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# The Open-Fracture Patient Evaluation Nationwide (OPEN) study

EPIDEMIOLOGY OF OPEN FRACTURE CARE IN THE UK

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## Aims

Understanding of open fracture management is skewed due to reliance on small-number lower limb, specialist unit reports and large, unfocused registry data collections. To address this, we carried out the Open Fracture Patient Evaluation Nationwide (OPEN) study, and report the demographic details and the initial steps of care for patients admitted with open fractures in the UK.

## Methods

Any patient admitted to hospital with an open fracture between 1 June 2021 and 30 September 2021 was included, excluding phalanges and isolated hand injuries. Institutional information governance approval was obtained at the lead site and all data entered using Research Electronic Data Capture. Demographic details, injury, fracture classification, and patient dispersal were detailed.

## Results

In total, 1,175 patients (median age 47 years (interquartile range (IQR) 29 to 65), 61.0% male (n = 717)) were admitted across 51 sites. A total of 546 patients (47.1%) were employed, 5.4% (n = 63) were diabetic, and 28.8% (n = 335) were smokers. In total, 29.0% of patients (n = 341) had more than one injury and 4.8% (n = 56) had two or more open fractures, while 51.3% of fractures (n = 637) occurred in the lower leg. Fractures sustained in vehicle incidents and collisions are common (38.8%; n = 455) and typically seen in younger patients. A simple fall (35.0%; n = 410) is common in older people. Overall, 69.8% (n = 786) of patients were admitted directly to an orthopaedic centre, 23.0% (n = 259) were transferred to an orthopaedic centre after initial management elsewhere, and 7.2% were managed outwith specialist units (n = 81).

## Conclusion

This study describes the epidemiology of open fractures in the UK. For a decade, orthopaedic surgeons have been practicing in a guideline-driven, network system without understanding the patient features, injury characteristics, or dispersal processes of the wider population. This work will inform care pathways as the UK looks to the future of trauma networks and guidelines, and how to optimize care for patients with open fractures.

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## Introduction

Defined as a “break in a bone complicated by a wound”,<sup>1</sup> open fractures are a challenge for the surgeon and threaten patient outcomes.<sup>2-5</sup> Severe injuries are

associated with worse outcomes and protracted treatment.<sup>6</sup>

Numerous guidelines exist for the management of open fractures. The British Orthopaedic Association Standards for Trauma and

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Orthopaedics (BOAST) for open fractures recommends prompt management by surgeons working together, in a coordinated system alongside several other parameters.<sup>7,8</sup> A National Major Trauma Network, introduced in parallel with the release of guidelines, brought improvements in major trauma outcomes, and orthoplastic centres have demonstrated a reduction in complications from severe open fractures.<sup>9-14</sup>

The Trauma Audit Research Network (TARN) monitors outcomes from major trauma and the performance of regional trauma networks. It is used to study open fracture care, despite not being created to do so.<sup>14</sup> Powerful at demonstrating population-level survival outcomes, there is less ability to report specifics of open fracture care; for example, hospitals in Scotland do not contribute to TARN. Furthermore, TARN-sourced reports over-emphasize high-energy transfer trauma in the young, not representative of the wider fracture population.<sup>14-16</sup> Increasing numbers of older patients presenting with significant trauma and low-energy open fractures who do not qualify as major trauma will not feature in registry studies.<sup>17-19</sup>

The evidence base is replete with studies of lower limb injuries in young patients,<sup>20,21</sup> but many are limited by: description of Gustilo-Anderson (GA)<sup>22</sup> grade III injuries of the tibia; single-centre data collection; limited sample size; and data predating the inception of modern trauma network systems and orthoplastic services.<sup>23-27</sup> Consequently there is no accurate reflection of contemporary injury patterns, demographics, or management of the UK open fracture population.

We conducted the Open-Fracture Patient Evaluation Nationwide (OPEN) study to address this absence of evidence. We describe for the first time the epidemiology of open fractures in the context of a well-established orthoplastics network and national management guidelines.

