## Introduction

The National Health Service (NHS) is currently experiencing a unique pressure never experienced before. Through COVID-19, there has been an increasing demand for healthcare and resources. National and local understanding of volume of work, patterns of patient flow and variables influencing these are crucial to allow appropriate allocation of scarce staff resources and changes to service design.

Ensuring adequate staff supply (right person, right time, and right place) to patient demand is imperative for patient safety, efficient functioning and optimal flow through hospital systems. [1] Complications of poor flow include increased waiting times, treatment delay, crowding, increased length of hospital stay and mortality. [2-5] Poor patient flow occurs when increased demand is accompanied by limited resources. [6, 7] The Acute Medical Unit (AMU) is the gateway into hospital for patients with acute medical problems. [8] A more detailed understanding of patterns of referrals, variability in waiting times, adherence to Clinical Quality Indicators (CQIs) and characteristics of acute medical patients will allow improvements in medical flow through appropriate changes in service design.

University Hospital Wales (UHW) is the largest hospital in Wales, and one of the largest in the United Kingdom (UK). The Acute Medical Service (AMS) is the largest admitting specialty, receiving more than 20,000 referrals a year. Approximately 2/3 of patients are referred from the Emergency Department (ED), with 1/3 referred from primary care. Non-ambulatory patients referred to AMS are seen in either the ED (8 resuscitation bays and 29 major beds) or the assessment unit (15 beds and 6 trolleys). Ambulatory patients are seen in separate ambulatory areas, which are used by any specialty. The majority of patients (~90%) are seen in the ED. For AMS patients, there is subspecialty retrieval for several medical specialties (gastroenterology, respiratory, infectious diseases etc).

In this study, we use data from a newly implemented electronic patient management system to determine 24-hour variability in referrals to AMS and waiting times to see junior and senior physicians, adherence to CQIs, and the impact of patient characteristics (age, NEWS) on these variables.

## Methods

### *Design, Setting and Population*

A single-centre retrospective cohort study was conducted at UHW, a large tertiary care teaching hospital. Computerised medical records were used to identify all patients aged ≥ 16 referred to AMS from any source (including ED and primary care) between 5th August and 4th December 2021. Key groups of patients not referred to AMS and therefore not included in this study include: (i) patients with certain time-critical illnesses, such as acute myocardial infarction, who bypass AMS and are referred to appropriate teams; (ii) patients referred to specialty takes (renal). Patients were excluded if there was missing data or if they were aged < 16 years at the time of presentation. The study protocol was approved by AMS consultants at the participating hospital. This was a service evaluation and therefore research ethics committee (REC review) was not needed. [9] The STROBE guidelines for observational studies were followed. [10]

### *Data Collection and Outcomes*

Box 1 shows ED and AMU CQIs, relevant to the AMS at UHW, as developed by several leading organisations. CQIs are used as targets for patient flow and the time frames in which patients should be seen.

**Box 1**

*Clinical Quality Indicators Relating to Acute Medical Flow*

AMU Clinical Quality Indicators *

- All patients should be seen by a Tier 1 or 2 (non-consultant) clinician within 4 hours of hospital attendance. This may be an ED/medical clinician depending on the route of referral.
- All patients arriving between 08:00-18:00 should be seen by a Tier 3 (consultant) clinician within 8 hours.
- All patients arriving between 18:00-08:00 should be seen by a Tier 3 (consultant) clinician within 14 hours.

Tiers of Physician and Length of Time Required Per Patient **

- Tier 1 – Competent clinical decision makers – Foundation Doctor (F1/F2), Senior House Officer (SHO), other appropriately trained healthcare professional (e.g. nurse practitioner, physicians associate). F1/F2/SHO typically have < 5 years of post-graduate experience.
  - 1.5 hour per patient.
- Tier 2 – Senior clinical decision makers - Specialist Trainee (Registrar), Associate Specialist, other appropriately trained healthcare professional (e.g. advanced nurse practitioner, physicians associate). Registrars/Associate Specialist typically have > 5 years of post-graduate experience.
  - 1 hour per patient if performing the initial assessment.
  - 25 minutes per patient if Tier 1 presents to Tier 2.
  - 25 minutes per patient for presentation and discussion with Tier 3.
- Tier 3 – Expert clinical decision makers with overall responsibility for patient care - Consultant. Consultants have > 9 years of post-graduate experience.
  - 1 hour per patient if performing the initial assessment.
  - 50 minutes per patient if Tier 1 presents directly to Tier 3.
  - 25 minutes per patient if Tier 2 presents to Tier 3.

*Note.*
* as set by: the National Institute for Health and Care Excellence (NICE) [11]; the Royal College of Physicians (RCP) [12]; the Royal College of Physicians of Edinburgh (RCPE) [13]; the Society of Acute Medicine (SAM). [14]
** as set by: the SAM [14]; the RCP. [15]

The ‘electronic whiteboard’ patient referral management system allows coordination between patient flow, medical staffing, and bed management. This technology has been in use in UHW since August 2021. All patients referred to AMS are recorded via this system. Patients ‘move’ through this system as they do in clinical practice with patients ‘waiting to be seen’, ‘being clerked’, ‘awaiting senior review’, ‘reviewed by senior but not discharged’ and ‘discharged’. When patients are seen by clinicians they record this on the system. We used the electronic whiteboard to extract the following data for all patients (ambulatory and non-ambulatory) referred to AMS: age, National Early Warning

Score (NEWS), time of referral to AMS, time taken to be seen by a junior (Tier 1-2) and senior (Tier 3) clinician in medicine. If the time to see an AMS clinician was greater than that recommended (Box 1), CQIs were regarded as failed. The electronic whiteboard does not record any information prior to referral to AMS (i.e. time=0 refers to time of referral, not attendance).

