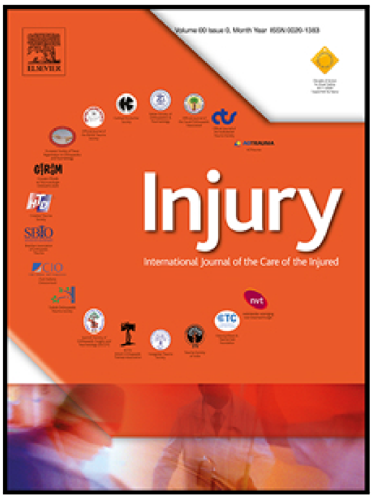
Journal Pre-proof



Lack of Regional Pathways Impact on Surgical Delay: analysis of the ORthopaedic Trauma Hospital Outcomes - Patient Operative Delays (ORTHOPOD) Study

Hussam Elamin Ahmed , Thomas Baldock , Nicholas Wei , Thomas Walshaw , Reece Walker , Alex Trompeter , Sharon Scott , William G.P. Eardley

PII: S0020-1383(23)00711-8
DOI: https://doi.org/10.1016/j.injury.2023.111007
Reference: JINJ 111007

To appear in: *Injury*

Accepted date: 20 August 2023

Please cite this article as: Hussam Elamin Ahmed , Thomas Baldock , Nicholas Wei , Thomas Walshaw , Reece Walker , Alex Trompeter , Sharon Scott , William G.P. Eardley , Lack of Regional Pathways Impact on Surgical Delay: analysis of the ORthopaedic Trauma Hospital Outcomes - Patient Operative Delays (ORTHOPOD) Study, *Injury* (2023), doi: https://doi.org/10.1016/j.injury.2023.111007

TITLE PAGE:

Title

Lack of Regional Pathways Impact on Surgical Delay: analysis of the **OR**thopaedic **T**rauma **H**ospital **O**utcomes - **P**atient **O**perative **D**elays (ORTHOPOD) Study

Authors:

Hussam Elamin Ahmed [a], Thomas Baldock [a], Nicholas Wei [a], Thomas Walshaw [a], Reece Walker [a], Alex Trompeter [b], Sharon Scott [c], William G.P. Eardley [a]

a- James Cook University Hospital, Marton Road, Middlesborough, United Kingdom, TS4 3BW
b- St George's Hospital, Blackshaw Road, London, United Kingdom, SW17 0QT
c- Aintree Hospital, Lower Lane, Liverpool, United Kingdom, L9 7AL

Authors' emails:

Nicholas Wei: nicholas.wei1@nhs.net

Thomas Baldock: thomas.baldock2@nhs.net

Hussam Elamin-Ahmed: hussam.elamin-ahmed@nhs.net

Thomas Walshaw: tom.walshaw@nhs.net

Reece Walker: reece.walker@nhs.net

Alex Trompeter: a.trompeter@nhs.net

Sharon Scott: sharon.j.scott@liverpoolft.nhs.uk

William G.P. Eardley: william.eardley@nhs.net

Declaration of interest:

- Mr William Eardley serves as the Vice-chair on the British Orthopaedic Association (BOA) Trauma Committee and the Clinical lead of the NHFD of England and Wales.
- Mr Alex Trompeter is a member of the BOA Trauma Committee and is the lead for the BOA Standards for Trauma and Orthopaedics (BOAST) guidelines.
- Ms Sharon Scott is a member of the National Clinical Reference Group for Major Trauma and Burns as well as the Best Practice Tariff for Major Trauma

Corresponding Author:

hussam.elamin-ahmed@nhs.net

James Cook University Hospital

Marton Road, Middlesborough, United Kingdom, TS4 3BW

Keywords:

Trauma, Fracture, Day-case trauma, Ambulatory, Cancellations, Delays, Time to surgery

Title

Lack of Regional Pathways Impact on Surgical Delay: analysis of the **OR**thopaedic **T**rauma **H**ospital **O**utcomes - **P**atient **O**perative **D**elays (ORTHOPOD) Study

Keywords:

Trauma, Fracture, Day-case trauma, Ambulatory, Cancellations, Delays, Time to surgery

Abstract

Introduction

Current practice following injury within the United Kingdom is to receive surgery, at the institution of first contact regardless of ability to provide timely intervention and inconsiderate of neighbouring hospital resource and capacity. This can lead to a mismatch of demand and capacity, delayed surgery and stress within hospital systems, particularly with regards to elective services. We demonstrate through a multicentre, multinational study, the impact of this at scale.

Methodology

ORTHOPOD data collection period was between 22/08/2022 and 16/10/2022 and consisted of two arms. Arm 1 captured orthopaedic trauma caseload and capacity in terms of sessions available per centre and patients awaiting surgery per centre per given week. Arm 2 recorded patient and injury demographics, time of decision making, outpatient and inpatient timeframes as well as time to surgery. Hand and spine cases were excluded. For this regional comparison, regional trauma networks with a minimum of four centres enrolled onto the ORTHOPOD study were exclusively analysed.

Results

Following analysis of 11,202 patient episodes across 30 hospitals we found no movement of any patient between hospitals to enable prompt surgery. There is no current system to move patients, between regional centres despite clear discrepancies in workload per capacity across the United Kingdom. Many patients wait for days for surgery when simple transfer to a neighbouring hospital (within 10 miles in many instances) would result in prompt care within national guidelines.

Conclusion

Most trauma patients in the United Kingdom are managed exclusively at the place of first presentation, with no consideration of alternative pathways to local hospitals that may, at that time, offer increased operative capacity and a shorter waiting time. There is no oversight of trauma workload per capacity at neighbouring hospitals within a regional trauma network. This leads to a marked disparity in waiting time to surgery, and subsequently it can be inferred but not proven, poorer patient experience and outcomes. This inevitably leads to a strain on the overall trauma system and across several centres can impact on elective surgery recovery. We propose the consideration of inter-regional network collaboration, aligned with the Major Trauma System.

Introduction

Theatre sessions on which patients with injuries or musculoskeletal infections undergo surgery are commonly referred to as ‘trauma lists’ (1). These lists occur in acute hospitals on a daily basis and for both inpatients and those injured who are waiting at home, of varying age, injury and surgical need, vying for access and prioritisation (2,3). Central to this work, ‘trauma lists‘ provide care often without dedicated pathways, a situation we have previously identified as impacting on resource use across the United Kingdom (4).

