■ TRAUMA

Incidence and quality of care for open fractures in England between 2008 and 2019

A COHORT STUDY USING DATA COLLECTED BY THE TRAUMA AUDIT AND RESEARCH NETWORK

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Aims

This study estimated trends in incidence of open fractures and the adherence to clinical standards for open fracture care in England.

Methods

Longitudinal data collected by the Trauma Audit and Research Network were used to identify 38,347 patients with open fractures, and a subgroup of 12,170 with severe open fractures of the tibia, between 2008 and 2019 in England. Incidence rates per 100,000 person-years and 95% confidence intervals were calculated. Clinical care was compared with the British Orthopaedic Association Standards for Trauma and National Major Trauma Centre audit standards.

Results

In total, 60% of all open fractures occurred in males; the median age was 48 years (interquartile range (IQR) 29 to 68). Between 2012 and 2019, the overall incidence in England was 6.94 per 100,000 person-years. In males, the highest incidence observed was in those aged 20 to 29 years (11.50 per 100,000 person-years); in females, incidence increased with age, peaking at 32.11/100,000 person-years at 90 years of age and over. Among those with severe open fractures of the tibia, there was a bimodal distribution in males, peaking at 20 to 29 years (3.71/100,000 person-years) and greater than 90 years of age (2.84/100,000 person-years) respectively; among females, incidence increased with age to a peak of 9.91/100,000 person years at 90 years of age and over. There has been variable improvement with time in the clinical care standards for patients with severe open fractures of the tibia. The median time to debridement was 13.0 hours (IQR 6.4 to 20.9); almost two-thirds of patients underwent definitive soft-tissue coverage within 72 hours from 2016 to 2019.

Conclusion

This is the first time the incidence of all open fractures has been studied using data from a national audit in England. While most open fractures occurred in young males, the incidence increased with age in females to a much greater level than observed in older males. The degree of missing data in the national audit is startling, and limits the certainty of inferences drawn concerning open fracture care.

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Introduction

Open fractures, where the soft-tissue envelope is breached, are complex injuries which risk the limb and are associated with substantial morbidity. Quality of life following this injury declines by more than half—this represents a greater burden of ill heath than that following a stroke.[1] The first-year costs associated with severe open fracture of the lower limb in the UK are estimated to be £14,000 per person injured.[2]

Clinical guidance and services for the management of open fractures has changed substantially over the last 15 years. In 2008, The British Orthopaedic Association Standard for Trauma 4 (BOAST4; updated in 2017 to Open Fracture BOAST)[3] was issued jointly by British Association of Plastic, Reconstructive and Aesthetic Surgeons and British Orthopaedic Association. In 2016 the National Institute for Health and Care Excellence published guidance for managing

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Table I. Descriptive characteristics of patients with open fractures and severe open fracture of the tibia treated in England from 2008 to 2019, as recorded by the Trauma Audit and Research Network.

Characteristic	All open fractures, n (%)	Severe open fracture of the tibia, n (%)
Total number of patients	38,347 (100)	12,170 (100)
Sex		
Male	23,123 (60)	7,731 (64)
Female	15,224 (40)	4,439 (36)
Age, yrs		
0 to 9	833 (2)	319 (3)
10 to 19	3,337 (9)	1,163 (10)
20 to 29	6,120 (16)	1,931 (16)
30 to 39	4,864 (13)	1,614 (13)
40 to 49	5,142 (13)	1,719 (14)
50 to 59	4,959 (13)	1,658 (14)
60 to 69	4,128 (11)	1,309 (11)
70 to 79	3,779 (10)	1,072 (9)
80 to 89	3,801 (10)	965 (8)
90+	1,384 (4)	420 (3)
Year of arrival at hospital		
2008	1,294 (3)	609 (5)
2009	1,713 (4)	845 (7)
2010	2,149 (6)	1,058 (9)
2011	2,699 (7)	1,400 (12)
2012	3,252 (8)	1,538 (13)
2013	3,479 (9)	1,031 (8)
2014	3,679 (10)	830 (7)
2015	3,764 (10)	868 (7)
2016	3,828 (10)	809 (7)
2017	4,189 (11)	1,032 (8)
2018	4,343 (11)	1,131 (9)
2019	3,958 (10)	1,019 (8)
Day and time of presentation at hospital		
Monday 00:00-07:59	681 (2)	219 (2)
Monday 08:00-15:59	2,004 (5)	653 (5)
Monday 16:00-23:59	2,289 (6)	736 (6)
Tuesday 00:00-07:59	669 (2)	218 (2)
Tuesday 08:00-15:59	2,173 (6)	678 (6)
Tuesday 16:00-23:59	2,330 (6)	761 (6)
Wednesday 00:00-07:59	605 (2)	170 (1)
Wednesday 08:00-15:59	2,035 (5)	647 (5)
Wednesday 16:00-23:59	2,328 (6)	744 (6)
Thursday 00:00-07:59	695 (2)	227 (2)
Thursday 08:00-15:59	2,239 (6)	715 (6)
Thursday 16:00-23:59	2,499 (7)	779 (6)
Friday 00:00-07:59	767 (2)	235 (2)
Friday 08:00-15:59	2,231 (6)	654 (5)
Friday 16:00-23:59	2,633 (7)	851 (7)
Saturday 00:00-07:59	1,283 (3)	414 (3)
Saturday 08:00-15:59	2,173 (6)	641 (5)
Saturday 16:00-23:59	2,571 (7)	853 (7)
Sunday 00:00-07:59	1,307 (3)	441 (4)
Sunday 08:00-15:59	2,099 (5)	623 (5)
Sunday 16:00-23:59	2,348 (6)	738 (6)
Missing	388 (1)	173 (1)
Most severely injured body region		
Abdo	197 (1)	33 (< 1)
Chest	1,635 (4)	326 (3)
Face	2 (< 1)	0 (0)
Head	1,571 (4)	424 (3)
Limbs	30,753 (80)	10,429 (86)
Multiple	3,996 (10)	914 (8)
Other	19 (< 1)	5 (< 1)