Referral times were split into time groups to compare and identify variability of characteristics. The first time group differentiated between weekday (Monday/Tuesday/Wednesday/Thursday/Friday) and weekend (Saturday/Sunday) referrals. The second time group differentiated between Time Periods: Period 1 (morning; 09:00–13:00), Period 2 (afternoon; 13:00–17:00), Period 3 (evening; 17:00–21:00), Period 4 (night; 21:00–09:00).

Outcomes included: (i) pattern of patient referrals; (ii) variance in characteristics (age and NEWS), time to see a junior (Tier 1-2) and senior (Tier 3) clinician, and CQI failure at different time groups; (iii) Impact of age, NEWS and being severely unwell (NEWS > 5) on time to see a junior (Tier 1-2) and senior (Tier 3) clinician, and CQI failure; (iv) variance in time to see a junior (Tier 1-2) and senior (Tier 3) clinician through the 24-hour period.

***Analysis and Statistics***

Data were analysed using STATA (version 16.1). [16] Descriptive statistics on age, NEWS, being severely unwell, day of week, Time Period, time to see a junior and senior clinician, and CQI failure were used to provide information on cohort composition and distribution. Continuous and discrete variables were expressed as means with 95% confidence intervals (95% CI), standard deviation (SD), interquartile range (IQR), and range. Categorical variables were expressed as numbers and percentages. The normalcy of distribution was evaluated using the skewness and kurtosis test and parametric and non-parametric tests were used as appropriate.

Odds ratios (OR) adjusted for age and NEWS were calculated using logistic regression to identify the likelihood of being severely unwell or failing CQIs at the weekday/weekend and different Time Periods. The OR of weekday analysis uses weekend data as its comparator, and vice versa. The OR of each Time Period uses a combination of the three other Time Periods as its comparator. Ordinary Least Squares (OLS) regression was used to identify the impact of age, NEWS, and being severely unwell on the time to see a clinician. Unless otherwise specified, exploratory analysis results were expressed as means with 95% CI and P value. A P value of < 0.05 was considered statistically significant.

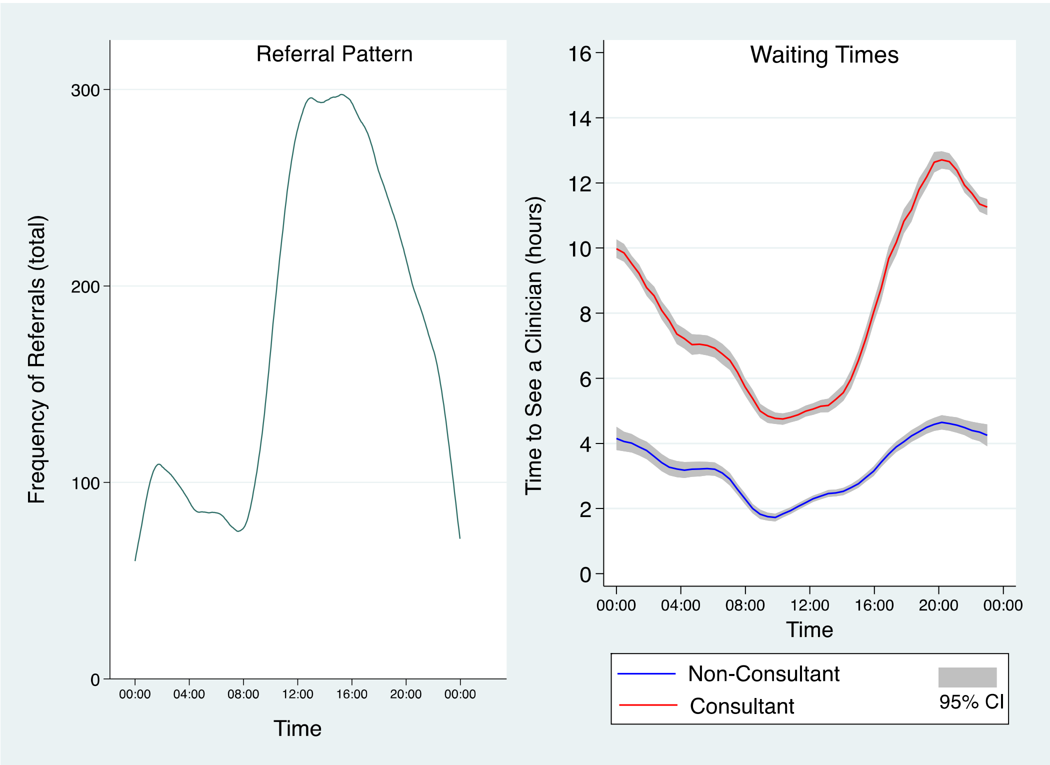
## Results

### *Patient Characteristics*

During the 4-month study period, there were a total of 6943 AMS referrals. Sixty-one patients (0.009%) were excluded on account of incomplete data (n = 43) and age of < 16 years (n = 8). Days with the most referrals were Monday (17.1%), Thursday (16.5%), Wednesday (16.0%), Tuesday (15.6%), Friday (15.3%), Sunday (10.1%) and Saturday (9.4%). Figure 1 shows the total number of referrals though a 24-hour period. Figure 2 is a heatmap showing referral distribution by hour of the day for each day of the week. Figures 1 and 2 show an increase in referrals between 09:00-21:00, with a peak between 11:00-19:00, particularly on weekdays.