## Methods

The BOAST open fracture guideline provided the metrics from which the datafields were derived.<sup>7</sup> Patients admitted to hospital with an open fracture between 1 June 2021 and 30 September 2021 were included, excluding phalanges and isolated hand injuries. Patient data were entered on admission, during admission or retrospectively, up until a Research Electronic Data Capture (REDCap; Vanderbilt University, USA) closing date of 31 October 2021. If a patient was still admitted on this date, this was recorded. Collaborator recruitment occurred via the British Orthopaedic Trainees Association (BOTA), the Collaborative Orthopaedic Research Network (CORNET), and social media. Institutional information governance approval was obtained by the project management team at the lead site (South Tees Hospitals NHS Trust). Using the Health Research Authority decision

tool,<sup>28</sup> Research and Ethics Committee approval was not required. All collaborators obtained local approval from their respective institutions and registered the study as service evaluation prior to data collection.

Patients aged 18 years or older were consented for follow-up contact for further related studies or ongoing service evaluation metrics in order to inform the engagement level in this population for other studies, or for researchers planning electronic follow-up data collection. Ethical approval was not obtained for consenting minors; therefore, patients aged under 18 years were not consented for follow-up study contact but were still included in the study. Patients' injuries were classified using the Muller AO,<sup>29</sup> Orthopaedic Trauma Society (OTS),<sup>30</sup> and GA classifications.<sup>22</sup> Ongoing management does not feature in this work, to allow for focus on population description and early presentation datapoints.

REDCap, on which the data were captured and held by South Tees NHS Trust servers, is a secure, web-based software platform providing an interface for validated data capture, audit trails for tracking data manipulation and export procedures, automated export procedures for seamless data downloads to common statistical packages, and procedures for data integration and interoperability with external sources.<sup>31,32</sup> The data fields in their entirety are available in the Supplementary Material. Each collaborator signed an information sharing agreement and a REDCap user registration form, and provided evidence of registration at their hospital prior to receiving access to REDCap for data submission. All data fields were analyzed for duplication and duplicate entries were removed.

**Statistical analysis.** This paper reports unit-level baseline open fracture epidemiology; data are summarized as absolute numbers and proportions, and continuous data as medians and interquartile ranges (IQRs). No comparison or proof of difference was carried out.

## Results

During the study period, 1,230 patients sustained one or more open fractures with data collected by 240 collaborators across 51 hospitals, including 31 declared orthoplastic centres. Following application of the exclusion criteria and removal of cross-hospital duplication (Figure 1), 1,175 patients had data analyzed. Due to variable amounts of complete data, not all proportions reach 100%; however, minimum data completeness is 91% (Figure 1).

The median age at presentation was 47 years (IQR 29 to 65), 717 patients (61.0%) were male, 995 (89.2%) patients identified as White, 61 (5.5%) as Asian or Asian British, 27 (2.4%) as Black, African, Black British, or Caribbean, and 33 (2.9%) as other ethnic groups (including mixed or multiple). Overall, 63 patients (5.4%) were diabetic and 335 were smokers (28.8%) (Table 1). The

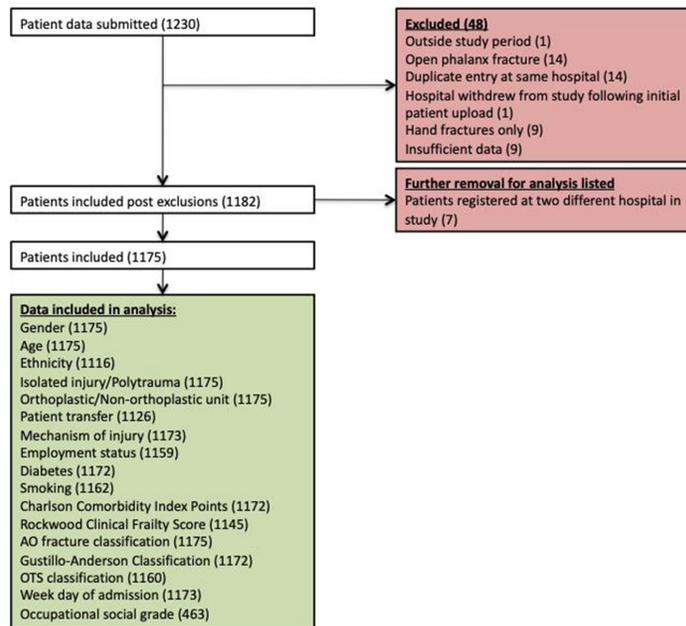


Fig. 1

Epidemiology of patients with open fractures included in the Open Fracture Patient Evaluation Nationwide study. OTS, Orthopaedic Trauma Society.

