

Seasonal variation in trauma admissions to a level III trauma unit over 10 years

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Title: Seasonal variation in trauma admissions to a level III trauma unit over 10 years.
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Keywords: Trauma; Wounds and Injuries; Patient Admissions; Epidemiology; Seasonal variation; Trends; Orthopaedics; Trauma Centres.

Declarations of interest: None.

1 **Title:** Seasonal variation in trauma admissions to a level III trauma unit over 10
2 years.

3
4 **ABSTRACT**

5
6 **Introduction**

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9 Major trauma centres have improved morbidity and mortality for moderate and severely
10 injured patients. Less injured patients may be treated in facilities less resourced for trauma
11 care. In these units, understanding the variations in injury presentation and treatment over
12 time allows service delivery to be tailored to demand. This study set out to describe
13 seasonal variations in trauma over a 10-year period at a level III trauma unit.
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16 **Materials and Methods**

17 Patient demographics, admission frequency, site of injury, season of admission,
18 management, complications, onward transfers, and length of stay were extracted on
19 consecutive patients admitted with traumatic injuries between January 2009 and December
20 2018 and recorded on a prospectively maintained database. Analysis was undertaken to
21 determine if there were reproducible patterns in trauma presentation across seasons, based
22 on the patient's age and gender, type of injury, management and length of stay.
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27 **Results**

28 There were 13,007 'first admissions' over 10 years, with a mean (SD) age of 55.6 (27.7)
29 years. Admissions were higher in summer (27%) and lower in winter (23.6%) and patients
30 were on average younger in the summer (52.8 years) and older in winter (59.2 years). The
31 proportion of female and male patients remained relatively constant across seasons (CV=6%
32 and 8%, respectively). There was seasonal variation in the incidence of forearm (36%) elbow
33 (19%), and multi-sites injuries (17%) compared with hip and wrist injuries (CV=5% for both).
34 A lower proportion of patients underwent operations in summer (72%) compared with
35 other seasons with winter having the highest at 77%. More patients aged less than 60 years
36 stayed in hospital during winter than summer (13.2% vs. 11.6-12.4%) although often for a
37 day. Patients aged 60 years stayed longer in spring and winter.
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43 **Conclusion**

44 The results of this study demonstrate trends in the admission and management of trauma
45 patients to a level III trauma unit. Some of the patterns in admission, treatment and length
46 of stay had not been identified previously. The results can be used to enhance patient care
47 and minimise health care costs by reduces unwarranted variations and enabling service
48 delivery to match the demand in all trauma units.
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51 **Keywords:** Trauma; Wounds and Injuries; Patient Admissions; Epidemiology; Seasonal variation;
52 Trends; Orthopaedics; Trauma Centres.
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55 Declarations of interest: None.
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INTRODUCTION

Trauma morbidity and mortality in the under 40's is an issue worldwide. Outcomes for the severely injured have improved in the United Kingdom (UK) with the introduction of major trauma networks,(1,2) however, less is known of the trauma patterns presenting to the other units within the UK. Patterns in fracture admissions have been documented,(1–3) however, these exclude soft tissue injuries and infections that also require treatment. Globally, seasonal variation of trauma is well documented with an overall trend of higher admissions during the summer season in with studies undertaken over time in level I trauma units in America(4–6) and Nepal.(7) Higher trauma admissions have been associated with increasing temperature and increased hours of sunlight.(8) The variation of site of injury has been noted to vary seasonally with hip(9,10) and ankle fractures(11) occurring more commonly in winter, and wrist fractures more commonly in summer.(12–14) It is unclear if these patterns are the same across the different areas of the UK and if they remain consistent over a prolonged time. It is also unclear whether the pattern of presentation to lower level trauma units has been altered by the introduction of major trauma centres. Understanding the variations in trauma admissions reduces unwarranted variations and follows the principle of the 'getting it right first time' (GIRFT), a national programme designed to improve the quality of care within the National Health Service (NHS) by optimising service efficiency and cost-effectiveness which has recently rolled out to include trauma care from 2019.(15) Reducing variations and mapping service delivery to demand, together, will result in more efficient and cost effective management strategies for trauma patient admissions.

This study examines all trauma admissions to a single level III trauma unit in the UK over a 10-year period as there appeared to be annual identifiable reproducible seasonal patterns in patient presentation dependent on gender, sex and the site of injury. It was unclear if the management of patients was consistent during that time because of resource allocation and it was felt that a better understanding of decision making would allow a consistent approach to care for the injured in this setting.

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2 **MATERIALS AND METHODS**
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4 Study setting
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7 An analysis of data prospectively collected on all trauma admissions to the Orthopaedic Department
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9 at a level III trauma unit in the UK was conducted. Data was collected for all the trauma admissions
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11 between 1st January 2009 and 31st December 2018.
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14 At our institution, trauma care is offered by the Orthopaedic department with a dedicated trauma
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16 ward and operating theatre. Neurosurgical, vascular, spinal, and cardiothoracic injuries were
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18 managed in consultation with three separate regional centres and managed according to their
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20 specialist advice and kept on a separate part of the database not included within the analysis.
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22 Severely injured patients, burns and complex hand injuries were transferred to the regional level I
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24 trauma centres as part of the trauma network.
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31 Data source

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33 Trauma admissions were entered on a prospectively maintained database (Microsoft Access) from
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35 2009 till date; these comprised of both patients who attended the Emergency Department as well as
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37 referrals from community minor injury centres and General Practitioners. Each admission was
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39 initially seen by the on call orthopaedic team. A data clerk entered the details of each patient onto a
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41 database. Patient demographics, type and site of injury, management of the injury, complications
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43 and length of stay were all collected onto the database. These were then validated by the senior
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52 Study population and data items

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54 Admissions between 1st January 2009 and 31st December 2018 were selected for further analysis.
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56 During this time there were 15,319 recorded admissions. Patient demographics, type and site of
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58 injury, management of the injury, and length of stay were extracted from the database. The injuries
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1 were then grouped together into eight separate categories: (1) Multiple injuries; (2) Hand and wrist
2 injuries; (3) Elbow and forearm injuries; (4) Clavicle, Humerus and Scapula injuries; (5) Femur and
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4 Tibia injuries; (6) Ankle and Foot injuries; (7) Knee injuries; and finally (8) Hip injuries. Head and chest
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6 trauma cases were excluded from the study as these are not regularly admitted under Orthopaedic
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8 teams throughout the UK. In addition, repeat admission for patients that had multiple admissions for
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10 the same trauma were excluded, along with patients that required transfer to a different hospital.
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16 Statistical analysis