**Figure 1**

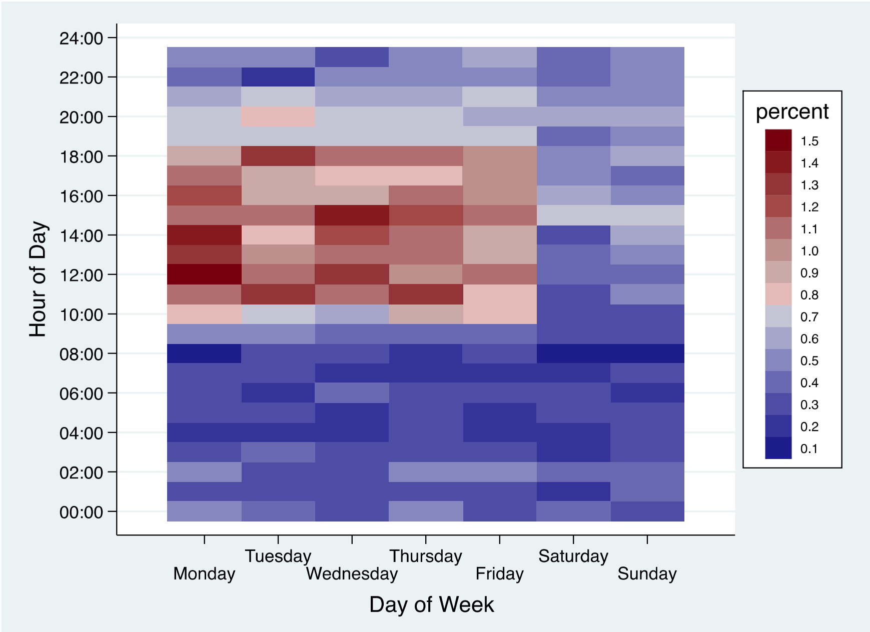
*Referral Pattern to AMS and Time to See a Clinician Through the 24-hour Period*




*Note.* 95% CI = 95% confidence intervals.

**Figure *2***

*Heatmap of Pattern of Referrals to AMS Through the Week*




The median age of the cohort (n=6882) was 67 (IQR 48-79). The median NEWS was 1 (IQR 0-7), with 68% presenting with NEWS of 0-2 and 10% being severely unwell (NEWS > 5) at referral to AMS (Table 1). Detailed data on source of referral and diagnoses were not consistently recorded.

**Table 1**

*NEWS Distribution of Cohort*

| Characteristic | All (n=6882) | Weekday (n=5539) | Weekend (n=1343) | Period 1 09:00-13:00 (n=1456) | Period 2 13:00-17:00 (n=1860) | Period 3 17:00-21:00 (n=1501) | Period 4 21:00-09:00 (n=2065) |
|---|---|---|---|---|---|---|---|
| NEWS | | | | | | | |
| Mean | 2.1 | 2.0 | 2.2 | 1.7 | 2.0 | 2.2 | 2.3 |
| 95% CI* | 2.0-2.1 | 2.0-2.1 | 2.1-2.4 | 1.6–1.8 | 1.9–2.2 | 2.1–2.3 | 2.2–2.4 |
| SD | 2.4 | 2.4 | 2.4 | 2.3 | 2.3 | 2.5 | 2.4 |
| Median | 1 | 1 | 2 | 1 | 1 | 1 | 2 |
| IQR | 0-7 | 0-3 | 0-3 | 0-3 | 0-3 | 0-3 | 0-4 |
| Range | 0-17 | 0-17 | 0-15 | 0-17 | 0-12 | 0-15 | 0-15 |
| NEWS Group | | | | | | | |
| 0 | 33.5% (n=2308) | 34.3% (n=1898) | 30.5% (n=410) | 41.0% (n=597) | 34.6% (n=644) | 33.0% (n=495) | 27.7% (n=572) |
| 1-2 | 34.5% (n=2373) | 34.5% (n=1911) | 34.4% (n=462) | 33.3% (n=485) | 34.3% (n=638) | 32.8% (n=493) | 36.6% (n=757) |
| 3-5 | 21.8% (n=1500) | 21.3% (n=1179) | 23.9% (n=321) | 18.3% (n=267) | 20.1% (n=388) | 22.5% (n=338) | 24.5% (n=507) |
| 6-10 | 9.5% (n=656) | 9.2% (n=512) | 10.7% (n=144) | 6.8% (n=99) | 9.5% (n=177) | 11.2% (n=168) | 10.3% (n=212) |
| >10 | 0.7% (n=47) | 0.7% (n=40) | 0.5 (n=7) | 0.6% (n=8) | 0.7% (n=13) | 0.5% (n=8) | 0.9% (n=18) |
| Severely Unwell (NEWS > 5) | 10.2% (n=703) | 10.0% (n=552) | 11.2% (n=151) | 7.3% (n=107) | 10.2% (n=190) | 11.7% (n=176) | 11.1% (n=230) |
| 95% CI* | 9.5–10.9 | 9.2-10.8 | 9.5–12.9 | 6.0–8.7 | 8.8–11.6 | 10.1–13.3 | 10.0–13.3 |
| Odds ratio** | | 0.89 | 1.12 | 0.67 | 1.37 | 1.20 | 1.13 |
| 95% CI* | | 0.73-1.08 | 0.93-1.36 | 0.54-0.83 | 1.07-1.75 | 1.00-1.44 | 0.95-1.33 |

*Note.* * $p < 0.001$ for all 95% confidence intervals (CI) for mean NEWS and mean percentage being severely unwell (NEWS > 5) for each Time Group. ** odds ratio adjusted for age using logistic regression. The OR of weekday analysis uses weekend data as its comparator, and vice versa. The OR of each Time Period uses a combination of the three other Time Periods as its comparator.