Procedure prioritisation, delay or cancellation is dependent upon caseload and operative capacity. A complex situation in its own right; this balance and decision making does not occur in isolation. Trauma provision is often entwined with elective surgery; the latter and day case provision being the subject of much attention with recovery from the COVID pandemic and the Get it Right First Time (GIRFT) programme (5). Centralisation of major and complex trauma is already in place as all component trauma hospitals in England were organised by networks established in 2012 into the National Major Trauma Network System (6,7).

Improving care in such complex systems and enabling more flexible access to day case surgery requires an understanding not only of individual hospital performance, but also inter-hospital and regional resource availability and utilisation. For fragility femur fracture care and major trauma, this information is available through the National Hip Fracture Database (NHFD) and the Trauma Audit Research Network (TARN) respectively (8,9). Key performance indicators enable comparison of performance across hospitals as well identifying variance across networks (10,11). These injury groups, whilst important, comprise a small proportion of orthopaedic trauma cases. There is currently no data available for all the other, vastly more numerous, patient groups operated on trauma lists. There is no understanding of case burden or resource availability between neighbouring hospitals. Multiple guidelines exist recommending treatment timelines, however there is no data to measure compliance with these across regional level, and thus for comparison between trauma networks (8,9).

The ‘region’ is the unit measure of healthcare communication, performance and training. It looks outside individual hospitals yet functions within a local system of relevance. Lack of standardisation in trauma resource capacity, as well as marked variance in overall trauma provision workload within and between regional networks will inevitably lead to a disparity in the quality of care provided and overall patient experience. Prior to this study, the trauma community have had no reliable method of evaluating whether in fact there is indeed significant variance in trauma capacity and workload.

The British Orthopaedic Association, in recognition of this evidence void and cognisant of variance in care between hospitals and across regions, commissioned a study of orthopaedic trauma list capacity and variance in delays to surgery. **OR**thopaedic **T**rauma **H**ospital **O**utcomes - **P**atient **O**perative **D**elays A Prospective Multicentre Service Evaluation of Trauma Burden and Resources (ORTHOPOD) investigated all cases undergoing surgery on orthopaedic trauma lists across the United Kingdom. Using data from ORTHOPOD we have assessed and compared in detail the performance of multiple component regions of the UK National Trauma Network. We aim to detail the distribution and variance of trauma within the United Kingdom in terms of trauma caseload and operative capacity, by providing a unique intra-regional and inter-regional perspective. These findings will inform construction of improved trauma patient pathways on a regional and national level.

Materials and Methodology

We have published detailed methodology previously on the ORTHOPOD Study (4) including information on pilot study and site recruitment. All patients listed for an operation for trauma, including adults and children, between 22/08/22 and 16/10/22 and operated on 31/10/22 were included. This comprised procedures subsequent to bony, ligamentous and/or joint injury or musculoskeletal sepsis (including hands and spine). Patients were also included in the trauma caseload analysis if they were on the trauma list for trauma or its sequelae; such as Fracture Related Infection (FRI) or non-union including soft tissue coverage even if the orthopaedic procedure had previously been completed. These were, however, removed from analysis of time to surgery. Patients undergoing an operation secondary to trauma but were escalated and undertaken on an elective operating list were also included.

Data collection comprised of two arms.

Arm 1 of the study captured caseload and theatre capacity. This was recorded prospectively each Monday of the study period at 0800 identifying the number of inpatient trauma lists(general trauma, spine or hands) as well as dedicated ambulatory lists. Dedicated theatre sessions were defined as: Morning 0800-1300, Afternoon 1400-1700, All Day 0800-1700 and a third Session 0800- >1900. In addition, the total number of patients awaiting a trauma operative procedure at each Monday at 0800 was also recorded.

Arm 2 recorded patient and injury demographics, time of decision making, outpatient and inpatient timeframes as well as time to surgery. Time to surgery was defined as the time from decision to operate to the time the patient was taken into the anaesthetic room and was measured in days. Time of diagnosis for fractures was the time of which the first radiograph was taken. Time of diagnosis for soft tissue injury without fracture was the time of clinical assessment by a specialist, for example, time seen by a hand surgeon for a tendon injury.

Patient data was entered on admission, during admission, or retrospectively, using the Research Electronic Data Capture (REDCap; Vanderbilt University, USA) up to the closing date of 31 October 2022. If a patient had not been discharged by this date, this was recorded. Collaborator recruitment occurred via social media, the British Orthopaedic Trainees Association (BOTA), and the Collaborative Orthopaedic Research Network (CORNET). Information governance sign-off was obtained by the lead site and reproduced locally by each collaborator.

Regional Analysis

Data from grouped regional hospitals representative of United Kingdom orthopaedic trauma services, in terms of regional trauma networks, were analysed to allow assessment of pathways at regional level. Regional units were isolated if there was a minimum of one major trauma centre (MTC) and a minimum of three trauma units (TU) in that respective region. 'Deep dive' analyses were then subsequently undertaken. Proximity to the nearest hospital was measured in miles. Distal radius fractures were analysed to assess for inter-hospital variability. The rationale behind this being they are predominantly ambulatory (4) and can act as a surrogate marker for the ambulatory patient who might move between two nearby hospitals.

Two hospitals (Whiston Hospital, Prescot, United Kingdom and St Helens Hospital, St Helens, United Kingdom) registered as one unit. St Helens is a purpose-built outpatient, day case and diagnostic hospital whilst Whiston Hospital is an acute hospital. Their data is displayed as one unit, with distances measured from Whiston Hospital for ease.

Study Registration

Using the Health Research Authority decision tool ethics committee approval was not required, as the information collected was a record of normal care and did not involve an intervention (12). All collaborators registered the study as a service evaluation prior to data collection.

Quality assurance checks were performed at the midpoint (14/10/22-18/10/22) and end of the study (05/11/22-08/11/22) to identify potential anomalies and/or missing data. All data was reviewed by the primary study team and individualised spreadsheets by the site leads at each hospital.

Data Management and Analysis

The REDCap electronic data capture tool was hosted on secure servers at the South Tees Hospitals NHS Foundation Trust. REDCap is a secure, web-based software platform designed to support data capture for research studies, providing an intuitive interface for validated data capture, audit trails for tracking data manipulation, automated export procedures for seamless data downloads to common statistical packages and procedures for data integration and interoperability with external sources (13,14).

Data are presented as absolute numbers and proportions. Continuous data were expressed as medians. No comparison or proof of difference was carried out.

Funding

The BOA provided funding for this study to cover database construction and data analysis.

Results

For comparative analysis, regional trauma networks which included data from a minimum of one major trauma centre (MTC) and a minimum of three trauma units (TU) were isolated and included.