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18 Trauma patients were described by age, gender, and year, season, month, and day of admission.
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20 Time in days from admission to treatment and to discharge and from treatment to discharge was
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22 recorded for each patient. We also noted whether surgery or conservative treatment was received,
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24 and what area of the body was affected by trauma. Categorical variables were reported as counts
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26 and percentages. Continuous variables were described as mean \pm standard deviations (SD) if
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28 normally distributed and median (interquartile range), trimmed mean (20% trim) \pm SD, and mean
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30 difference (MD) with 95% confidence intervals (95% CIs) if data were skewed (non-normal).
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35 To show variability in the mean age of patients across years and seasons, we used the coefficient of
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37 variation (CV). Chi-squared analysis was employed to compare the following categorical variables:
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39 gender versus age categories; gender versus treatment received; and age categories versus
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41 treatment received. Due to non-normal distributions, Yuens robust t-tests were utilised to analyse
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43 differences in age by gender and treatment received, and age and gender by area of body affected.
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45 Differences in age of patients across season was analysed via the robust one-way ANOVA based on
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47 20% trimmed means with pairwise trimmed mean differences. Because length of hospital stay data
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49 were skewed and there was evidence of heteroscedasticity, we performed a Kruskal-Wallis test to
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51 analyse seasonal variation in time from admission to discharge. In addition, we also categorised
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53 length of stay (3 levels: 0-1, 2-4, and ≥ 5 days) and employed a multinomial logistic regression to
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1 explore differences in length of stay across seasons with and without adjusting for age, gender, and
2 treatment received.
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4 A two-sided p value of $<.05$ was considered statistically significant. However, because even small
5 changes within a large dataset can give rise to statistically significant results, we adopted an
6 estimation approach focusing on the magnitude of mean differences, 95% confidence intervals, and
7 effect sizes. All statistical analyses were carried out in Rstudio version 1.2.5019 (release name:
8 "Elderflower") and all robust analyses were performed via the WRS2 package.
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RESULTS

Summary of admissions

A total of 15,319 admissions were recorded from 1st January 2009 to 31st December 2018. Of these admissions, 11,486 patients (75%) were admitted once, whereas the remaining admissions were readmitted to the trauma clinic on multiple occasions. When considering all 'first admissions', we had 13,146 patients. Almost all the first admission patients underwent surgery (73%) or conservative treatment (26%); only 1% were transferred and these were excluded from the analysis. With the removal of transferred patients, we had a sample of 13,007 "first admission" trauma patients with a mean (SD) age of all patients was 55.6 (27.7) years (CV of annual mean age = 4.8%). Slightly more female patients were admitted (female: 52.5%, male: 47.5%; Table1). Female patients were on average 25.5 years older than male patients. There was a larger proportion of male patients under the age of 60 years, however, after this age the proportion of females admitted was greater—they accounted for 74% of all patients admitted aged at least 80 years (Table 1).

Number of admissions across seasons

The mean number of first admissions in summer (26.8%) was slightly higher than spring (25.5%), autumn (24.2%), and winter (23.4%). The highest number of admissions was observed in summer for seven of the 10 years (Figure 1).

Patient gender and age across seasons

All seasons had on average more female than male patients (supplementary figure 1). The proportion of female patients was highest in winter (55%) and lowest in autumn (51%). There were statistical differences in the average age of patients across seasons ($p < .005$; Figure 2B). Winter admissions were older than spring (Trimmed MD = 4.5 years, 95% CI 2.1 to 6.9), summer (7.7 years, 5.3 to 10.2), and autumn (4.3 years, 1.9 to 6.7), whereas, summer patients were younger than those in spring (-3.3 years, -5.9 to -0.7) and autumn (-3.5 years, -6.0 to -0.9). There was little difference in

1 the age of female patients across season of admission (Figure 2A and 2C). However, male patients in
2 winter were considerably older compared with spring (Trimmed MD = 6.8 years, 95% CI 3.2 to 10.3),
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4 summer (9.9 years, 6.4 to 13.3), and autumn (6.8 years, 3.2 to 10.3). Furthermore, the mean age of
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6 male patients varied by season over the 10-year study period considerably more than female
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8 patients (CV = 12.1% vs. 3.3%; supplementary figure 1). This higher variation in the age of male
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10 patients was observed across all seasons (CVs = 7.9 to 12.1%).
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16 *Seasonal variation in admissions per trauma site: overall and by gender*

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18 Hip trauma was by far the most common trauma overall (28% of all admissions). Female hip
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20 trauma patients over the age of 80 years was by far the largest group and accounted for 12% of all
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22 trauma cases (n = 1,595 cases). There was particularly high seasonal variation for the number of
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24 forearm (CV = 35%), elbow (18%), and multiple site (15%) trauma cases. The high variation in
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26 forearm and elbow trauma cases was due to a higher number of cases of both in summer (forearm
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28 and elbow cases: 37% and 30%) and a lower number in the winter (17% vs. 19%; Figure 3). The
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30 highest number of admissions for forearm (37%), multiple limb (31%), elbow (30%), foot (29%),
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32 femur (28%) ankle (27%), and wrist (26%) trauma cases were all observed in summer (Figure 3).
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38 When trauma site data was separated by patient gender, some clear between-gender differences in
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40 the pattern of trauma emerged. Hip trauma was more than twice as common in female patients
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42 (71% vs. 29%), whereas, hand (75% vs. 25%) and clavicle/scapula (82% vs. 18%) trauma cases were
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44 almost three times more frequent in male patients (Figure 3). Male patients also presented with
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46 more foot (64% vs. 36%), forearm (60% vs. 40%), and knee (58% vs. 42%) trauma cases.
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52 *Age of patients per trauma site across the season of admission*

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1 for a higher number of ankle and knee (both 34%). In patients aged over 80 years, knee trauma
2 admissions were particularly more common in spring (28%) and autumn (29%). The pattern of hip
3 trauma admissions also differed by patient gender. Summer saw the highest number of female hip
4 trauma patients (n = 427), but the lowest number of male hip admissions (n = 117). In spring and
5 summer, elbow and forearm trauma patients were younger on average than in winter (elbow: -15.5,
6 -26.5 to -4.6 vs. -17.0, -27.6 to -6.4 years; and forearm: -11.4, -21.9 to -1.0 vs. -10.4, -20.2 to -0.6
7 years). Wrist trauma patients were considerably older in winter than all other seasons (winter vs.
8 spring: 19.0, 11.3 to 26.6; winter vs. summer: 25.8, 18.4 to 33.2; and winter vs. autumn: 15.4, 7.9 to
9 22.9 years; figure 4). The only age differences we observed across seasons for female patients was
10 that women with elbow and wrist trauma were older in winter than summer (elbow: trimmed mean
11 = 25.3, 95% CI 8.9 to 41.8 years; wrist: 11.7, 1.6 to 21.8 years; Figure 4 and Supplementary figure 2).

