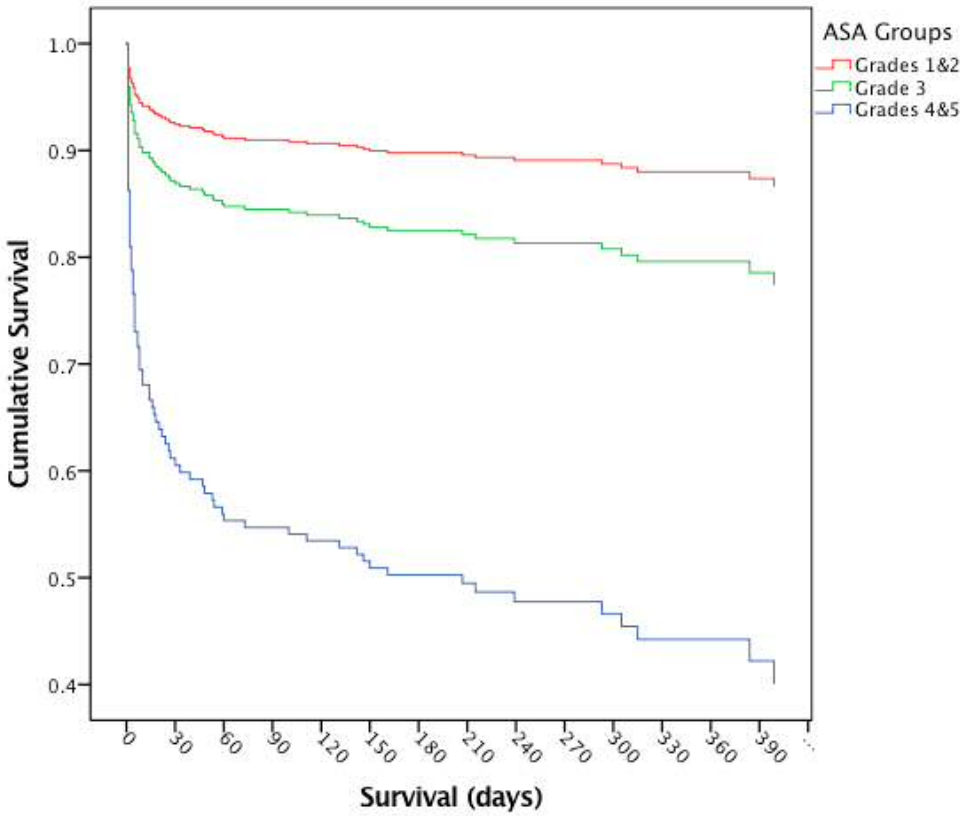
Time (days)	30	60	90	120	180	240	300
No. at Risk							
Female	139	137	137	136	115	86	69
Male	136	130	128	127	103	82	61

Figure 3. Survival Plots for patients in different Age groups following Emergency Laparotomy



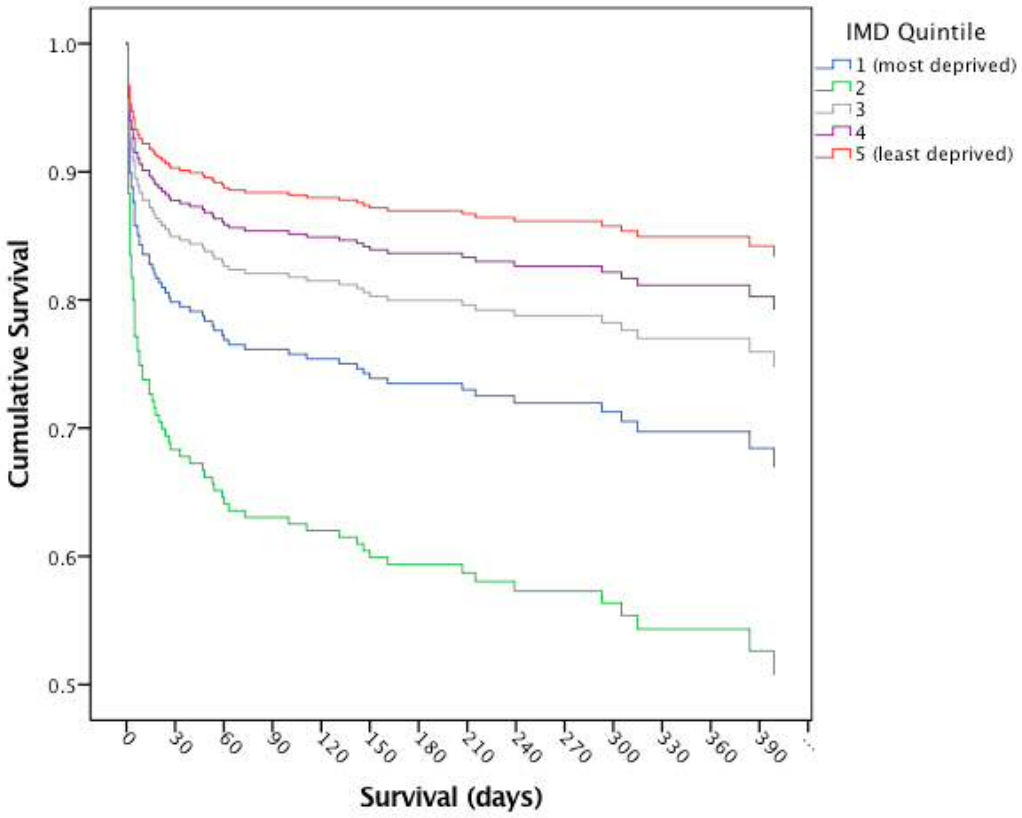
Time (days)	30	60	90	120	180	240	300
No. at Risk According to Age Groups							
<50	58	58	57	57	45	36	26
50-59	43	42	42	41	32	24	19
60-69	70	69	69	68	60	43	36
70-79	53	51	51	51	42	33	24
≥80	52	47	46	46	39	32	25

Figure 4. Survival Plots for patients in different American Socety of Anaesthesiology (ASA) groups following Emergency Laparotomy



Time (days)	30	60	90	120	180	240	300
No. at Risk According to ASA Groups							
Grades 1&2	115	114	114	114	93	76	58
Grade 3	116	112	112	110	92	69	53
Grades 4&5	41	38	37	37	31	21	17

Figure 5. Survival Plots for patients in different Index of Multiple Deprivation (IMD) Quintiles following Emergency Laparotomy



Time (days)	30	60	90	120	180	240	300
No. at Risk according to IMD Quintiles (Q)							
Q 1	94	89	89	88	75	59	50
Q 2	22	21	21	20	16	10	6
Q 3	39	38	37	37	32	23	19
Q 4	38	38	38	38	32	24	18
Q 5	75	74	73	73	60	49	35

Table 6. Univariate Cox Regression analysis for variables (gender, age groups, American Society of Anaesthesiology {ASA} groups and Index of Multiple Deprivation quintiles) related to Survival following Emergency Laparotomy

Variable	HR	95% C.I	p value
Gender			
Female	0.701	0.451 – 1.090	0.115
Male (REF)			
Age (years)			
≥80	5.549	2.136 – 14.415	<0.001
70-79	4.588	1.744 – 12.070	0.002
60-69	2.890	1.073 – 7.785	0.036
50-59	2.102	0.688 – 6.426	0.192
<50 (REF)			0.001
ASA Groups			
Grades 4&5	6.383	3.450 – 11.810	<0.001
Grade 3	1.785	0.932 – 3.419	0.081
Grades 1&2 (REF)			<0.001
IMD Quintile			
1 (most deprived)	2.207	1.146 – 4.252	0.018
2	3.735	1.726 – 8.085	0.001
3	1.600	0.691 – 3.705	0.273
4	1.279	0.523 – 3.129	0.590
5 (least deprived, REF)			0.009

Figure 6. Survival Plots for Males and Females following Emergency Laparotomy (adjusted)

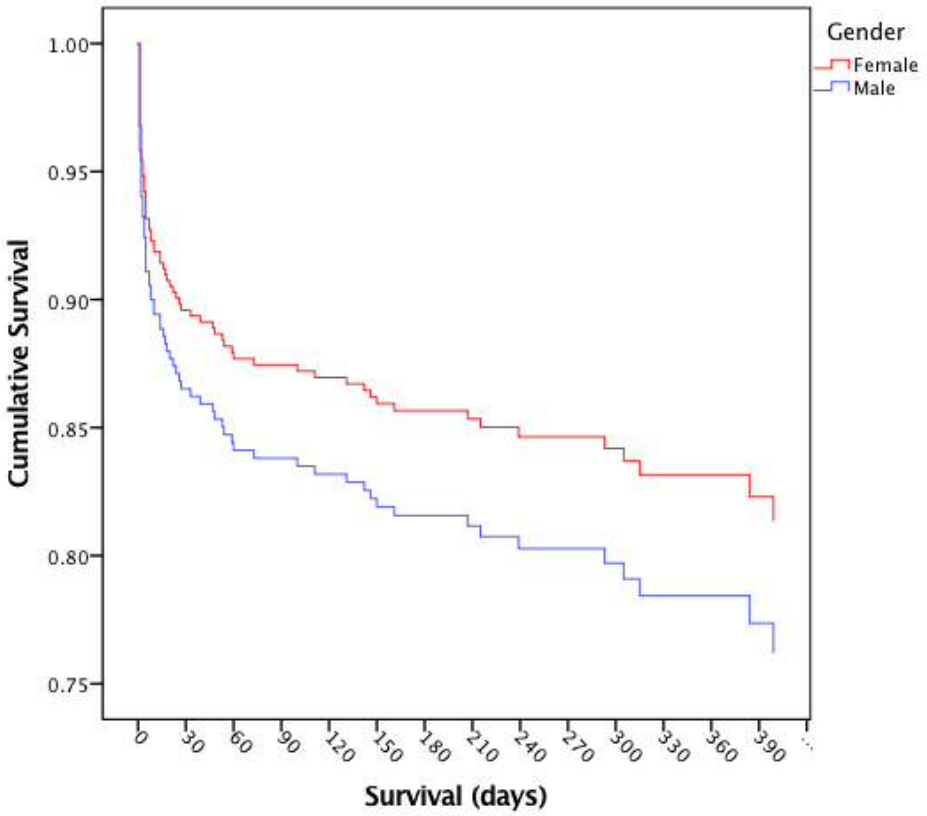


Figure 7. Survival Plots for patients in different Age groups following Emergency Laparotomy (adjusted)

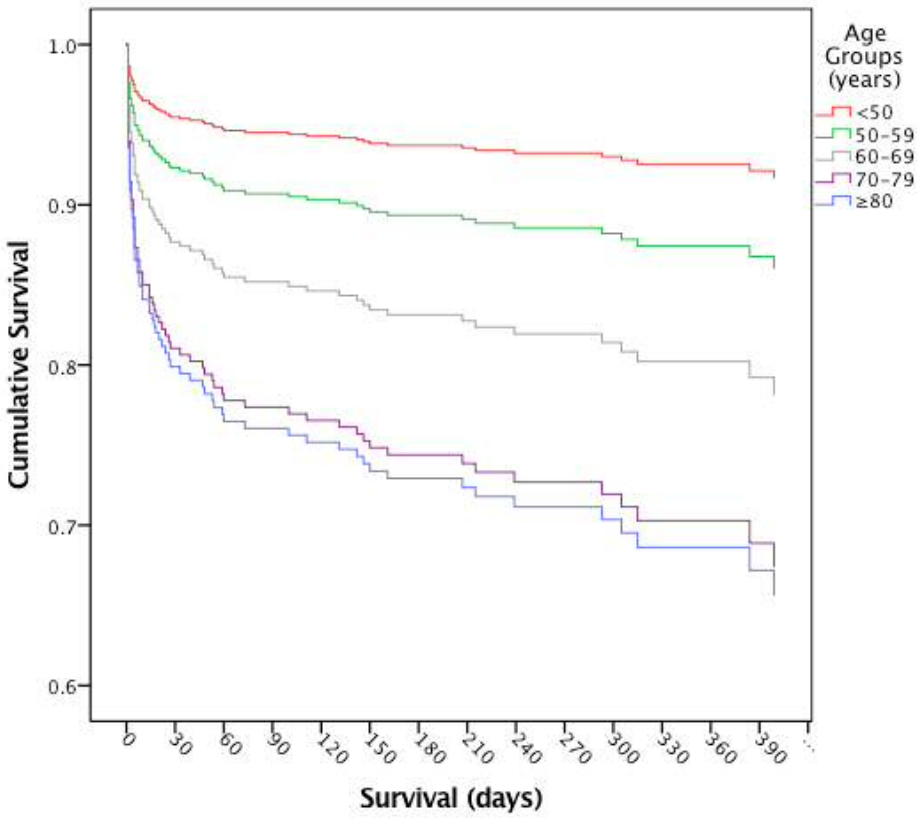


Figure 8. Survival Plots for patients in different American Society of Anaesthesiology (ASA) groups following Emergency Laparotomy (adjusted)

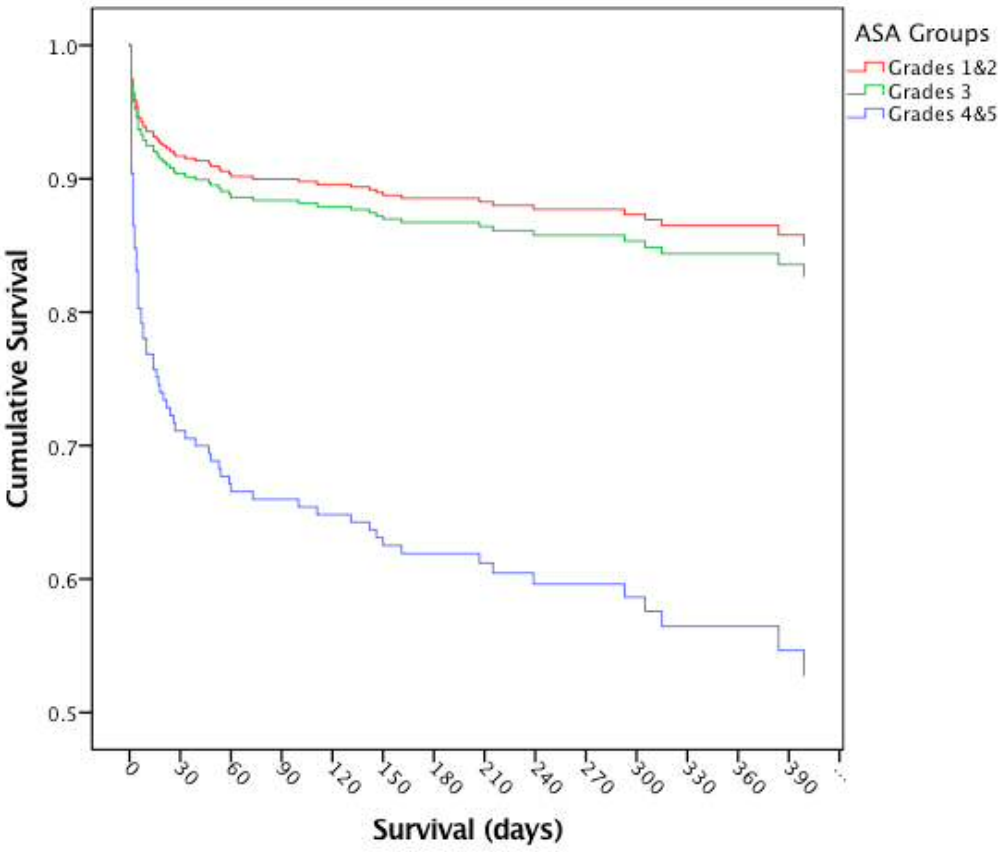


Figure 9. Survival Plots for patients in different Index of Multiple Deprivation (IMD) quintiles following Emergency Laparotomy (adjusted)

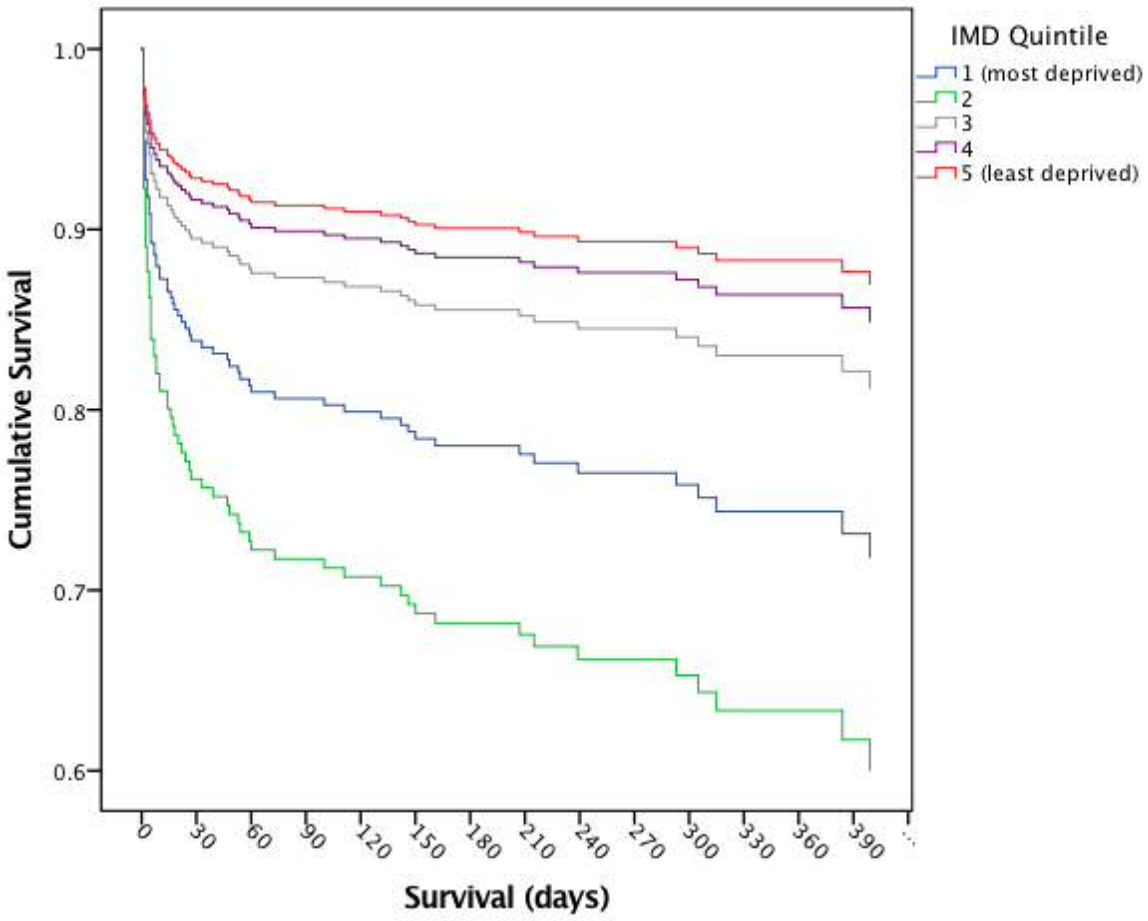


Table 7. Cox regression analysis for variables (gender, age groups, American Society of Anaesthesiology {ASA} grades and Index of Multiple Deprivation quintiles) related to survival following Emergency Laparotomy (adjusted)