**Table 1.** Age comparison of demographic domains.

Variable	Age ≤ 64 yrs	Age ≥ 65 yrs	Total
Patients, n (%)	876 (74.6)	299 (25.4)	1,175
Median CCI (IQR)	0 (0 to 1)	4 (3 to 5)	0 (0 to 2)
Median Rockwood score (IQR)	1 (1 to 2)	3 (3 to 5)	2 (1 to 3)
OTS classification simple, n (%)	654 (70.4)	222 (74.2)	876 (71.3)
Diabetes, n (%)	32 (3.7)	31 (10.4)	63 (5.4)
Smoker (including e-cigarettes), n (%)	309 (35.8)	26 (8.7)	335 (28.8)
Managed fully at non-orthopaedic centre, n (%)	53 (6.3)	28 (9.9)	81 (7.2)
Direct presentation to orthopaedic centre, n (%)	604 (71.6)	182 (64.3)	786 (69.8)
Employed, n (%)	527 (61.2)	19 (6.4)	546 (47.1)

CCI, Charlson Comorbidity Index; IQR, interquartile range; OTS, Orthopaedic Trauma Society.

median Charlson Comorbidity Index (CCI)<sup>33,34</sup> was 0 (IQR 0 to 2) and Clinical Frailty Score (CFS)<sup>35</sup> was 2 (IQR 1 to 3).

Of those employed, 185 (40.0%) were in skilled manual work, 55 (11.9%) were in professional/managerial positions, 117 (25.3%) were administrative or clerical workers, and 106 (22.9%) were semiskilled and unskilled manual workers.

Overall, 341 patients (29.0%) were admitted with multiple injuries; 56 (4.8%) had two or more open fractures. The most common mechanisms of injury involved a vehicle or collision (38.8%) or a fall from less than two metres (35.0%), with median ages of 35 (24 to 51) and 66 (49 to 79) years, respectively. Patients aged ≥ 65 years were more likely to sustain fractures from low-energy transfer; 71.8% of open fractures in older patients were due to a fall of less than 2 m (n = 214), with 22 (10.3%)

having more than one injury. Younger patients usually had a history of greater energy transfer, with 420 patients (48.0%) aged ≤ 64 years injured in a vehicle or a collision. Of this group, 195 (46.4%) had multiple injuries. The most commonly broken bones were the tibia and fibula (51.3%) (Figure 2). Using the GA grade, 342 open fractures were classified as type 1 (27.6%), 430 type 2 (34.7%), and 467 type 3 (37.7%). Using the OTS classification, 876 patients required simple wound closure (71.3%).

A total of 357 patients were admitted on a Saturday or Sunday (30.4%). Overall, 786 patients (69.8%) were admitted directly to an orthopaedic centre and 340 patients initially presented to a non-orthopaedic centre, of whom 259 (23.0%) patients were transferred to an orthopaedic centre (median age 49 years (IQR 32