Continued

Table I. Continued

Characteristic	All open fractures, n (%)	Severe open fracture of the tibia, n (%)
Spine	174 (< 1)	39 (< 1)
AIS Limb		
0	264 (1)	0 (0)
1	47 (< 1)	0 (0)
2	7,506 (20)	0 (0)
3	30,453 (79)	12,156 (100)
4	77 (< 1)	14 (< 1)
ISS		
All open fractures, mean (SD)	12.7 (10.3)	
Open long bone fracture of lower limb, mean (SD)	12.9 (9.4)	
ISS		
1 to 8 (minor)	5,590 (15)	0 (0)
9 to 15 (moderate)	25,024 (65)	10,072 (83)
16 to 24 (severe)	3,019 (8)	751 (6)
> 24 (very severe)	4,714 (12)	1,347 (11)
Injury type		
Blunt	36,460 (95)	11,583 (95)
Penetrating	1,887 (5)	587 (5)
Injury mechanism		
Blast	91 (< 1)	0 (0)
Blow(s) without weapon	1,474 (4)	0 (0)
Burn	2 (< 1)	0 (0)
Crush	770 (2)	0 (0)
Fall < 2 m	13,842 (36)	4,025 (33)
Fall > 2 m	4,356 (11)	1,168 (10)
Other	656 (2)	1,191 (10)
Shooting	373 (1)	0 (0)
Stabbing	340 (1)	0 (0)
Vehicle incident/collision	16,443 (43)	5,786 (48)
Pre-existing condition?		
Yes	18,600 (49)	5,573 (46)
No	19,747 (51)	6,597 (54)
Pre-existing conditions*		
Hypertension	6,204 (16)	1,840 (15)
Asthma	2,920 (8)	902 (7)
Depression	2,333 (6)	732 (6)
Diabetes mellitus (type 2)	1,803 (5)	578 (5)
Alcohol abuse	1,654 (4)	575 (5)
Other - heart disease	1,461 (4)	440 (4)
COPD	1,386 (4)	398 (3)
Thyroid disease	1,127 (3)	312 (3)
Hypercholesterolaemia	1,118 (3)	304 (3)
Osteoporosis	918 (2)	206 (2)
Five most frequent operations*		
Skin debridement	18,581 (48)	6,560 (54)
Internal fixation: other and debridement	10,012 (26)	3,757 (31)
Internal fixation: nail and debridement	5,050 (13)	2,659 (22)
External fixation to bone	4,262 (11)	1,957 (16)
Internal fixation: plate and debridement	3,645 (10)	1,777 (15)
Was the open fracture heavily contaminated?		
Yes	N/A	247 (< 1)
No	N/A	5,770 (47)
Missing	N/A	6,153 (51)
Was there vascular impairment?		
Yes	N/A	688 (6)
No	N/A	5,316 (44)
Missing	N/A	6,166 (51)

*Categories are not mutually exclusive.
AIS, Abbreviated Injury Scale; COPD, chronic obstructive pulmonay disease; IQR, interquartile range; ISS, Injury Severity Score; N/A, not available; SD, standard deviation.

Table II. The number and incidence rates of open fractures by age and sex within the Trauma Audit Research Network dataset from 2008 to 2019 in England.