Variable	HR	95% C.I	p value
Gender			
Female	0.759	0.472 – 1.222	0.256
Male (REF)			
Age groups (years)			
≥80	4.856	1.597 – 14.766	0.005
70-79	4.549	1.529 – 13.538	0.006
60-69	2.842	0.928 – 8.700	0.067
50-59	1.732	0.481 – 6.241	0.401
<50 (REF)			0.011
ASA			
Grades 4&5	3.939	2.035 – 7.623	<0.001
Grade 3	1.170	0.594 – 2.306	0.650
Grades 1&2 (REF)			<0.001
IMD Quintile			
1 (most deprived)	2.375	1.197 – 4.712	0.013
2	3.663	1.629 – 8.239	0.002
3	1.494	0.616 – 3.622	0.374
4	1.174	0.469 – 2.943	0.732
5 (least deprived, REF)			0.008

Figure 10. Colour scale for Deprivation ranks for areas within Cardiff and Vale. Adapted from https://statswales.wales.gov.uk/Catalogue/Community-Safety-and-Social-Inclusion/Welsh-Index-of-Multiple-Deprivation/WIMD-2011/All-Wales-Maps Accessed 10th May 2016

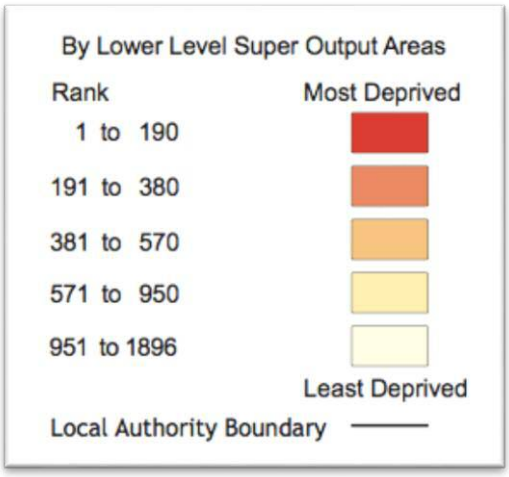
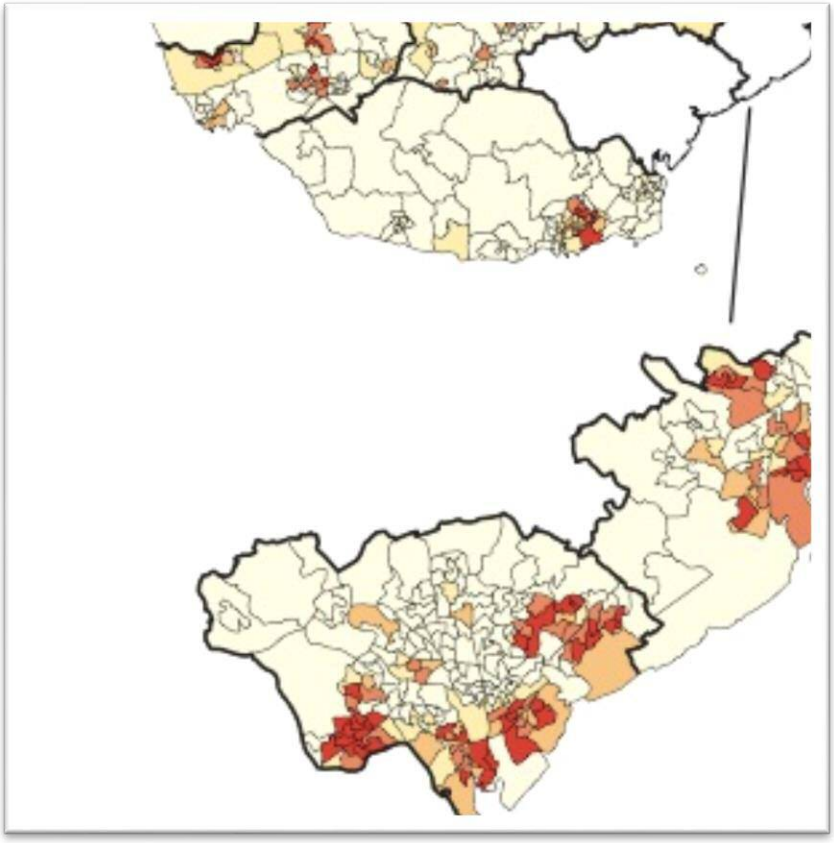


Figure 11. Map showing the two areas comprising Cardiff and Vale Health Board. Adapted from https://statswales.wales.gov.uk/Catalogue/Community-Safety-and-Social-Inclusion/Welsh-Index-of-Multiple-Deprivation/WIMD-2011/All-Wales-Maps Accessed 10th May 2016



Chapter 3: Relative accuracy of emergency CT in adults with non- traumatic abdominal pain

3.1 Abstract

Objective: CT examination prior to emergency laparotomy has become ubiquitous in contemporary clinical practice, but the relative accuracy of CT in this context has not been widely reported. The aim of this study was to determine the accuracy and strength of agreement between the perceived pre-operative CT diagnosis and operative findings.

Methods: Data from patients undergoing pre-operative CT prior to emergency laparotomy from January 2013 to June 2014 in a large teaching hospital were analysed. The CT diagnosis was compared with operative findings using the x^2 test and weighted kappa statistic (Kw). Results were further analysed related to the time of day the CT was reported, anatomical location and grade of the reporting radiologist.

Results: 361 patients [median age 67 years (18–98 years); 180 males] underwent CT prior to emergency laparotomy. CT reports were deemed accurate in 318 (88.1%) cases and inaccurate in 43 (11.9%) cases, which resulted in 5 negative laparotomies in this latter cohort (11.6%, x^2 37.50, df 1; p<0.0001). Accuracy and strength of agreement varied with anatomical location of the pathology; upper gastrointestinal (UGI) 75.5%, Kw 0.673 (0.531–0.815; p , 0.001); small bowel 89.9%, Kw 0.781 (0.687–0.875, p<0.001); lower gastrointestinal (LGI) 90.4%, Kw 0.821 (0.749–0.893; p<0.001). CT examinations reported within normal working hours had higher strength of agreement [Kw 0.832 (0.768–0.896), p<0.001] than CTs reported out of hours [Kw 0.789 (0.721–0.857), p<0.001], but there was no significant difference in overall accuracy (89.9 vs 86.0%; x^2 1.306, df 1, p=0.253). Reporter seniority was not associated with improved diagnostic accuracy (x^2 1.825, df 1; p=0.177).

Conclusion: CT agreement with emergency operative pathology was good to excellent, but the strength of agreement varied in relation to anatomical location

of pathology.

3.2 Introduction

3.2.1 Emergency General Surgery

Patients requiring emergency surgery are amongst the most sick patients managed by the National Health Service (NHS), and the delivery of emergency general surgery care is currently suboptimal (ASGBI 2012, RCS 2011, ASGBI 2015). For elderly, patients who are frail with significant comorbidities, the risk of death or serious complications is high. In general surgery alone, emergency cases account for 14,000 admissions to intensive care unit (ICU) in England and Wales annually, carrying a mortality rate of over 25% and associated costs of at least £88 million (ASGBI 2012, RCSEng 2011, RCSEng/DOH 2011). It is a key hospital service, which has seen significant and ongoing change over the last 15 years and requires further substantial development to meet the needs of contemporary NHS and society.

3.2.2 Radiological Assessment of Abdominal Pain

Assessment protocols for patients with abdominal pain vary, not only from hospital to hospital but internationally based on healthcare resource. The historical radiological assessment by plain abdominal and chest films is often superseded by CT (Fred HL 2004). While possessing self-evident advantages over plain-film radiology and ultrasonography in many instances, the modality still has limitations including expense, high radiation dose, limited availability compared with plain films and the potential for misinterpretation (van Randen et al. 2009, van Randen A et al. 2011). The NHS faces a significant reconfiguration of regional services and in many hospitals out-of-hours (OOH) radiology reporting is outsourced to external reporting services to meet increasing demand. This reduces the opportunity for initial ultrasound evaluation and face-

to-face discussion with image review between the operating surgeon and the reporting radiologist. Whether CTs are reported in-house or outsourced, the quality of radiology reporting must be high to ensure patient safety and help to facilitate optimal surgical outcomes.

3.2.3 Aims

The aim of this study was to determine the accuracy and strength of agreement between the pre-operative CT and emergency laparotomy findings in adult patients with non-traumatic abdominal pain, in the setting of unscheduled care in a UK teaching hospital serving a tertiary population of 1.4 million. Differences in CT findings between the timing of the examination, various anatomical locations and reporter seniority were assessed.

3.4 Methods and Materials

3.4.1 Data Collection

Evaluation of a surgical database containing details of the emergency laparotomy findings and review of the corresponding radiology CT report was carried out by a senior surgical trainee. Data were extracted from the running theatre database that records all operations performed within the large tertiary teaching hospital. Consecutive patients were identified who underwent both pre-operative CT (within 24h of operation) and operative assessment between 1 January 2013 and 30 June 2014. Data from the first 12 months of the study period were collected prospectively and subsequently analysed. However, to increase sample size and study power, a further 6 months of data were collected retrospectively and added to the original data set. The combined data

set was then analysed retrospectively. All adult patients undergoing their first emergency laparotomy over the 18-month period were included. Exclusion criteria were patients who underwent laparotomy without prior CT, primary procedures of the appendix or biliary tree, repeat laparotomies and patients in whom the CT findings led to laparoscopic investigation rather than emergency laparotomy. Appendix and biliary pathologies were excluded in line with the current National Emergency Laparotomy Audit methodology (NELA, 2015).

3.4.2 Computerised Tomography Protocol

All CT examinations were reported by radiologists working within the same NHS trust (in-house) rather than being out- sourced to external reporting services. CT examinations were performed with a GE HD 750 Discovery 64-slice scanner (GE Healthcare, Pollards Wood, Buckinghamshire, UK). A collimation of 40 mm, pitch of 0.984: 1 and tube rotation speed of 0.4 s were used. Tube output was 120 kVp with smart milliampere dose modulation between 60 and 600mA. Slice thickness was 0.625 mm with acquisition of images in coronal and sagittal planes using soft tissue and bone algorithms in 3-mm reconstructions. At this institution, standard protocols were used depending on the clinical indication for CT. A standard CT of the abdomen and pelvis was performed in the portal venous (PV) phase (timing 70 s) with positive oral contrast. 100ml of Niopam 300 was given intravenously (i.v) at 3–4 ml s^{-1}, followed by 20 ml of saline. 20 ml of Omnipaque 350 in 500 ml of water was used as oral contrast, 250 ml given 1 h prior to CT, 250 ml given 30 min prior to CT and 10–50 ml given immediately before scanning. i.v. contrast was withheld according to local guidelines in patients with impaired renal function or previous adverse reaction and where the clinical indication was for renal tract stones. Alternative CT protocols include investigation of small-bowel obstruction, performed with i.v. contrast in the PV

phase without oral contrast. Suspicion of bowel ischaemia was investigated with i.v. contrast in the arterial (timing 20–30 s) and PV phases without oral contrast. Investigation of gastrointestinal (GI) bleeding was performed in three phases: pre-contrast, arterial and PV phases without oral contrast. Laparotomies were performed in the emergency setting by senior surgical registrars or the on-call consultant surgeon within an appropriate timeframe, depending on clinical priority and following assessment by an on-call anaesthetist to assess pre-operative risk and comorbidities. The comparison between CT report and laparotomy was performed by a higher surgical trainee. However, any “grey” cases were discussed with a consultant surgeon before being marked accurate or inaccurate. No specific rules were applied in this process. The decision was based on surgical opinion.

3.4.3 Surgical Pathology

The patient cohort was subclassified based on the location of their pathology, i.e. upper gastrointestinal (UGI), small bowel, lower gastrointestinal (LGI), vascular and other (including gynaecological and anterior abdominal wall pathology) (Table 2). UGI pathology was defined as acute conditions involving the oesophagus, stomach and duodenum. Small-bowel pathology included those of the jejunum and ileum, and LGI pathology included the colon and rectum.

3.4.4 Computerised Tomography Reports

The patients were also subdivided into groups separated by the grade of CT reporter, either a training grade or consultant radiologist. CT reports were evaluated to assess whether or not the CT had been reviewed by a consultant

radiologist and those reviewed were further subdivided into absolute agreement, addendums or amendments. Addendums were defined as CT reports in which the reviewing radiologist essentially agreed with the original report, but added supplementary comments that were not clinically significant, e.g. incidental findings of cysts. Amendments were defined as supplementary reports which contained findings regarded as clinically significant by the reviewing radiologist. However, initial clinical management was based on the first report. Definitions of addendums and amendments were prespecified during the design of the study, prior to data collection. This study was deemed to be service evaluation rather than original research; therefore, ethical approval was not required.

3.5 Statistical analysis

The pre-operative CT diagnosis and the intraoperative surgical findings were compared, and overall accuracy was calculated. The weighted kappa statistic (Kw) (Landis and Koch 1977, McHugh 2012) was used as a novel method to provide a robust measure of strength of agreement, by taking into account the degree to which the report was inaccurate, when compared with the “gold-standard” operative pathological findings. To facilitate calculation of Kw, a virtual mathematical matrix was constructed so that different levels of agreement were classified related to the pathological findings found at operation. When UGI pathology was found at operation, and the CT reported small-bowel pathology, this was classified as 1 degree of error, and if colonic pathology was reported on CT, this was classified as 2 degrees of error. Similarly, addendums to reports were classified as 1 degree of error; amendments were classified as 2 degrees of error.

The maximum value of Kw is 1.00 when agreement is perfect; a value of 0 indicates no agreement better than chance, and negative values show worse than chance agreement. The hypothesis of Kw = 0 was tested, and the value of Kw was assessed for strength of agreement and categorized according to the method of Landis and Koch (Landis and Koch 1977). Intergroup comparison of overall accuracy between reporter seniority, timing of CT and anatomical location was made using the x^2 test (Altman 1991). A p-value of ≤0.05 was considered statistically significant. All statistical tests were pre-specified at the outset of the study prior to data collection and analysis. Data analysis was carried out with the SPSS® v. 13 (IBM Corp., New York, NY; formerly SPSS Inc., Chicago, IL).

3.6 Results

3.6.1 CT accuracy

A consecutive series of 519 patients undergoing emergency laparotomy were examined. 361 (69.6%) patients out of 519 patients underwent laparotomy following CT and were included in the study. The median age was 67 years (range 18 – 98 years); 177 patients were male and 184 patients were female. Table 1 details the diagnoses identified at laparotomy. Of the 361 cases included, 318 cases were found to have a correct diagnosis at CT, giving an overall CT accuracy of 88.1% (Table 2) and Kw of 0.812 [95% confidence interval (CI) 0.766–0.858, p<0.001]. In contrast, 43 cases were found to have incorrect diagnoses, which was associated with an incidence of 5 negative laparotomies (11.6%, x^2 37.50, df 1; p<0.0001).

3.6.2 Timing of Computerised Tomography and Reporting

189 (52.4%) CTs were performed in normal working hours from 8 AM to 5 PM, from Monday to Friday (excluding bank holidays). CTs performed and reported OOH accounted for the remaining 172 (47.6%) CTs. OOH CTs were further subdivided (Table 3) with 74 (20.5%) CTs of the overall scans performed at night (8.30 PM–8 AM), 63 (17.5%) CTs performed on a weekend day or bank holiday [from 5 PM Friday to 8.30 PM on Sunday (excluding nights)] and 35 (9.7%) CTs performed on weekday evenings (5 PM–8.30 PM).

3.6.3 Use of Computerised Tomography Contrast

Three hundred and forty-three (95.0%) CT protocols were contrast enhanced. 169 (46.8%) patients had i.v. contrast in PV phase only with 150 (41.6%) patients receiving oral contrast in addition. Eighteen (5.0%) patients had non-contrast scans owing to either clinical suspicion of calculi or contraindication to contrast media and 9 (2.5%) patients had oral contrast only. 9 (2.5%) patients had i.v. contrast in arterial and PV phases and 6 (1.6%) patients underwent pre-contrast arterial and PV phases. 186 (51.5%) CTs were reported by consultant radiologists and 175 (48.5%) CTs by training radiologists. 180 (95.2%) CTs performed in normal working hours were reported by consultant radiologists compared with 9 (4.8%) CTs reported by radiologists in training. Overall, CTs performed in normal working hours reported the highest overall accuracy (89.9%) (Table 3).

3.6.4 Seniority of Reporting Radiologists and Correlation with Accuracy of Reports

OOH CTs were largely reported by training radiologists (96.5%), with consultant reports accounting for 3.5% CTs (Table 3). The difference in reporting seniority grade within hours vs OOH was highly significant (x^2 303.498, 1 df; p<0.001). The overall accuracy of consultant reports was 90.3% compared with the training radiologist accuracy of 85.7%, but this difference was not statistically significant (x^2 1.825, df 1; p=0.177). The number of CTs reviewed by a consultant radiologist was assessed. Six out of 184 (3.3%) of consultant-reported CTs were reviewed. Four reports were not changed and two (1.1%) reports were given an addendum. There were no amendments. All of the 175 training radiologist reports were reviewed by consultants. There was absolute agreement in 95 (54.3%) reports. Eighty (45.7%) reports were changed (18 amendments, 62 addendums). Training radiologist CT reports were more likely to have an amendment or addendum than consultant reports (x^2 102.346, df 1; p<0.001); however, this may reflect the system of checking OOH CT scans by the on-call consultant the following morning. The timing of the CTs, when reports were reviewed by a consultant, was also evaluated. Four (2.1%) in-hours reports were subsequently changed (one amendment, three addendums). In contrast, 78 (45.4%) of OOH CT reports were changed (17 amendments, 61 addendums), following consultant review (x^2 95.874, df 1; p<0.001). The true significance, and in particular accuracy, of any changes made following consultant review is unknown, as the initial clinical management was based on the first report and will be the subject of a subsequent study.

There was no significant difference between the overall accuracy of normal working hours and OOH reports (89.9 vs 86.0%; x^2 1.306, df 1, p=0.253). Similarly, Kw for normal working-hour reports and OOH reports were 0.832

(95% CI 0.768–0.896, df 1; p<0.001) and 0.789 (95% CI 0.721–0.857; p<0.001), respectively. Although categorized by Landis and Koch as excellent and good strength of agreement, respectively, the CIs for each Kw overlap, which implies no difference between in-hours and OOH agreement (Landis and Koch, 1977).