12 *Treatment received by season*

13 On average over the 10 years, 965 (SD = 64; CV = 6.7%) patients received surgery each year
14 and 335 (SD = 48; CV = 14.5%) were treated conservatively. A higher proportion of female patients
15 received surgery [53.1% vs. 46.7%; n = 5,122 vs. 4,506; NA = 26 (0.3%); figure 5], whereas, the same
16 proportion of female and male patients received conservative treatment [50.1% vs. 49.5%; n = 1,680
17 vs. 1,659; NA = 14 (0.4%)]. Female patients who received surgery and conservative treatment were
18 on average equivalent ages, however, male patients who underwent surgery were on average
19 (trimmed mean) seven years younger than those who received conservative treatment
20 (bootstrapped 95% CI -9.1 to -5.2; robust $d = -0.21$). A lower proportion of patients underwent
21 operations in summer (72%) compared with other seasons (range = 74-77%; winter had the highest,
22 77%) and more female patients were treated conservatively in summer compared with the other
23 seasons (30% vs. 22-24% in other seasons). Patients who received surgery in winter were older than
24 those in spring (trimmed MD = 4.8, 95% CI 2.1 to 7.5 years), summer (9.4, 6.5 to 12.2 years), and
25 autumn (4.9, 2.1 to 7.7 years; Supplementary figure 3), and younger in summer. Regarding hip
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1 trauma, females aged over 80 were more often treated conservatively in summer compared with
2 other seasons (n = 172 vs. 131-140; Supplementary figure 4). The older age of winter patients
3 receiving surgery can be attributed to the higher average age of male patients in winter versus
4 spring and a marked reduction in the number of patients aged under 20 years undergoing surgery
5 (15% of patients aged under 20 years; Supplementary figure 4). Further analysis by age categories
6 revealed a considerable difference between summer and winter surgeries for patients aged under
7 10 years admitted for elbow (summer vs. winter: 37% vs. 9%; n = 50 vs. 12), forearm (43% vs. 11%; n
8 = 89 vs. 24), and wrist (38% vs. 10%; n = 64 vs. 17) trauma, and in those aged 10-19 years receiving
9 surgery for forearm (32% vs. 15%; n = 38 vs. 18) and wrist (31% vs. 13%; n = 59 vs. 29) trauma
10 (Supplementary figure 4). The disparity for forearm and wrist trauma admissions was greater for
11 boys aged under 10 years compared with girls.
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28 *Length of stay*

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30 There was a statistical difference between seasons in the number of days spent in hospital
31 (Kruskal-Wallis chi-squared = 33.468, df = 3, p-value = 2.566e-07). Patients stayed in hospital longer
32 in winter compared with spring (p-adjusted = .019), summer (p-adjusted = 1.3e-06), and autumn (p-
33 adjusted = 6.7e-06). Although statistically significant, the median difference between winter and
34 other seasons was 1 day (Supplementary table 2 and supplementary figure 5). Female patients
35 stayed on average (median difference) 4-5 days longer in hospital than male patients regardless of
36 season (Supplementary table 2 and supplementary figure 5). The median length of stay for patients
37 who received surgery was similar to those who were treated conservatively across all seasons
38 (Figure 6A and Supplementary table 2). Although male and female patients who received
39 conservative treatment had similar length of stays across seasons, female surgery patients had
40 longer stays than male surgery patients, particularly in spring and winter (Figure 6B). The length of
41 hospital stay increased with age across all seasons overall and regardless of gender or treatment
42 received (Supplementary figure 6). There was a marked difference in the length of stay in patients
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1 aged at least 60 years compared with those aged under 60 years. Consistently across seasons those
2 aged at least 60 years stayed in hospital 8-9 days (median difference) longer than those aged under
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4 60 years (Supplementary Table 2). Only 12% of patients aged under 60 years stayed in hospital for 5
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6 days or longer compared with 69% of patients aged over 60 years (Supplementary figure 7). The
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8 length of stay differences between ages can be at least partially explained by the abundance of hip
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10 trauma cases in patients aged 60 years and over compared with the under 60's (supplementary
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12 figure 8) Hip trauma patients had longer hospital stays [median = 11-13 (IQR = 12-15] days across
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14 seasons) than any other trauma site (although the less common femur trauma patients was
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16 equivalent; supplementary figure 6).
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23 **DISCUSSION**

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25 A third of the work presenting to orthopaedic and trauma units across the UK involves caring for
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27 injured patients. Unfortunately, the care of these patients has often been under resourced,
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29 attracting a lower tariff for care. A number of important changes to trauma care have had big
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31 impacts on outcomes at all levels such as the National Hip Fracture Database (NHFD) and Trauma
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33 Audit and Research Networks (TARN). Research from these groups has informed practice and slowly
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35 begun to change the way that trauma is viewed attracting more interest as to the best way to
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37 manage trauma patients. Analysing seasonal variation in trauma admissions to our hospital has
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39 identified consistencies in certain patterns of trauma admission and has also identified new patterns
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41 that can be used to optimise patient care.
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49 *Annual rate of admissions*

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51 A major strength of our study is that it involves 10 years of trauma admission to a single
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53 level III unit. This appears to be the largest sample for a single level III unit in the literature. This large
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55 dataset highlights the remarkable consistency in the number of admissions each year, with around
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57 1300 patients annually. Admissions did not gradually increase each year as one may expect with a
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1 population that is ageing and increasing in size, nor did the admissions decrease as others may argue
2 could happen through the introduction of injury prevention strategies addressing risk factors for
3 injury, particularly in the elderly, from polypharmacy to falls prevention.(16)
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9 *Influence of Season on Total admissions*