Variable	All open fractures			Severe open fracture of the tibia		
	n	Person-years*	Incidence rate (95% CI)†	n	Person-years*	Incidence rate (95% CI)†
Total	38,347	649,375,982	5.91 (5.90 to 5.91)	12,170	649,375,982	1.87 (1.87 to 1.87)
Sex						
Male	23,123	320,026,809	7.23 (7.22 to 7.23)	7,731	320,026,809	2.42 (2.42 to 2.42)
Female	15,224	329,349,173	4.62 (4.62 to 4.62)	4,439	329,349,173	1.35 (1.35 to 1.35)
Age, yrs						
0 to 9	833	78,734,689	1.06 (1.06 to 1.06)	319	78,734,689	0.41 (0.41 to 0.41)
10 to 19	3,337	76,110,335	4.38 (4.38 to 4.39)	1,163	76,110,335	1.53 (1.53 to 1.53)
20 to 29	6,120	87,076,226	7.03 (7.03 to 7.03)	1,931	87,076,226	2.22 (2.22 to 2.22)
30 to 39	4,864	86,467,619	5.63 (5.62 to 5.63)	1,614	86,467,619	1.87 (1.87 to 1.87)
40 to 49	5,142	90,478,418	5.68 (5.68 to 5.68)	1,719	90,478,418	1.90 (1.90 to 1.90)
50 to 59	4,959	82,184,517	6.03 (6.03 to 6.04)	1,658	82,184,517	2.02 (2.02 to 2.02)
60 to 69	4,128	69,209,144	5.96 (5.96 to 5.97)	1,309	69,209,144	1.89 (1.89 to 1.89)
70 to 79	3,779	48,307,024	7.82 (7.82 to 7.83)	1,072	48,307,024	2.22 (2.22 to 2.22)
80 to 89	3,801	25,466,355	14.93 (14.92 to 14.93)	965	25,466,355	3.79 (3.79 to 3.79)
90+	1,384	5,341,655	25.91 (25.89 to 25.93)	420	5,341,655	7.86 (7.86 to 7.87)
Age, yrs (male)						
0 to 9	535	40,319,180	1.33 (1.33 to 1.33)	228	40,319,180	0.57 (0.57 to 0.57)
10 to 19	2,608	38,989,849	6.69 (6.69 to 6.69)	904	38,989,849	2.32 (2.32 to 2.32)
20 to 29	5,053	43,952,235	11.50 (11.49 to 11.50)	1,630	43,952,235	3.71 (3.71 to 3.71)
30 to 39	3,903	43,103,928	9.05 (9.05 to 9.06)	1,327	43,103,928	3.08 (3.08 to 3.08)
40 to 49	3,753	44,834,588	8.37 (8.37 to 8.37)	1,295	44,834,588	2.89 (2.89 to 2.89)
50 to 59	3,208	40,649,521	7.89 (7.89 to 7.89)	1,074	40,649,521	2.64 (2.64 to 2.64)
60 to 69	2,094	33,764,688	6.20 (6.20 to 6.20)	699	33,764,688	2.07 (2.07 to 2.07)
70 to 79	1,148	22,578,394	5.08 (5.08 to 5.09)	351	22,578,394	1.55 (1.55 to 1.56)
80 to 89	655	10,286,448	6.37 (6.36 to 6.37)	179	10,286,448	1.74 (1.74 to 1.74)
90+	166	1,547,978	10.72 (10.71 to 10.74)	44	1,547,978	2.84 (2.84 to 2.85)
Age, yrs (female)						
0 to 9	298	38,415,509	0.78 (0.78 to 0.78)	91	38,415,509	0.24 (0.24 to 0.24)
10 to 19	729	37,120,486	1.96 (1.96 to 1.96)	259	37,120,486	0.70 (0.70 to 0.70)
20 to 29	1,067	43,123,991	2.47 (2.47 to 2.47)	301	43,123,991	0.70 (0.70 to 0.70)
30 to 39	961	43,363,691	2.22 (2.22 to 2.22)	287	43,363,691	0.66 (0.66 to 0.66)
40 to 49	1,389	45,643,830	3.04 (3.04 to 3.04)	424	45,643,830	0.93 (0.93 to 0.93)
50 to 59	1,751	41,534,996	4.22 (4.21 to 4.22)	584	41,534,996	1.41 (1.41 to 1.41)
60 to 69	2,034	35,444,456	5.74 (5.74 to 5.74)	610	35,444,456	1.72 (1.72 to 1.72)
70 to 79	2,631	25,728,630	10.23 (10.22 to 10.23)	721	25,728,630	2.80 (2.80 to 2.80)
80 to 89	3,146	15,179,907	20.72 (20.71 to 20.74)	786	15,179,907	5.18 (5.18 to 5.18)
90+	1,218	3,793,677	32.11 (32.07 to 32.14)	376	3,793,677	9.91 (9.90 to 9.92)

*Person-years used as the denominator for incidence rates, as obtained from the Office for National Statistics population estimates for 2008 to 2019.[14]
†Per 100,000 person-years.
CI, confidence interval.

complex fractures (NG37).[4] In line with the international trend,[5-7] regional trauma networks (RTNs) were established in England in 2012, each with one or more dedicated specialist hub hospitals or major trauma centres (MTCs). There is some evidence this health system change has been associated with improved outcomes.[8] Current clinical guidelines recommend patients to be immediately transferred from the point of injury to the care of specialist orthoplastic multidisciplinary teams, usually located at the MTC.[3,4]

The Trauma Audit and Research Network (TARN) has been collecting information on all patients who are severely injured and received hospital care in England since 1989. From 2000 onwards, item completeness for eligible cases was approximately 75% from MTCs. Since the inception of the BOAST,[9] many of the clinical standards for severe open fracture of the tibia have been reported at a hospital level; currently these standards are reported within the quarterly National MTC Dashboard.[10]

The TARN database includes patients of all ages who sustain injury resulting in hospital admission longer than 72 hours, critical care admission, transfer to a tertiary/specialist centre, or death within 30 days. Isolated femoral neck or single pubic ramus fracture in patients aged over 65 years, and simple isolated injuries, are excluded. A dataset of prospectively recorded variables, including demographic details, injury type, mechanism, physiological parameters, investigations, treatments, and outcomes, are collated using a standard web-based case reporting form that is completed by TARN audit