***Referral Times***

*Weekend Versus Weekday*

Application of the Mann Whitney U test showed that median age was higher on weekdays [69 (IQR 48-79)], in comparison to the weekend [66 (IQR 51-81)], z = 3.243, P = 0.001 (supplementary Table A). Application of the Mann Whitney U test showed that median NEWS was higher on the weekend [2 (IQR 0-3)] in comparison to the weekday [1 (IQR 0-3)], z = 3.170, P = 0.002 (Table 1). The adjusted odds ratio for being severely unwell (NEWS > 5) on the weekday in comparison to the weekend was not statistically significant [OR 1.12 (95% CI 0.93-1.36)].

*Time Periods*

There was an average (mean) of 56 referrals a day, with 12 (21%), 15 (27%), 12 (22%) and 18 (30%) referrals occurring in Time Periods 1-4 respectively. The mean number of referrals on a weekday was 61 (split 14, 17, 13, 17 by Time Periods), and 38 on a weekend (split 6, 9, 8 and 15 by Time Periods). A greater proportion of weekend referrals occurred in the night (39.9%) in comparison to weekdays (27.6%) [$X^2$(1, N = 2065) = 6.919, P < 0.001], where the latter experienced a steadier rate of referrals through the day. Both mean and median age and NEWS increased through Time Periods 1-4, peaking in evenings and nights (Table 1 and Supplementary Table A). A Kruskal-Wallis test showed that age [H(3) = 68.819, P < 0.001] and NEWS [H(3) = 79.724, P < 0.001] differed between Time Periods. Post hoc Dunn's test shows the distribution between each group is significant (P < 0.001), except for age between Time Periods 3 and 4. Using logistic regression, the odds ratio (adjusted for age) for being severely unwell was highest in afternoons (OR 1.37) and evenings (1.20), and lowest in the morning (OR 0.67). The OR of each Time Period uses a combination of the three other Time Periods as its comparator.

***Waiting Times***

The median time to see a junior and senior clinician was 2.4 (IQR 0.8-4.9) and 6.5 hours (IQR 3.8-12.0) respectively. Figure 3 shows box plots of time to see a clinician at different time groups. Supplementary Table C shows more detailed information regarding waiting times.

*Weekend Versus Weekday*

Mann Whitney U test analysis showed the median time to see a junior clinician was greater among the patients presenting on a weekday [2.6 hours (IQR 0.9-5.2)]in comparison to the weekend [1.5 hours (0.6-3.5)], z = 11.556, P < 0.001. The median time to see a senior clinician was similar on a weekday [6.5 hours (IQR 3.9-12.3)] in comparison to the weekend [6.6 hours (3.6-11.2)], $z = 2.908$, $P = 0.004$.