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11 The influence that seasons have on overall trauma admissions is well documented in the
12 literature. Several studies in the UK, and others elsewhere around the world, have identified
13 increased admissions during the summer season. (4–8,17–24) The results from this study are
14 consistent with these findings. Three years we examined however did not demonstrate higher
15 admissions during the summer (2010, 2011 and 2017). This is useful as previous studies that
16 examined one year of trauma data may not accurately represent the trauma admissions across each
17 season, but rather review the trauma admissions over that particular year. The reason for the
18 anomalies in our result is likely multifactorial, with a particular influence from the environment.
19 Effects of weather on trauma admissions is well documented,(18,19,24–28) and has been identified
20 to significantly influence trauma admissions, particularly the weather gradient.(20)
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37 *Influence of Season on Age of admissions*

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39 There is a well-known increase in admissions of younger patients during the summer, usually
40 presenting with injuries to the wrist, forearm or elbow.03/07/2020 07:34:00 This results from
41 increased outdoor activities in younger patients in summer, with prolonged daylight hours and
42 increased school holidays. Our study corroborates these findings and attributes these injuries, in
43 these patients, to be the main contributor towards the increased admissions seen in the summer.
44 One study, however, has identified lower fracture rates in individuals younger than 16 years of age
45 in hot weather.(29) Additionally, our results also demonstrate an increase in adult admissions during
46 the summer, although less significantly to the younger patients. Although less studied, the literature
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does support this finding too, and some authors have noticed a particular increase in adult admissions following motorcycle crashes during the warmer and sunnier conditions.(22,23,30,31)

Age and gender of trauma

Most trauma admissions in this paper occurred in the summer and occurred in patients over the age of 60, a finding consistent with those found in the TARN database.(32) Females aged over 60 in particular represented the single highest peak in trauma admissions. Interestingly, the second highest peak in trauma admission is seen in young males. This finding was consistent each year in summer, spring and autumn. Winter did not share this pattern due to the significant increase in the age of male patients being admitted. The impact of more elderly patients during winter can exacerbate the annual winter bed crisis issues in the UK,(33) and this higher demand of bed occupancy from trauma orthopaedic patients may delay urgent orthopaedic care.

Length of Stay

In this study, there was an increase in length of hospital stay during the winter season which adds additional pressures on health resources. Increased length of stay (LOS) during the winter season is multi-factorial with patient factors and resource issues, both within hospitals and in the community. This study identified three patient factors that resulted in increased LOS: [1] Age of patients admitted in winter, with increased LOS of 8-9 days in those >60 years old; [2] Gender of patients admitted in winter, with females staying an average of 4-5 days longer; and [3] Hip injuries during the winter, which were also associated with prolonged LOS and have been associated with increased LOS previously.(34) This highlights a problematic area in trauma as most patients admitted in the winter are females aged over 60 and with hip injuries. All three of these factors contribute independently towards increased LOS and increased bed pressure. Treatment received, surgery or conservative, did not seem to affect the length of stay in this study. Other factors documented to influence the length of stay include delay to surgery,(35) and prolonged winter admission times.(36)

1 Seasonal comorbidities, such as viral illnesses(37,38) should also be considered as an influencing
2 factor towards increased LOS. The importance of efficient care for these patients with hip injuries,
3 particularly in females aged >60, in reducing LOS and bed pressure is clear from this data. Fast track
4 admissions for hip injuries, guidelines on timing to surgery, orthogeriatric input, enhanced recovery
5 programmes and early rehabilitation options (in hospital and community) are some of the strategies
6 implemented to help this group of patients and the effect they have on bed pressure.
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16 *Site of Injury Patterns*

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18 Young patients have a peak in trauma admissions during the summer, predominantly due to
19 injuries to wrist, forearm and elbow. Our study supports this finding. There is some discrepancy
20 however, as some studies have identified a bimodal distribution of upper limb fracture in children
21 with high admission in summer and autumn, and spring and autumn respectively.(29,39)
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28 Hip injuries were by far the most common injury in our study sample, and in others,(9,17,40)
29 and were more common in the winter. Wrist injuries in older patients were also seen to occur most
30 frequently during the winter. These two findings are significant as they represent two large
31 subgroups of patients that have been identified with inferior outcomes. One paper identified wrist
32 fractures treated surgically in the elderly during winter were associated with reduced functional
33 capacity,(41,42) and another identified hip fracture treated surgically in winter had increased risk of
34 impaired healing and converting to arthroplasty,(43) and increased risk of mortality.(44)
35 Understanding this, attention can be focused on reducing the risk of these negative outcomes by
36 reviewing more definitive surgical options for hip fractures and reviewing post-operative
37 management and physiotherapy to wrist fractures. Except for the aforementioned, other patterns in
38 the site of injury are less well documented. Hand and clavicle/scapular injuries were more common
39 in male patients, and, to a lesser extent foot, forearm and knee injuries were too.
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59 *Decision to Treat*

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1 Seasonal variation of treatment is also less well documented, and this study provides some
2 new insights into the variations in trauma management. Our study identified more operations
3 occurred during the winter for trauma patients, and less occur during the summer. This alone is
4 valuable as it can be used to determine the resources required through the different season. This
5 study also identified an increase in hip injuries managed conservatively in the summer with more
6 pubic rami fractures rather than neck of femur fractures. This too is valuable in managing these
7 patients as these patients may require care whilst their injuries heal, and this often involves referring
8 patients to community and rehabilitation hospitals. In younger patients, more elbow, forearm and
9 wrist injuries are treated surgically in the summer, requiring the availability of upper limb surgeons
10 and paediatric specialists at this time. Others have noted these injuries are more complex and
11 difficult to manage during this season with a higher complication rate.(45) More work is needed to
12 understand exactly what surgical interventions are undertaken seasonally and what support for
13 discharge or rehabilitation is required. The data on operations performed is difficult to analyse
14 because of the large number of hip fractures skewing the data as they account for 300 cases out of
15 1300 presenting. However, there remains a significant proportion of patients with injuries in a level
16 III trauma unit not involving the hip, who would benefit from a similar degree of scrutiny as hip
17 fractures into their outcomes and related factors such as delay in operating because of a lack of
18 available resources.