3.6.5 Relationship between Report Accuracy and Location of Surgical Pathology

The commonest pathology was small bowel related in 149 (41.3%) patients, LGI in 146 (40.4%) patients, UGI in 49 (13.6%) patients, vascular in 6 (1.7%) patients and other pathology in 11 (3%) patients. Amongst the GI subdivisions, overall accuracy was highest in the LGI pathology group with 90.4% (in 132/146 patients), followed by small-bowel pathology, with an overall accuracy of 89.9% (in 134/149 patients). UGI pathology was least accurately reported (75.5%; in 37/49 patients). Presentations with vascular disease showed a CT accuracy of 100%. Pathologies determined as “other” had an accuracy of 81.8% (in 9/ 11 patients). The accuracy of UGI reports was significantly lower than that of small-bowel (x^2 6.513, df 1, p=0.011) and LGI reports (x^2 7.259, df 1, p=0.007). There was no significant difference between the accuracy of small-bowel and LGI reports (x^2 0.019, df 1; p=0.890). In addition, the strength of agreement varied with anatomical location of the pathology. UGI agreement was good (Kw 0.673, 95% CI 0.531–0.815, p<0.001), small-bowel agreement was good (Kw 0.781, 95% CI 0.687–0.875, p<0.001) and LGI agreement was excellent (Kw 0.821, 95% CI 0.749–0.893, p<0.001). Table 4 contains the Kw values relating to anatomical location of pathology and timing of CT reporting.

3.7 Discussion

This large observational cohort study examines the accuracy and strength of agreement between emergency abdominal CT examination and operative pathology in adult patients undergoing emergency non-traumatic laparotomy. The principal findings were that variations in diagnostic accuracy exist between anatomical pathological locations, with UGI pathology least accurately reported. Inaccurate CT diagnoses occurred in 11.9% of cases and were associated with a significant rate (11.6%) of avoidable negative laparotomy. Arguably, this may reflect reduced exposure of radiologists to acute UGI pathology, as there were approximately three times as many CTs performed for small-bowel and large-bowel pathologies when compared with UGI. This is also reflected in the lower Kw values (Table 4).

Approximately half of CT reporting was performed OOH, predominately by training radiologists, and later checked by a consultant radiologist. All reports by trainees were later reviewed by a consultant radiologist, which reflects a robust on-call review process within the department. However, the timing of review, accuracy of amendments and influence on surgical outcomes has not been assessed. The need for high-quality CT reporting relating to improved management of patients undergoing surgery has already been recognized by the Royal College of Radiologists, with recent publication of their audit of the 'Accuracy of Interpretation of Emergency Abdominal CT in Adult Patients Who Present with Non-Traumatic Abdominal Pain 2014' (Howlett et al. 2017). The audit reported on 4,931 patients (2,568 surgical, 2,363 non-surgical) from 109 UK departments and looked at discrepancy rates for CT reports. Audit standards for provisional CT report major discrepancy was achieved for training registrars (target <10%, achieved 4.6%), for on-site consultants (target <5%, achieved 3.1%) and consultant addendum (target <5%, achieved 2.9%) (Howlett et al.

2017). Off-site or outsourced reporters failed to meet the standard (target <5%, achieved 12.7% in surgical patients). These results are considered unfavourable by the radiology profession and meetings are planned later this year to discuss the challenges of OOH reporting. Our results are even less favourable and the department will engage with the RCR to improve outcomes.

The relative importance of various statistical analyses regarding accuracy of diagnostic tests varies according to the clinical situation. An emergency laparotomy is a high-risk operation, one defined as having an operative mortality of >5% by the National Emergency Laparotomy Audit (NELA 2015). Obtaining a correct diagnosis prior to emergency laparotomy is vital, especially in patients who are elderly or have significant comorbidities, where the risk of complication or death is high. Ideally, the best diagnostic test available would have 100% accuracy, sensitivity and specificity. A reduction in sensitivity will result in fewer "true-positive" CTs, meaning more patients will have a delay in treatment/laparotomy owing to a missed diagnosis. This increases the subsequent risk of morbidity and mortality associated with delayed surgery. A reduction in specificity results in more patients undergoing an emergency laparotomy owing to more "false positives" from "overcalls". This exposes the patient to the risks associated with unnecessary surgery.

The study has several strengths. Data were collected on a large cohort of patients in a UK teaching hospital. Evaluation of the reports by a senior surgical trainee, as described above, is pragmatic and reflects the "real world", which could be regarded as a further strength of this study. All emergency CTs were reported by in-house radiologists and not outsourced. Even with increasing use of outsourcing, this study remains relevant to emergency CT reporting. The results of this study are comparable with those reported in similar studies with accuracies of 82–87% (Weir-McCall et al. 2012, Priola et al. 2013, Salem et al. 2015). The results are also in keeping with reports of specific acute abdominal

diagnoses such as appendicitis with an accuracy of 80.6–99% (Gaitini et al. 2008, Hof et al. 2004, Raman et al. 2002) gastrointestinal perforation with an accuracy of 86% (Hainaux et al. 2006), bowel ischaemia with an accuracy of 79.2–81% (Wiesner et al. 2004, Jang et al. 2010), diverticulitis with an accuracy of 98% (Werner et al. 2003) and bowel obstruction with an accuracy of 65–97% (Barnett et al. 2013, Pongpornsup et al. 2009, Maglinte et al. 1993, Maglinte et al. 1996, , Megibow et al. 1994). However, the variable accuracy related to anatomical location of the pathology has not been described. Lameris et al conducted a large study including over 1000 patients investigating the diagnostic accuracy of different imaging strategies in acute abdominal pain (Lameris et al. 2009). The sensitivity of CT was found to be superior to ultrasound (89 vs 70%, p=0.001) and the study concluded that the best conditional strategy was initial ultrasound examination followed by CT in negative or inconclusive cases, which provided the highest sensitivity with the lowest overall radiation exposure. The diagnostic accuracy of ultrasound has not been investigated in this study, but the overall accuracy of CT reporting is in keeping with that reported by **Stoke**r (88.0% vs 89%). Weir-McCall et al reported a trend towards improved accuracy of consultant radiologist CT reports when compared with radiologists in training, with the duty registrar reports associated with a 78% diagnostic accuracy (Weir-McCall et al. 2012). The overall accuracy of the initial CT report by either registrar or consultant was 81%, which improved to 93% following review by a second consultant, although this difference was not significant (p=0.15). These findings are therefore consistent, and indeed again, no significant difference was found to be related to radiologist grade. Relative report accuracy following consultant radiologist review was not assessed in this study. This raises the question of what constitutes a clinically significant difference in overall CT accuracy between groups. Arguably, from statistical principles, since equivalence may be

interpreted as outcomes in numerical terms that approach each other to within a degree of 15%, then differences larger than this might be considered relevant. A figure in keeping with this could also be derived from a combination of this study's results (overall accuracy between training radiologists and consultants of 85.7–90.3%) and the report of Weir-McCall (range 78–93%), neither of which demonstrated a statistically significant difference related to overall accuracy (Weir-McCall et al. 2012).

This study has several potential limitations. No power calculation was performed prior to the study because of the relative lack of relevant literature available. Only patients who underwent laparotomy following CT were studied, i.e. patients who underwent surgical intervention during their hospital stay. This excludes assessment of the accuracy and benefit of CT in the group of patients with non-traumatic abdominal symptoms who are managed conservatively and do not proceed to emergency laparotomy. It was assumed that the CT report was correct in this cohort, but patients were reviewed and managed appropriately on an individual basis according to clinical symptoms and signs. Moreover, patients who underwent diagnostic laparoscopy as a result of their CT findings were not included. No specific rules were used to determine whether a "grey" case was deemed accurate or inaccurate. This decision was subjective, as the opinion of a consultant surgeon was used. The discrepancies were identified by the surgical authors and may arguably be judged to be too harsh from a radiological perspective. For example, the CT protocol varied, according to the clinical indication at the time of the referral, and no account for this was taken in the evaluation of the radiological report (Figure 1). This suggests the need for further education of surgeons regarding the limitations of certain CT protocols and may also reflect the need for reporting radiologists to clarify such limitations.

3.8 Conclusion

In conclusion, this study has shown that diagnostic accuracy varies with anatomical location and the strength of agreement between CT diagnosis, and operative pathology varied from good to excellent. The reason for the significantly lower accuracy of UGI pathology reporting is uncertain and may be related to exposure to caseload effect. Reassuringly, no significant difference was apparent in the diagnostic accuracy of CTs reported by consultant radiologists when compared with training radiologists. The overall high accuracy facilitates appropriate management decisions, aids pre-operative decision-making regarding surgical access and the choice of a surgeon of appropriate general surgical speciality and seniority, to perform the inherently high-risk procedure of emergency laparotomy, thus optimizing patient safety and minimizing risk.

Table 1. Patient diagnoses and anatomical location identified at Emergency Laparotomy (GI, gastrointestinal; NAD, no abnormality detected.)

Diagnosis	Upper GI	Small bowel	Large bowel	Vascular	Other	Total
NAD	2	1	3	–	–	6
Inflammation	3	2	16	–	–	21
Perforation	19	9	37	–	–	65
Obstruction	2	105	52	–	–	159
Sepsis/ collection	13	10	17	–	7	47
Ischaemia	1	17	8	–	–	24
Tumour	1	–	10	–	–	11
Haemorrhage	4	–	1	6	3	14
Ileus	–	1	1	–	–	2
Other	4	4	3	–	1	12

Table 2. Relative accuracy of computerized tomography (CT) reports for different anatomical locations using emergency laparotomy findings as the standard (GI, gastrointestinal.)

Anatomy	Total CTs performed	CT correct	CT incorrect	Accuracy %
All sites	361	318	43	88.1
Upper GI	49	37	12	75.5
Small bowel	149	134	15	89.9
Lower GI	146	132	14	90.4
Vascular	6	6	0	100
Other	11	9	2	81.8
All sites excluding vascular	365	312	43	87.9

Table 3. Details of computerised tomography (CT) examinations related to time performed ar

number of CTs (%). Weekend, Friday 5 PM–8.30 PM, Saturday, Sunday and bank holidays, 8 AM

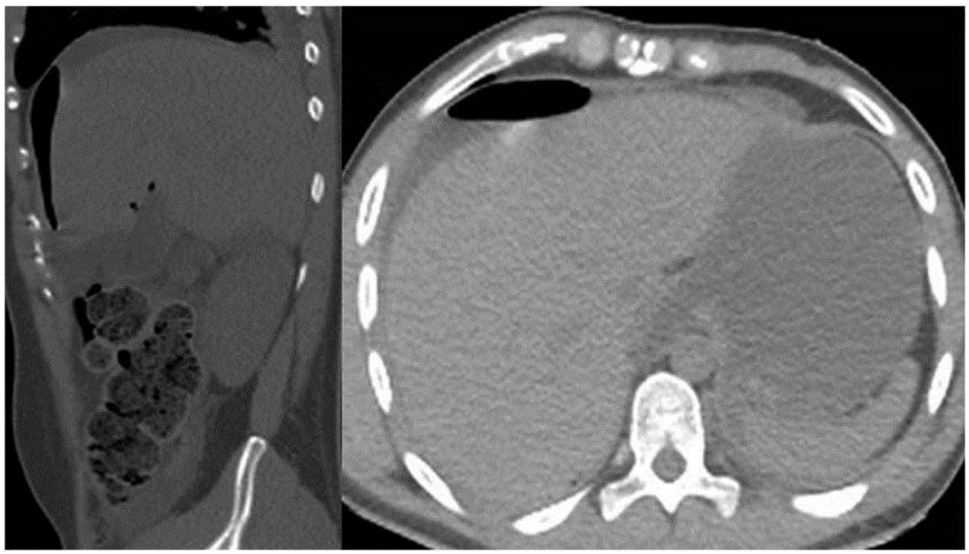
excluding bank holidays; weekday evenings, Monday–Thursday 5 PM –8.30PM; nights, 8.30 PM–8

Time CT performed	Total number (%)	Consultant CT reports (%)	Training radiologist CT reports (%)	Reports changed (%)	Amendments (%)
Weekday	189 (52.4)	180 (95.2)	9 (4.8)	4 (2.1)	1 (0.5)
Weekend Day	63 (17.5)	2 (3.2)	61 (96.8)	22 (35.0)	3 (4.8)
Weekend Evening	35 (9.7)	2 (5.7)	33 (94.3)	18 (51.5)	1 (2.9)
Nights	74 (20.5)	2 (2.7)	72 (97.3)	38 (51.4)	13 (17.6)
All out-of-hours reports	172 (47.6)	6 (3.5)	166 (96.5)	78 (45.4)	17 (9.9)
Total	361	186 (51.5)	175 (48.5)	82 (22.7)	18 (5.0)

Table 4. Weighted kappa statistic (Kw) related to the time the computerised tomograph (CT) was performed for patients undergoing Emergency Laparotomy (UGI, upper gastrointestinal. 95% confidence intervals are in parentheses.)

Anatomical location	**Total**	**In hours**	**All out of hours**
UGI Kw	0.67 (0.53 – 0.82)	0.68 (0.49 – 0.88)	0.66 (0.45 – 0.87)
Small-bowel Kw	0.78 (0.687 – 0.875)	0.78 (0.626 – 0.926)	0.78 (0.652 – 0.90)
Large-bowel Kw	0.82 (0.75 – 0.89)	0.86 (0.77 – 0.95)	0.78 (0.67 – 0.90)

Figure 1. Computerised tomograph (CT) slices showing pneumoperitoneum. The clinical question was “renal colic”; therefore, a stone protocol was performed without oral or intravenous contrast. Pneumoperitoneum was reported, but the final diagnosis of the perforated duodenal ulcer was not mentioned and this report was judged as incorrect.



Chapter 4: Prognostic influence of Sarcopenia on Emergency Laparotomy Outcome

4.1 Abstract

Objective: Sarcopenia is a progressive loss of skeletal muscle mass and function related to age. Although various diagnostic criteria exist, sarcopenia has been shown to be associated with post-operative morbidity and worse survival in elective surgical patients. The aim of this study was to investigate the prognostic influence of sarcopenia on emergency laparotomy outcome.

Methods: 341 consecutive adult patients undergoing emergency laparotomy for in a tertiary University teaching hospital were studied. Patients who had pre-operative computerized tomograms suitable for the assessment of sarcopenia were included in the analysis. Psoas muscle density and psoas muscle area were used to calculate Hounsfield Unit Average Calculation value and the lowest quartile was the cut-off for sarcopenia. Data collected included age, ASA and gender. Outcome measures were 30-day mortality, 90-day mortality, length of stay and survival.

Results: 341 patients [median age 68 years, range 18-98 years, 172 males] were studied. 238/341 patients had a pre-operative CT and HUAC was measured in 203/238 patients. On univariable binary logistic regression, age ($p=0.023$), ASA ($p<0.001$) and sarcopenia ($p=0.010$) were associated with 30-day mortality. Age ($p=0.010$), ASA ($p<0.001$) and sarcopenia ($p=0.004$) were associated with 90-day mortality. Gender was not associated with 30-day or 90-day mortality ($p=0.460$ and $p=0.956$ respectively). On multivariable binary logistic regression, ASA ($p<0.001$) was related to 30-day mortality, age ($p=285$) and sarcopenia ($p=0.186$) were not significant. ASA was an independent predictor of 90-day mortality, age ($p=0.084$) and sarcopenia ($p=0.053$) were not related.

Conclusion: Following emergency laparotomy, sarcopenia is not related to 30-day mortality but is close to significance for 90-day mortality. When considered with age, ASA and gender, sarcopenia is not associated with survival.

4.2 Introduction

The European Working Group on Sarcopenia in Older People (EWGSOP) define sarcopenia as ‘a syndrome characterised by progressive and generalised loss of skeletal muscle mass and strength with a risk of adverse outcomes such as physical disability, poor quality of life and death’ (Cruz-Jentoft 2010). Diagnostic criteria include include low muscle function; either low strength and/or low physical performance (Cruz-Jentoft 2010). The International Working Group on Sarcopenia (IWGS) also provided a consensus definition of sarcopenia as ‘age-associated loss of skeletal muscle mass and function’ (Fielding 2011). Patients who require emergency laparotomy usually present acutely and due to the nature of their surgical condition, may be far off their baseline function. Peri-operative objective measurements of their muscle strength and function are therefore likely to yield inaccurate results. The measurement of psoas muscle has been used as a proxy marker for function but the lack of a standardized practices and external validation for the diagnosis of sarcopenia have led to several diagnostic criteria being used in the literature.

4.3 Materials and Methods

4.3.1 Patient Identification

Between 1st January 2013 and 31st December 2013, 341 consecutive adult patients underwent emergency laparotomy under the care of general and vascular surgery in the University Hospital of Wales. The patient list was obtained from the Theatre Information Technology department and cross-referenced with the handwritten theatre log. Patient details and results were obtained from the Welsh Clinical Portal online information and AGFA Healthcare IMPAX radiology results system. Patients who had pre-operative computerized

tomograms suitable for the assessment of sarcopenia were included in the analysis.

4.3.2 Psoas Muscle Density and Area

The axial CT slice at the lower border of the third lumbar vertebra was identified and the region of interest delineated around each psoas muscle. The mean psoas muscle CT density (PMD) was calculated within the region in Hounsfield units (HU), and the area of the psoas muscles were measured in a semi-automated fashion by the Agfa PACS system bilaterally.

4.3.3 Hounsfield Unit Average Calculation

Hounsfield Unit Average Calculation (HUAC) was also performed by evaluating the right and left psoas muscles and calculating the average for the final HUAC calculation.

Right Hounsfield unit calculation = (right Hounsfield unit (PMD) x right psoas area) / (total psoas area)

Left Hounsfield unit calculation = (left Hounsfield unit (PMD) x left psoas area) / (total psoas area)

HUAC = (right Hounsfield unit calculation + left Hounsfield unit calculation) / 2 (Joglekar et al. 2015).

4.3.1 Data Collection

Demographics such as age, gender and dietetic input were collected. Patients were graded according to the American Society of Anaesthesiologists (ASA) grading system. The length of hospital stay, unplanned 30-day re-admission rates, and survival data were collected and analysed. Exclusion criteria were patients undergoing primary procedures of the appendix or biliary tree, patients who had vascular procedures and patients who had CTs deemed unsuitable for analysis.

4.3.2 Outcome Measures

Outcome measures were 30-day mortality, 90-day mortality, length of stay (LOS) and survival.

4.4 Statistical Analysis

Statistical analyses appropriate for non-parametric data (Mann-Whitney U and Kruskal-Wallis) were used, and correlation determined by means of Spearman's rho. Pearson's chi-squared values for calculated to distinguish between groupings for each variable individually. Binary logistic regression was used to identify variables significantly associated with outcome. A survival analysis was conducted through Cox proportional hazard regression models to assess the association between prognostic variables and survival with and without adjustment for potential confounding factors. Multivariable analysis was performed to allow for confounding factors. Variables with a $p<0.05$ were considered statistically significant independent predictors of outcome. Data analysis was carried out using the Statistical Package for the Social Sciences version 23 (SPSS, Chicago, Illinois, USA).