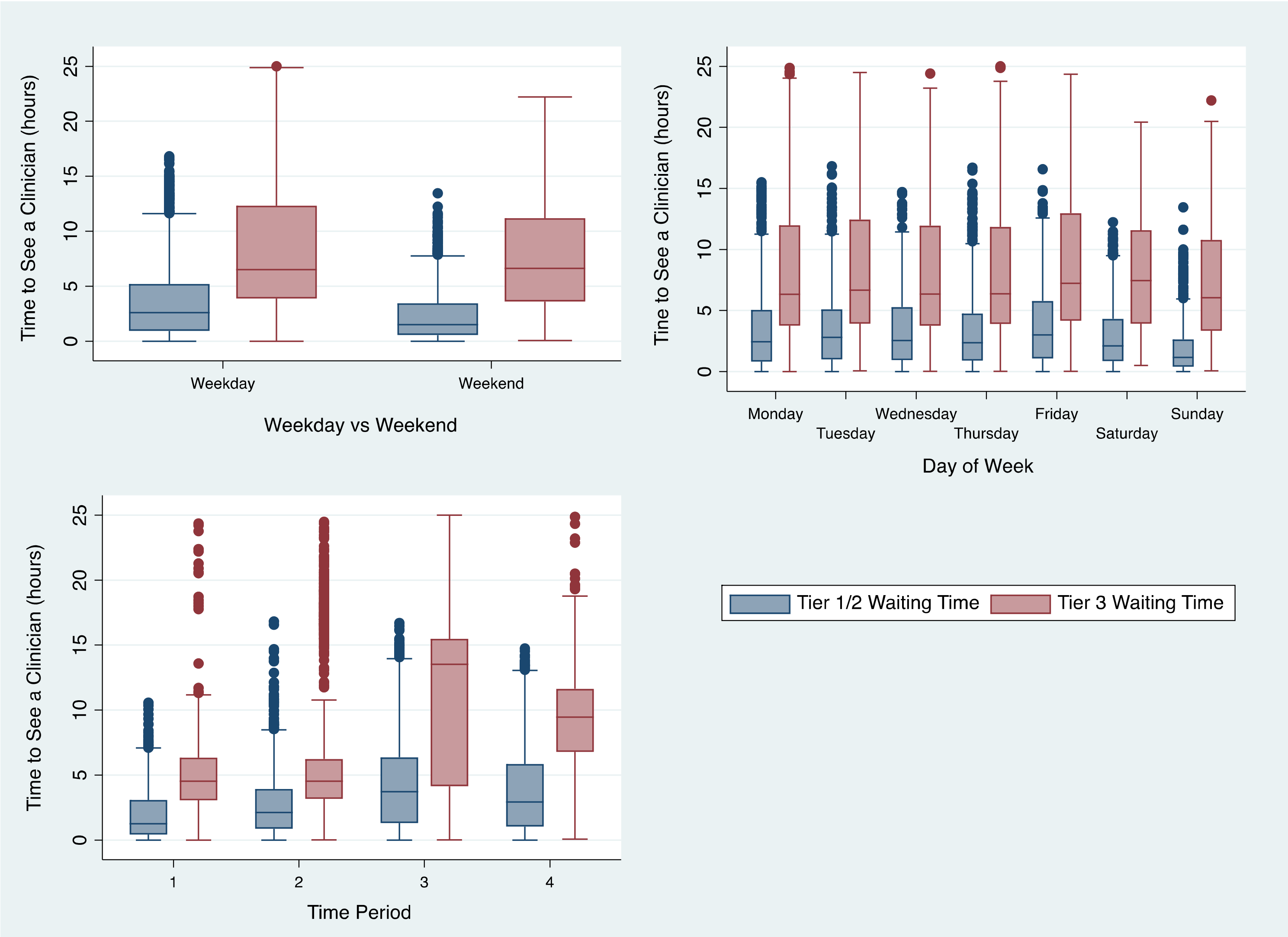
*Time Periods*

The median waiting time to see both a junior and senior clinician increased through the day, peaking for referrals between 17:00-21:00 (medians of 3.7 and 13.5 hours for junior and senior clinicians respectively) where median waiting times were more than twice than that of the morning. Median waiting times remained high in the night in comparison to the day. A Kruskal-Wallis test showed that time to see junior [$H(3) = 516.202$, $P < 0.001$] and senior clinicians [$H(3) = 1592.252$, $P < 0.001$] differed between Time Periods. Post hoc Dunn's test shows the distribution between each group is significant ($P < 0.001$).

Figure 1 presents the variability in mean time to see a junior (Tier 1-2) and senior (Tier 3) clinician throughout a 24-hour period, with a graph of 24-hour referral pattern for comparison. Whilst peak referrals occur between 11:00-19:00, the time to see a junior and senior clinician steadily increases from 10:00, peaks between 17:00-01:00 and then steadily decreases. Therefore, a 6-hour delay between peak in referrals and peak in mean waiting times is observed.

**Figure 3**

*Box Plots of Variation in Time to See a Clinician at Different Time Groups*



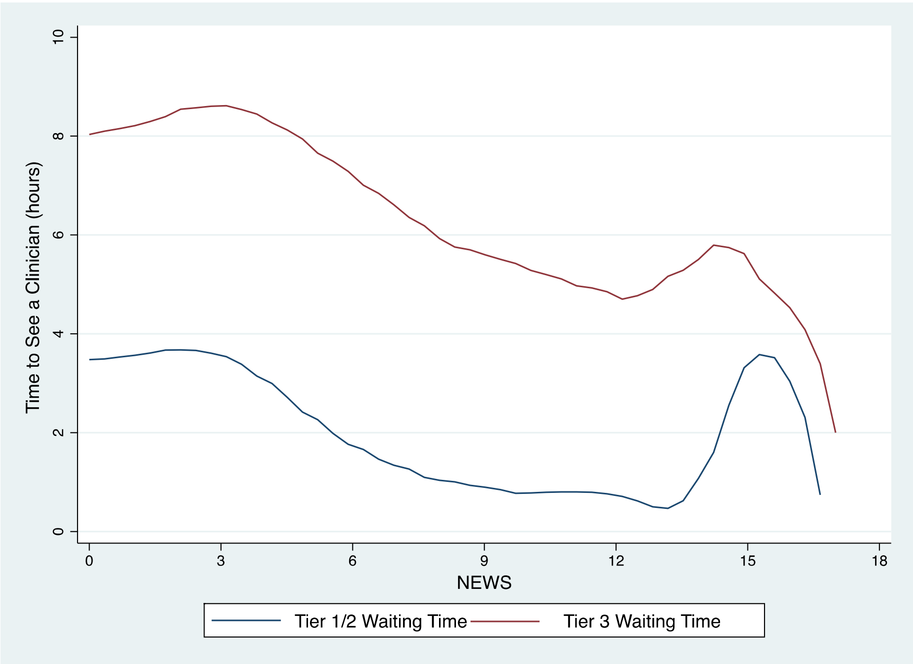

*Note.* Time Periods: 1 (09:00-13:00), 2 (13:00-17:00), 3 (17:00-21:00), 4 (21:00-09:00).

*Adjusting for NEWS and Age*

Figure 4 shows NEWS and its effect on mean time to see a junior and senior clinician. As NEWS increases, mean waiting times reduce. After NEWS of 12, the mean times to see a clinician rises. This period is hard to interpret as there are relatively few data (n = 21, 0.3%) and patients may be either palliative or seen by intensivists, hence omitting the need to rapidly be seen by an AMS clinician, Using OLS regression, we found that as NEWS increased by one, the mean time to be seen by a junior and senior reduced by 0.3 hours (95% CI 0.2-0.3, P < 0.001) and 0.2 hours respectively (95% CI 0.1-0.2, P < 0.001). Patients classified as severely unwell (NEWS > 5) had reduced mean waiting times by > 2 hours [junior: reduced by 2.2 hours (95% CI 2.0-2.4), P < 0.001; senior: reduced by 2.0 hours (95% CI 1.6-2.4), P < 0.001]. There was negligible clinical impact of age on waiting times. As age increased by one year, time to be seen by a junior increased by 0.004 hours (95% CI 0.000007-0.007, P < 0.05), and time to be reviewed by a senior increased by 0.02 hours (95% CI 0.02-0.3, P < 0.001).