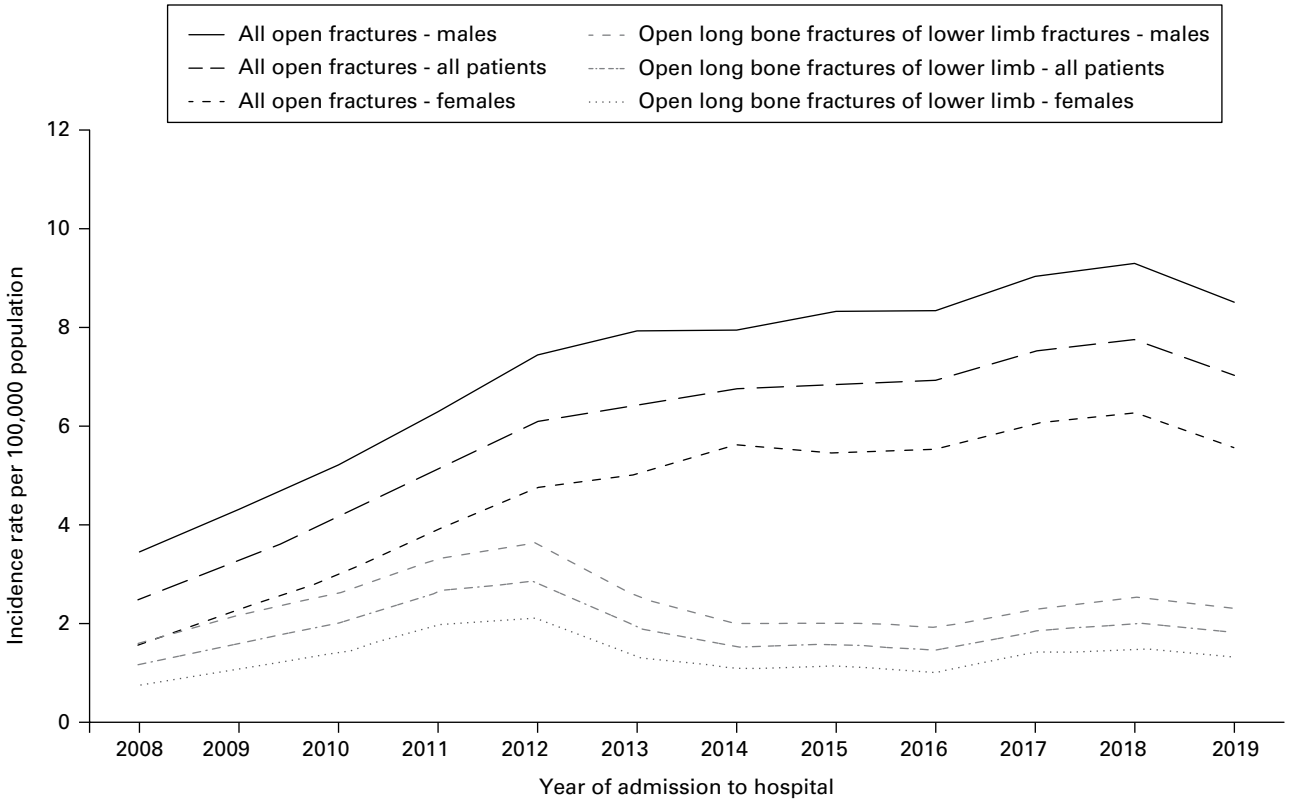

Fig. 1

Incidence of patients, organized by sex, with an open fracture and severe open fracture of the tibia who were admitted to a hospital in England from 2008 to 2019, as recorded in the Trauma Audit and Research Network.

coordinators at each hospital. These coordinators are trained in reporting the TARN dataset in accordance with the TARN manual. Injury descriptions based on imaging, operative, and post-mortem examination reports are also provided by TARN coordinators. Injuries are coded centrally using the Abbreviated Injury Scale (AIS),[11] which enables calculation of the Injury Severity Score (ISS).[12] The ISS is used to assess the overall severity of a patient's injuries by weighting the severity of injuries in each of six body regions.

The objectives of this study were to evaluate national trends and contemporary age- and sex-specific incidence of all open fractures, as well as the subgroup of severe open fractures of the tibia, and to report the national delivery of the clinical standards for the care for patients with severe open fracture of the tibia during the period of system reorganization.

Methods

All patients who were admitted to hospital with an open fracture in England between 2008 and 2019, for whom information had been processed and anonymized by TARN up to 27 February 2020, were included in the study. Duplicates arising from participants coded for the same episode at multiple hospitals were removed by TARN. The data included all open fractures, with the exception of those involving the orbit or phalanges, described fully in Supplementary Table i. A subgroup of participants with severe open fracture of the tibia were selected from the TARN dataset as those who were eligible for reporting against the Open Fracture BOAST standards (defined as patients with Gustilo-Anderson grading of IIIB, IIIC, or unknown).[13] This definition was used, since it is the group of patients for whom the relevant metrics of the National MTC Dashboard are reported.

In the event that items within the BOAST directly reported fields are missing, data items are derived for the Dashboard from the TARN dataset for the following audit standards: time to first debridement, presence of a consultant orthopaedic and plastic surgeon at first debridement, and time to soft-tissue closure. Here, for eligible participants, we report both the directly reported data items and the derived Dashboard items. Details of the derivation of each of these standards is included in Supplementary Table ii.

Descriptive and clinical information including patient sex, age grouped by ten-year increments, date and time of presentation at hospital, AIS scores, ISS score, mechanism of injury, and whether the patient had a pre-existing condition (and if so, what type) were reported. The five most frequent operations undergone by these patients were also described.

The achievement of each of the Open Fracture BOAST clinical standards for the eligible subgroup was determined from both the directly reported TARN dataset and the derived National MTC Dashboard dataset. Each of these items were grouped by three time periods, each bounded by major changes