4.5 Results

4.5.1 Patient Demographics

Consecutive 341 patients consisting of 172 males and 169 females, with a median age of 68 years (range 18-98 years), necessitating emergency laparotomy during a calendar year were studied prospectively. Two hundred and thirty-eight patients had a pre-operative CT (69.8%) and the psoas muscle density (PMD) and psoas muscle areas were calculated at the lower border of L3 on axial CT slices in Hounsfield units (HU) by the Agfa PACS for 203 patients. CTs deemed unsuitable for analysis due to indiscrete psoas borders (n=27) or non-standard CT slices 2.5mm (n=8).

HUAC were divided into quartiles and sarcopenia defined as HUAC within the lowest quartile. One hundred and one males (median age 64, range 19-92 years) had CTs suitable for analysis and calculation of HUAC. When HUAC was divided into quartiles, the LQ cut off was 18.82 (25^{th} percentile 18.82, 50^{th} percentile 23.00, 75^{th} percentile 27.74). Twenty-five male patients had LQ HUAC (sarcopenia) with a median age 69 (range 44-87 years). One hundred and two females had pre-operative CTs analysable for HUAC measurement (median age 71 years, range 22-93 years). When HUAC was divided into quartiles, the LQ cut off was 18.96 (25^{th} percentile 18.96, 50^{th} percentile 23.52, 75^{th} percentile 27.10). Twenty-five females had LQ HUAC with a median age 81 years (range 49-93 years).

4.5.1.1 Age groups

Table 1a shows the demographics of different age groups and the relationship with other variables. There were a similar number of males and females in the <50 years age group and the majority (69.2%) had ASA grades 1 or 2; only

7.7% of patients had ASA grades of 4 or 5 at the time of emergency laparotomy. In this age group, only 7.5% of patients had sarcopenia and overall, this age group had the lowest 30-day and 90-day mortality (5% and 7.5% respectively). In addition, their LOS was lowest at a median of 12 days (range 1-68 days). In comparison, the ≥80 years age group had over twice as many females than males (34 vs. 14) and at the time of surgery, 18.8% had ASA grades 1 or 2, 50% had ASA grade 3 and 31.3% had ASA grades 4 or 5. A higher proportion of the patients in the ≥80 year age group had sarcopenia (39.6% vs. 7.5%) and this age group also experienced higher 30-day (29.2% vs. 5%) and 90-day (33.2% vs. 7.5%) mortality. LOS was also higher in the older age group at median 21.5 days (range 1-187 days). In general, the 30-day mortality increased with age; 5% in those <50 years, 11.5% in the 50-59 age group, 8.7% in the 60-69 age group, 20.9% in the 70-79 age group and 29.2% in those ≥80 years. This trend is also seen with 90-day mortality; 7.5% in those <50 years, 11.5% in the 50-59 age group, 10.9% in the 60-69 age group, 27.9% in the 70-79 age group and 33.3% in those >80 years. The 60-69 year age group is the exception to this trend with relatively lower 30-day and 90-day mortality than the 50-59 age group and the reasons for this is unclear.

4.5.1.2 Gender

Table 1b shows the demographics of the cohort according to gender and the relationship with other variables. The majority of males undergoing emergency laparotomy with CTs analysable for HUAC were in the 60-69 year age group and the fewest in the ≥80 year age group. The majority of females were in the ≥80 year age group; the fewest in the 50-59 year age group. The difference in ASA grading between the sexes was not statistically significant. The majority of males were ASA grades 1 or 2 (45%), 33% are ASA grade 3 and 22% were ASA grades 4 or 5. The majority of females were ASA 3 (48%), 34.3% were

ASA grades 1 or 2, and 17.6% were ASA grades 4 or 5. Gender was not a predictor of sarcopenia (p=0.904). There is no significant difference in 30-day mortality (p=0.459) and 90-day mortality (p=0.832) between genders, or in LOS (p=0.294). Males had a 30-day mortality of 13.9%, and females a 30-day mortality of 19.8%. Ninety-day mortality was 17.6% in males and 18.6% in females. The median LOS was 15.2 days for males and 16.5 days for females.

4.5.1.3 American Society of Anaesthesiology Grades

Table 1c shows the patient group divided by ASA grades. Patients with higher ASA grades were in the older age groups; 37.5% of patients with ASA grades 4 or 5 are ≥80 years, 7.5% were <50 years. The majority of patient with ASA grades 1 or 2 were in the younger age groups; 33.3% are <50 years and 11.3% were ≥80 years. Age was significantly related to ASA groups (p=0.001). ASA grades were significantly associated with sarcopenia; 2.5% of patients with ASA grades 1 or 2 have sarcopenia compared with 25.6% of patients with ASA grade 3, and 45% of patients with ASA grades 4 or 5 (p=0.002). Thirty-day and 90-day mortality was 2.5% and 3.8% respectively for ASA grades 1 or 2, 15.9% and 19.5% respectively for ASA grade 3, and 42.5% and 47.5% respectively for ASA grades 4 or 5. These findings were statistically significant (p<0.001). The difference in LOS across the ASA grades was also significant; ASA grades 1 or 2 had a median LOS of 10 days, ASA grade 3 had a median LOS of 20 days rising to 25 days for ASA grades 4 or 5 (p<0.001).

4.5.2 Relationship between Sarcopenia and Mortality

The relationship between sarcopenia and mortality is shown in Table 1d. Patients with sarcopenia had a higher 30-day mortality rates when compared

with those without (27.5% vs. 11.8%, p=0.008), and higher 90-day mortality rates (33.3% vs. 14.5%, p=0.003). Length of stay was longer in those with sarcopenia 26 vs. 13 days, p=0.001).

Non-parametric Spearman's rank coefficents were calculated for the variables and the results are shown in Table 2. Gender correlated with age but not ASA or sarcopenia; age correlated with ASA and sarcopenia; ASA correlated strongly with sarcopenia.

4.5.3 Univariable binary logistic regression

Table 3 shows the results of univariable binary logistic regression. Age was associated with 30-day mortality (p=0.023) and 90-day mortality (p=0.010). Gender was not associated with 30-day or 90-day mortality (p=0.460 and p=0.956 respectively). ASA was strongly associated with 30-day and 90-day mortality (p<0.001); compared with the lowest ASA groups (1 and 2), ASA grades 4 and 5 had an odds ratio of 28.8 for 30-day mortality and 23.2 for 90-day mortality. Sarcopenia was associated with 30-day mortality (p=0.010) and more strongly associated with 90-day mortality (p=0.004).

4.5.3 Multivariable binary logistic regression

On multivariable binary logistic regression (Table 4), age was no longer associated with 30-day or 90-day mortality. ASA remains an independent predictor of both 30-day (p<0.001) and 90-day mortality (p<0.001); relative to ASA grades 1 or 2, grades 4 or 5 have an odds ratio of 22.6 and 17.7 for 30-day and 90-day mortality respectively. When adjusted for other variables, sarcopenia was no longer associated with 30-day mortality (p=0.186) but there is an indication of an association with 90-day mortality (p=0.053).

4.5.4 Survival

Figure 1 shows the survival plot for patients with and without sarcopenia following emergency laparotomy. The chances of survival decreased considerably within the first 60 days and then levelled off in both cohorts.
Table 5 shows the Cox regression analysis for the variables related to survival and table 6 shows this analysis when adjusted for all of the variables. There was no significant difference in survival between the sexes on the unadjusted or adjusted analysis (p=762 and p=0.454 respectively).
On the unadjusted analysis, age groups were related to survival (p=0.012) with age groups >60 all being associated with poor survival. When adjusted for the other variables, age was no longer related to survival (p=0.107). This may be because age was correlated with ASA. Looking at specific age groups on the adjusted analysis, age group ≥80 was close to significance (p=0.070) and age 70-79 was significant (p=0.048). Patients with ASA grade 3 are nearly 3 times more likely not to survive after emergency laparotomy and patients with ASA grades 4 or 5 have a 7-fold risk of not surviving when compared to patients with ASA grades 1 or 2. These findings were significant (p<0.001) and this trend was also seen in the adjusted analysis (ASA grade 3 HR 2.2, ASA grade 4 or 5 HR 5.4, p=0.001). Patients with sarcopenia had poorer survival than those without (table 5, p=0.006) but when adjusted for other variables this relationship no longer reached statistical significance (p=0.092).

4.5.5 Dietetic Involvement and Outcome

The assessment of dietetic involvement was a separate study and it should be noted that Psoas Muscle Density (PMD) rather than HUAC was used for

analysis so these groups of sarcopenia patients were not comparable. Nonetheless, the results from this study give a general overview of the dietetic involvement and outcome in patients following emergency laparotomy. Dietetic assessment occurred in 104/203 (51.2%) and reasons for referral included Screening Tool triggers (53.8%), request for parenteral nutrition (9.6%) and directly from ICU (11.5%). Although not statistically significant, a higher proportion of patients with LQ PMD were referred to dietetics (53.8% vs. 50.3%, p=0.794) had a shorter median time to referral (4 {1-26} vs. 6 {0-25} days, p=0.307) and underwent intervention (44.2% vs. 41.7%, p=0.792) (Table 7).

4.6 Discussion

The principal findings of this study were that 30-day mortality amongst patients undergoing emergency laparotomy who had an analyzable CT was high at 15.8% and 90-day mortality rose to 19.2%. ASA grade was an independent risk factor for 30-day and 90-day mortality and sarcopenia (as defined as lower quartile HUAC) was not a significant independent predictor of 30-day mortality but nearly reached significant for 90-day mortality. ASA was also independently associated with survival and sarcopenia was no longer associated with survival when adjusted for other variables.

The strengths of the study are it's originality; it is the first study to look at sarcopenia related to emergency laparotomy outcome. The data was collected prospectively and the patients were consecutive for the duration of the year studied. There were no patients lost to follow-up. The weakness of the study is that no access to nutritional scores on admission was possible due an inability to access medical records. Differing definitions of sarcopenia exist; the European Working Group of Sarcopenia in Older People (EWGSOP) definition

of sarcopenia is based on muscle mass and muscle strength or physical performance; the rationale for including muscle strength in the diagnostic criteria is that muscle strength may not be dependent solely on muscle mass and the relationship between strength and mass may not be linear (Goodpaster et al. 2006). Goodpaster and colleagues reported that the loss of lean mass was independently associated with strength decline in both men and women, however the decline in strength was much more rapid than the loss of muscle mass, suggesting that muscle quality is a factor (Goodpaster et al. 2006). Assessing sarcopenia using this definition is not possible for the majority of patients requiring emergency laparotomy due to the inability to test muscle or physical strength when they are acutely ill with a surgical condition.

When comparing the lowest (<50 years) and highest (≥ 80 years) age groups, the latter had a higher proportion of females, higher proportion of patients in the higher ASA grades, more patients with sarcopenia, and higher 30-day and 90-day mortality; all of these findings were statistically significant (Table 1a). The LOS was longer for the older age group and this was close to significance (p=0.078).

The association between advancing age and higher ASA grades at the time of emergency laparotomy may be explained in several ways. It may reflect underlying co-morbidities i.e. older patients have are physiologically less fit and would be expected to have more underlying health problems than their younger counterparts. Another possible explanation is that older patients may present late to the acute surgical services and are therefore more unwell with their acute surgical pathology. Possible reasons for late presentation in this age group are poor access to healthcare because of poor mobility or social isolation. Older patients have a longer LOS and this may be multifactorial; it may represent a slower recovery from emergency laparotomy or may be related to difficult home circumstances or the need for additional support on discharge. The latter may

be associated with delays whilst waiting for appropriate home help to be arranged, delays due to referrals to external agencies or bed shortages in rehabilitation units, or for long-term care such as nursing or residential homes. In this study, patients with sarcopenia had more than double the 30-day mortality rates, and 90-day mortality rates and length of hospital stay that was twice as long following emergency laparotomy when compared with patients without sarcopenia. On analysis of 259 patients, Peng and colleagues (2011) reported that patients with sarcopenia undergoing surgery for hepatic colorectal metastases had more post-operative complications, a longer length of hospital stay and a longer ICU admission compared with those without sarcopenia. Sixteen per cent of the patients in their study had sarcopenia compared with 33% of patients in this study. Patients with sarcopenia and colorectal metastases were more than 3 times more likely to have 3 more post-operative complications (Clavien grade ≥3), were in hospital for an additional day (6.6 vs 5.4 days, p=0.03) and stayed in ICU for at least 2 additional days (p=0.004) than those without sarcopenia. Their study used Total Psoas Area (TPA) as a measurement of sarcopenia rather than HUAC but their findings remain interesting and suggest that patients with sarcopenia undergong major surgery are likely to require more time in hospital. Interestingly in Peng and colleagues' study, the presence of sarcopenia did not affect long-term survival. The same group of investigators demonstrated a different relationship with sarcopenia and long-term outcome in patients with sarcopenia and pancreatic cancer (Peng et al. 2012); sarcopenia was associated with a 63% increased risk of mortality at 3 years follow-up. Other findings from this present study differed from Peng's study of patients with colorectal hepatic metastases; they found that median ICU and length of hopital stay was similar in patients with and without sarcopenia (Peng et al. 2013).

A systematic review by Levolger and colleagues (2015) examined post-operative morbidity, length of stay, disease-free survival and overall survival in patients with and without sarcopenia in patents undergoing surgery for gastrointestinal and pancreatohepatobiliary cancer. Although this present study did not specifically investigate post-operative morbidity in patients undergoing emergency laparotomy, the results of Levolger's systematic review were of interest. Patients with sarcopenia undergoing surgery for colorectal cancer or hepatic metastases had increased post-operative morbidity. Lieffers et al. (2012) reported a doubling of post-operative infections in patients with sarcopenia undergoing colorectal surgery and this finding was particularly pronounced in elderly patients. Of interest, patients with sarcopenia and oesophageal or hepatocellular cancer who underwent resection were not found to have increased morbidity or mortality compared to their non-sarcopenic counterparts (Awad et al. 2012, Voron et al. 2015, Harimoto 2013, Sheetz 2013). There was also no difference in post-operative morbidity in patients undergoing pancreatic resection with sarcopenia (Peng et al. 2012).

Overall survival appears to be decreased in patients with resectable gastrointestinal and hepatopancreaticobiliary malignancies with sarcopenia compared with those without sarcopenia (Levolger et al. 2015).

It is not clear how the findings from this systematic review can be related patients undergoing emergency surgery in this study. Patients with malignancy may have a period of anorexia and vomiting in addition to the catabolic effects of the disease which may result in nutritional decline. Patients requiring emergency surgery are a heterogenous group and may present with an acute illness, such as mesenteric ischaemia or bowel obstruction due to adhesions, which are unlikely to affect their nutritional status, or with bowel obstruction or perforation due to underlying malignancy which may cause nutritional decline. Patients who require emergency surgery for malignancy are expected to have

less favourable outcomes than those who are diagnosed and operated on electively. In addition, this study did not examine specifically post-operative morbidity as it was not possible to retrieve the case notes to allow a thorough analysis. Post-operative morbidity would have to be inferred from radiology and blood results which was deemed to not be sensitive enough to allow accurate morbidity recording. It is also unclear why sarcopenia predicts outcome in some malignancies but not others.

Attention has focussed on the effect of sarcopenia on outcomes after elective surgery but information is lacking on emergency surgery patients. Du Y et al. (2014) analysed 100 patients with CTs within 30 days of emergency surgery, mean age 84 years, with an in-hospital mortality of 18%. Their diagnostic criteria differed from this study as they used cross-sectional area of all skeletal muscles at the level of L3 and normalized for height to acquire the skeletal muscle index (SMI). Patients over the age of 80 years had a high prevalence of sarcopenia compared to our population (73% vs. 39.6%) accepting the difference in definition of sarcopenia. They reported postoperative complications more frequently in sarcopenic patients compared to non-sarcopenic patients (45% vs. 15%, p=0.005) and also found that ASA was in independant predictor of mortality.

Early identification and focused targeting of patient-specific risk factors, such as sarcopenia, is crucial in order to improve emergency surgery outcomes. The changing age structure of the UK population, partly as a result of 1960's baby boom, and increased life expectancy, has resulted in an ageing population who are susceptible to sarcopenia. The NHS faces huge financial and logistical challenges when managing these patients who require emergency surgery. Preoperative risk stratification is important in patient selection for surgery, especially as the outcomes for emergency surgery are being measured in NELA and are worse than previously appreciated. There is significant interest in

developing robust methodologies for risk stratification for the surgical patient but the majority of research focuses on patients undergoing elective surgery for malignancy. Accurate identification of elderly patients at risk of perioperative morbidity and mortality may highlight patients for early intervention in the post-operative period, as well as assisting patient and surgeon decisions regarding the potential benefits of surgery.

The lack of a standardized practices and external validation have led to several diagnostic criteria being used in the literature. There is debate regarding the most appropriate parameter to use when measuring sarcopenia. Sarcopenia has been defined by measuring total psoas area (TPA) or total psoas volume (TPV) or Hounsfield units average calculation (HUAC) issues with diagnosing sarcopenia. Bioelectical impedance analysis, dual-energy X-ray absorptiometry and skinfold measurement are all useful adjuncts in the assessment of frailty and may be more suitable for the assessment of patients undergoing emergency laparotomy than strength assessments required to fulfil the criteria for sarcopenia as 'a syndrome characterised by progressive and generalised loss of skeletal muscle mass and strength with a risk of adverse outcomes such as physical disability, poor quality of life and death' by The European Working Group on Sarcopenia in Older People (EWGSOP). It proposed criteria for diagnosis to include low muscle function; either low strength and/or low physical performance (Cruz-Jentoft 2010) and The International Working Group on Sarcopenia (IWGS) also provided a consensus definition of sarcopenia as 'age-associated loss of skeletal muscle mass and function' (Fielding 2011).