Included Patient Episodes and Hospital Trust Data

In total, 11,202 operative case episodes were included for analysis within this study. Spinal and hands specific cases were excluded for comparability across all regional networks as well as individual hospital trusts.

With respect to Arm 1 of the study, theatre list provision and trauma surgery waiting volume were collected per hospital outlined in table 1 (Analysed Major Trauma Networks and Corresponding Hospital Trusts).

<u>Geographical Relationship Within Regional Trauma Networks</u>

Table 2 (Distance (miles) from trauma unit to corresponding major trauma centre within each regional trauma network) from trauma unit to corresponding major trauma centre within each regional trauma network) displays the geographical relationship between major trauma centre and corresponding trauma units. In addition, more importantly, the table displays the relationship to the closest neighbouring hospital, highlighting potential options for mobilising patients dependent on real time capacity and workload.

Trauma operative capacity relationship to operative waiting volume

Both table 3 (Trauma operative capacity relationship to operative waiting volume) and figure 4 (Overall trauma capacity and workload – Median number of patients awaiting surgery and median number of patients awaiting surgery per session) highlight the discrepancy of capacity per given workload for individual hospitals both within and between regional networks.

As observed in figure 3 (Geographical representation of capacity to workload ration per hospital (median number of patients listed and awaiting theatre per trauma list available per week), the highest disparity is noted within the Mersey and Northern Ireland regional networks. This being made even more considerable by the fact that hospitals with high workload per capacity (highlighted in red) are within ten miles of hospitals with low workload per capacity (highlighted in green).

Overall Trauma Capacity and Workload

Figure 4 (Overall trauma capacity and workload – Median number of patients awaiting surgery and median number of patients awaiting surgery per session) provides a snapshot of trauma workload and efficiency as well as capacity in terms of patients awaiting surgery per session available per given week.

What is most clearly highlighted is the marked discrepancy both within regional trauma networks as well as between networks.

This represents a lack of consistency across the United Kingdom in terms of deployment of trauma resources per workload per given time.

Injury specific discrepancies

Focusing upon distal radius fractures, table 4 (Overall and weekly median time to surgery for distal radius fractures) highlights the week-on-week discrepancy in time to surgery for patients presenting with distal radius fractures.

Most notably, weeks 4 to 8 within the Mersey regional network outlines a continued disparity between trust within the same network, whereby at least on trust had a median waiting time of more than 7 days and at least one trust with a median waiting time of less than three days.

This same trend is also observed in the Peninsula network during weeks 1 to 3 as well as the Northern network during weeks 5 to 7.

Discussion

Orthopaedic trauma care logistics have changed little over recent years, despite huge alterations in collaborative working and networks (3). Across healthcare, patients move within and between regions for sub-specialist care, both in the acute and elective settings.

Patients with injuries, by contrast, receive no such networked care. Simple fractures presenting to Major Trauma Centres or Trauma Units with an existing considerable caseload are not dispersed according to capacity and workload. Within elective orthopaedics, and also Major Trauma Services, networks and hubs exist to bring the patient to the right place (5,9). General fracture care has no such system despite representing a huge proportion of service demand regarding both bed occupancy and operating capacity. This study is the first of its kind to detail the distribution and variance of trauma within established regional trauma networks in terms of trauma caseload and operative capacity. Without a focused assessment of trauma 'supply and demand' across regional trauma networks, there is no way of understanding how performance in trauma may be maximised to improve patient experience and outcomes.

Lack of consistency within any healthcare system may inevitably lead to discrepancy in care provided and overall outcomes for patients (15). The results of this study display marked variation both within and between regional trauma networks. We have established that major trauma networks and trauma units may be 'busier' than one another. Several trauma units have greater a caseload than major trauma centres. This is seen in terms of disparity of workload within and between hospitals in a given trauma network as well as variance of available trauma capacity (highlighted in figure 4 (Overall trauma capacity and workload – Median number of patients awaiting surgery and median number of patients awaiting surgery per session)). Hence, it is vital that we acknowledge such variations and work to improve the provision of trauma services with the aim of creating a more standardised system overall (16).

Regional Major Trauma Networks have yielded significant improvements to severely injured patient care in England and Wales (10,17). Integration of auditing, incentivisation and informing practice through contemporary evidence drive improvement in care of badly injured patients (18,19). TARN and NHFD examine many aspects of care for major trauma and hip fracture patients (8,9). However, this only amplifies the necessity for comprehensive service evaluation in *all* trauma patients and there is evidence emerging to demonstrate a benefit of a data-driven approach to care overall (11,18).

Assessment of workload per capacity alone highlights the marked discrepancy both between hospitals within a regional network, as well as between regional networks. This is best observed when comparing directly the number of patients listed and awaiting surgery per trauma list available. Figure 4 (Overall trauma capacity and workload – Median number of patients awaiting surgery and median number of patients awaiting surgery per session) confirms a marked discrepancy both within regional trauma networks as well as between networks, thus representing a lack of consistency across the United Kingdom in terms of deployment of trauma resources per workload per given time.

What is more vital, however, is the ability to assess methods in which this may be improved, and the imbalance levelled out. This comes with geographical context. Figure 3 (Geographical representation of capacity to workload ration per hospital (median number of patients listed and awaiting theatre per trauma list available per week)) displays that there is a mix of hospitals with a "high", "medium" and "low" workload per capacity within each given regional trauma network. This further highlights the imbalance of trauma provision across the United Kingdom.

The Mersey regional network really reinforces the intra-regional imbalance in trauma workload per capacity. As highlighted in figure 3 (Geographical representation of capacity to workload ration per hospital (median number of patients listed and awaiting theatre per trauma list available per week)), there are two hospitals with "high" workload per capacity within fifteen miles of two hospitals with "low" workload per capacity. This may easily be balanced by an appreciation of this in real time, followed by effective communication between hospitals in a co-ordinated manner, with view of mobilising appropriate patients. In essence, this will improve patient experience across all hospitals, rather than the experience be dictated by the hospital the patient first presents to.

As well as an overall understanding of workload per capacity, week-on-week perspective also highlights the opportunity for inter-regional trust collaboration. Table 4 (Overall and weekly median time to surgery for distal radius fractures) displays week on week time to surgery for distal radius fractures. This highlights three different regional networks with a minimum of three consecutive weeks whereby a minimum of one trust observed a waiting time of more than seven days and a minimum of one trust with a waiting time of less than three days. A formal collaboration within regional trauma networks would allow recognition of this in real-time, with the opportunity to standardise the waiting times within networks with effective mobilisation of ambulant trauma patients.