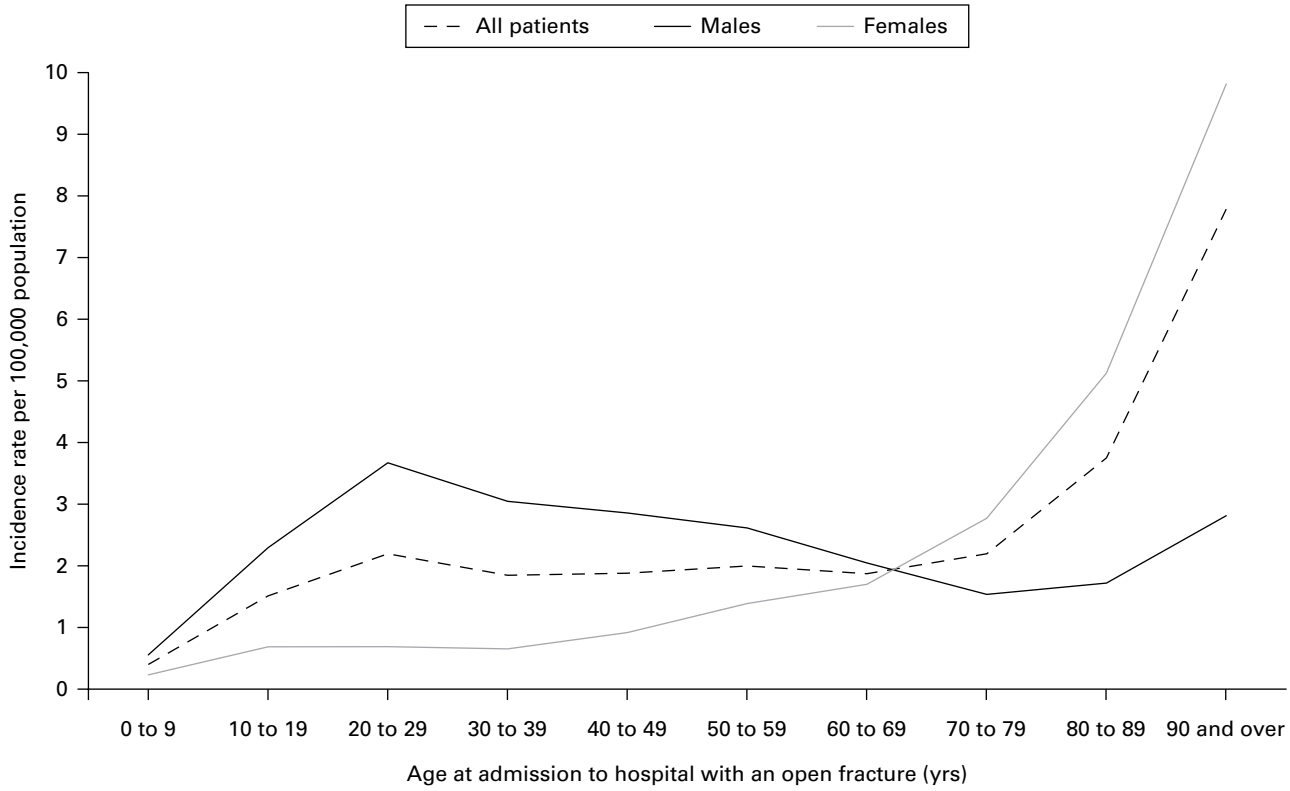

Fig. 2

Incidence of patients with a severe open fracture of the tibia by age and sex who were admitted to a hospital in England from 2008 to 2019, as recorded in the Trauma Audit and Research Network.

in clinical services or guidance: 2008 to 2011 (the publication of the first edition of BOAST4); 2012 to 2016 (the introduction of RTNs); and 2017 to 2019 (the publication of NG37).

Ethical approval. Access to these data, and the processing that has been undertaken in the conduct of this study, was approved by the Confidentiality Advisory Group of the Health Research Agency 28 September 2017 (Ref 17/CAG/0157). A fair processing statement for the study is available.[10]

Statistical analysis. Descriptive statistics were used to summarize the epidemiology of open fractures by demographic and clinical factors. The achievement of clinical standards, summarized both as overall proportions and for the subset where data were available, is provided. Incidence rates by age and sex per 100,000 person-years with 95% confidence intervals (CIs) were calculated using STATA v. 15.1 (StataCorp, USA). Denominators for England by year, age, and sex for the incidence rates were obtained from the Office for National Statistics.[14]

Results

All open fractures. A cohort of 38,347 patients with open fractures aged 0 to 109 years in England between 2008 and 2019 were included in the study (Table I). The majority were male (60%; n = 23,123) and the median age was 48 years (interquartile range (IQR) 29 to 68). In total, 190 different hospitals submitted information on patients with open fractures; 75 hospitals submitted data to TARN in 2008, which increased to 164 hospitals in 2012. Following this, between 161 and 168 hospitals submitted data to TARN during 2013 to 2019, reflecting reorganizations of care in several regions of England. The increase in the number of hospitals submitting information to TARN is reflected in the increase in patient numbers that was marked between 2008 and 2012, and then a steadier increase from 2012 to 2019.

Overall, 90% of patients (n = 34,351) had isolated injuries; the limbs were the most common body region affected (80%; n = 30,753). The most frequent AIS score was 3 (79%; n = 30,453), meaning most patients had a clinically serious injury. The median ISS score was 9 (IQR 9 to 10) and 20% of patients (n = 7,733) had a score of more than 16. Most patients suffered blunt trauma injury (95%; n = 36,460), with the most common mechanisms being vehicle incident or collision (43%; n = 16,443), a fall of less than two metres (36%; n = 13,842), or a fall of more than two metres (11%; n = 4,356). Many patients had a pre-existing condition (49%; n = 37,149), such as hypertension (16%; n = 6,204), asthma (8%; n = 2,920), or depression (6%; n = 2,333).

The proportion of patients presenting to hospital each day was similar from Monday to Wednesday (13%); slightly more were admitted from Thursday to Sunday (14% to 16%), with the peak occurring on Saturday (Supplementary Table iii). Most presented during the ‘evening’ (44% from 16:00 to 23:59) and 39% during the ‘day’ (08:00 to 15:59), with the remainder (16%) admitted at ‘night’ (00:00 to 07:59).

Table III. The number of open long bone fractures of lower limb by compliance with the Open Fracture British Orthopaedic Association Standards for Trauma clinical standards and chronological time of presentation at hospital within the Trauma Audit Research Network dataset between 2008 and 2019 in England.