44 *Recommendations*

45 This study develops on our knowledge of trauma patterns and highlights additional trends in
46 the admission, management and length of hospital stay for trauma patients. It confirms that there is
47 a seasonal increase in summer admissions, particularly in young patients, but this is not always
48 consistent. This has enabled increased provision for day case surgery to be arranged in summer
49 months to match with demand in our institution. This study has also identified elderly patients,
50 particularly female, at risk of inferior outcomes from wrist and hip injuries and allowed strategies to
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be implemented to overcome this, including increased input from orthogeriatricians and an enhanced recovery programme. Collecting similar data from different trusts will enable other level III units to understand the patterns of trauma presentations specific to their population and enhance patient care by reducing unwarranted variations and mapping service delivery to demand. A national framework of data collection might help units compare patient flows and develop regional strategies in smaller units to help with the volume of work.

The introduction of major trauma networks did not appear to have influenced the age, gender or pattern of injury. This is probably because we had pre-existing systems that already worked unofficially at these various levels with established pathways for injured patients. A large amount of trauma is still undertaken in level III units to and focus should be on reducing morbidity by applying GIRFT principles and recommendations from organisations such as NHFD.

Limitations

This study was performed in a single level III trauma centre, and therefore the results may not be generalised to trauma units of different levels. However, the data was rigorously collected over a prolonged time period and the results are a perspective of a smaller unit providing a significant service to a population of a million people, as one of two non-trauma centres. This shared service with a different trust may also affect the generalisability of the results, as more seriously injured were often transferred directly to this other hospital. To correct this, one recommendation is to standardise a data set for all trauma admissions between all units to allow collaboration between units. This will further enhance our understanding of the true variations of trauma. There are likely to be marked regional variations in trauma presentation dependent on the prevailing population, facilities available locally and the need for people to commute. Environmental factors, patient factors and hospital factors may also affect the results from other trauma units.

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7 **CONCLUSION**
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9 The results of this study highlight the burden of trauma admissions to a single level III
10 trauma unit. Most of the admissions occur in summer season, with a particular demand for care of
11 more complex wrist and forearm injuries in younger patients. In winter, a higher proportion of
12 patients require surgery and have a longer length of hospital stays. Elderly patients with hip injuries
13 are particularly at susceptible to prolonged length of stay. Understanding these variations in injury
14 site, treatment received, and the length of stay can be used to enhance patient care and minimise
15 health care costs by reduces unwarranted variations and enabling service delivery to match the
16 demand.
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HIGHLIGHTS

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2 1. Patterns of trauma presenting to lower level trauma units appear reproducible year on year.
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5 2. The Impact of Major trauma centres introduced in 2011 on the trauma admissions in level III
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7 units has previously not been described
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10 3. This study contains one of the largest datasets for all the trauma admissions to a level III trauma
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12 unit in the UK.
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15 4. The results show seasonal patterns in the patient demographics, site of injury, treatment
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17 received, and length of hospital stay for trauma patients.
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20 5. The results can be used to develop algorithms to improve healthcare provision by matching the
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22 service delivery to the demand.
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25 6. Implementing a national database for trauma admissions could further develop our
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27 understanding of the patterns of trauma admissions and further optimise healthcare delivery.
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Table 1 Characteristics of first admissions per season*

	Total	Spring	Summer	Autumn	Winter
Total number (%) of first admissions	13,007	3,322 (25.5%)	3,482 (26.8%)	3,153 (24.2%)	3,050 (23.4%)
Mean (SD) admissions per year, 2009-18:	1,300.7 (80.2)	332.2 (23.0)	348.2 (26.5)	315.3 (22.0)	305.0 (32.3)
Number (%) of operations by 5-y period:					
2014-18	6,282 (48.3%)	1,602 (25.5%)	1,706 (27.2%)	1,520 (24.2%)	1,454 (23.1%)
2009-13	6,725 (51.7%)	1,720 (25.6%)	1,776 (26.4%)	1,633 (24.3%)	1,596 (23.7%)
Weekday admissions	9,765 (75.1%)	2,392 (24.5%)	2,589 (26.5%)	2,455 (25.1%)	2,329 (23.9%)
Weekend admissions	3,242 (24.9%)	930 (28.7%)	893 (27.5%)	698 (21.5%)	721 (22.2%)
Sex (%):					
Female	6,802 (52.5%)	1,705 (25.1%)	1,822 (26.8%)	1,597 (23.5%)	1,678 (24.7%)
Male	6,165 (47.5%)	1,605 (26.0%)	1,649 (26.7%)	1,547 (25.1%)	1,364 (22.1%)
Mean age (SD) in years:					
Overall sample	55.6 (27.7)	58.6 (31.8)	55.4 (35.0)	58.9 (31.4)	63.1 (26.4)
Female	70.5 (21.4)	70.8 (20.9)	68.4 (24.3)	71.2 (20.5)	71.4 (19.3)
Male	45.1 (32.9)	44.3 (34.1)	41.2 (33.0)	44.3 (33.0)	51.1 (30.6)
Patients aged 80 years or above (%)	3,240 (24.9%)	832 (25.7%)	815 (25.2%)	797 (24.6%)	796 (24.6%)
Female patients aged 80 years or above (%)	2,402 (74.2%)	610 (25.4%)	627 (26.1%)	581 (24.2%)	584 (24.3%)
Male patients aged 80 years or above (%)	837 (25.8%)	221 (26.4%)	188 (22.5%)	216 (25.8%)	212 (25.3%)
Treatment received (%):					
Surgery	9,654 (74.2%)	2,473 (25.6%)	2,502 (25.9%)	2,345 (24.3%)	2,334 (24.2%)
Treated conservatively	3,353 (25.8%)	849 (25.3%)	980 (29.2%)	808 (24.1%)	716 (23.4%)
Weekday operation	7,452 (77.2%)	1,869 (25.1%)	1,918 (25.1%)	1,873 (25.1%)	1,792 (24.0%)
Weekend operation	2,202 (22.8%)	604 (27.4%)	584 (26.5%)	472 (21.4%)	542 (24.6%)
Median (IQR) admission to discharge days	3 (9)	3 (10)	3 (8)	3 (9)	4 (10)
Median (IQR) admission to procedure days	1 (1)	1 (3)	1 (3)	1 (4)	1 (3)
Median (IQR) procedure to discharge days	2 (8)	1 (3)	1 (3)	1 (4)	1 (3)
Days from procedure to discharge (%):					
0-1 day	4,390 (47.3%)	1,152 (26.2%)	1,202 (27.4%)	1,083 (24.7%)	953 (21.7%)
2-4 days	1,436 (15.5%)	339 (23.6%)	396 (27.6%)	338 (23.5%)	363 (25.5%)
≥5 days	3,453 (37.2%)	904 (26.2%)	805 (23.3%)	824 (23.9%)	920 (26.6%)

* Missing data: Age = 521 (4.0%); Sex = 40 (0.3%); Days from admission to discharge = 89 (0.7%); Days from admission to procedure = 3,353 (25.8%) with removal of conservatively treated patients; Days from procedure to discharge = 3,395 (26.1%) with removal of conservatively treated patients; Season = 0 (0%); Year/period = 0 (0%); Admission days = 0 (0%); Procedure day = 0 (0%) after removal of conservatively treated patients; Complications = 68 (0.5%).