**Figure 4**

*Impact of NEWS on Time to See a Clinician*




Note. NEWS > 12 in n = 21 (0.3%).

***Adherence to Clinical Quality Indicators***

Adherence to CQIs are shown in Table 2.

**Table 2**

*Clinical Quality Indicators (CQI) Failure*

| Characteristic | All (n=6882) | Weekday (n=5539) | Weekend (n=1343) | Period 1 09:00-13:00 (n=1456) | Period 2 13:00-17:00 (n=1860) | Period 3 17:00-21:00 (n=1501) | Period 4 21:00-09:00 (n=2065) |
|---|---|---|---|---|---|---|---|
| Clinical Quality Indicators (CQI) Failure | | | | | | | |
| Junior CQI Failure | 32.3% (n=2224) | 35.1% (n=1945) | 20.8% (n=280) | 16.9% (n=246) | 24.0% (n=446) | 47.2% (n=708) | 39.9% (n=825) |
| 95% CI* | 31.2-33.4 | 33.9-36.4 | 18.7-23.0 | 15.0-18.8 | 22.0-25.9 | 44.6-49.7 | 37.8-42.0 |
| Odds ratio** | | 2.05 | 0.49 | 0.32 | 1.61 | 2.40 | 1.75 |
| 95% CI* | | 1.78-2.37 | 0.42-0.56 | 0.27-0.37 | 1.35-1.92 | 2.13-2.71 | 1.57-1.96 |
| Senior CQI failure | 18.7% (n=1289) | 20.4% (n=1131) | 11.8% (n=158) | 9.5% (n=139) | 16.9% (n=314) | 43.6% (n=655) | 8.8% (n=181) |
| 95% CI* | 17.8-19.6 | 19.4-21.5 | 10.0-13.5 | 8.0-11.1 | 15.2-18.6 | 41.1-46.1 | 7.5-10.0 |
| Odds ratio** | | 1.95 | 0.51 | 0.39 | 1.93 | 5.94 | 0.32 |
| 95% CI* | | 1.63-2.33 | 0.43-0.61 | 0.32-0.47 | 1.56-2.39 | 5.20-6.78 | 0.27-0.37 |

Note. * $p < 0.001$ for all 95% confidence intervals (CIs) for mean percentage failing CQIs for each Time Group.; ** odds ratio adjusted for age and NEWS using logistic regression. The OR of weekday analysis uses weekend data as its comparator, and vice versa. The OR of each Time Period uses a combination of the three other Time Periods as its comparator.

Junior CQIs were failed in 32.3% of cases and senior CQIs were failed in 18.7% of cases. Application of logistic regression showed that failure was more likely on weekdays (junior OR 2.05, senior OR 1.95) using weekend as a comparator. Following the same trends in increased median waiting times, the rate of CQI failure for both junior and seniors increases through the day, peaking at Time Period 3 (junior OR CQI failure 2.40, senior OR CQI failure 5.94) with 47.2% and 43.6% failing junior and senior CQIs respectively. Junior CQIs were failed least in Time Period 1 (OR 0.32), and senior CQIs were failed least in Time Period 4 (OR 0.32) followed by Time Period 1 (OR 0.39). The OR of each Time Period uses a combination of the three other Time Periods as its comparator. The odds ratio for junior CQI failure during Time Period 3 on weekdays was 2.97 (95% CI 2.60-3.40, $P < 0.001$) using Time Period 3 on weekends as its comparator. The odds ratio for senior CQI failure during Time Period 3 on weekdays was 6.28 (95% CI 5.43-7.26, $P < 0.001$) using Time Period 3 on weekends as its comparator.

**Discussion**

In this large retrospective analysis of Wales' largest hospital, the data shows a significant variability in referrals and waiting times. Referrals to AMS followed a daily rhythm, with a peak in referrals between 11:00-19:00. Patients referred in evenings were more likely to fail CQIs, with a peak delay in time to see a clinician between 17:00-01:00, approximately 6 hours after the peak in referrals (Fig. 1). Waiting times were significantly longer on weekdays. Patients referred at this time were also older and more unwell (higher NEWS). Although other studies have investigated the variance in referrals to AMS and CQIs, [17, 18] to our knowledge this is the first to show 24-hour variability in time to be seen by a junior and senior clinician, and investigate the influence of confounders (age and NEWS) on waiting times and adherence to CQIs at different Time Periods.

This study identified two primary concerns: (i) AMS waiting times are greatest during hours 17:00–09:00; (ii) patients referred during these hours are older and more unwell (higher median age and NEWS). These data provide valuable information regarding volume of work support changes in working patterns to better match supply and demand. Increasing NEWS resulted in shorter times to be seen by clinicians. This shows that the electronic whiteboard system is effectively allowing patients to be risk stratified and seen in order of priority vs. waiting time. However, it is important for clinicians to remember that not all time-critical illnesses, such as acute stroke, present with high NEWS. Effective triage, history and examination skills are important to ensure that these important presentations are not under-prioritised.