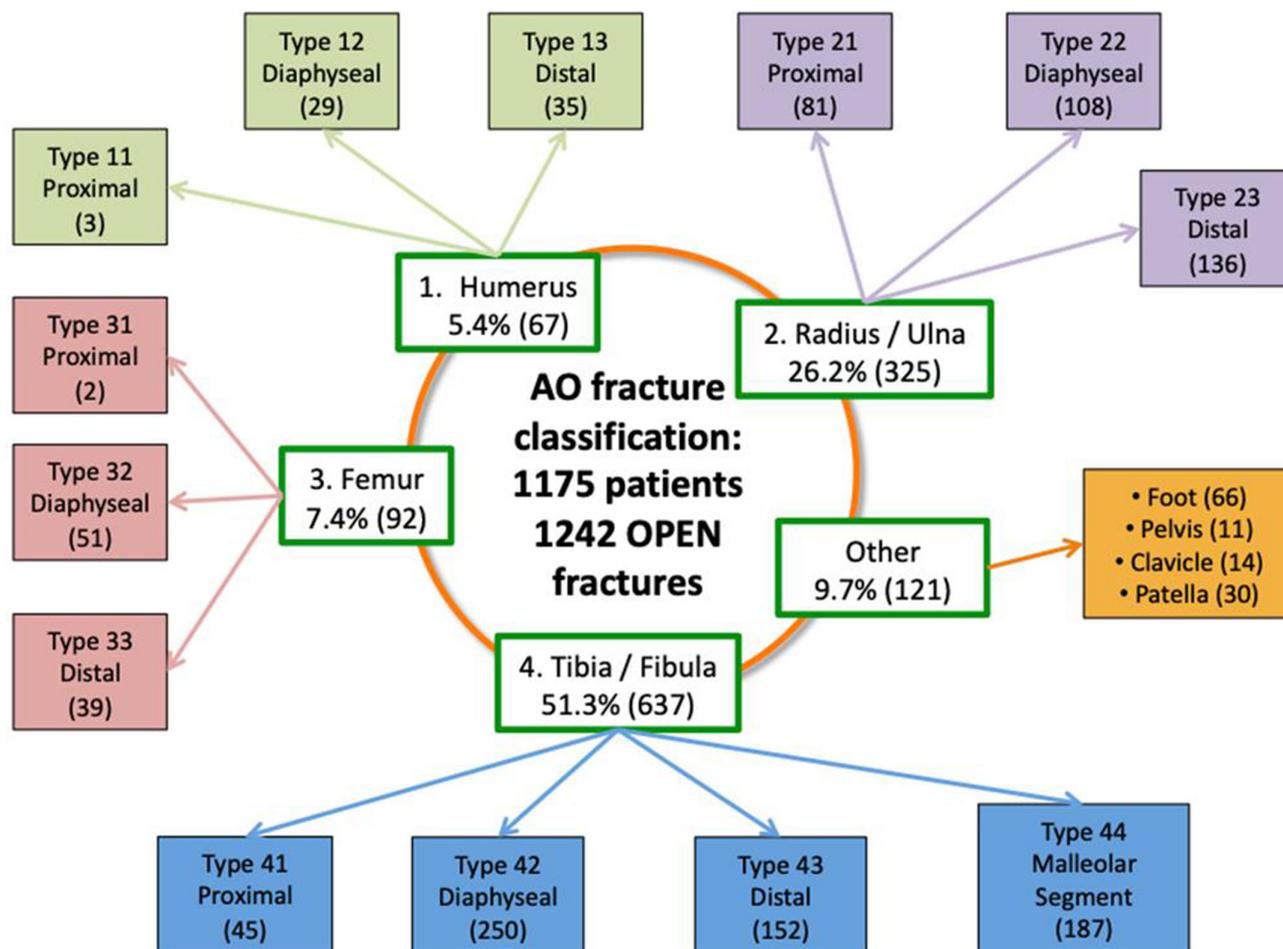


Fig. 2  
Open fractures by AO classification.

to 67) following initial treatment and 81 patients (7.2%) were managed entirely at a non-orthoplastic centre (median age 55 years (IQR 36 to 74)).

Of the 340 patients presenting to a non-orthoplastic centre, 85 (25.8%) had one or more wounds defined as 'complex' by the OTS classification system,<sup>30</sup> 78 (91.8%) were transferred to an orthoplastic centre following initial treatment, while 73 (21.5%) had multiple injuries, of whom 49 (67.1%) were transferred. The most common fractures to be transferred were to the tibia and fibula ( $n = 164$ ; 61.9%). The most common sites of injury to be managed entirely at a non-orthoplastic centre were the radius and ulna ( $n = 40$ ; 46.5%).

Furthermore, 338 patients (28.8%) were consented for contact for further studies or data collection as part of the service evaluation.

## Discussion

Understanding what constitutes an open fracture patient and their subsequent management is fundamental to the provision and measurement of high-quality orthoplastic

care. Evidence of current practice is lacking. Available evidence is dominated by registry datasets or small studies reporting single limb segment injuries presenting to specialist services. Overall care of the wider injury population is predominantly measured against this skewed group.