Once sarcopenia has been diagnosed in the patient requiring emergency laparotomy, it is unclear whether intervention will change outcomes. The 'POPS' model (Proactive care of Older People undergoing Surgery) (Harari et al. 2007) recommends early multidisciplinary input rather than a reactive approach with the aim of reducing early postoperative complications and length

of stay. Fearon and co-authors suggested that 3 weeks of pre-operative rehabilitation may be sufficient to obtain a moderate gain in aerobic and muscle strength reserve (Fearon et al. 2013). Studies on prehabilitation before elective thoracic and GI cancer surgery showed an increase in postoperative functional exercise capacity, decreased postoperative complications and shorter hospital stay (Valkenet et al. 2011, Mayo et al. 2011). The challenges faced in emergency surgery are clear; by definition it cannot be predicted who will require emergency surgery and therefore the opportunity to intervene pre-operatively is limited. The focus therefore, needs to be on targeting these patients early in the post-operative period. Sheetz et al found that sarcopenic patients represent a uniquely costly patient demographic in terms of major surgery (Sheetz et al. 2013). These costs may be personal, not only for the patient but also the supporters, and social in terms of out of work welfare, and social care. There are also costs to the health care system as bed occupancy will be affected and sarcopenic patients will require more resources if they develop post-operative complications and require longer stays in hospital and consume more resources. With the nationwide cuts to health budgets, we are unable to provide targeted nutritional and physiotherapy input to all. By identifying the sarcopenic elective population who may derive the most benefit in terms of outcomes and cost, a combination of lifestyle, nutritional, pharmacological and physical interventions is the most promising strategy to tackle this condition (Beaudart et al. 2013). When patients are acutely unwell and require emergency surgery, the opportunity to make pre-morbid lifestyle modifications does not exist. Nutritional interventions, however, should be commenced whilst in hospital and ongoing support in the community may be required. There is no set protocol for referring emergency surgery patients to dietetic services and because patient medical records could not be accessed, dietician records were used to evaluate nutritional input. Just over half of

patients undergoing emergency laparotomy received input from the dietetic team. In this cohort, 44% of patients with lower quartile PMD received nutritional intervention compared to 42% of patients with highest quartile PMD. NICE guidelines state that nutrition support should be considered in people who are malnourished, as defined by a BMI < 18.5 kg/m^2, unintentional weight loss >10% within the last 3–6 months, or a BMI of < 20 kg/m^2 and unintentional weight loss >5% within the last 3–6 months (NICE 2006). NICE also recommend consideration of nutritional support in people at risk of malnutrition who have eaten little or nothing for >5 days and/or are likely to eat little or nothing for the next 5 days or longer. In addition, patients who have a poor absorptive capacity, and/or high nutrient losses and/or increased nutritional needs from causes such as sepsis-related catabolism should be considered for nutritional support. Most patients requiring emergency surgery fall into at least one of these categories and so should be assessed by a dietician promptly. The first step in nutritional intervention is oral nutritional supplementation (ONS) which is typically used in addition to a normal diet in situations when diet alone is insufficient to meet the patients daily nutritional requirements. ONS increases total energy and protein intake in addition to the intake of micronutrients and are not thought to reduce the intake of normal food (Stratton 2013). It is important for the nursing and dietetic staff to match the ONS to the patients' preferences and needs as there are a wide range of ONS flavours, styles (juice, yoghurt, milk, savoury), formats (liquid, powder, pudding, pre-thickened), types (high protein, high fibre) and energy densities (1-2.4kcal/ml). Most ONS provide ~300kcal, 12g of protein and a full range of vitamins and minerals. Clinical benefits of ONS include reductions in complications (e.g. pressure ulcers, poor wound healing, infection, mortality (in acutely ill older people), hospital admissions and readmissions (NICE 2006). The majority of patients who have undergone emergency laparotomy should be able to take ONS within the first

post-operative week. The next step up in enteral feeding is via nasogastric, nasojejunal, gastrostomy or jejunostomy feeding.

Patients who undergo emergency surgery may be unable to commence ONS in the immediate post-operative period if oral intake has not yet been established. Multiple surgical conditions can lead to ileus and immediate post-operative commencement of oral nutrition may lead to abdominal distension, pain, vomiting and aspiration. Patients who had undergone gastric or bowel resection and restoration of gastrointestinal continuity will have an anastomosis, which may also preclude the use of ONS in the immediate post-operative period. Other conditions where enteral nutrition is contraindicated are intestinal obstruction, malabsorption, multiple high-output fistulas, intestinal ischemia, severe shock with impaired splanchnic perfusion, and fulminant sepsis, and in these situations, the early use of TPN should be considered.

4.7 Conclusion

Using the strict definition of sarcopenia as set out by the European Working Group on Sarcopenia in Older People (EWGSOP) and The International Working Group on Sarcopenia (IWGS) is likely to over-diagnose sarcopenia in acutely unwell surgical patients who require emergency laparotomy. Using psoas muscle measurements should avoid this problem and is a straightforward and relatively quick proxy marker available from commonly used pre-operative CT scans. ASA grading was an independent risk factor for 30-day and 90-day mortality and sarcopenia, as defined as lower quartile HUAC, was not a significant independent predictor of 30-day or 90-day mortality. The results suggest that sarcopenia may have more of a role in long-term outcomes but further research is required to confirm this. Dietetic involvement occurred in just

over half of the patients investigated and this falls short of our expectations. Development of an Emergency Laparotomy Pathway should highlight the importance of nutrition in the perioperative period and achieve higher rates of dietetic assessment and intervention at an early stage.

Table 1a. Demographics of patients in different Age groups who underwent Emergency Laparotomy. Also shown is the relationship with other variables (gender, American Society of Anaesthesiology {ASA} groups and sarcopenia), 30-day mortality, 90-day mortality and median length of stay (LOS). Statistical analysis results are shown as p values. [N=non-missing data, m=missing data, (%)]

	Age (years)					p value
Variables	**<50**	**50-59**	**60-69**	**70-79**	**≥80**	**Pearson Chi-squared**
M:F	21M:19F	17M:9F	27M:19F	22M:21F	14M:34F	p=0.015
ASA Groups	N=39, m=1	N=26, m=0	N=46, m=0	N=43, m=0	N=48, m=0	p=0.001
Grades 1&2	27/39 (69.2%)	12/26 (46.2%)	17/46 (37%)	15/43 (34.9%)	9/48 (18.8%)	
Grade 3	9/39 (22.5%)	12/26 (46.2%)	18/46 (39.1%)	19/43 (44.2%)	24/48 (50%)	
Grades 4&5	3/39 (7.7%)	2/26 (7.7%)	11/46 (23.9%)	9/43 (20.9%)	15/48 (31.3%)	
Sarcopenia (lowest quartile HUAC)	N=40	N=26	N=46	N=43	N=48	p=0.008
Yes	3/40 (7.5%)	4/26 (15.4%)	12/46 (26.1%)	13/43 (30.2%)	19/48 (39.6%)	
No	37/40 (92.5%)	22/26 (84.6%)	34/46 (73.9%)	30/43 (69.8%)	29/48 (60.4%)	
30-day mortality	2/40 (5%)	3/26 (11.5%)	4/46 (8.7%)	9/43 (20.9%)	14/48 (29.2%)	p=0.012
90-day mortality	3/40 (7.5%)	3/26 (11.5%)	5/46 (10.9%)	12/43 (27.9%)	15/48 (33.3%)	p=0.005
						Kruskal-Wallis
Median LOS in days (range)	12 (1-68)	13.5 (3-426)	13 (2-223)	15 (2-233)	21.5 (1-187)	0.078

Table 1b. Demographics of patients of different Gender who underwent Emergency Laparotomy. Also shown is the relationship with other variables (age groups, American Society of Anaesthesiology {ASA} groups, sarcopenia), 30-day mortality, 90-day mortality and length of stay (LOS). Statistical analysis results are shown as p values. [N=non-missing data, m=missing data, (%)]

	Gender		**p value**
	M	**F**	**Pearson Chi-squared**
Age (years)	N=101, m=0	N=102, m=0	p=0.015
<50	21/101 (20.8%)	19/102 (18.6%)	
50-59	17/101 (16.8%)	9/102 (8.8%)	
60-69	27/101 (26.7%)	19/102 (18.6%)	
70-79	22/101 (21.8%)	21/102 (20.6%)	
≥80	14/101 (13.9%)	34/102 (33.3%)	
ASA Groups	N=100, m=1	N=102, m=0	p=0.093
Grades 1&2	45/100 (45%)	35/102 (34.3%)	
Grade 3	22/100 (33%)	49/102 (48%)	
Grades 4&5	22/100 (22%)	18/102 (17.6%)	
Sarcopenia (lowest quartile HUAC)	N=101	N=102	p=0.904
Yes	25/101 (24.8%)	26/102 (25.5%)	
No	76/101 (75.2%)	76/102 (74.5%)	
30-day mortality	14/101 (13.9%)	18/102 (17.6%)	p=0.459
90-day mortality	20/101 (19.8%)	19/102 (18.6%)	p=0.832
			Mann-Whitney U
Median LOS in days (range)	15.2 (2-426)	16.5 (1-233)	p=0.294

Table 1c. Demographics of the different American Society of Anaesthesiology (ASA) groups undergoing Emergency Laparotomy. Also shown is the relationship with other variables (gender, age groups, sarcopenia), 30-day mortality, 90-day mortality and median length of stay (LOS). Statistical analysis results are shown as p values. [N=non-missing data, m=missing data, (%)]

	ASA Groups					p value
	Grades 1&2	**Grade 3**	**Grades 4&5**	**Missing Data (m)**	**Non-missing Data**	**Pearson Chi squared**
Gender	45M:35F	33M:49F	22M:18F	1M	100M:102F	p=0.093
Age (years)	N=80, m=0	N=82, m=0	N=40, m=0	N=1	N=202	p=0.001
<50	27/80 (33.3%)	9/82 (11%)	3/40 (7.5%)	1/1 (100%)	39/202 (19.4%)	
50-59	12/80 (15%)	12/82 (14.6%)	2/40 (5%)		26/202 (12.9%)	
60-69	17/80 (21.3%)	18/82 (22%)	11/40 (27.5%)		46/202 (22.9%)	
70-79	15/80 (18.8%)	19/82 (23.2%)	9/40 (22.5%)		43/202 (21.4%)	
≥80	9/80 (11.3%)	24/82 (29.3%)	15/40 (37.5%)		48/202 (23.9%)	
Sarcopenia (lowest quartile HUAC)						p=0.002
Yes	2/80 (2.5%)	21/82 (25.6%)	18/40 (45%)		41/202 (20.3%)	
No	78/80 (97.5%)	61/82 (74.4%)	22/40 (55%)	1/1 (100%)	161/202 (79.7%)	
30-day mortality	2/80 (2.5%)	13/82 (15.9%)	17/40 (42.5%)	0	32/202 (15.8%)	p<0.001
90-day mortality	3/80 (3.8%)	16/82 (19.5%)	19/40 (47.5%)	0	35/202 (17.3%)	p<0.001
						Kruskal-Wallis
Median LOS in days (range)	10 (1-224)	20 (2-426)	25 (1-233)	15	15 (1-426)	p<0.001

Table 1d. Demographics of patients with and without Sarcopenia who underwent Emergency Laparotomy. Also shown is the relationship between other variables (gender, age groups, American Society of Anaesthesiology (ASA groups), 30-day mortality, 90-day mortality and length of stay (LOS). Statistical analysis results are shown as p values. [N=non-missing data, m=missing data, (%)]

	Sarcopenia (lowest quartile HUAC)		**p value**
	Yes	**No**	
			Pearson Chi-squared
Gender	25M:26F	76M:76F	p=0.904
Age (years)	N=51, m=0	N=152, m=0	p<0.001
<50	3/51 (5.9%)	37/152 (24.5%)	
50-59	4/51 (7.8%)	22/152 (14.6%)	
60-69	12/51 (23.5%)	34/152 (22.5%)	
70-79	13/5 1(25.5%)	30/152 (19.9%)	
≥80	19/51 (37.3%)	29/152 (19.2%)	
ASA	N=51, m=0	N=151, m=1	p<0.001
Grades 1&2	12/51 (23.5%)	68/151 (45%)	
Grade 3	21/51 (41.2%)	61/151 (40.4%)	
Grades 4&5	18/51 (35.3%)	22/151 (14.6%)	
30-day mortality	14/51 (27.5%)	18/152 (11.8%)	p=0.008
90-day mortality	17/51 (33.3%)	22/152 (14.5%)	p=0.003
			Mann-Whitney U
Median LOS in days (range)	26 (2-426)	13 (1-233)	p=0.001

Table 2. Non-parametric Spearman's rank correlation coefficient for the variables (gender, age groups, American Society of Anaesthesiology {ASA} groups and the presence of sarcopenia). p values are shown in brackets.

		Gender	**Age Groups**	**ASA group**	**Sarcopenia (lowest quartile HUAC)**
Gender	Correlation coefficient	1	-0.186 (p=0.008)	-0.055 (p=0.434)	0.009 (p=0.904)
Age Groups	Correlation coefficient		1	0.333 (p<0.001)	-0.258 (p<0.001)
ASA Groups	Correlation coefficient			1	-0.241 (p=0.001)
Sarcopenia (lowest quartile HUAC)	Correlation coefficient				1

Table 3. Univariable binary logistic regression analysis of variables (age, gender, American Society of Anaesthesiology {ASA} groups, sarcopenia) related to 30-day Mortality and 90-day Mortality for patients undergoing Emergency Laparotomy

	30 day mortality			90 day mortality		
Age	Overall p=0.023			Overall p=0.010		
	OR	**95% C.I**	**p value**	**OR**	**95% C.I**	**p value**
≥80	7.824	1.657 – 36.940	0.009	6.167	1.646 – 23.102	0.007
70-79	5.029	1.015 – 24.924	0.048	4.774	1.235 – 18.456	0.023
60-69	1.81	0.313 – 10.446	0.507	1.504	0.336 – 6.732	0.593
50-59	2.478	0.385 – 15.961	0.34	1.609	0.229 – 8.656	0.58
<50 (REF)						
Gender	Overall p=0.460			Overall p=0.946		
Female	1.332	0.623 – 2.848	0.46	0.832	0.461 – 1.864	0.927
Male (REF)						
ASA Groups	Overall p<0.001			Overall p<0.001		
ASA 4&5	28.826	6.197 – 134.085	<0.001	23.222	6.267 – 86.045	<0.001
ASA 3	7.348	1.601 – 33.715	0.01	6.222	6.267 – 86.045	0.005
ASA 1&2 (REF)						
Sarcopenia (lowest quartile HUAC)	Overall p=0.010			Overall p=0.004		
Yes	2.817	1.2821 – 6.192	0.01	2.955	1.414 – 6.174	0.004
No (REF)						

Table 4. Multivariable binary logistic regression analysis (adjusted) of variables (age, gender, American Society of Anaesthesiology {ASA} groups, sarcopenia) related to 30-day Mortality and 90-day Mortality for patients undergoing Emergency Laparotomy

	30 day mortality			90 day mortality		
Age	Overall p=0.285			Overall p=0.084		
	OR	**95% C.I**	**p value**	**OR**	**95% C.I**	**p value**
≥80	2.713	0.499 – 14.752	0.248	3.715	0.703 – 19.634	0.122
70-79	2.464	0.438 – 13.855	0.306	3.871	0.726 – 20.639	0.113
60-69	0.712	0.106 – 4.775	0.727	0.88	0.141 – 5.497	0.891
50-59	1.812	0.248 – 13.260	0.558	1.744	0.243 – 12.500	0.58
<50 (REF)						
Gender	Overall p=0.080			Overall p=0.416		
Female	1.08	0.437 – 2.670	0.867	0.7	0.297 – 1.652	0.416
Male (REF)						
ASA	Overall p<0.001			Overall p<0.001		
Grades 4&5	22.58	4.583 – 111.260	<0.001	17.677	4.445 – 70.299	<0.001
Grade 3	5.725	1.197 – 27.373	0.029	5.173	1.371 – 19.512	0.015
Grades 1&2 (REF)						
Sarcopenia (lowest quartile HUAC)	Overall p=0.186			Overall p=0.053		
Yes	1.608	0.657 -3.935	0.299	1.851	0.794 – 4.318	0.154
No (REF)						

Figure 1. Survival plot for patients with and without Sarcopenia following Emergency Laparotomy (Sarcopenia = lowest quartile HUAC)

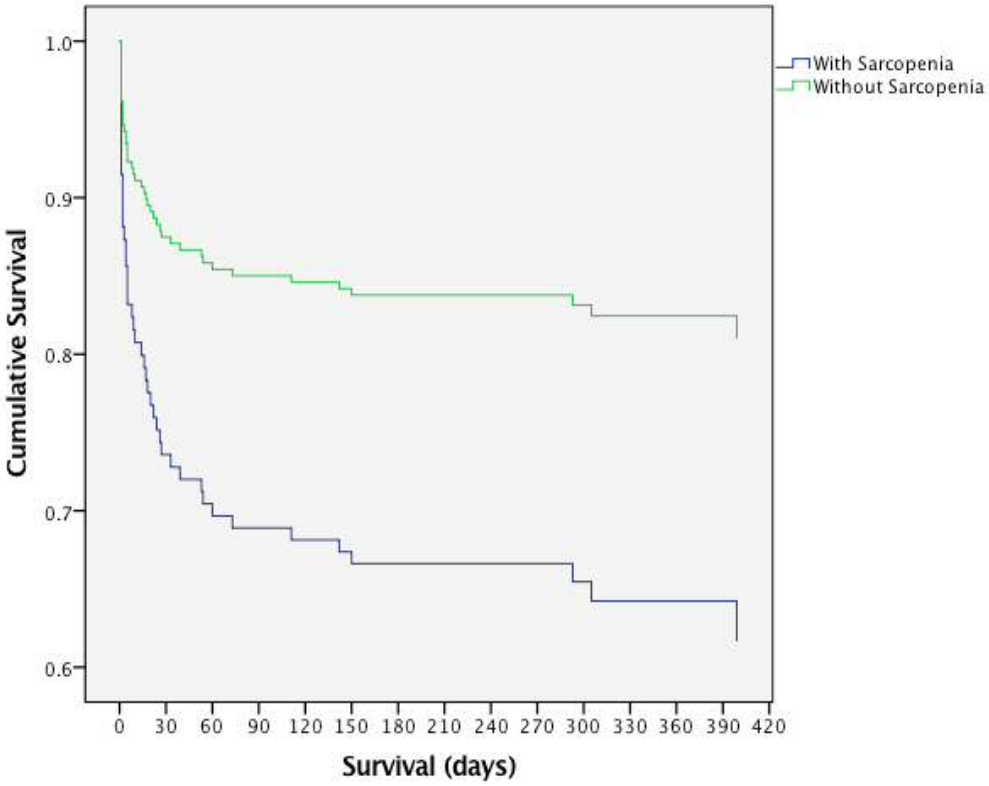


Table 5. Cox Regression analysis for variables (age, gender, American Society of Anaesthesiology {ASA} groups, sarcopenia) related to Survival for patients following Emergency Laparotomy

Variable	HR	95% C.I	p value
Gender			
Female	0.913	0.505 – 1.649	0.762
Male (REF)			
Age (years)			
≥80	8.206	0.895 – 35.533	0.005
70-79	7.204	1.637 – 31.705	0.009
60-69	3.192	0.663 – 15.368	0.018
50-59	3.169	0.580 – 17.302	0.183
<50 (REF)			0.012
ASA Groups			
Grades 4&5	7.646	3.206 – 18.236	<0.001
Grade 3	2.733	0.141 – 6.547	0.024
Grades 1&2 (REF)			<0.001
Sarcopenia (lowest quartile HUAC)			
Yes	2.308	1.265 – 4.212	0.006
No (REF)			

Table 6. Cox Regression analysis for variables (age, gender, American Society of Anaesthesiology {ASA} groups, sarcopenia) related to Survival for patients following Emergency Laparotomy (adjusted)

Variable	HR	95% C.I	p value
Gender			
Female	0.787	0.420 – 1.475	0.454
Male (REF)			
Age (years)			
≥80	4.098	0.893 – 18.802	0.070
70-79	4.556	1.011 – 20.539	0.048
60-69	1.759	0.354 – 8.747	0.490
50-59	2.749	0.500 – 15.130	0.245
<50 (REF)			0.107
ASA Groups			
Grades 4&5	5.375	2.137 – 13.517	<0.001
Grade 3	2.168	0.881 – 0.799	0.009
Grades 1&2 (REF)			0.001
Sarcopenia (lowest quartile HUAC)			
Yes	1.430	0.765 – 5.336	0.092
No (REF)			

Table 7. Outcome of dietetic assessment in patients in lowest and highest quartiles Psoas Muscle Density (PMD) following Emergency Laparotomy

	Lowest Quartile PMD	**Upper Quartiles PMD**
Intervention	23/52 (44.2%)	62/151 (41.7%)
Oral Nutritional Supplements	8/23 (15.4%)	30/63 (19.9%)
Parenteral Nutrition	4/23 (7.7%)	15/63 (9.9%)
Enteral Nutrition	11/23 (47.8%)	18/63 (28.6%)

Chapter 5: General Discussion and Prospect

Emergency general surgery presents several challenges and has become the focus of attention in light of the National Emergency Laparotomy Audit (NELA). Variations in outcomes across the United Kingdom and variation in workforce have been highlighted by the NELA. There are also organizational and operational issues across with National Health Service, which can impact in the delivery and outcome of emergency general surgery. This thesis examines the relationship between multiple deprivation and sarcopenia on emergency laparotomy outcome. The outcome measures used are 30-day and 90-day mortality, length of stay and survival. In addition, the accuracy of CT reports in the patients who undergo laparotomy is assessed.