There are two main factors influencing our findings and their variability: patient characteristics and hospital management. Patients, unless very unwell, are more likely to seek medical advice from either the ED or primary care during daytime hours, from where they may be referred to AMS. Patients who first present to primary care with an acute medical condition are commonly not seen or referred until after midday, meaning arrival to hospital in mid-to-late afternoon. [19] This contributes to the peak in referral times between 11:00-19:00. Certain diseases are more likely to present at particular times and therefore may influence daily periodicity. For example, cardiovascular disease peaks in late morning and a greater frequency of cases occur on Mondays. [20, 21]. Generally, referrals to AMS at UHW are not screened/discussed or refused beforehand due to the opportunity cost of fielding multiple calls. This potentially results in many patients arriving from primary care late in the afternoon/evening with sub-acute illnesses that could be better managed using a same day emergency care (SDEC) model and booked appointments the following day. Since these results the medical SDEC and virtual ward services at UHW have been significantly developed following significant staffing issues in the wake of the pandemic. As the number of patients waiting accumulates, a mismatch between demand and supply of care is created, resulting in increased waiting times throughout the day and peaking between 17:00-01:00. This is partly due to hospital management, with contributing factors including low staffing, limited availability of space, and limited hospital bed availability. Although this study did not systematically record physical bed availability, from our experience of real-world practice we can acknowledge that in periods of high volume of work, flow becomes particularly problematic with medical patients spending long periods in the emergency unit before moving to wards/assessment areas. Weekends appear to be less busy than weekdays. This likely due to reduced access to primary care and fewer onward referrals.

The mean number of non-consultant clinicians staffing AMS on a weekday was: 7-8 between 09:00–21:00, 5-6 between 21:00-23:00, and 4-5 between 23:00–09:00. On a weekend, there were 6 non-consultant clinicians between 09:00–21:00, and 4-5 clinicians between 21:00–09:00. There were 1-3 consultants available 09:00-22:00, with an on-call overnight rota. These clinicians were split between to two teams guided by demand: (i) new intake; (ii) caring for patients admitted on the acute unit who hadn't yet moved to the wards. The latter team do not contribute to the new intake and therefore do not affect waiting times. As staffing levels fall, the waiting times and proportion of patients failing CQIs increase, with patients presenting with higher NEWS. Altering AMS workforce, according to SAM safe medical staffing guidance, [15] to ensure supply matches demand should reduce CQI failure. Demand can be determined using these results regarding peak referral and waiting times. Improvements in other aspects of patient flow, both in the acute phase (for example reduction in ED waiting times and overcrowding) and secondary phase would be expected. One study showed that adjustment of AMS junior doctor staffing to match demand reduced the average waiting time to see a Tier 1-2 doctor (from 190 to 71 minutes), as well as reducing the proportion of patients waiting > 4 hours (from 40% to 10%). [22] In our cohort, 47.2% (708) patients presenting in Time Period 3 (17:00-21:00) failed junior CQIs. It takes a Tier 1 clinician approximately 1.5 hours to see one patient (Box 1). Employing three Tier 1 clinicians for 4.5 hours between 17:00-21:30 would mean nine extra patients are seen. If this was done for each weekday over the 4-month length of study, 720 extra patients would be seen, which is the effect size required to reduce CQI failure. For patients referred from ED with thorough documentation and without serious illness, it is likely that a Tier 1 clinician would require much less time per patient, further increasing clinician productivity on AMS. However, changing workforce provision in this way is challenging in an already stretched rota.

There are other ways to reduce pressures on AMS and prevent overcrowding. Using individual service needs to guide appropriate use, competent allied health professionals such as the physician's associates may allow junior doctors to see more complex patients whilst the associate clerks less urgent cases and performs basic procedures such as venepuncture and cannulation. [23]

***Strengths and Limitations***

Strengths of this study include a large sample size allowing for accurate analysis, ability to adjust for confounders, and highly statistically significant results. However, there are several important limitations. The electronic whiteboard system can be edited in retrospect. Whilst clinicians are encouraged to input administrative details in 'real-time', we acknowledge that some cases will be inputted after the event takes place, due to forgetfulness and volume of work. Anecdotally, this was more of an issue for consultants, particularly at the introduction of the system with some patients erroneously not recorded as being seen for many hours. As we did not perform an exhaustive review of paper notes we elected to use the time recorded even when the time to review may have been larger than expected. Therefore, the data reported here represents the upper bound of time to see a clinician. The electronic whiteboard system only records information from time of referral to AMS. For patients referred from the ED, the patient journey may have already involved considerable waiting times in the ED. Therefore, waiting times are likely to be even longer, and adherence to CQI worse than reported in this study. For those adequately clerked by a junior ED physician, the time of clerking was entered as the same as the time of referral to AMS. The electronic whiteboard did not systematically record route of referral to AMS and therefore the impact of this variable on waiting times was unable to be explored. Analysis over 4 months meant that we were unable to investigate for seasonal variation. Since this was a single centre study, results may not be fully representative of other centres in the UK, which have differing levels of acute service care provision and hospital design. Nevertheless, timing of peak demand and resource availability may be similar in other tertiary care centres in the UK with similar service design, staffing models and resource allocation.

Future possibilities of analysis include: (i) investigating the impact of route of referral, time of attendance to ED (if applicable), sex and disease on AMS outcomes; (ii) statistically link AMS findings to ED data (waiting times, number in department) to prove correlation between AMS and ED flow; (iii) statistically link AMS findings to length of stay and mortality data to prove correlation between AMS and secondary phase flow.