With this in mind, it is essential to appreciate the procedural discrepancy in trauma surgery allocation per trust, with no clear unified policies across regional networks at present. This is dependent upon multiple factors, including cross-centre flexibility and collaboration may be considered as a method to even the overall weekly 'backlog' in unison across a given region. More importantly, there is no national agreed compensatory protocol should there be unmanageable 'backlog' at a certain centre within a given regional network.

It would be convenient to be able to recommend a specific ratio of theatre capacity to case load that takes into account seasonal variation and case mix presentation. This is out of the scope of this work and would entail complex modelling, unique to each unit and unique to each week. A more achievable perspective is to suggest 'triggers' for when elective capacity (cancellations) is brought into play or when consideration for moving patients between units is examined. Pre-arranged and agreed baseline activity breaches remove pressure of the individual clinicians and management staff and render the issue less emotive and numerical. A framework for this has been established through the Orthopaedic Trauma Society and British Orthopaedic Association; this is outlined in table 5 (Orthopaedic Trauma Society / British Orthopaedic Association Trauma Committee time to surgery guidance). We commend this as a pragmatic approach to communicating circumstances of clinical pressure through caseload.

This study opens the forum for discussion with regards to a collaborative unified approach to ensure that trauma burden and workload may be dealt with in a consistent manner, with possibility of inter-trust transfer of care should this be more beneficial to patient experience and overall outcome. In addition, the consideration of formal regional day-case centres (DTC's) across a given regional network may be a method to minimise the risk of sudden overwhelming burden, subsequently leading to delayed operative intervention and overall poorer patient outcomes. This would be in keeping with GIRFT principles of improving the treatment and care of patients through innovative change in keeping with the evidence (5).

The mismatch between resource and capacity is not confined to patients vying for prioritisation on operating lists. Trauma and elective services are entwined. There are very few hospitals in the United Kingdom where all elective activity is segregated geographically from that of trauma. Most hospitals share theatre capacity and overall inpatient bed base. Looking broadly therefore, the issue is bigger than trauma numbers, it is inextricably linked overall to elective performance or lack of it. Many thousands of patients are waiting protracted times for elective operations, suffering on a par with trauma patients being delayed (20). It is transparent therefore that there is a reluctance to cancel elective surgery on lists hugely impacted by the recent pandemic (21). 'Escalation' to cancel elective lists therefore is not an option in the same manner as prior to the COVID-19 pandemic.

Another perspective for this situation is renumeration. Losses occurring through inability to provide elective surgery may lead the trust management to prioritise elective cases through financial gain as much as to decrease waiting times overall (22) . It's a difficult balance but all of these elements play a role.

This situation of inability to utilise elective lists at time of surge capacity reinforces even further the need to utilise local assets more effectively. It may be that a neighbouring centre has list cancellations or underfilled lists and coordinating this with sites in extremes will help flatten the peaks and troughs evident in our work.

It is inevitable that cases waiting at home for surgery; such as distal radius fractures, clavicle fractures and some ankle fractures, are most likely to be delayed. These injuries, ideal for day case trauma operating, are often 'trumped' when operated on inpatient lists by other injuries such as limb and life-threatening sepsis, open fractures, and fragility femur fractures.

There comes a time when through necessity and the appropriate desire to prevent morbidity, that this pendulum swings. The nearly three-week-old distal radius fracture in a young patient' simply has to go' and those previously prioritised are delayed. This swing in prioritisation is a very poor experience for all patients and is a stressful situation for the lead clinician responsible for the decision making. This feature again would be improved through the combination of networked trauma capacity and improved utilisation of day case trauma lists.

Upon interpretation of the results, one must note the limitations associated with the data collection process. Seasonal variability of trauma presentations and surgery must be taken into account (23). Furthermore, it is essential to acknowledge logistic variation in theatre availability and resource allocation between centres as well as cross-specialty variance between sites.

This work was commissioned by the British Orthopaedic Association. It informs the strategy of the organisation and its wider scope of addressing the overall recovery from the recent pandemic. It is written by and carried out predominantly by surgeons working within trauma. Any bias is countered by the number and spread of hospitals and the fact that the vast majority of lead principal investigators in each unit are surgeons operating in both elective and trauma capacities.

The scope of this study has presented a unique opportunity to compare units on both a regional and national scale. In doing so, cases undertaken as well as cases awaiting surgery were assessed, providing an understanding of trauma demand and capacity at any given time throughout the duration of the study; assessing a variety of trauma cases, not unique to index procedures in isolation. The ability to group units per network regardless of unit type (major trauma centre or trauma unit) has allowed an opportunity to obtain a true understanding of the potential improvements that may be gained through introduction of effective collaboration on a regional level in trauma provision.

This study displays variation within individual regional trauma networks as well as between trauma networks on a larger scale. This is in terms of trauma theatre capacity and workload per available capacity. Furthermore, this study displays a clear opportunity to mobilise the trauma patient in response to real time discrepancy and imbalance between neighbouring hospitals. Frankly, this is not happening at present.

Conclusion

In the context of a lack of inter-hospital pathways for trauma patients and a lack of dedicated ambulatory trauma lists, we propose the consideration of inter-regional network collaboration. This should focus upon dispersal of patients within regional networks, with a view of standardising workload per capacity, which in addition to reducing waiting times for specific injuries could improve overall patient experience, care and outcomes. We also propose the introduction of 'Day-case Trauma Centres (DTC's)' as a formal re-structuring of the present trauma provision delivery, with similar aims for ambulatory patients.

References

1. Bhattacharyya T, Vrahas MS, Morrison SM, Kim E, Wiklund RA, Smith RM, et al. The value of the dedicated orthopaedic trauma operating room. J Trauma. 2006 Jun;60(6):1331–6.

2. Iyengar KP, Monga P, Elbana H, Singh B. Orthopaedic surgical prioritisation: can it be made fairer to minimise clinical harm? Vol. 98, Postgraduate medical journal. England; 2022. p. e61–2.

3. Scott S. Prioritisation of patients requiring orthopaedic trauma surgery: A call for action. Vol. 53, Injury. 2022. p. 819–20.