5.1 Multiple Deprivation

The Welsh Index of Multiple Deprivation (WIMD) is the official measure of deprivation in Wales and focuses on small areas (WIMD 2011). The Index comprises eight separate domains of deprivation: income, employment, health, education, housing, access to services, environment and community safety. The effect of deprivation on emergency general surgery is unknown and a paucity of published research exists in the literature. It is clear that multiple deprivation may impact the presentation of many surgical conditions and one example of this is the association with colorectal cancer screening and socioeconomic status in the National Health Service (NHS). The NHS Bowel Screening Programme (BCSP) in England offers biennial colorectal screening by guaiac-based Faecal Occult Blood testing (gFOBT) to all adults aged 60-74 years and the use of these tests has been shown to reduce colorectal cancer mortality (Hewitson et al. 2007). Uptake of this test from 2006-2009 was only 54%; lower than that for breast screening (73%) and cervical screening (79%) programmes (Health and Social Care Information Centre 2013). There is a

strong gradient in uptake by socioeconomic status; ranging from 35% in the most deprived area quintile to 61% in the least deprived area quintile (Hewitson et al. 2007). Von Wagner et al. (2011) analysed the inequalities in participation in the organised national CRC screening programme in the first 2.6 million invitations in England, performed multivariate generalized linear regression to examine area-based variation by age, gender, ethnicity and socioeconomic (multiple) deprivation. They reported an independent effect of deprivation, with more pronounced effects in women and older people. If patients do not participate in screening tools, they may miss the benefits of an early diagnosis and treatment. Late presentation of colorectal cancer with perforation or obstruction is likely to lead to emergency laparotomy with poorer outcomes. If patients present early then they can be optimized for elective surgery for earlier cancers with the option of neo-adjuvant chemoradiotherapy. Further work could compare the outcomes of patients from different socioeconomic backgrounds who present electively or as emergencies with conditions, which require surgical intervention.

A recent study compared outcomes for patients in New York State and England following emergency laparotomy for open bowel surgery (Tan et al. 2017). They used patient demographics, in-hospital, and 30-day outcomes from Hospital Episode Statistics (HES) in England and the New York Statewide Planning and Research Cooperative System (SPARCS) administrative database. Their primary outcome measure was all-cause mortality within 30 days of the index laparotomy and they analysed a total of 137,869 patient records (61% from England and 38.1% from New York State). The study did not examine socioeconomic factors specifically but did highlight several important differences, which could explain the higher 30-day mortality rates found in England compared with New York State. More than 30% of laparotomies were performed in patients older than 75 years in both cohorts but the mortality rates

were notably different; 22.9% in England compared to 9.9% in New York State. The authors suggested that this may be due to perioperative care and referenced a UK study by Ozdemir et al. (2016) who found that UK hospitals with the lower mortalities following emergency surgery had higher proportions of medical and nursing staff ratios and the greatest number of critical care beds. Access to critical care remains an issue in the UK and this has been flagged up by the NELA.

Critical care wards provide patients with advance treatments to support life and/or organ function and patients may be admitted if they need this support immediately or need closer observation than a surgical ward can offer because of their high risk of developing complications following emergency laparotomy. The NELA audits (2015, 2016, 2017) highlighted that the highest risk patients following emergency laparotomy were not admitted to critical care post-operatively in 25% of hospitals that took part in the audits. Studies in the USA suggest that more than 50% of all patients were admitted to critical care following emergency surgery (Lissauer et al. 2014). These authors examined 6098 non-traumatic surgical critical care admissions in an academic, tertiary care centre; 1053 acute care emergency general surgery, 1964 general surgery, 1491 transplant surgery, 995 facial surgery/otolaryngology and 595 neurosurgery. Acute care emergency surgery patients had statistically longer critical care stays ($p<0.01$), required longer mechanical ventilation ($p<0.01$), had higher renal replacement therapy ($p<0.01$), were more likely to require interhospital transfers for tertiary care services ($p<0.001$) and were more likely to require emergent surgery ($p< 0.001$) than the other surgical sub-specialities. It is clear that patients who require emergency laparotomy are a distinct population with multiple demands with associated financial implications to a health service. Pritchard et al. (2011) reported considerable variation in healthcare resources between the USA and UK. The UK has one of the lowest

health expenditures as a proportion of Gross Domestic Product among 19 Western countries compared to the USA, which has one of the highest. This may be an important factor in the difference in 30-day mortality rates between the UK and USA (Tan et al. 2017).

The Second Patient NELA report (2016) stated that co-morbidity, disability and frailty need to be recognized as independent markers of risk in the elderly and recommended the involvement of multidisciplinary teams who are skilled in managing this vulnerable group of patients. Recommendations from the NELA (2015) included the early involvement of Medicine for the Care of Older People clinicians for patients over the age of 70 who have undergone emergency laparotomy. The First and Second Patient Reports from NELA (2015, 2016) found that only 10% of patients are actually seen by these specialist clinicians. The Third Patient Report of the NELA (2017) found that 19% of patients aged 70 or older had input from specialists in the care of older people despite the standard being 80%. Only 5 UK hospitals (3%) met this NELA standard for postoperative review of patients aged 70 and over by geriatricians or specialists in the care of older people.

The WIMD 2011 was used for this present study and although the Index is updated every few years, a selection of indicators that compile the index are updated annually and the most recent one was published in 2017 (WIMD, 2017). In this report, the Welsh Assembly Government divide deprivation into tenths and the most deprived 10% have income deprivation 7-fold compared to the 10% least deprived (38% vs. 5%). The 10% most deprived have over 5-fold use of employment related benefits compared to the 10% least deprived (26% vs 5%). There is a similar trend with education; the least deprived areas have almost double the number of people entering higher education aged 18-19 than the most deprived (89% vs 44%). The WIMD also examined health and one of

the indicators is illness; there are almost double (32,828 vs. 16,016 per 100,000) people with long-term limiting illness in the most deprived 10% compared with the least deprived 10% population. Marked differences in community safety also exist; the police recorded violent crime rate per 100 population. Access to services is analysed by classification of settlement types and settlements of less than 2,000 people have been identified as having particular access to services (WIMD 2014). These settlements account for approximately 20% of the population in Wales and travel times to services are greatly increased when travelling without a car. The Welsh Government assesses time to various amenities such as food shops, schools, post offices, pharmacy, GP etc. One of the considerations in this thesis was that more deprived patients may have to travel further to hospital therefore present late and are more unwell. The WIMD does not examine the travel time or distance to hospital but does assess the average public and private time to a GP surgery

This present study showed that, on multivariable analysis, factors associated with 30-day mortality were age ≥80 years (relative to age <50 years, p=0.019), ASA grades 4 or 5 (relative to ASA grades 1 or 2, p<0.001), and the second most deprived Index of Multiple Deprivation quintile (relative to the least deprived IMD quintile, p=0.031). On multivariable analysis, factors associated with 90-day mortality were age over 80 years and age 70-79 years (relative to age <50 years, p=0.003, p=0.025 respectively), ASA grades 4 or 5 (relative to ASA grades 1 or 2, p<0.001), the most and second most deprived quintiles (relative to the least deprived quintile, p=0.015, p=0.026, respectively). It is not unsurprising that the older, sicker patient is likely to have poorer 30-day (operative) and 90-day mortality. The median length of stay for all patients was 15 days (1-457). Age was related to LOS (p=0.031); patients aged >80 years spent twice in long in hospital than those <50 years (median 20 vs.10 days). Higher ASA grades were associated with a longer LOS; median LOS was 19

days for patients with ASA grades 4 or 5, and 11 days for patients with ASA grades 1 or 2 ($p<0.001$). Patients in the most deprived IMD quintile had median LOS of 17 days compared to 12 days for those in the least deprived IMD quintile, although this finding was not significant ($p=0.614$). These findings present considerable far-reaching challenges, as deprivation is a complex and longstanding problem. In addition, we are faced with an older, co-morbid population who will present with surgical pathology requiring emergency laparotomy.

5.2 Computerised Tomography Accuracy

Over the past 20 years, the use of computerized tomography (CT) has become an integral component of the urgent assessment of patients who present with acute abdominal pathology. These patients are often ill and co-morbid and many proceed to emergency laparotomy. Pre-operative CT scanning is likely to provide a diagnosis, assess the patient's anatomy and may guide important decisions on the seniority or sub-specialisation of staff required in theatre, equipment required, suitable post-operative destination and risk assessment which helps inform patients and their relatives about likely outcomes. CT may also help identify patients who can be treated conservatively rather than exposing them to an unnecessary or 'exploratory' laparotomy with the associated surgical risk. Given the key role of CT in modern surgical practice, many advocate it's routine use in the emergency setting.

In this present study, three hundred and sixty-one patients with pre-emergency laparotomy CTs were studied. There were 177 males and 184 females with a median age of 67 years (range 18 – 98 years). Three hundred and eighteen cases had a correct diagnosis at CT, giving an overall CT accuracy of 88.1%.

Forty-three cases were found to have incorrect diagnoses leading to 5 negative laparotomies. Almost equal numbers of CTs are reported by consultant radiologists and by training radiologists however the majority of CTs performed in normal working hours were reported by Consultant radiologists and the majority of out-of-hours CTs were reported by training radiologists. Consultant reports were more accurate than training radiologists (90.3% vs 85.7%). Overall accuracy was highest in the lower gastrointestinal pathology group (90.4%), followed by small-bowel pathology (89.9%) and the lowest accuracy was seen in patients with upper gastrointestinal pathology (75.5%).

The Royal College of Radiologist's (RCR) publication 'Standards for the communication of critical, urgent and unexpected significant radiological findings' was first published in 2008 and a revised publication was available in 2012 (RCR 2012). The focus of this publication was the issuing of the verified report of the investigation and the communication of this report to the referrer within an appropriate time frame. This is of particular importance in a patient with an acute surgical problem, which may necessitate emergency laparotomy. Key research, undertaken on behalf of the RCR and published recently, examined almost 5,000 patients who had emergency CTs and approximately half of these patients when on to have a laparotomy. Notable findings were that there was a discrepancy rate of 4%(204 CTs) of provisional reports and these discrepancies were more common in surgical than non-surgical patients (Howlett et al. 2017). A discrepancy rate of 6% between the reports and surgical findings was found; more than 2/3 were false negatives or misdiagnoses. In 1.5% of surgical patients (n=36) and 0.6% of non-surgical patients (n=15), the discrepancies were deemed to have caused harm as a result of delays in diagnosis or unnecessary intervention (Howlett et al. 2017). High standards of practice will only be maintained by learning from experience and discrepancies as part of a

continuing learning process. Because of the importance of accurate reporting of CT images in critically ill patients, this will be an important aspect of this thesis.

5.3 Sarcopenia

The International Working Group on Sarcopenia (IWGS) consensus definition of sarcopenia is 'age-associated loss of skeletal muscle mass and function' (Fielding 2011). The assessment of function is difficult and existing evaluations can involve subjective parameters (Hodari et al. 2013) or assessement tools requiring up to varables (Mitnitski et al. 2001). Other tools involve physical testing such as walking speed or hand grip strength (Mitnitski et al. 2001). These tests are unrealistic in the emergency setting in an acutely ill patient so there is a demand to find a straightforward, quick, objective method of identifying patients at risk of adverse outcomes following emergency surgery. The diagnosis of sarcopenia using a straightforward and easily reproducible method may help identification vulnerable patients for improved preoperative patient and relative counselling, consideration of less invasive approaches and setting realistic goals of care.

Computerised tomography (CT) is an important part of the assessment of the acutely unwell surgical patient to aid diagnosis. Recently, it has also been used to detect a depletion of lean muscle mass, which is a surrogate marker for sarcopenia. Throughout the literature, the diagnosis of sarcopenia has been derived from various CT measurements; Total Psoas Area (TPA), Total Psoas Volume (TPV), Psoas Muscle Density (PMD) or Hounsfield Units Average Calculation (HUAC) and different cut-offs have been used (absolute values or quintiles/quartiles). The use of lean muscle measurements have provided an simple, objective and reproducible method of detecting sarcopenia patients pre-

operatively but as there is no consensus on the best method of sarcopenia measurement, the present study used the lowest sex-specific quartile Hounsfield Unit Average Calculation (HUAC). Sarcopenia reflects the chronic overall health rather than the severity of the acute surgical illness, so it is an attractive measure to use in the emergency surgery setting.

This present study suggested that there may be an association between sarcopenia and longer-term survival in patients undergoing emergency laparotomy but it did not demonstrate a relationship with 30-day mortality, 90-day mortality or survival when other factors were considered such as age and American Association of Anaesthesiologists (ASA) classification.

Similar results were reported in another recent study from the USA. Dirk et al. (2017) measured the cross-sectional area of psoas muscles (Total Psoas Area [TPA]) at the vertebral level T4 on preoperative Computerised tomography (CT) of patients within 30 days of undergoing emergency laparotomy over a 5 year period from 2008 until 2013. They obtained patient data from the Institutional American College of Surgeons National Surgical Quality Improvement Program. In their study, 75.9% of 781 patients had CT scans suitable for measurement of TPA. On univariate analysis, a significant association was found between TPA and length of stay ($p<0.001$) and 90-day mortality ($p<0.001$) but not 30-day mortality ($p=0.260$). In similarity to the findings in this present study, the authors found that TPA lost it's significance when compared to other predictors of mortality such as age, ASA grades, functional dependency (Dirk et al. 2017).

Recent evidence may support our suggestion that sarcopenia may be more important in longer-term outcomes. Rangel et al. (2017) found that sarcopenia, as measured by lowest quartile Total Psoas Index (TPI), was a strong independent predictor for mortality after emergency abdominal surgery. They calculated TPI by averaging the bilateral psoas muscle cross-sectional area at L3 and normalizing it for height, in 297 of the 390 patients who required

emergency abdominal surgery. The one-year mortality was 32% and sarcopenic patients had lower body mass index, greater need to ITU, and longer hospital stay. The sarcopenic group had higher in-hospital, 30-day, 90-day, 180-day and one year mortality.

Future prospective studies involving a larger sample size should be performed and co-morbidities should be included in the model. In addition to mortality, other important long-term outcomes, such as loss of function and productivity should be considered as these outcomes may be of particular importance to older patients.

5.4 Prospect

5.4.1 Co-morbidity

One weakness of the deprivation and sarcopenia studies is that co-morbidity was not taken in to account when examining outcomes such as 30-day mortality, 90-day mortality, length of stay and survival. ASA was used as a proxy marker for co-morbidity but this may not truly represent functional and physiological status in the setting of an acute surgical pathology. Future studies on patients undergoing emergency laparotomy in this institution should include co-morbidities and these should be classified using a robust system.

5.4.2 Post-Operative Morbidity

Furthermore, the present studies used mortality as the primary outcome measures and did not consider post-operative morbidity. Inference from online blood results and radiographs were not felt to be robust method for determining complications. Access to medical notes was not possible due to hospital restrictions; an upper limit of 50 sets of notes per study is currently permitted.

Collection of data whilst the patient is an inpatient would avoid the need to pull notes following discharge but this requires additional manpower. Post-operative morbidity is clearly an important outcome and future research should include this data. Furthermore, post-operative complications should be graded using a recognized classification system such as Clavien-Dindo, which was originally described in 2004 (Dindo et al. 2004).

Clavien-Dindo Classification System:

Grade 1: Any deviation from the usual post-operative course which does not required endoscopic, radiological or surgical intervention e.g the administration of drugs, physiotherapy or local wound care

Grade 2: Post-operative complications requiring other drug treatments, blood transfusions or total parenteral nutrition

Grade 3: Complications requiring endoscopic, radiological or surgical intervention (Grade 3a – not requiring general anaesthetic, Grade 3b – requiring general anaesthetic)

Grade 4: Life-threatening complications (Grade 4a – single-organ dysfunction, Grade 4b – multi-organ dysfunction)

Grade 5: Death

Disability after discharge: suffix 'd' is added to the grade of complication

5.4.3 Discharge Destination

Length of stay was examined but the study did not look at discharge destination. It cannot be assumed that all patients went home and there is a conceivable difference in outcome between the pre-morbidly independent patient who leaves hospital to return to an independent lifestyle at home, and one who goes into a nursing home and requires assistance with activities of daily living. Other

patients may require prolonged rehabilitation either in hospital or at home with re-enablement involvement. Length of stay as an outcome measure does not discriminate between these very different scenarios and future work should consider this.

5.4.4 Quality of Life

Thirty-day mortality, 90-day mortality, length of stay and survival are 'hard' markers of outcome and their use may ignore a more patient-centric outcome: quality of life. A patient may survive for 90 days but may be in Intensive Care or reliant on activities of daily living such as washing, dressing and feeding from nursing staff. Another example is a patient who has been independent and living at home pre-operatively, who is then wheelchair bound and destined for a nursing home following a lengthy recovery from their emergency laparotomy. The failure to regain independence is not recorded in the outcome measures used for the deprivation and sarcopenia studies. Future research should investigate other important long-term patients outcomes, such as quality of life assessment, loss of functional status and productivity following emergency laparotomy.