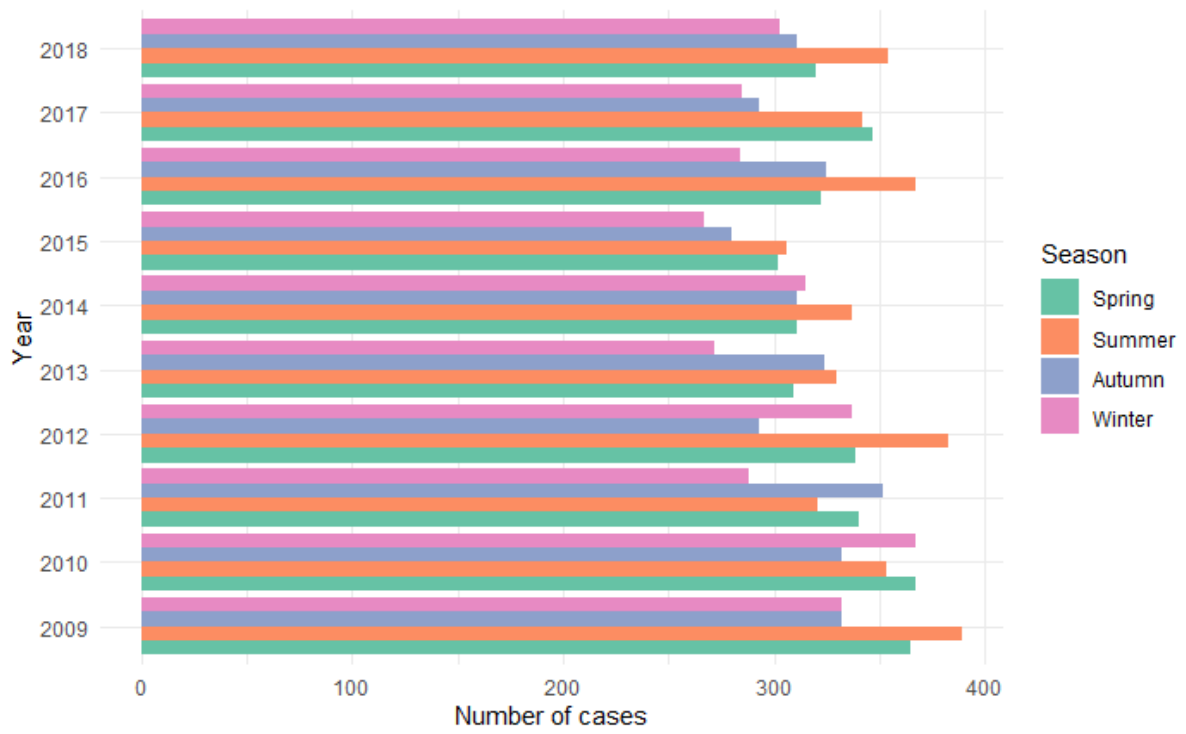


Figure 1. Number of cases in each season between 2009 and 2018 (In colour)

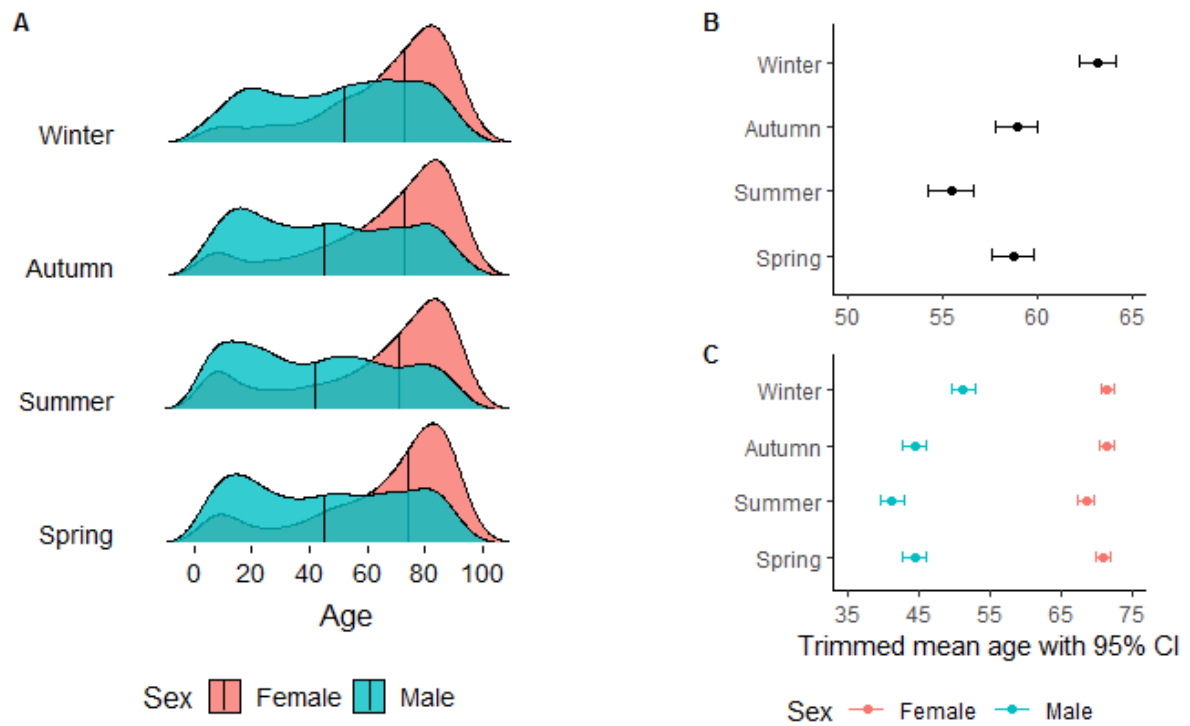


Figure 2. Age profile of male and female patients admitted each season (A) and mean (95% CI) age of patients overall (B) and by gender (C). (In Colour)