4. Wei N, Baldock TE, Elamin-Ahmed H, Walshaw T, Walker R, Trompeter A, et al. ORthopaedic trauma hospital outcomes-Patient operative delays (ORTHOPOD) Study: The management of day-case orthopaedic trauma in the United Kingdom. Injury. 2023;

5. Harrison S. GIRFT programme national specialty report. NHS Improv July. 2018;

6. McCullough AL, Haycock JC, Forward DP, Moran CG. II. Major trauma networks in England. BJA Br J Anaesth [Internet]. 2014 Aug 1;113(2):202–6. Available from: https://doi.org/10.1093/bja/aeu204

7. Moran CG, Lecky F, Bouamra O, Lawrence T, Edwards A, Woodford M, et al. Changing the System - Major Trauma Patients and Their Outcomes in the NHS (England) 2008–17. eClinicalMedicine [Internet]. 2018 Aug 1;2:13–21. Available from: https://doi.org/10.1016/j.eclinm.2018.07.001

8. National Hip Fracture Database (2022) Best Practice Tariff [Internet]. Available from: https://www.nhfd.co.uk/20/nhfdcharts.nsf/vwInfo/Bestpractice

9. About Tarn [Internet]. The Trauma Audit and Research Network (TARN). 2020 [cited 2022 Sep 1]. Available from: https://www.tarn.ac.uk/Content.aspx?ca=2

10. Gabbe BJ, Biostat GD, Simpson PM, Sutherland AM, Dip G, Wolfe R, et al. Improved Functional Outcomes for Major Trauma Patients in a Regionalized, Inclusive Trauma System. Ann Surg [Internet]. 2012;255(6). Available from: https://journals.lww.com/annalsofsurgery/Fulltext/2012/06000/Improved_Functional_Outcomes_for_Major_Trauma.1.aspx

11. Dixon J, Bouamra O, Lecky F, Hing CB, Baxter M, Eardley W. Regional variation in the

provision of major trauma services for the older injured patient. Injury [Internet]. 2022;53(7):2470–7. Available from: https://www.clinicalkey.com/#!/content/1-s2.0-S0020138322002820

12. listed N authors. Health Research Authority Decision tool. Heal Res Auth. 2022;

13. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform. 2009 Apr;42(2):377–81.

14. Harris PA, Taylor R, Minor BL, Elliott V, Fernandez M, O'Neal L, et al. The REDCap consortium: Building an international community of software platform partners. J Biomed Inform. 2019 Jul;95:103208.

15. Blouin AS, McDonagh KJ, Neistadt AM, Helfand B. Leading tomorrow's healthcare organizations: strategies and tactics for effective succession planning. JONA J Nurs Adm. 2006;36(6):325–30.

16. Park Y, Nahm AY. Ambidexterity: realising organisational innovation in healthcare organisations. Int J Bus Excell. 2023;29(1):17–30.

17. Lockey DJ. Improved Trauma Outcomes after the Introduction of a Trauma System in England. eClinicalMedicine [Internet]. 2018 Aug 1;2:3–4. Available from: https://doi.org/10.1016/j.eclinm.2018.08.002

18. Griffiths A, Dixon J, Egglestone A, Edwards A, Handley R, Trompeter A, et al. Evidence-based orthopaedic trauma care in the United Kingdom: Guidelines, registries, carrots and sticks. Eur J Orthop Surg Traumatol [Internet]. 2021;31(5):937–45. Available from: https://doi.org/10.1007/s00590-021-02954-w

19. Celso B, Tepas J, Langland-Orban B, Pracht E, Papa L, Lottenberg L, et al. A Systematic Review and Meta-Analysis Comparing Outcome of Severely Injured Patients Treated in Trauma Centers Following the Establishment of Trauma Systems. J Trauma Acute Care Surg [Internet]. 2006;60(2). Available from: https://journals.lww.com/jtrauma/Fulltext/2006/02000/A_Systematic_Review_and_Meta_Analysis_Comparing.20.aspx

20. Farrow L, Jenkins PJ, Dunstan E, Murray A, Blyth MJG, Simpson AHRW, et al. Predicted waiting times for orthopaedic surgery. Bone Joint Res [Internet]. 2022;11(12):890–2. Available from: https://doi.org/10.1302/2046-3758.1112.BJR-2022-0404

21. Sibanda V, Anazor FC, Bhadresha A, Altaf K, De C, Relwani J. The impact of the post- COVID 19 pandemic elective waiting list delays on patient reported symptoms and intention to proceed with planned upper limb surgeries-A prospective cohort study. Musculoskeletal Care. 2023 Jun;21(2):453–61.

22. Mayne AIW, Cassidy RS, Magill P, Mockford BJ, Acton DA, McAlinden MG. The feasibility of achieving Elective Care Framework targets for total hip arthroplasty and total knee arthroplasty in Northern Ireland. Bone Jt open. 2022 Apr;3(4):302–6.

23. Waldron J, Denisiuk M, Sharma R, Boura J, Afsari A, Best B. Does seasonal variation in orthopaedic trauma volume correlate with adverse hospital events and burnout? Injury. 2022;53(6):2053–9.

Tables

Table 1: Analysed Major Trauma Networks and Corresponding Hospital Trusts

Region	MTC	TU
Mersey	Aintree Hospital	Alder Hey Children's Hospital Arrowe Park Hospital Southport and Ormskirk NHS Trust Warrington & Halton NHS Teaching Hospitals Whiston Hospitals Combined
Glasgow	Queen Elizabeth University Hospital, Glasgow	Glasgow Royal Infirmary Royal Alexandra Hospital University Hospital Crosshouse The Royal Hospital for Children, Glasgow University Hospital Wishaw
Peninsula	Derriford Hospital	North Devon District Hospital Royal Cornwall Hospital Royal Devon & Exeter Hospital
Severn	Southmead Hospital	Bristol Royal Infirmary Gloucestershire Royal Hospital Great Western Hospital
West Yorkshire	Leeds General infirmary	Bradford Royal Infirmary Harrogate and District NHS Foundation Trust Pinderfields Hospital
Newcastle	Royal Victoria Infirmary, Newcastle-upon-Tyne	Cumberland Infirmary Northumbria Specialist Emergency Care Hospital Sunderland Royal Hospital University Hospital North Durham Queen Elizabeth Hospital, Gateshead
South-West London	St George’s Hospital	East Surrey Hospital Epsom and St Helier Ashford and St Peter’s
Northern Ireland	Royal Victoria Hospital, Belfast	Belfast Children's Hospital Ulster Hospital Altnagelvin Area Hospital

Table 2: Distance (miles) from trauma unit to corresponding major trauma centre within each regional trauma network