5.4.5 Race/Ethnicity

An additional factor, which was not considered in this study, was the race/ethnicity of the patients undergoing emergency laparotomy. Several studies from the USA have highlighted disparities in outcomes for patients of different race/ethnicity (Satcher et al. 2005) but few studies have focused on emergency general surgery. Zogg and colleagues (2017) recently reported on a survival analysis on a total of 1,292,937 patients (737,092 adults 18-64 years,

552,945 ≥ 65 years) and when they considered patients of different race/ethnicity who underwent operative intervention, no difference in mortality or acute care morbidity. Relative to non-Hispanic white patients, non-Hispanic black patients (<65 years old) who underwent surgery were more likely to have an unplanned re-admission (HR 1.11, 95% C.I 1.09-1.15). Patients ≥65 years of different race/ethnicity also had different re-admission rates; compared to white patients, black and Hispanic patients are more likely to have an unplanned readmission (HR 1.16 95% C.I 1.13-1.19, HR 1.06 95% C.I 1.04-1.07 respectively).

Hall and colleagues (2015) investigated risk of mortality in 116,344 patients of different race/ethnicity following emergency surgery within 24 hours of admission. Their patients underwent colectomy, small bowel resection or ulcer repair. African American patients had 10% higher odds of death than Caucasians (p=0.02). They explained the disparity in racial/ethnicity outcomes by hospital level factors; patients treated in hospitals with greater than 6% African American emergency general surgical patients had poorer outcomes in terms of mortality than those with fewer African American patients (adjusted OR 1.16 vs 1.42, p=0.002).

Causey et al. (2013) had some conflicting results in their study of 75,280 patients from the American College of Surgeons National Surgical Quality Improvement Program database from 2005 until 2009. Mortality was higher in black patients (5.3%) compared to white patients (4.6%), however on combining minorities, mortality was reduced by 1.7-fold. In contrast, complications were higher in this group (1.056-fold).

5.4.6 Enhanced Recovery After Surgery

Professor Henrik Kehlet pioneered the concept of ‘fast-track surgery’ in the 1990s in Denmark. He proposed a multi-modal surgical approach using a number of techniques to minimize surgical stress and improve post-operative outcome (White et al. 2007, Kehlet 2008). Enhanced recovery after surgery (ERAS) is a modern, evidence based approach to patient care which has been extended to the perioperative period. It is now standard practice for many elective general surgical procedures and follows 2 principles: clear communication with the patient to ensure all information is explained thoroughly and use of a structured care pathway. All healthcare professionals must work from the same pathway. There are preoperative, intra-operative and post-operative elements to an ERAS programme and healthcare professionals and the patient have active roles. Pre-operatively, the focus is on patient information and counselling, and the optimization of organ function. This may relate to abstinence of smoking and alcohol, the avoidance of prolonged fasting, carbohydrate loading and the avoidance of bowel preparation. Antibiotic prophylaxis and thromboprophylaxis should be given and premedication is avoided. We can apply some of these recommendations to patients undergoing emergency laparotomy and others are not relevant e.g smoking and alcohol habits cannot be changed when the patient presents acutely, patients may be vomiting so may be already fasting, bowel obstruction or perforation may prevent the use of oral carbohydrates pre-operatively and bowel preparation is not used in the emergency scenario. Antibiotics are often given to a patient requiring emergency laparotomy as part of the ‘Sepsis Six’ bundle and thromboprophylaxis is used unless there is a contraindication such as an abdominal pathology with bleeding (spontaneous ruptured spleen, bleeding peptic ulcer). Perioperative ERAS measures in elective surgery include the use of short-acting anaesthetic drugs, epidural anesthesia and analgesia, careful administration of intravenous fluids, maintenance of normothermia using heating

blankets/mattresses and warm intravenous fluids, and the avoidance of drains. In the emergency general surgery patient, epidurals may be contraindicated due to sepsis or the urgency of the situation may not permit a procedure which could potentially delay getting the patient onto the operating table. Some of the other perioperative ERAS elements may need to be adapted due to the acute physiological disturbance that is often associated with general surgical pathology, for example, patients may have an acute kidney injury requiring active resuscitation or bowel obstruction necessitating the use of a nasogastric tube. Drains are often used in patients who had faecal peritonitis due to bowel perforation due to risk of developing pelvic abscesses, or in the patient who has had a patch repair of a perforated peptic ulcer in order to detect and drain a potential leak from the repair.

It is clear that some elements of the ERAS protocols used in elective surgery could be used in emergency laparotomy pathways. Only a few studies have examined the use of ERAS protocols in patients undergoing emergency general surgery. Gonenc and colleagues (2014) performed a small, single centered, randomized controlled trial comparing 21 patients who underwent laparoscopic repair of perforated peptic ulcers in an ERAS program with 26 patients who underwent conventional care. The age range of their patients was 18-65 with a mean of 35 years. The patients in the ERAS group had their nasogastric tube and urinary catheter removed on day 0. Sixty-two patients were randomized; 36 in the control group of which 26 patients were analysed, and 26 in the ERAS group of which 21 were analysed. The length of hospital stay was significantly shorter in the ERAS group (3.8 vs. 6.9 days, p=0.001) but there was no difference in mortality or morbidity such as superficial surgical site or organ infections, post-operative ileus, pulmonary complications, or post-operative bleeding between the two groups. The time to start oral intake was significantly shorter in the ERAS group (1.55 vs 4.82 days, p=0.001) but there was no

difference in the need to re-insert nasogastric tubes, re-admission or re-operation. This study of ERAS in emergency surgery for perforated peptic ulcer disease is not directly comparable to the present study of patients undergoing emergency laparotomy as they only looked at patients undergoing laparoscopic surgery. They also excluded patients with septic shock, which is likely to be a feature in many of our patients with abdominal pathology requiring emergency surgery. Gonenc's trial only included patients with ASA grades 1 or 2 and these patients comprise only 75% of the present study's population. Lohsiriwat (2014) compared outcomes for patients undergoing an ERAS protocol following emergency bowel resection for obstructing bowel cancer with patients undergoing conventional care. The protocols differed for the pre-operative, peri-operative and post-operative period. Pre-operatively, the ERAS patients received detailed information and education including breathing exercises, mobilization, dietary goals and an estimation of their anticipated length of hospital stay. The patients on the conventional protocol received advice from the on call consultant, the author does not state the content of this advice. The operation performed was at the discretion of the surgeon and the main intra-operative differences were the use of a transverse incision for right colon resections, the use of a wound retractor and avoidance of drains in the ERAS group. Active warming of intravenous fluids, the use of a Bair Hugger, warm packs around the bowel, and use of local anaesthetic was standard for the patients on the ERAS protocol whereas the these elements were not in the conventional protocol. The ERAS protocol included prophylaxis for post-operative nausea and vomiting based on patient risk factors. Post-operative care for the ERAS patients included intravenous fluids to maintain a specific urine output and set times for nasogastric tube and urinary catheter removal, oral nutrition was commenced following removal of the nasogastric tube and multimodal analgesia was used with the preferential use of elective cyclo-

oxygenase inhibitors rather than opioids. The ERAS patients had daily physiotherapy and aimed to be discharged by day 5. The author reported a shorter median length of hospital stay in the ERAS group (5.5 vs. 7.5 days, p=0.009) and the re-admission rate was the same in both groups. Although the incidence of post-operative complications was less in the ERAS group, the finding did not reach statistical significance (p=0.094). Patients in the ERAS groups had a shorter time to the first passage of flatus but there significance of this in unclear as the time to defaecation was the same in both groups. Patients in the ERAS group started adjuvant chemotherapy 12 days sooner than the conventional group but it is not known whether this had am impact on long-term outcomes. These studies are the first to look at enhanced recovery in emergency general surgery and some elements of their ERAS pathways should be considered in selected emergency general patients.

5.5 Conclusion

Despite significant improvements in surgical outcomes over recent years, morbidity and mortality following major non-traumatic abdominal surgery still poses challenges. This thesis set out to identify potential novel prognostic indicators for patients undergoing emergency laparotomy. Socio-economic deprivation and sarcopenia may not be amenable to change in the pre-operative period in patients who require emergency surgery, however identification of these patients may allow targeted intervention in the post-operative period and may improve prognostification. Further research will then be required to assess the efficacy and cost-effectiveness of these interventions.

Highlighting the inaccuracies in diagnostic CT reporting has led to changes in reporting in our institution and ongoing audit is important to ensure that standards improve.

Emergency surgery accounts for about half the surgical workload in the NHS and the NELA is driving standards forward by highlighting the poor outcomes associated with this surgery, and by publishing outcomes in the public domain. The results from this thesis should be used to improve outcomes for our patients who require high risk emergency general surgery.

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Appendix A

Publications and communications derived from work in this thesis

Publications

Perry H, Foley K, **Witherspoon J**, Powell-Chandler A, Abdelrahman T, Roberts SA, Lewis WG

Relative Accuracy of emergency CT in adults with non-traumatic abdominal pain

British Journal of Radiolology. 2016 Mar;89(1059):20150416

Published Abstracts

Witherspoon J, Howell G, Lewis WG

Outcomes and nutritional intervention in patients with CT-defined sarcopenia undergoing emergency laparotomy.

British Journal of Surgery 2016; 103 (S6):104–209

Witherspoon J, Aslanyan A, Davies IL, Roberts AS, Lewis WG

Relative Accuracy of Computerised Tomography Examination in the Acute Abdomen: A Prospective Observational Cohort Study

British Journal of Surgery 2015;102(S1):232

Witherspoon J, Powell-Chandler A, Aslanyan A, Lewis WG

Relative Influence of Socioeconomic and Health Deprivation on Emergency Laparotomy Outcome and Prognosis

British Journal of Surgery 2015;102(S1):

Witherspoon J, Powell-Chandler A, Aslanyan A, Brown C, Karran A, Thomas C, Lewis WG

Prognostic Significance of Deprivation in Patients Undergoing Emergency Laparotomy

Gastroenterology 2014;146(5),S-254

Witherspoon J, Powell-Chandler A, Aslanyan A, Roberts S.A, Lewis WG

Influence of CT Muscle Density defined Sarcopenia on Emergency Laparotomy Outcome

British Journal of Surgery 2015;102(S1):

Oral Presentation to learned societies

Witherspoon J, Howell G, Lewis WG

Outcomes and nutritional intervention in patients with CT-defined sarcopenia undergoing emergency laparotomy.

Oral Presentation ASGBI 2016, Belfast

Witherspoon J, Aslanyan A, Davies IL, Roberts AS, Lewis WG

Relative Accuracy of Computerised Tomography Examination in the Acute Abdomen: A Prospective Observational Cohort Study

Oral Presentation at ASGBI 2014, Harrogate

Witherspoon J, Powell-Chandler A, Aslanyan A, Lewis WG

Relative Influence of Socioeconomic and Health Deprivation on Emergency Laparotomy Outcome and Prognosis

Oral Presentation at ASGBI 2014, Harrogate

Witherspoon J, Powell-Chandler A, Aslanyan A, Roberts SA, Lewis WG

Influence of CT Muscle Density defined Sarcopenia on Emergency Laparotomy Outcome

British Journal of Surgery 2015;102(S1):

Oral Presentation at ASGBI 2014, Harrogate

Prognostic significance of CT-defined sarcopenia on emergency laparotomy outcome

Witherspoon J, Powell-Chandler A, Roberts SA, Lewis WG

Royal Society of Medicine 2016, London

Posters of Distinction to learned societies

Witherspoon J, Powell-Chandler A, Aslanyan A, Brown C, Karran A, Thomas C, Lewis WG

Prognostic Significance of Deprivation in Patients Undergoing Emergency Laparotomy

Gastroenterology 2014;146(5),S-254

Poster of Distinction Presentation at DDW 2014, Chicago

Poster Presentations to learned societies

Witherspoon J, Perry H, Foley K, Powell-Chandler A, Abdelrahman T, Roberts SA, Lewis WG

Relative accuracy of emergency CT in adults with non-traumatic abdominal pain

Poster Presentation at DDW 2016, San Diego

Witherspoon J. Powell-Chandler A, Karran A, Lewis WG

Optimising Emergency Care Outcomes by targeting Sarcopenia

Poster Presentation at the International Forum on Quality and Safety in Healthcare 2014, London

Witherspoon J. Powell-Chandler A, Karran A, Lewis WG

Optimising Emergency General Surgery Outcomes in the Era of Enhanced Recovery After Surgery (ERAS) programmes

Poster Presentation at the International Forum on Quality and Safety in Healthcare 2014, Paris

Witherspoon J, Aslanyan A, Davies L, Karran A, Roberts S.A, Lewis WG

Relative accuracy of computed tomography examination of the acute abdomen: a prospective observational cohort study

Poster Presentation at ASGBI 2014, Harrogate

Appendix B

BJR

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FULL PAPER

Relative accuracy of emergency CT in adults with non-traumatic abdominal pain

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Objective: CT examination prior to emergency laparotomy has become ubiquitous in contemporary clinical practice, but the relative accuracy of CT in this context has not been widely reported. The aim of this study was to determine the accuracy and strength of agreement between the perceived pre-operative CT diagnosis and operative findings.
Methods: Data from patients undergoing pre-operative CT prior to emergency laparotomy from January 2013 to June 2014 in a large teaching hospital were analysed. The CT diagnosis was compared with operative findings using the χ^2 test and weighted kappa statistic (Kw). Results were further analysed related to the time of day the CT was reported, anatomical location and grade of the reporting radiologist.
Results: 361 patients [median age 67 years (18–98 years); 180 males] underwent CT prior to emergency laparotomy. CT reports were deemed accurate in 318 (88.1%) cases and inaccurate in 43 (11.9%) cases, which resulted in 5 negative laparotomies in this latter cohort (11.6%, χ^2 37.50, df 1; $p < 0.0001$). Accuracy and strength of agreement varied with anatomical location of the pathology; upper gastrointestinal (UGI) 75.5%, Kw 0.673 (0.531–0.815; $p < 0.001$); small bowel 89.9%, Kw 0.781 (0.687–0.875, $p < 0.001$); lower gastrointestinal (LGI) 90.4%, Kw 0.821 (0.749–0.893; $p < 0.001$). CT examinations reported within normal working hours had higher strength of agreement [Kw 0.832 (0.768–0.896), $p < 0.001$] than CTs reported out of hours [Kw 0.789 (0.721–0.857), $p < 0.001$], but there was no significant difference in overall accuracy (89.9 *vs* 86.0%; χ^2 1.306, df 1, $p = 0.253$). Reporter seniority was not associated with improved diagnostic accuracy (χ^2 1.825, df 1; $p = 0.177$).
Conclusion: CT agreement with emergency operative pathology was good to excellent, but the strength of agreement varied in relation to anatomical location of pathology.
Advances in knowledge: Overall accuracy was 88.1% with good to excellent agreement between pre-operative CT and emergency laparotomy findings in adult patients with non-traumatic abdominal pain in the acute setting. Diagnostic accuracy of CT reporting varies with anatomical location of pathology.

INTRODUCTION

Patients requiring emergency surgery are amongst the most sick patients managed by the National Health Service (NHS), and the delivery of emergency general surgery care is currently suboptimal.[1–3] For elderly, patients who are frail with significant comorbidities, the risk of death or serious complications is high. In general surgery alone, emergency cases account for 14,000 admissions to intensive care unit (ICU) in England and Wales annually, carrying a mortality rate of over 25% and associated costs of at least £88 million.[1,2,4] It is a key hospital service, which has seen significant and ongoing change over the last 15 years and requires further substantial development to meet the needs of contemporary NHS and society.

Assessment protocols for patients with abdominal pain vary, not only from hospital to hospital but internationally based on healthcare resource. The historical radiological assessment by plain abdominal and chest films is often superseded by CT.[5] While possessing self-evident advantages over plain-film radiology and ultrasonography in many instances, the modality still has limitations including expense, high radiation dose, limited availability compared with plain films and the potential for misinterpretation.[6,7]

The NHS faces a significant reconfiguration of regional services and in many hospitals out-of-hours (OOH) radiology reporting is outsourced to external reporting services to meet increasing demand. This reduces the opportunity for initial ultrasound evaluation and face-to-face discussion

with image review between the operating surgeon and the reporting radiologist.

Whether CTs are reported in-house or outsourced, the quality of radiology reporting must be high to ensure patient safety and help to facilitate optimal surgical outcomes.

The aim of this study was to determine the accuracy and strength of agreement between the pre-operative CT and emergency laparotomy findings in adult patients with non-traumatic abdominal pain, in the setting of unscheduled care in a UK teaching hospital serving a tertiary population of 1.4 million. Differences in CT findings between the timing of the examination, various anatomical locations and reporter seniority were assessed.

METHODS AND MATERIALS

Evaluation of a surgical database containing details of the emergency laparotomy findings and review of the corresponding radiology CT report was carried out by a senior surgical trainee. Data were extracted from the running theatre database that records all operations performed within the large tertiary teaching hospital.

Consecutive patients were identified who underwent both pre-operative CT (within 24 h of operation) and operative assessment between 1 January 2013 and 30 June 2014. Data from the first 12 months of the study period were collected prospectively and subsequently analysed. However, to increase sample size and study power, a further 6 months of data were collected retrospectively and added to the original data set. The combined data set was then analysed retrospectively.

All adult patients undergoing their first emergency laparotomy over the 18-month period were included. Exclusion criteria were patients who underwent laparotomy without prior CT, primary procedures of the appendix or biliary tree, repeat laparotomies and patients in whom the CT findings led to laparoscopic investigation rather than emergency laparotomy. Appendix and biliary pathologies were excluded in line with the current National Emergency Laparotomy Audit methodology.[8]

All CT examinations were reported by radiologists working within the same NHS trust (in-house) rather than being outsourced to external reporting services.

CT examinations were performed with a GE HD 750 Discovery 64-slice scanner (GE Healthcare, Pollards Wood, Buckinghamshire, UK). A collimation of 40 mm, pitch of 0.984: 1 and tube rotation speed of 0.4 s were used. Tube output was 120 kVp with smart milliampere dose modulation between 60 and 600 mA. Slice thickness was 0.625 mm with acquisition of images in coronal and sagittal planes using soft tissue and bone algorithms in 3-mm reconstructions. At this institution, standard protocols were used depending on the clinical indication for CT.

A standard CT of the abdomen and pelvis was performed in the portal venous (PV) phase (timing 70 s) with positive oral contrast. 100 ml of Niopam 300 was given intravenously at 3–4 ml s^{-1}, followed by 20 ml of saline. 20 ml of Omnipaque 350 in 500 ml of water was used as oral contrast, 250 ml given 1 h prior to CT, 250 ml given 30 min prior to CT and 10–50 ml given immediately before scanning. i.v. contrast was withheld according to local guidelines in patients with impaired renal function or previous adverse reaction and where the clinical indication was for renal tract stones.