The key performance indicators (KPIs) recorded by TARN are drivers for quality improvement but focus on the severely injured. TARN is not a focused fracture database. Consequently, our knowledge of the open fracture population demographics and care is limited. Knowledge of presentation and management of younger, badly injured patients with complex tibial injuries is abundant; however, the remainder of the population is underserved in research and quality assessment.

There is currently no national open fracture database. There are no routinely collected, injury-specific outcome measures with which clinicians and healthcare funders can refine management strategies. It is impossible to compare outcomes between centres, and meaningful performance is based on surrogate measures such as

time to theatre. By performing the OPEN study, we have demonstrated the ability to collect key data points that could form the basis of a registry, should funding permit.

Through over 1,000 consecutive cases, we described the open fracture population of the UK. Unrestricted by age, admitting hospital, injury mechanism or fracture, this is the only population-scale description of open fractures. This is the reality of our population. The breadth of injuries, and the nature of how and where patients present and are managed, is now available. We can now provide a complete insight into open fractures in the UK.

A total of 51 centres contributed, reporting cases across the four constituent nations of the UK. The four-month study period enabled scale but prevented attrition through fatigue. Run almost entirely through orthopaedic trainee collaboration, this is a powerful demonstration of the potential of trainee networks in enabling population-scale injury assessment. Data completeness in this study is unprecedented. Multiple data fields were included to allow for as near complete collection of data as possible. With increasing data fields, the likelihood of fatigue increases, but we have been able to collect full data on 1,175 patients with completeness at a minimum of 91% for all metrics. This is exceptional and unparalleled in similar work in which the level of completeness is highlighted as a significant weakness threatening presented results.<sup>36</sup> Much registry data are based on data completeness that does not reach this level.<sup>37,38</sup> We are therefore able to provide the most accurate description of open fracture care that currently exists.

We have used this opportunity to introduce the orthopaedic community to the use of the OTS open fracture classification over the traditional GA system.<sup>22,30</sup> This is the first time this system has been used prospectively at scale and offers insight into the ease of dividing injury into simple or complex. Within this work across all fractures, 874 cases (71.3%) were classed as simple.

Across the UK, 637 open fractures seen were of the lower leg (51.3%). When combined with the forearm, these body segments accounted for 962 open fractures (77.5%). This enables focus for further evaluation on these injury groups. The proximal limb segments of the shoulder and hip are rarely involved, accounting for only five cases combined (0.4%).

Case presentation and transfer practices across the UK were previously unknown. Through this work, we have been able to detail the reality of patient flow. Guidance from the British Orthopaedic Association (BOA) is clear: "patients with open fractures of long bones, hindfoot or midfoot should be taken directly or transferred to a specialist centre that can provide orthoplastic care".<sup>7</sup> The definition of an orthoplastic centre as described by the National Institute for Health and Care Excellence (NICE) is "a hospital with a dedicated, combined service for orthopaedic and plastic surgery in which consultants

from both specialties work simultaneously to treat open fractures as part of regular, scheduled, combined orthopaedic and plastic surgery operating lists. Consultants are supported by combined review clinics and specialist nursing teams".<sup>8</sup> These points are detailed specifically to enable reflection on our data. We have shown that 7.2% of cases were managed entirely at a non-orthoplastic hospital. Most open fracture cases across the UK are therefore managed in specialist centres directly without other hospital involvement ( $n = 786$ ; 69.8%) or via initial management at a non-specialist site followed by onward transfer ( $n = 259$ ; 23.0%). We show for the first time, at scale, that adherence to recommendations of both the BOA and NICE is high, with over 90% of cases either managed entirely at a specialist centre or via appropriate transfer.