* Centres situated as separate hospitals on the same geographical site

Regional Network	Hospital	Miles to closest hospital	Miles to MTC
Mersey	MTC	4.8	n/a
	TU 1	4.8	4.8
	TU 2	11	14
	TU 3	13	14
	TU 4	15	18
	TU 5	8.2	8.2
West Scotland	MTC	0.1*	n/a
	TU 1	6.6	6.6
	TU 2	5.7	5.7
	TU 3	19	26
	TU 4	0.1*	0.1*
	TU 5	19	20
Peninsula	MTC	46	n/a
	TU 1	55	59
	TU 2	54	58
	TU 3	46	46
Severn	MTC	3.9	n/a
	TU 1	3.9	3.9
	TU 2	27	36
	TU 3	36	42
West Yorkshire	MTC	12	n/a
	TU 1	12	12
	TU 2	16	16
	TU 3	12	12
Northern	MTC	4.7	n/a
	TU 1	60	60
	TU 2	9	9
	TU 3	11	14
	TU 4	4.7	4.7
	TU 5	13	17
South-West London	MTC	9.2	n/a
	TU 1	10	21
	TU 2	10	17
	TU 3	9.2	9.2
Northern Ireland	MTC 1	0.3*	n/a
	TU 1	0.3*	0.3*
	TU 2	6.7	6.7
	TU 3	66	66

Table 3: Trauma operative capacity relationship to operative waiting volume

Regional Network	Hospital	Median Patients awaiting surgery at start of week	Median Weekly general trauma sessions	Average number of Patients waiting surgery per weekly list available
Mersey	MTC	74.0	38.0	**1.95**
	TU 1	2.5	4.0	**0.63**
	TU 2	14.0	23.0	**0.61**
	TU 3	6.0	14.0	**0.43**
	TU 4	20.0	11.0	**1.82**
	TU 5	34.0	14.0	**2.43**
West Scotland	MTC	10.0	31.0	**0.32**
	TU 1	12.0	15.0	**0.80**
	TU 2	29.0	50.0	**0.58**
	TU 3	26.0	35.0	**0.74**
	TU 4	4.0	5.0	**0.80**
	TU 5	22.0	24.0	**0.92**
Peninsula	MTC	38.0	34.0	**1.12**
	TU 1	7.0	10.0	**0.70**
	TU 2	60.0	41.0	**1.46**
	TU 3	7.0	14.0	**0.50**
Severn	MTC	27.0	31.0	**0.87**
	TU 1	16.0	14.0	**1.14**
	TU 2	46.0	33.0	**1.39**
	TU 3	11.0	16.0	**0.69**
West Yorkshire	MTC	41.0	42.0	**0.98**
	TU 1	12.0	14.0	**0.86**
	TU 2	11.0	10.0	**1.10**
	TU 3	40.0	22.0	**1.82**
Northern	MTC	6.0	21.0	**0.29**
	TU 1	21.0	14.0	**1.50**
	TU 2	29.0	24.0	**1.21**
	TU 3	8.0	19.0	**0.42**
	TU 4	9.0	14.0	**0.64**
	TU 5	8.0	14.0	**0.57**
South-West London	MTC	35	26	**1.35**
	TU 1	4	12	**0.33**
	TU 2	19	14	**1.36**
	TU 3	13	13	**1.0**
Northern Ireland	MTC 1	54.0	33.0	**1.64**
	TU 1	9.0	1.0	**9.0**
	TU 2	14.0	15.0	**0.97**
	TU 3	10	13	**0.77**

Table 4: Overall and weekly median time to surgery for distal radius fractures

Regional Network	Hospital	Overall median time to surgery	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Mersey	MTC	6.5	2	11	5	7	17	7.5	6	3.5
	TU 1	1	2	0.5	n/a	3	0	n/a	0.5	n/a
	TU 2	1	0.5	1	2.5	1	2	0	2.5	n/a
	TU 3	1	3	1	1.5	2.5	1	3.5	1	1
	TU 4	9	n/a	2	1	9	11	n/a	7.5	9
	TU 5	9	1.5	12	1	9	10.5	9	8.5	8
West Scotland	MTC	2	1	1.5	2	4.5	6	1.5	2	1
	TU 1	1	1.5	1	3	1	1	1	1	3
	TU 2	2	2	3	2	1.5	1	1	1	1
	TU 3	2	2.5	1.5	2	1	2	2	4	0
	TU 4	1	20	n/a	n/a	1	1	2.5	1	2
	TU 5	1	1	1	0	1	4	3.5	0	1.5
Peninsula	MTC	8	12	11	6.5	2.5	2	11	n/a	4
	TU 1	1	3	8	1	0	3	2	0	0.5
	TU 2	1	1.5	0	2	6	1	2	3	4.5
	TU 3	1	2	5	3	1	n/a	1	0	2
Severn	MTC	4	1.5	5	n/a	5.5	5	2	5	5.5
	TU 1	5	5	n/a	3	3.5	7	n/a	4	3
	TU 2	4	n/a	n/a	3	3	5	3	6	5
	TU 3	2	8	0.5	3.5	n/a	1	8	1	1
West Yorkshire	MTC	3	5	3	3	4	2.5	3	1	1.5
	TU 1	4	4	6	6	3	1	0.5	n/a	10
	TU 2	1	n/a	n/a	1.5	0.5	6	5	n/a	1
	TU 3	4	4	1	2	2	8	4	8	6.5
Northern	MTC	1	1	n/a	1	2	1	2	2	2
	TU 1	3	3	1	2	4.5	9.5	10	7	n/a
	TU 2	2	2	3	2	2	2	1	2	2
	TU 3	1	1	4	4	1	0.5	1	3	n/a
	TU 4	1	2.5	2	2	1	1	2	0	1
	TU 5	1	n/a	2	4	0	1	1	2	2
South-West London	MTC	1	1	3	2	n/a	1	7	5	1
	TU 1	4	1	1	7	5	3	1	5.5	6
	TU 2	3	3	4	17	6	3	2	16	1
	TU 3	5	3	1	1	n/a	4	14	15	6.5
Northern Ireland	MTC 1	5	5	4	5	5	3	6	1	2
	TU 1	1	n/a	1	1	3	n/a	1	n/a	n/a
	TU 2	2	1	4	1.5	3	n/a	1	1	3.5
	TU 3	4	n/a	n/a	6	1	4	10	n/a	6

Red = ≥ 7 days   Amber = 3-6 days   Green = ≤ 2 days

*n/a – complete dataset not available for given week

Table 5: Orthopaedic Trauma Society / British Orthopaedic Association Trauma Committee time to surgery guidance

Code	Category	Examples
1A	Immediate (life saving)	• Open pelvic fracture • Septic patients with MSK involvement
1B	Immediate (limb saving)	• Vascular injury • Compartment syndrome
2A	Urgent <12 hours	• Debridement & stabilisation (temporary or definitive) high energy open fractures • Reduction native joint dislocations +/- surgical stabilisation if persistent instability