**Conclusion**

This study has shown that evening and nights on weekdays are particularly problematic in terms of acute medical patient flow, with waiting times greatest between 17:00-01:00. Patients presenting within these periods appear to be older and more unwell than at other times. Interventions, including workforce provision, should be targeted towards these findings.

**References**


1. Griffiths P, Ball J, Murrells T, Jones S, Rafferty AM. Registered nurse, healthcare support worker, medical staffing levels and mortality in English hospital trusts: a cross-sectional study. *BMJ Open*. Feb 9 2016;6(2):e008751. doi:10.1136/bmjopen-2015-008751
2. Verelst S, Wouters P, Gillet JB, Van den Berghe G. Emergency Department Crowding in Relation to In-hospital Adverse Medical Events: A Large Prospective Observational Cohort Study. *J Emerg Med*. Dec 2015;49(6):949-61. doi:10.1016/j.jemermed.2015.05.034
3. Richardson DB. Increase in patient mortality at 10 days associated with emergency department overcrowding. *Med J Aust*. Mar 6 2006;184(5):213-6. doi:10.5694/j.1326-5377.2006.tb00204.x
4. Bernstein SL, Aronsky D, Duseja R, et al. The effect of emergency department crowding on clinically oriented outcomes. *Acad Emerg Med*. Jan 2009;16(1):1-10. doi:10.1111/j.1553-2712.2008.00295.x
5. Jones S, Moulton C, Swift S, et al. Association between delays to patient admission from the emergency department and all-cause 30-day mortality. *Emerg Med J*. Mar 2022;39(3):168-173. doi:10.1136/emermed-2021-211572
6. NHS Improvement. National priorities for acute hospitals 2017. Good practice guide, focus on improving patient flow. 2017. URL: https://learn.nes.nhs.scot/40842/scottish-government-health-and-social-care-resources/scottish-access-collaborative-making-connections-for-staff-and-patients/team-service-planning-development-programme/good-practice-guide-focus-on-improving-patient-flow
7. Jones. R. Hospital bed occupancy demystified. *British Journal of Healthcare Management*. 2013;doi:2011.17.6.242

8. Ward D, Potter J, Ingham J, Percival F, Bell D. Acute medical care. The right person, in the right setting--first time: how does practice match the report recommendations? *Clin Med (Lond)*. Dec 2009;9(6):553-6. doi:10.7861/clinmedicine.9-6-553

9. Health Research Authority MRC. Is my study research? Accessed 08/09/2022, 2022. URL: http://www.hra-decisiontools.org.uk/research/

10. Cuschieri S. The STROBE guidelines. *Saudi J Anaesth*. Apr 2019;13(Suppl 1):S31-S34. doi:10.4103/sja.SJA_543_18

11. National Institute for Health and Care Excellence. Emergency and acute medical care in over 16s: service delivery and organisation. 2018. URL: https://www.nice.org.uk/guidance/ng94

12. Royal College of Physicians. Acute medical care. The right person, in the right setting – first time. *Report to the Acute Medicine Task Force*. 2007. URL: https://cdn.shopify.com/s/files/1/0924/4392/files/acute_medical_care_final_for_web.pdf?1709961806511712341

13. Langlands A, Dowdle R, Elliott A, et al. RCPE UK Consensus Statement on Acute Medicine, November 2008. *Br J Hosp Med (Lond)*. Jan 2009;70(1 Suppl 1):S6-7.

14. Society of Acute Medicine. Clinical Quality Indicators for Acute Medical Units (AMUs). 2011. URL: https://www.acutemedicine.org.uk/wp-content/uploads/clinical_quality_indicators_for_acute_medical_units_v18.pdf

15. Royal College of Physicians. Guidance on safe medical staffing. Report of a working party. London: RCP; 2018. URL: https://www.rcplondon.ac.uk/projects/outputs/safe-medical-staffing

16. *Stata Statistical Software: Release 16.* 2021.

17. Dauncey SJ, Kelly PA, Baykov D, Skeldon AC, Whyte MB. Rhythmicity of patient flow in an acute medical unit: relationship to hospital occupancy, 7-day working and the effect of COVID-19. *QJM*. Jan 5 2022;114(11):773-779. doi:10.1093/qjmed/hcaa334

18. Atkin C, Knight T, Cooksley T, et al. Society for Acute Medicine Benchmarking Audit 2021 (SAMBA21): assessing national performance of acute medicine services. *Acute Med*. 2022;21(1):19-26. doi:10.52964/AMJA.0888

19. The Health Foundation. Improving the flow of older people. 2013. URL: https://www.health.org.uk/sites/default/files/ImprovingTheFlowOfOlderPeople.pdf

20. Cantwell K, Morgans A, Smith K, Livingston M, Dietze P. Temporal trends in cardiovascular demand in EMS: Weekday versus weekend differences. *Chronobiol Int*. 2015;32(6):731-8. doi:10.3109/07420528.2015.1041600

21. Ekelund U, Akbarzadeh M, Khoshnood A, Bjork J, Ohlsson M. Likelihood of acute coronary syndrome in emergency department chest pain patients varies with time of presentation. *BMC Res Notes*. Aug 8 2012;5:420. doi:10.1186/1756-0500-5-420

22. Powter L, Brougham T, Gillett C. Tracking the take - Using patient flow data to improve AMU performance and safety. *Acute Med*. 2016;15(2):51-7.

23. Drennan VM, Halter M, Wheeler C, et al. What is the contribution of physician associates in hospital care in England? A mixed methods, multiple case study. *BMJ Open*. Jan 30 2019;9(1):e027012. doi:10.1136/bmjopen-2018-027012