Alternative CT protocols include investigation of small-bowel obstruction, performed with i.v. contrast in the PV phase without oral contrast. Suspicion of bowel ischaemia was investigated with i.v. contrast in the arterial (timing 20–30 s) and PV phases without oral contrast. Investigation of gastrointestinal (GI) bleeding was performed in three phases: pre-contrast, arterial and PV phases without oral contrast.

Laparotomies were performed in the emergency setting by senior surgical registrars or the on-call consultant surgeon within an appropriate timeframe, depending on clinical priority and following assessment by an on-call anaesthetist to assess pre-operative risk and comorbidities.

The comparison between CT report and laparotomy was performed by a higher surgical trainee. However, any "grey" cases were discussed with a consultant surgeon before being marked accurate or inaccurate. No specific rules were applied in this process. The decision was based on surgical opinion.

The patient cohort was subclassified based on the location of their pathology, *i.e.* upper gastrointestinal (UGI), small bowel, lower gastrointestinal (LGI), vascular and other (including gynaecological and anterior abdominal wall pathology) (Table 2). UGI pathology was defined as acute conditions involving the oesophagus, stomach and duodenum. Small-bowel pathology included those of the jejunum and ileum, and LGI pathology included the colon and rectum.

The patients were also subdivided into groups separated by the grade of CT reporter, either a training grade or consultant radiologist. CT reports were evaluated to assess whether or not the CT had been reviewed by a consultant radiologist and those reviewed were further subdivided into absolute agreement, addendums or amendments.

Addendums were defined as CT reports in which the reviewing radiologist essentially agreed with the original report, but added supplementary comments that were not clinically significant, *e.g.* incidental findings of cysts.

Amendments were defined as supplementary reports which contained findings regarded as clinically significant by the reviewing radiologist. However, initial clinical management was based on the first report. Definitions of addendums and amendments were pre-specified during the design of the study, prior to data collection.

This study was deemed to be service evaluation rather than original research; therefore, ethical approval was not required.

Statistical analysis

The pre-operative CT diagnosis and the intraoperative surgical findings were compared, and overall accuracy was calculated.

Table 1. Diagnoses identified at laparotomy

Diagnosis	Upper GI	Small bowel	Large bowel	Vascular	Other	Total
NAD	2	1	3	–	–	6
Inflammation	3	2	16	–	–	21
Perforation	19	9	37	–	–	65
Obstruction	2	105	52	–	–	159
Sepsis/collection	13	10	17	–	7	47
Ischaemia	1	17	8	–	–	24
Tumour	1	–	10	–	–	11
Haemorrhage	4	–	1	6	3	14
Ileus	–	1	1	–	–	2
Other	4	4	3	–	1	12

GI, gastrointestinal; NAD, no abnormality detected.

The weighted kappa statistic (Kw)[9,10] was used as a novel method to provide a robust measure of strength of agreement, by taking into account the degree to which the report was inaccurate, when compared with the "gold-standard" operative pathological findings.

To facilitate calculation of Kw, a virtual mathematical matrix was constructed so that different levels of agreement were classified related to the pathological findings found at operation. When UGI pathology was found at operation, and the CT reported small-bowel pathology, this was classified as 1 degree of error, and if colonic pathology was reported on CT, this was classified as 2 degrees of error. Similarly, addendums to reports were classified as 1 degree of error; amendments were classified as 2 degrees of error.

The maximum value of Kw is 1.00 when agreement is perfect; a value of 0 indicates no agreement better than chance, and negative values show worse than chance agreement. The hypothesis of Kw = 0 was tested, and the value of Kw was assessed for strength of agreement and categorized according to the method of Landis and Koch.[9]

Intergroup comparison of overall accuracy between reporter seniority, timing of CT and anatomical location was made using the χ^2 test.[11] A p-value of <0.05 was considered statistically significant. All statistical tests were pre-specified at the outset of the study prior to data collection and analysis. Data analysis was carried out with the SPSS® v. 13 (IBM Corp., New York, NY; formerly SPSS Inc., Chicago, IL).

RESULTS

A consecutive series of 519 patients undergoing emergency laparotomy were examined. 361 (69.6%) patients out of 519 patients underwent laparotomy following CT and were included in the study. The median age was 67 years (range 18–98 years); 177 patients were male and 184 patients were female. Table 1 details the diagnoses identified at laparotomy.

Of the 361 cases included, 318 cases were found to have a correct diagnosis at CT, giving an overall CT accuracy of 88.1% (Table 2) and Kw of 0.812 [95% confidence interval (CI) 0.766–0.858, $p < 0.001$]. In contrast, 43 cases were found to have incorrect diagnoses, which was associated with an incidence of 5 negative laparotomies (11.6%, χ^2 37.50, df 1; $p < 0.0001$).

189 (52.4%) CTs were performed in normal working hours from 8 AM to 5 PM, from Monday to Friday (excluding bank holidays). CTs performed and reported OOH accounted for the remaining 172 (47.6%) CTs. OOH CTs were further subdivided (Table 3)

Table 2. Relative accuracy of CT reports

Anatomy	Total CTs performed	CT correct	CT incorrect	Accuracy %
All sites	361	318	43	88.1
Upper GI	49	37	12	75.5
Small bowel	149	134	15	89.9
Lower GI	146	132	14	90.4
Vascular	6	6	0	100
Other	11	9	2	81.8
All sites excluding vascular	355	312	43	87.9

GI, gastrointestinal.

Table 3. Details of CT examinations related to time performed and grade of radiologist

Time CT performed	Total number	Consultant CT reports	Training radiologist CT reports	Reports changed	Amendments	Addendums	Overall correct
Weekday	189 (52.4)	180 (95.2)	9 (4.8)	4 (2.1)	1 (0.5)	3 (1.6)	170 (89.9)
Weekend day	63 (17.5)	2 (3.2)	61 (96.8)	22 (35.0)	3 (4.8)	19 (30.2)	53 (84.1)
Weekday evening	35 (9.7)	2 (5.7)	33 (94.3)	18 (51.5)	1 (2.9)	17 (48.6)	31 (88.6)
Nights	74 (20.5)	2 (2.7)	72 (97.3)	38 (51.4)	13 (17.6)	25 (33.8)	64 (86.5)
All out-of-hours reports	172 (47.6)	6 (3.5)	166 (96.5)	78 (45.4)	17 (9.9)	61 (35.5)	148 (86.0)
Total	361	186 (51.5)	175 (48.5)	82 (22.7)	18 (5.0)	64 (17.7)	318 (88.1)

Data are number of CTs (%).
Weekend, Friday 5 PM–8.30 PM, Saturday, Sunday and bank holidays, 8–8.30; weekday, 8 AM–5 PM excluding bank holidays; weekday evenings, Monday–Thursday 17.00–20.30; nights, 8.30 PM–8 AM.

with 74 (20.5%) CTs of the overall scans performed at night (8.30 PM–8 AM), 63 (17.5%) CTs performed on a weekend day or bank holiday [from 5 PM Friday to 8.30 PM on Sunday (excluding nights)] and 35 (9.7%) CTs performed on weekday evenings (5 PM–8.30 PM).

343 (95.0%) CT protocols were contrast enhanced. 169 (46.8%) patients had i.v. contrast in PV phase only with 150 (41.6%) patients receiving oral contrast in addition. 18 (5.0%) patients had non-contrast scans owing to either clinical suspicion of calculi or contraindication to contrast media and 9 (2.5%) patients had oral contrast only. 9 (2.5%) patients had i.v. contrast in arterial and PV phases and 6 (1.6%) patients underwent pre-contrast arterial and PV phases.

186 (51.5%) CTs were reported by consultant radiologists and 175 (48.5%) CTs by training radiologists. 180 (95.2%) CTs performed in normal working hours were reported by consultant radiologists compared with 9 (4.8%) CTs reported by radiologists in training. Overall, CTs performed in normal working hours reported the highest overall accuracy (89.9%) (Table 3).

OOH CTs were largely reported by training radiologists (96.5%), with consultant reports accounting for 3.5% CTs (Table 3). The difference in reporting seniority grade within hours *vs* OOH was highly significant (χ^2 303.498, 1 df; $p < 0.001$). The overall accuracy of consultant reports was 90.3% compared with the training radiologist accuracy of 85.7%, but this difference was not statistically significant (χ^2 1.825, df 1; $p = 0.177$).

The number of CTs reviewed by a consultant radiologist was assessed. 6 out of 184 (3.3%) of consultant-reported CTs were reviewed. Four reports were not changed and two (1.1%) reports were given an addendum. There were no amendments. All of the 175 training radiologist reports were reviewed by consultants. There was absolute agreement in 95 (54.3%) reports. 80 (45.7%) reports were changed (18 amendments, 62 addendums). Training radiologist CT reports were more likely to have an amendment or addendum than consultant reports (χ^2 102.346, df 1; $p < 0.001$); however, this may reflect the system of checking OOH CT scans by the on-call consultant the following morning.

The timing of the CTs, when reports were reviewed by a consultant, was also evaluated. Four (2.1%) in-hours reports were subsequently changed (one amendment, three addendums). In contrast, 78 (45.4%) of OOH CT reports were changed (17 amendments, 61 addendums), following consultant review (χ^2 95.874, df 1; $p < 0.001$). The true significance, and in particular accuracy, of any changes made following consultant review is unknown, as the initial clinical management was based on the first report and will be the subject of a subsequent study.

There was no significant difference between the overall accuracy of normal working hours and OOH reports (89.9 *vs* 86.0%; χ^2 1.306, df 1, $p = 0.253$). Similarly, Kw for normal working-hour reports and OOH reports were 0.832 (95% CI 0.768–0.896, df 1; $p < 0.001$) and 0.789 (95% CI 0.721–0.857; $p < 0.001$), respectively. Although categorized by Landis and Koch[9] as excellent and good strength of agreement, respectively, the CIs for each Kw overlap, which implies no difference between in-hours and OOH agreement.

The commonest pathology was small bowel related in 149 (41.3%) patients, LGI in 146 (40.4%) patients, UGI in 49 (13.6%) patients, vascular in 6 (1.7%) patients and other pathology in 11 (3%) patients.

Amongst the GI subdivisions, overall accuracy was highest in the LGI pathology group with 90.4% (in 132/146 patients), followed by small-bowel pathology, with an overall accuracy of 89.9% (in 134/149 patients). UGI pathology was least accurately reported (75.5%; in 37/49 patients). Presentations with vascular disease showed a CT accuracy of 100%. Pathologies determined as "other" had an accuracy of 81.8% (in 9/11 patients). The accuracy of UGI reports was significantly

lower than that of small-bowel (χ^2 6.513, df 1, $p = 0.011$) and LGI reports (χ^2 7.259, df 1, $p = 0.007$). There was no significant difference between the accuracy of small-bowel and LGI reports (χ^2 0.019, df 1; $p = 0.890$).

In addition, the strength of agreement varied with anatomical location of the pathology. UGI agreement was good (Kw 0.673, 95% CI 0.531–0.815, $p < 0.001$), small-bowel agreement was good (Kw 0.781, 95% CI 0.687–0.875, $p < 0.001$) and LGI agreement was excellent (Kw 0.821, 95% CI 0.749–0.893, $p < 0.001$).

Table 4 contains the Kw values relating to anatomical location of pathology and timing of CT reporting.

DISCUSSION

This large observational cohort study examines the accuracy and strength of agreement between emergency abdominal CT examination and operative pathology in adult patients undergoing emergency non-traumatic laparotomy. The principal findings were that variations in diagnostic accuracy exist between anatomical pathological locations, with UGI pathology least accurately reported.

Inaccurate CT diagnoses occurred in 11.9% of cases and were associated with a significant rate (11.6%) of avoidable negative laparotomy. Arguably, this may reflect reduced exposure of radiologists to acute UGI pathology, as there were approximately three times as many CTs performed for small- and large-bowel pathologies when compared with UGI. This is also reflected in the lower Kw values(Table 4).

Approximately half of CT reporting was performed OOH, predominately by training radiologists, and later checked by a consultant radiologist. All reports by trainees were later reviewed by a consultant radiologist, which reflects a robust on-call review process within the department. However, the timing of review, accuracy of amendments and influence on surgical outcomes has not been assessed.

The need for high-quality CT reporting relating to improved management of patients undergoing surgery has already been recognized by the Royal College of Radiologists, with their forthcoming audit of the "Accuracy of Interpretation of Emergency Abdominal CT in Adult Patients Who Present with Non-Traumatic Abdominal Pain 2014", the data from which is currently undergoing statistical analysis.

The relative importance of various statistical analyses regarding accuracy of diagnostic tests varies according to the clinical situation. An emergency laparotomy is a high-risk operation, one defined as having an operative mortality of >5% by the National Emergency Laparotomy Audit.[8] Obtaining a correct diagnosis prior to emergency laparotomy is vital, especially in patients who are elderly or have significant comorbidities, where the risk of complication or death is high.

Ideally, the best diagnostic test available would have 100% accuracy, sensitivity and specificity. A reduction in sensitivity will result in fewer "true-positive" CTs, meaning more patients will have a delay in treatment/laparotomy owing to a missed diagnosis. This increases the subsequent risk of morbidity and mortality associated with delayed surgery. A reduction in specificity results in more patients undergoing an emergency laparotomy owing to more "false positives" from "overcalls". This exposes the patient to the risks associated with unnecessary surgery.

The study has several strengths. Data were collected on a large cohort of patients in a UK teaching hospital. Evaluation of the reports by a senior surgical trainee, as described above, is pragmatic and reflects the "real world", which could be regarded as a further strength of this study. All emergency CTs were reported by in-house radiologists and not outsourced. Even with increasing use of outsourcing, this study remains relevant to emergency CT reporting.

The results of this study are comparable with those reported in similar studies with accuracies of 82–87%.[12–14] The results are also in keeping with reports of specific acute abdominal diagnoses such as appendicitis with an accuracy of 80.6–99%,[15–17] gastrointestinal perforation with an accuracy of 86%,[18] bowel ischaemia with an accuracy of 79.17–81%,[19,20] diverticulitis with an accuracy of 98%[21] and bowel obstruction with an accuracy of 65–97%.[22–26] However, the variable accuracy related to anatomical location of the pathology has not been described.

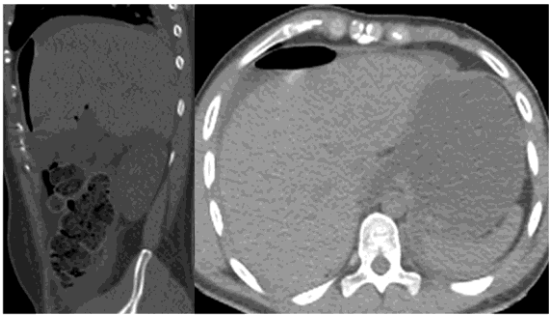
Stoker et al conducted a large study including over 1000 patients investigating the diagnostic accuracy of different imaging strategies in acute abdominal pain.[27] The sensitivity of CT was found to be superior to ultrasound (89 *vs* 70%, $p < 0.001$) and the study concluded that the best conditional strategy was initial ultrasound examination followed

Table 4. Weighted kappa statistic (Kw) related to the time the CT was performed

Anatomical location	Total	In hours	All out of hours
UGI Kw	0.67 (0.53–0.82)	0.68 (0.49–0.88)	0.66 (0.45–0.87)
Small-bowel Kw	0.78 (0.687–0.875)	0.78 (0.626–0.926)	0.78 (0.652–0.90)
Large-bowel Kw	0.82 (0.75–0.89)	0.86 (0.77–0.95)	0.78 (0.67–0.90)

UGI, upper gastrointestinal.
95% confidence intervals are in parentheses.

Figure 1. The clinical question was "renal colic"; therefore, a stone protocol was performed without oral or i.v. contrast. Pneumoperitoneum was reported, but the final diagnosis of the perforated duodenal ulcer was not mentioned and this report was judged as incorrect.



by CT in negative or inconclusive cases, which provided the highest sensitivity with the lowest overall radiation exposure. The diagnostic accuracy of ultrasound has not been investigated in this study, but the overall accuracy of CT reporting is in keeping with that reported by Stoker (88.0% *vs* 89%).

Weir-McCall et al reported a trend towards improved accuracy of consultant radiologist CT reports when compared with radiologists in training, with the duty registrar reports associated with a 78% diagnostic accuracy.[12] The overall accuracy of the initial CT report by either registrar or consultant was 81%, which improved to 93% following review by a second consultant, although this difference was not significant ($p = 0.15$). These findings are therefore consistent, and indeed again, no significant difference was found to be related to radiologist grade. Relative report accuracy following consultant radiologist review was not assessed in this study.

This raises the question of what constitutes a clinically significant difference in overall CT accuracy between groups. Arguably, from statistical principles, since equivalence may be interpreted as outcomes in numerical terms that approach each other to within a degree of 15%, then differences larger than this might be considered relevant. A figure in keeping with this could also be derived from a combination of this study's results (overall accuracy between training radiologists and consultants of 85.7–90.3%) and the report of Weir-McCall (range 78–93%), neither of which demonstrated a statistically significant difference related to overall accuracy.

This study has several potential limitations. No power calculation was performed prior to the study because of the relative lack of relevant literature available. Only patients who underwent laparotomy following CT were studied, *i.e.* patients who underwent surgical intervention during their hospital stay. This excludes assessment of the accuracy and benefit of CT in the group of patients with non-traumatic abdominal symptoms who are managed conservatively and do not proceed to emergency laparotomy.

It was assumed that the CT report was correct in this cohort, but patients were reviewed and managed appropriately on an individual basis according to clinical symptoms and signs. Moreover, patients who underwent diagnostic laparoscopy as a result of their CT findings were not included. No specific rules were used to determine whether a "grey" case was deemed accurate or inaccurate. This decision was subjective, as the opinion of a consultant surgeon was used.

The discrepancies were identified by the surgical authors and may arguably be judged to be too harsh from a radiological perspective. For example, the CT protocol varied, according to the clinical indication at the time of the referral, and no account for this was taken in the evaluation of the radiological report (Figure 1).

This suggests the need for further education of surgeons regarding the limitations of certain CT protocols and may also reflect the need for reporting radiologists to clarify such limitations.

CONCLUSION

In conclusion, this study has shown that diagnostic accuracy varies with anatomical location and the strength of agreement between CT diagnosis, and operative pathology varied from good to excellent. The reason for the significantly lower accuracy of UGI pathology reporting is uncertain and may be related to exposure to caseload effect. Reassuringly, no significant difference was apparent in the diagnostic accuracy of CTs reported by consultant radiologists when compared with training radiologists. The overall high accuracy facilitates appropriate management decisions, aids pre-operative decision-making regarding surgical access and the choice of a surgeon of appropriate general surgical speciality and seniority, to perform the inherently high-risk procedure of emergency laparotomy, thus optimizing patient safety and minimizing risk.

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