Variable	Total patients, n (%)	2008 to 2011, n (%)	2012 to 2015, n (%)	2016 to 2019, n (%)
Total who were BOAST-eligible	12,170 (100)	3,912 (100)	4,267 (100)	3,991 (100)
Combined orthopaedic and plastic surgery management plan				
Yes	4,577 (38)	341 (9)	2,193 (51)	2,043 (51)
No	1,635 (13)	392 (10)	970 (23)	273 (7)
Missing	5,958 (49)	3,179 (81)	1,104 (26)	1,675 (42)
'Yes' of those recorded*	4,577 (74)	341 (47)	2,193 (69)	2,043 (88)
Systematic assessment of vascular and neurological status				
Yes	4,800 (39)	487 (21)	2,464 (58)	1,849 (46)
No	1,074 (9)	162 (4)	556 (13)	356 (9)
Missing	6,296 (52)	3,263 (83)	1,247 (29)	1,786 (45)
'Yes' of those recorded*	4,800 (82)	487 (75)	2,464 (82)	1,849 (84)
Antibiotics given within one hour of incident?				
Yes	6,795 (56)	1,673 (43)	3,001 (70)	2,121 (53)
No	572 (5)	129 (3)	198 (5)	245 (6)
Missing	4,803 (39)	2,110 (54)	1,068 (25)	1,625 (41)
'Yes' of those recorded*	6,795 (92)	1,673 (93)	3,001 (94)	2,121 (90)
Wound dressing – local guidance followed?				
Yes	5,282 (43)	1,156 (30)	2,471 (58)	1,655 (41)
No	855 (7)	112 (3)	294 (7)	449 (11)
Missing	6,033 (50)	2,644 (68)	1,502 (35)	1,887 (47)
'Yes' of those recorded*	5,282 (86)	1,156 (91)	2,471 (89)	1,655 (79)
Limb splint – local standard met?				
Yes	4,677 (38)	1,586 (41)	1,877 (44)	1,214 (30)
No	1,851 (15)	180 (5)	813 (19)	858 (21)
Missing	5,642 (46)	2,146 (55)	1,577 (37)	1,919 (48)
'Yes' of those recorded*	4,677 (72)	1,586 (90)	1,877 (70)	1,214 (59)
Did the fracture have surgical stabilization?				
Yes	3,914 (32)	10 (< 1)	1,851 (43)	2,053 (51)
No	851 (7)	3 (< 1)	423 (10)	425 (11)
Missing	7,405 (61)	3,899 (99)	1,993 (47)	1,513 (38)
'Yes' of those recorded*	3,914 (82)	10 (77)	1,851 (81)	2,053 (83)
Was definitive soft-tissue cover of the injury achieved?				
Yes	3,019 (25)	3 (< 1)	1,290 (30)	1,726 (43)
No	1,743 (14)	10 (< 1)	983 (23)	750 (19)
Missing	7,048 (61)	3,899 (99)	1,994 (47)	1,515 (38)
'Yes' of those recorded*	3,019 (63)	3 (23)	1,290 (57)	1,726 (70)
Was definitive coverage achieved within 72 hours?				
Yes	1,622 (13)	0 (0)	550 (13)	1,072 (27)
No	654 (5)	0 (0)	171 (4)	483 (12)
Missing	9,894 (81)	3,912 (100)	3,546 (83)	2,436 (61)
'Yes' of those recorded*	1,622 (71)	0 (0)	550 (76)	1,072 (69)
Was definitive stabilization achieved at same time as wound coverage?				
Yes	1,669 (14)	0 (0)	489 (11)	1,180 (30)
No	466 (4)	0 (0)	163 (4)	303 (8)
Missing	10,035 (82)	3,912 (100)	3,615 (85)	2,508 (63)
'Yes' of those recorded*	1,669 (78)	0 (0)	489 (75)	1,180 (80)
Gustilo-Anderson grade recorded?				
Yes	4,253 (35)	2 (< 1)	1,590 (37)	2,661 (67)
No	1,142 (9)	0 (0)	107 (3)	1,035 (26)
Missing	4,498 (37)	3,910 (99)	293 (7)	295 (7)
'Yes' of those recorded*	4,253 (79)	2 (100)	1,590 (94)	2,661 (72)

*These numbers and percentages exclude the patients with missing data. Only those patients recorded as having a 'Yes' or a 'No' are included in the denominator for the percentage.
BOAST, British Orthopaedic Association Standards for Trauma.

Table IV. The number of open long bone fractures of lower limb by compliance with the National Major Trauma Centre Dashboard reporting standards and chronological time of presentation at hospital, derived from data items recorded in the Trauma Audit Research Network dataset from 2008 to 2019 in England.

Variable	Total patients, n (%)	2008 to 2011, n (%)	2012 to 2015, n (%)	2016 to 2019, n (%)
Total who were BOAST-eligible	12,170 (100)	3,912 (100)	4,267 (100)	3,991 (100)
First debridement				
Yes	7,932 (65)	2,556 (65)	3,122 (73)	2,254 (56)
No	4,238 (35)	1,356 (35)	1,145 (27)	1,737 (44)
First debridement with a consultant orthopaedic and plastic surgeon present				
Yes	1,175 (10)	51 (1)	376 (9)	748 (19)
No	10,959 (90)	3,861 (99)	3,891 (91)	3,243 (81)
First debridement with any grade of orthopaedic and plastic surgeons				
Yes	1,984 (16)	115 (3)	725 (17)	1,144 (29)
No	10,186 (84)	3,797 (97)	3,542 (83)	2,847 (71)
Debridement within 12 hours of presentation at hospital				
Yes	2,929 (24)	869 (22)	1,213 (28)	847 (21)
No	3,338 (27)	878 (22)	1,270 (30)	1,190 (30)
Missing	5,903 (49)	2,165 (55)	1,784 (42)	1,954 (49)
Soft-tissue coverage of the injury was achieved				
Yes	4,904 (40)	560 (14)	2,009 (47)	2,335 (59)
No	7,266 (60)	3,352 (86)	2,258 (53)	1,656 (41)
Soft-tissue coverage was achieved within 72 hours of incident				
Yes	2,656 (22)	149 (4)	1,093 (26)	1,414 (35)
No	1,680 (14)	237 (6)	689 (16)	754 (19)
Missing	7,834 (64)	3,526 (90)	2,485 (58)	1,823 (46)

BOAST, British Orthopaedic Association Standards for Trauma.