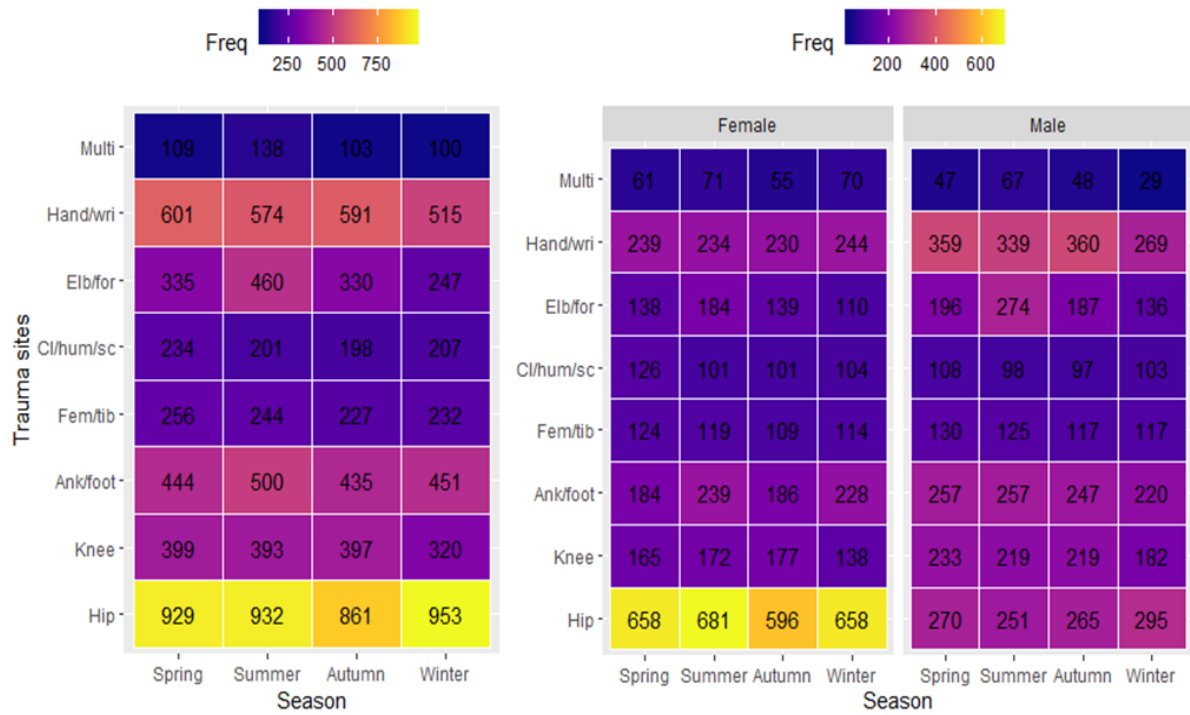


Figure 3. Heat map of number of admissions in each season per trauma site overall and for female and male patients. (In Colour)

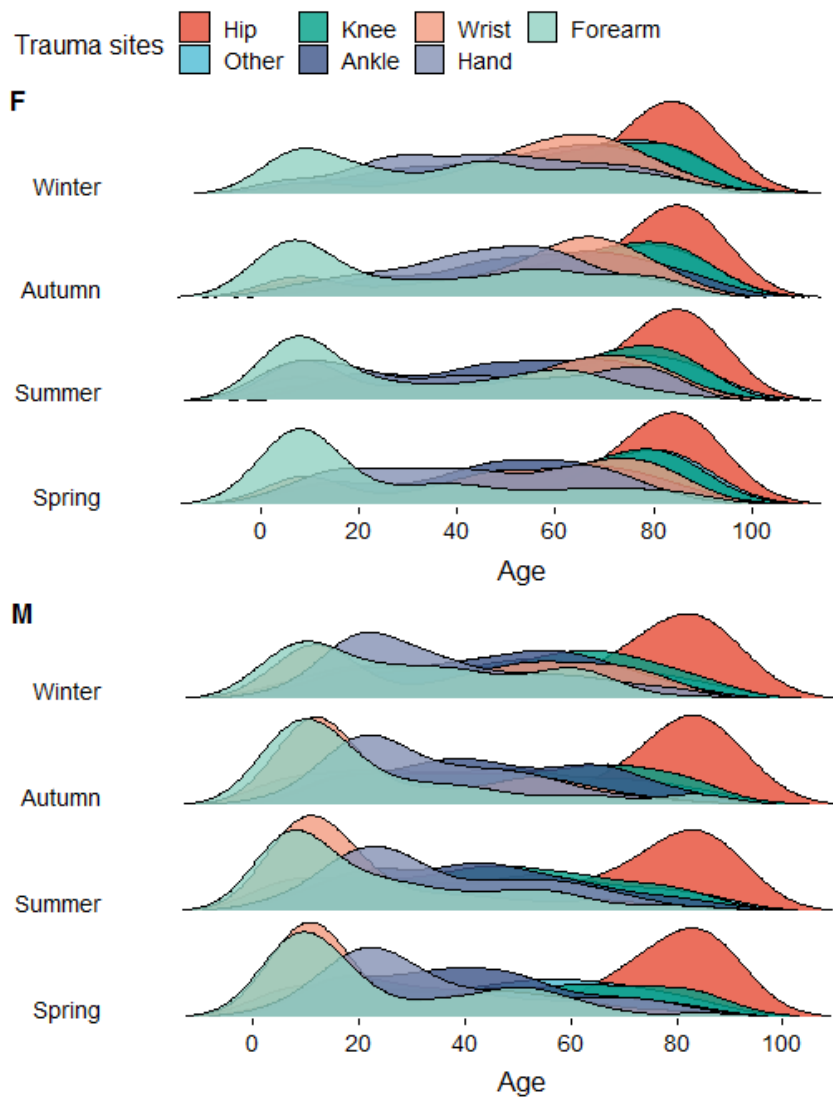


Figure 4. Age of patients for the six most common trauma sites per season by patient gender (B). (In colour)