The median age at presentation is 47 years, reflecting the gradual ageing of the trauma population.<sup>19,20</sup> Traditionally described as a high-energy injury of the young, our results corroborate those of several injury-specific UK studies, suggesting that the open fracture is an injury increasingly seen in older patients.<sup>17–20,39</sup> Over one-quarter of patients in this cohort were aged 65 years or older. This group is previously under-reported, and this could influence service provision and the wider operative and rehabilitative needs of patients.<sup>15,40</sup>

A significant proportion of open fracture patients were smokers ( $n = 335$ ; 28.8%). The prevalence of smoking in patients with open fractures is twice that of the background UK population rates.<sup>41</sup> Interventions to help with smoking cessation are warranted given the prevalence we have demonstrated, coupled with the recognized risk of poor fracture healing in smokers.<sup>34</sup> While prevalence of smoking has been demonstrated to be double baseline, patients with an open fracture are less likely to have diabetes ( $n = 63$ ; 5.4%) than the baseline UK population (7%).<sup>42</sup>

Frailty is increasingly noted across ageing injury groups<sup>43</sup>; however, we found that the incidence of comorbidities is less than expected in this group. We used the CCI to assess this. Categorized as mild (1 to 2), moderate (3 to 4), and severe ( $\geq 5$ ), we have shown a median CCI of 0 (IQR 0 to 2). Vander Voort et al<sup>44</sup> looked at similar population characteristics in a small study of 111 consecutive adults who underwent operative fixation of open fractures of the tibia or ankle. It is pleasing to note corroboration across our larger and more general study group. Noting a similar average age of 43 years, the authors reported a CCI of 1.21.

Frailty was assessed by the CFS and revealed a median score of 2. This score highly correlates with the risk of death for each incremental category. A score of 2 places this group in the category of "well without active disease".<sup>17,35</sup> As expected, both the CCI and Frailty Scores are greater in the older population.

Finally, we show the causative mechanism across all open fractures. Seen both in isolation and as part of a multiple injury accident, there is a clear and expected correlation between energy transfer and injury severity. Younger patients are more likely to sustain multiple injuries following high-energy transfer traumas from vehicle accidents or collisions, whereas older patients are less likely to sustain multiple injuries and more likely to present with open fractures following a low-energy transfer accident, such as a fall from standing height.

There are important findings in this study that for the first time accurately describe, at many stages, the nature and presentation of patients with open fractures across the UK over four months. There are limitations. We cannot comment on anything other than population-level detail. Overall, 51 centres represent a generalizability of contemporary UK practice, but not every hospital. We did not collect data on workplace injuries. In the employed patients in our cohort, 291 (62.9%) skilled or unskilled manual workers sustained open fractures, an important avenue for future research. The strength of this work is the pragmatic data entry across all levels of trauma centres in the UK. The data completeness exceeded expectations and strengthens the ability to comment on patterns seen. We demonstrate an expected recruitment trajectory of centres and patients for groups looking to study any of the above factors in a comparative trial through an established network. This study forms part of a platform of work coordinated through the OTS to support and inform orthopaedic trials.

Furthermore, 28.8% of patients are consented and enrolled in follow-up to be contacted for outcome assessment of key metrics, such as return to work and driving. This provides an opportunity to assess the level of follow-up that can be achieved with an electronic system alone, without assistance from a dedicated research team. Another strength of the work is the ability to use enrolled patients in follow-up studies. This enables research efficiency and prevents multiple repeated cohorts being recruited. Future work is therefore enabled to look specifically at outcomes and the patient experience of rehabilitation following an open fracture without requiring further recruitment.

We have detailed for the first time the contemporary description of open fractures across the UK. We have described the population in depth from patient characteristics, through injury mechanism, location, and classification. We have strengthened the data collected through the OTS open fracture classification and enabled its use as a baseline for all open fractures. We have demonstrated dispersal and transfer processes, and have clearly shown that national guidelines are being followed at a level previously unknown. This work will inform pathways of care and help research groups more effectively design comparative interventions. Equally, national

guidelines, when revised, will be better informed to focus on improved patient care.



### Take home message

- With over 90% data compliance, this study provides an accurate estimation of the burden of open fracture care and how this impacts on everyday practice.

- An increase in older patients presenting with open fractures mandates changes in how care is provided to this group of patients.

- Mechanisms of injury of open fractures largely mirror those of major trauma, with younger patients involved in collisions often involving vehicles, whereas older patients typically present following falls from less than 2 m.

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### Supplementary material



Electronic case report form: Demographics, Consent, Assessment, Classification of Fractures and Discharge; full list of OPEN study collaborative authors.

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