The overall incidence in England during 2008 to 2019 was 5.91 per 100,000 person-years (95% CI 5.90 to 5.91), increasing from 2.50 per 100,000 person-years in 2008 to 7.03 per 100,000 person-years in 2019 (Table II and Figure 1). During the entire study period of 2008 to 2019, incidence in males demonstrated a bimodal distribution, peaking between 20 to 29 years (11.50 per 100,000 person years (95% CI 11.49 to 11.50)) and greater than 90 years of age (10.72 per 100,000 person years (95% CI 10.71 to 10.74)) (Supplementary Figure a). In contrast, incidence in females increased with age to a peak of 32.11 per 100,000 person years among those aged 90 years and over (95% CI 32.07 to 32.14). The increase in incidence in females was gradual until the age of 60 to 69 years, and then there was a marked increase. Most patients underwent one (46%, n = 17,769) or two operations (19%, n = 7,417); 8,119 (21%, n = 8,119) were not recorded as having had an operation. The most frequently recorded procedures are in Table I.

Given that 2008 to 2012 was a period when increasing numbers of hospitals submitted data to TARN, we have also chosen to present incidence figures from 2012 onwards. Thus, during 2012 to 2019 the overall incidence in England was 6.94 per 100,000 person-years (95% CI 6.94 to 6.94); the incidence in males was 8.36 per 100,000 person-years (95% CI 8.36 to 8.36) and in females was 5.55 per 100,000 person-years (95% CI 5.45 to 5.55).

Severe open fractures of the tibia. Among the entire cohort, 12,170 participants aged 0 to 108 years sustained a severe open fracture of the tibia (Table I). The majority were male (64%; n = 7,731) and the median age was 46 years (IQR 28 to 65). In total, 183 different hospitals submitted information to TARN for this subgroup: 70 hospitals in 2008, 155 hospitals in 2012, 124 in 2016, and finally 126 in 2019. These patients had similar characteristics in terms of day and time of admission (Supplementary Table iv), injury location, ISS score, cause and mechanism of injury, and pre-existing conditions, to patients with all open fractures.

Most participants underwent one (34%; n = 4,133) or two operations (22%; n = 2,673); 3,158 (26%) were not recorded as having had an operation. The most frequent procedures were debridement alone (54%; n = 6,560), internal fixation (other) and debridement (31%; n = 3,757), and internal fixation (intramedullary nail) and debridement (22%; n = 2,659) (Table I). This overall pattern was consistent between the subgroups of older females and younger males; however, fewer females underwent staged procedures or intramedullary nailing (47% vs 58% and 16% vs 30%).

The overall incidence in England from 2008 to 2019 was 1.87 per 100,000 person-years (95% CI 1.87 to 1.87), increasing from 1.18 per 100,000 person-years in 2008 to 2.88 per 100,000 person-years in 2012 (Table II and Figure 1).

Across the entire study period, incidence in males again demonstrated a bimodal distribution, peaking between the age of 20 and 29 years (3.71 per 100,000 person-years (95% CI 3.71 to 3.71)) (Figure 2). In males aged 20 to 29 years, the most common mechanism of injury was a vehicle incident or collision (69%) and a fall of more than two metres (9%). In contrast, incidence in females increased with age to a peak of 9.91 per 100,000 person-years among those aged 90 years and over (95% CI 9.90 to 9.92). In males and females aged over

70 years, the most frequent mechanism of injury was a fall of less than two metres, but a higher proportion of females than males had this mechanism of injury (81% vs 47%); the second most frequent mechanism was a vehicle incident or collision (14% in females vs 42% in males).

There was a substantial proportion of data missing (overall > 25%) from the directly reported BOAST dataset throughout the study period (Table III). Between 2008 and 2011 there were considerable data missing across all standards. Between 2012 and 2015, the proportion of missing data decreased, but was highest for the standards of "definitive coverage achieved within 72 hours" (83%) and "definitive stabilization achieved at the same time as wound coverage"[3] (85%). During the 2016 to 2019 period, other than recording the Gustilo-Anderson grade, the proportion of data missing increased again, ranging from 38% to 63%.

The BOAST standards were achieved in fewer than 25% of participants between 2008 and 2011, with the exceptions of 'received antibiotics', 'wounds dressing', and 'injured limb splinted to clinical standards' (Table III). After 2012 there was an increase in the recorded proportion of participants who received care for each of the BOAST standards. For six of 13 BOAST standards, this improvement was sustained between 2016 and 2019, such as 'combined orthopaedic and plastic surgery management plan' and 'definitive stabilization achieved at the same time as wound coverage'. For other standards, however, the proportion for whom BOAST standards were met decreased, such as 'definitive coverage achieved within 72 hours' and 'standards met for limb splinting'.[3]

Table IV shows the derived data items reported in the National MTC Dashboard, and as such the rate of missing data improved. However, despite the derivation of these items, more than 49% of the data for 'debridement within 12 hours of presentation at hospital' and 'soft tissue coverage achieved within 72 hours of incident' is missing. Overall, only a small proportion of participants had their debridement conducted by both consultant orthopaedic and plastic surgeons (10%; n = 1,175); more commonly, any grade of orthopaedic and plastic surgeons worked together with an increase from 3% to 29% over the study period. Overall, median time to debridement was 13.0 hours (IQR 6.4 to 20.9). The proportion of participants who had a debridement within 12 hours of incident fluctuated minimally: 24% across the entire study period, 28% between 2012 and 2015, and decreased to 21% from 2016 to 2019. Overall, the median time to soft-tissue coverage was 105 hours (IQR 17 to 114). Among participants who underwent soft-tissue coverage, the proportion achieved within 72 hours of incident increased from 4% (n = 149) during 2008 to 2011 to 35% (n = 1,414) during 2016 to 2019.