2B	Urgent <24 hours	• Debridement low energy open fractures
		• Debridement contaminated open wounds (no fracture)
		• Stabilisation (temporary or definitive):
		  ○ complete articular fractures
		  ○ unstable ankle fractures
		  ○ high energy femoral fractures
		• Reduction and stabilisation paediatric supra-condylar humeral fractures

2C	Urgent <36 hours	• Lower limb fragility fractures • ORIF ankle fracture • Reduction of dislocated joint replacements • MUA paediatric distal radius / forearm fractures
3A	Expedited <3 days	• Definitive stabilisation and closure open fractures • ORIF displaced intra-articular distal radial fractures • ORIF rib fractures • ORIF pelvic ring injuries • Definitive stabilisation tibial shaft fractures
3B	Expedited <5 days	• ORIF acetabulum
3C	Expedited <7 days	• ORIF displaced extra-articular distal radius • Definitive stabilisation: • -complete articular fractures • -unstable ankle fractures • -high energy femoral fractures • Other non-specified injuries
4	Elective	

Figures

Figure 1: Flowchart displaying process of exclusion for all patient episodes

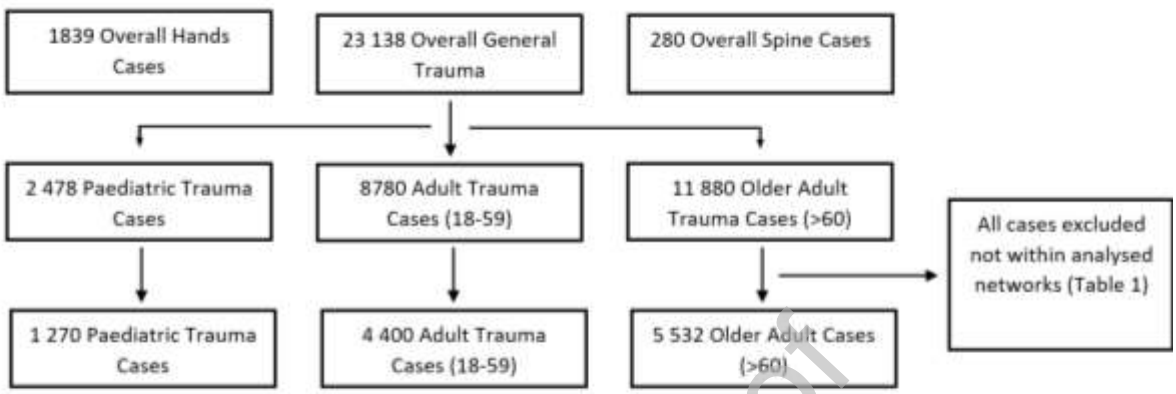


Figure 2: United Kingdom map representation of all included regional networks and hospitals

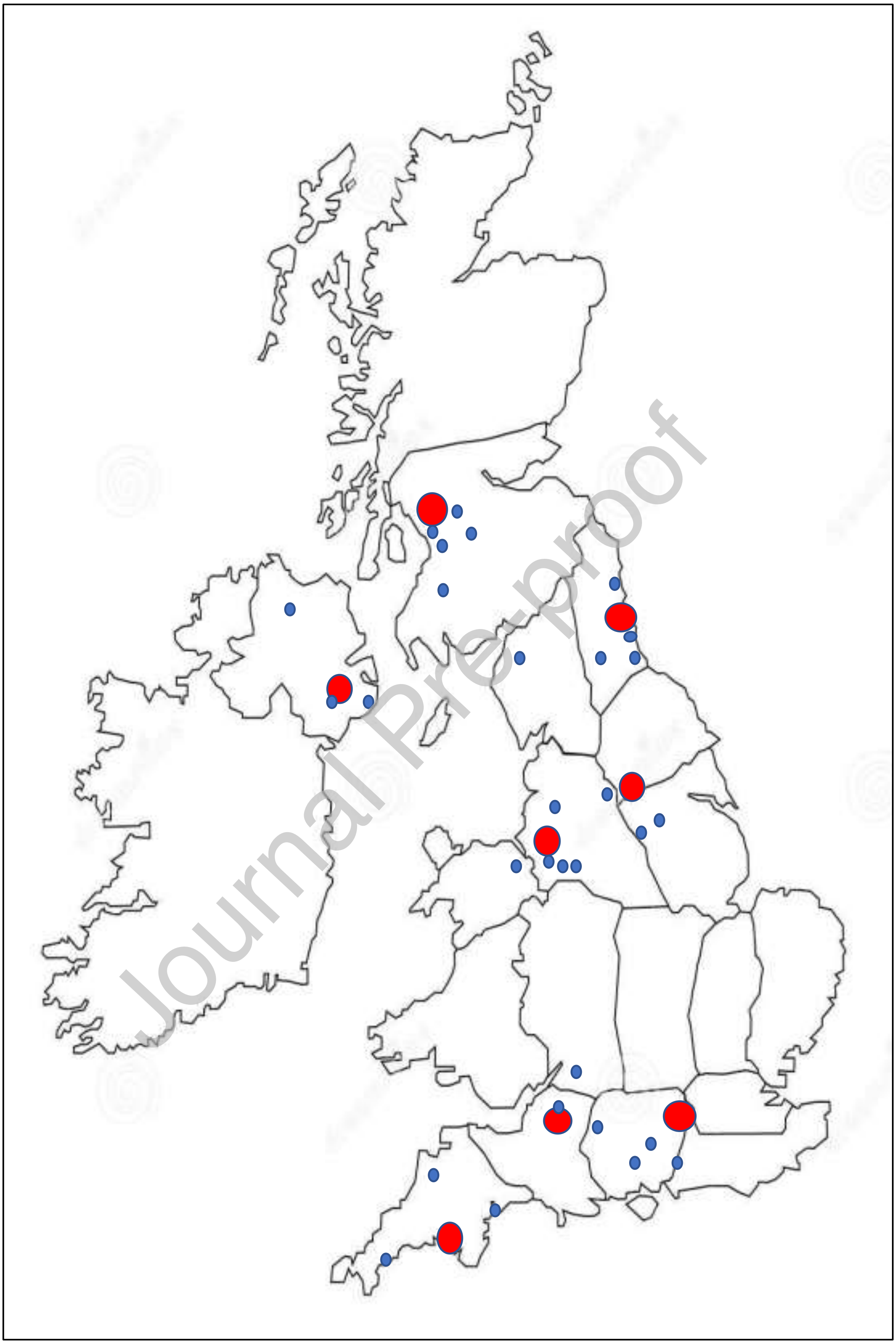


Figure 3: Geographical representation of capacity to workload ration per hospital (median number of patients listed and awaiting theatre per trauma list available per week)