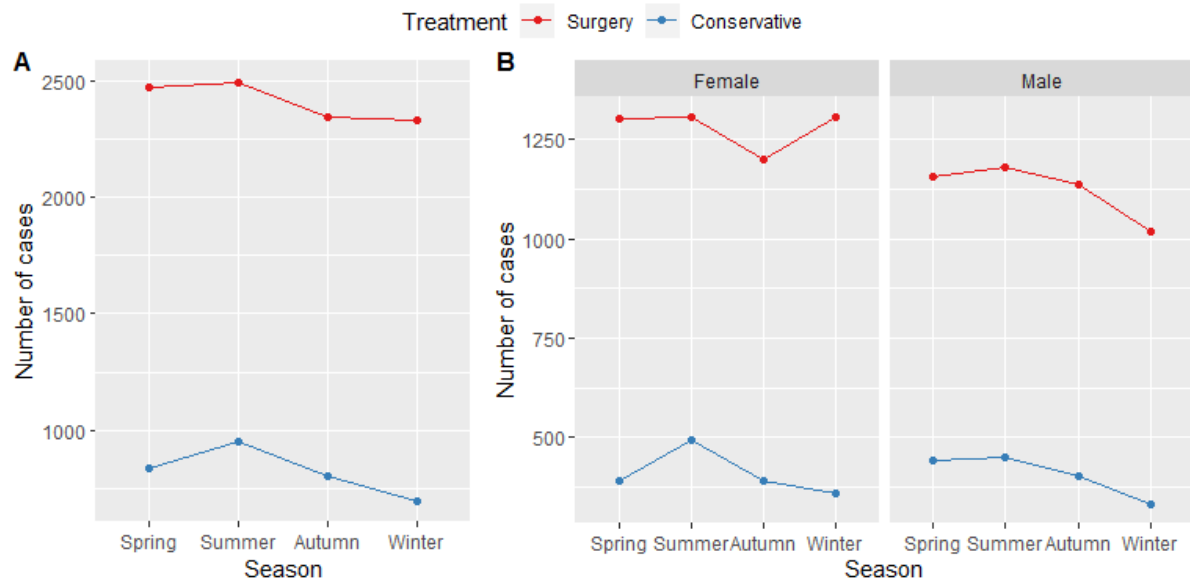


Figure 5. Number of patients treated surgically vs conservatively across each season: overall (A) and by patient gender (B). (In Colour)

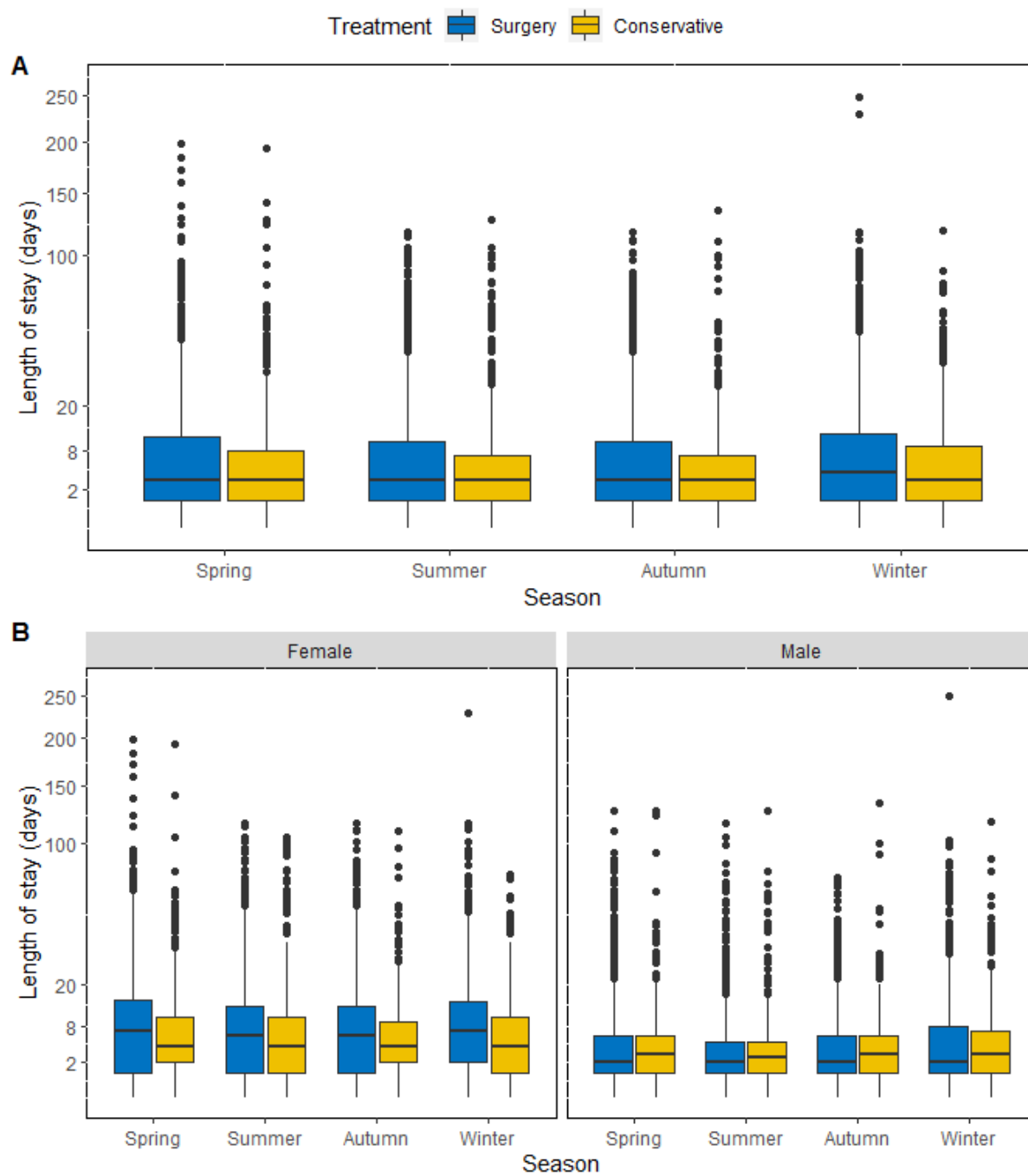


Figure 6. Length of stay in hospital across seasons, (A) overall and for (B) female and male patients. (In Colour)

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