Discussion

We have reported a large population-based cohort in England, identified within the TARN dataset between 2008 and 2019, of 38,347 patients with any open fracture, and a subgroup of 12,170 with severe open fracture of the tibia. From 2012 to 2019, the overall incidence of open fracture in England was 6.94 per 100,000 person-years: 8.36 and 5.55 per 100,000 person-years in males and females, respectively. A minority of these injuries were severe open fractures of the tibia; the overall incidence was 1.87 per 100,000 person-years: 2.42 and 1.35 per 100,000 person-years in males and females, respectively. Over the entire study period, the highest incidence in both cohorts was observed in males aged 20 to 29 years. The incidence in females increased with age to a peak of 32.11 and 9.91 per 100,000 person-years for any open and severe open fracture of the tibia, respectively, among those aged 90 years and over, some three to four times higher than similarly aged males. The operative management of these patients is relatively consistent across subgroups, although there is evidence that a greater proportion of older females are treated with single-stage procedures, with minimal debridement and fewer intramedullary nails. This perhaps reflects the different injury pattern of soft and bony injury seen in the older, lower-energy fracture population.

The achievement of the national standards for clinical care of severe open fracture of the tibia fluctuated during the study period. Some criteria, such as achieving soft-tissue coverage within 72 hours,[3] have shown marked improvement from 14% between 2008 and 2011 to 59% between 2016 and 2019. However, this is not consistent across the standards; achievement of six of 13 recorded criteria declined from 2012/15 to 2016/19 even for some crucial interventions such as time to debridement.

National epidemiological data for open fracture incidence rates are scarce. In a small historical study of 474 patients with 515 open long bone fractures from the Edinburgh Orthopaedic Trauma Unit from 1988 to 1993, the annual UK incidence of open fractures of the lower limb was estimated to be 11.5 per 100,000 adults.[15]

Data from TARN regarding severe open tibia fracture have been reported previously. Young et al[16] reported clinical practice in 27 MTCs between 2014 and 2016 including 646 patients; the authors highlighted that this provided an incomplete picture nationally, excluding those injuries managed in Trauma Units (TUs). Here, we have included these data where available, and report overall lower data completeness and generally worse delivery of national standards. Dixon et al[17] have highlighted important differences in casemix between MTCs and TUs, showing that the majority of older patients who sustain major trauma are managed in TUs, often with severe multisystem injury and high ISS scores. Formal evaluation of systematic differences between MTCs and TUs is in preparation.

The main strength of this study is the large population-based cohort using clinical practice data submitted from hospitals to the national audit TARN. This national audit is the means through which hospitals in England are benchmarked for trauma care; the comparative data are publicly available and used by various oversight bodies such as Care Quality Commission[18] and Getting It Right First Time.[19] This is the first time, to our knowledge, that the incidence of open fractures has been studied using population-based secondary care data for patients of all ages, and the first time that results for the whole of England have been reported.

We believe that our cohort is likely to be as comprehensive a report of the entire population of open fractures as possible from routinely collected national data. TARN collects data from NHS hospitals only; while independent healthcare services are provided within England, we are not aware of any such services capable of delivering the emergent and complex care required for patients with these injuries. We assess that while it is unlikely that someone suffering an open fracture would not present to hospital, some hospitals may not have reported all cases, and as such our estimate of incidence is likely to be a minimum estimate.

The key limitation of this study is the obverse of this strength; these data are collected for audit purposes and to improve service evaluation, not to answer the research questions of this study. There was a very substantial proportion of data missing; this was also the case for the subgroup of patients with severe open fractures of the tibia, which persists even after including data from derived fields. For example, 26% of this subgroup (n = 3,158) have no recorded operation for their injury, which is unlikely to be clinically plausible. The pattern of these missing data showed an initial improvement after the introduction of RTNs, although this has not been sustained.

During the study period, not all hospitals were consistently reporting data for patients with open fractures, particularly between 2008 and 2012. From 2012 onwards, and the subsequent introduction of mandatory case-reporting to TARN for MTCs in 2016, the overall data completeness improved dramatically. Hence, we believe the incidence rates between 2012 and 2019 reported here are more likely to be indicative of the true incidence, and that the observed earlier trend of an increase in incidence is likely to be more fully explained by improved reporting.

Interpretation of these data, which the orthoplastic community use for national benchmarking, is therefore potentially unreliable. Furthermore, the description of the patients, fractures, and treatments provided that we have been able to report is limited by the data that are available within TARN. Some of the clinically important descriptors, such as severity of the injury, are missing or not collected for all open fractures.

In conclusion, open fracture is a relatively uncommon but potentially devastating condition that mostly occurs in younger people,[20] but with a substantial incidence in older people. RTNs and orthoplastic units can use these data to model service requirements, and consider modifying their services to deliver better clinical standards of care.

Take home message

- Open fractures, and the subgroup of severe open fractures of the tibia, are most common in males aged 20 to 29 years, but there is also substantial incidence in older people.
- The achievement of the British Orthopaedic Association Standard national for clinical care of severe open fracture of the tibia fluctuated during the study period, and was inconsistent across the individual recommendations.
- These findings should be interpreted in the light of a substantial proportion of missing data in the Trauma Audit and Research Network dataset.

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Supplementary material

Tables describing the open fractures included in the analysis, how the BOAST4 measures were derived, the pattern of presentation of patients with open fractures to hospital by day and time, the pattern of presentation of patients with severe open tibial fractures to hospital by day and time, and a figure presenting the incidence of patients with open fracture by age and sex.

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