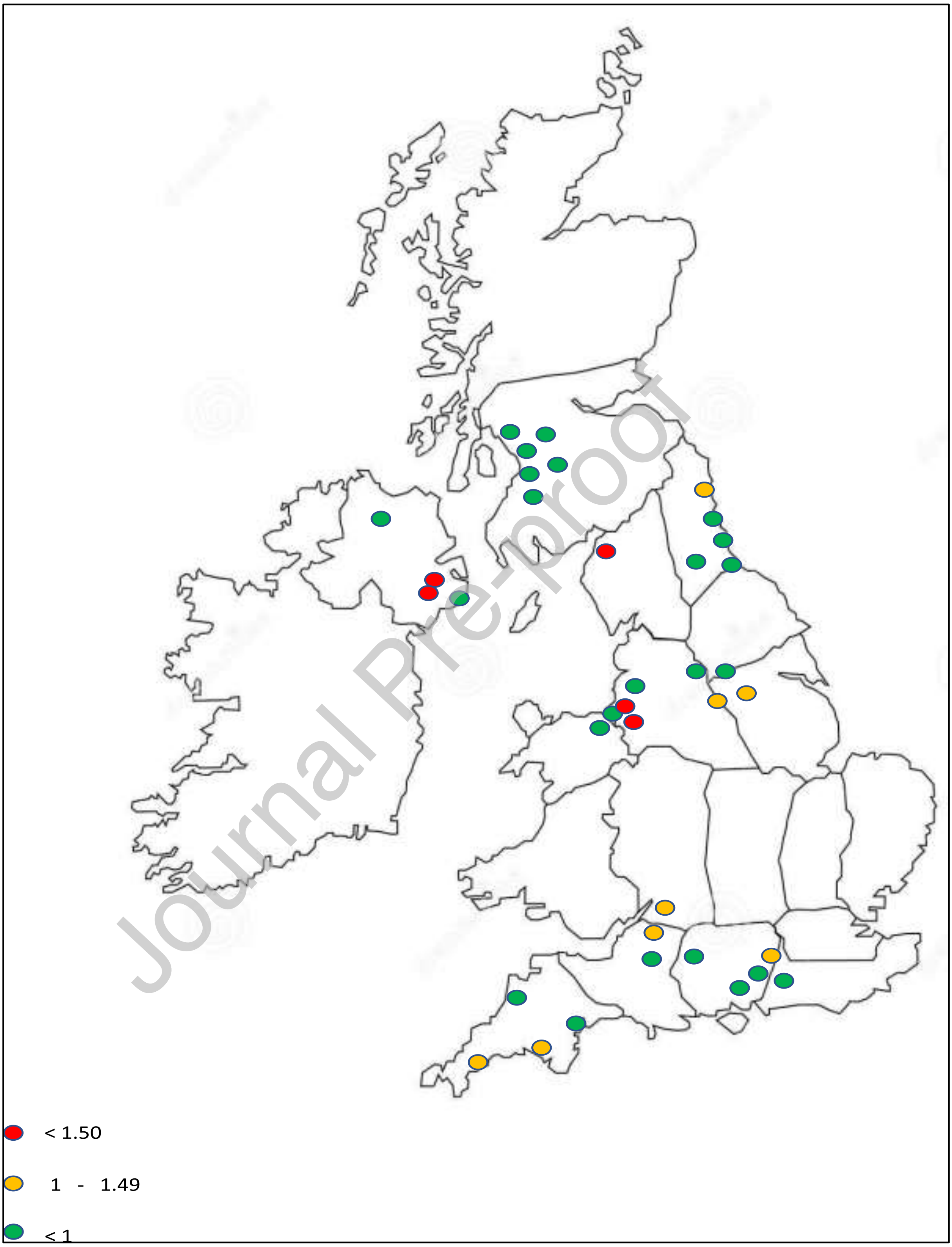
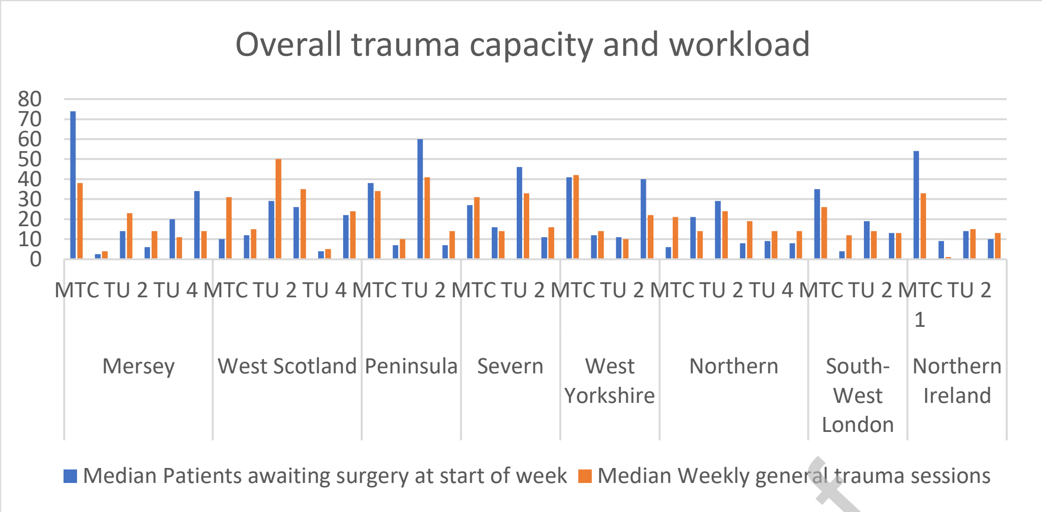


Figure 4: Overall trauma capacity and workload – Median number of patients awaiting surgery and median number of patients awaiting surgery per session



Declaration of interest:

- Mr William Eardley serves as the Vice-chair on the British Orthopaedic Association (BOA) Trauma Committee and the Clinical lead of the NHFD of England and Wales.
- Mr Alex Trompeter is a member of the BOA Trauma Committee and is the lead for the BOA Standards for Trauma and Orthopaedics (BOAST) guidelines.
- Ms Sharon Scott is a member of the National Clinical Reference Group for Major Trauma and Burns as well as the Best Practice Tariff for Major Trauma