
Article:
Hay-David, A., Stacey, T., Pallister, I. et al. (1 more author) (2018) Motorcyclists and pillion passengers with open lower-limb fractures: a study using TARN data 2007-2014. Annals of The Royal College of Surgeons of England, 100 (3). pp. 203-208. ISSN 0035-8843

https://doi.org/10.1308/rcsann.2017.0222

Royal College of Surgeons
ADVANCING SURGICAL CARE

TRAUMA AND ORTHOPAEDIC SURGERY

Ann R Coll Surg Engl 2018; **100:** 203–208
doi 10.1308/rcsann.2017.0222

Motorcyclists and pillion passengers with open lower-limb fractures: a study using TARN data 2007–2014

AGC Hay-David[1], T Stacey[2], I Pallister[3], on behalf of the Trauma Audit and Research Network Research Committee, University of Manchester

[1]Glasgow Royal Infirmary, Glasgow, UK
[2]Trauma Audit and Research Network, Salford Royal NHS Foundation Trust, Salford, UK
[3]Morriston Hospital, Swansea, UK

ABSTRACT

INTRODUCTION We aimed to identify population demographics of motorcyclists and pillion passengers with isolated open lower-limb fractures, to ascertain the impact of the revised 2009 British Orthopaedic Association/British Association of Plastic Reconstructive and Aesthetic Surgeons joint standards for the management of open fractures of the lower limb (BOAST 4), in terms of time to skeletal stabilisation and soft-tissue coverage, and to observe any impact on patient movement.

METHODS Retrospective cohort data was collected by the Trauma Audit and Research Network (TARN). A longitudinal analysis was performed between two timeframes in England (pre-and post-BOAST 4 revision): 2007–2009 and 2010–2014.

RESULTS A total of 1564 motorcyclists and 64 pillion passengers were identified. Of these, 93% (1521/1628) were male. The median age for males was 30.5 years and 36.7 years for females. There was a statistically significant difference in the number of patients who underwent skeletal stabilisation (49% vs 65%, $P < 0.0001$), the time from injury to skeletal stabilisation (7.33 hours vs 14.3 hours, $P < 0.0001$) and the proportion receiving soft-tissue coverage (26% vs 43%, $P < 0.0001$). There was no difference in the time from injury to soft-tissue coverage (62.3 hours vs 63.7 hours, $P = 0.726$). The number of patients taken directly to a major trauma centre (or its equivalent) increased between the two timeframes (12.5% vs, 41%, $P < 0.001$).

CONCLUSIONS Since the 2009 BOAST 4 revision, there has been no difference in the time taken from injury to soft-tissue coverage but the time from injury to skeletal stabilisation is longer. There has also been an increase in patient movement to centres offering joint orthopaedic and plastic care.

KEYWORDS
Open fractures – Motorcyclists – Pillion passengers – BOAST 4 – TARN

Accepted 3 December 2017

CORRESPONDENCE TO
AGC Hay-David, E: a.hay-david@nhs.net

Introduction

Reports from the National Audit Office, the Royal College of Surgeons of England, the British Orthopaedic Association (BOA) and the National Confidential Enquiry into Patient Outcome and Death have revealed that care and rehabilitation could be better in the UK.[1–3] To address this concern, regional trauma networks were introduced in 2012 with 22 major trauma centres (MTCs) established to centralise the care of major trauma, with the most severely injured receiving the highest level of care in specialist centres.[4]

Motorcyclists constitute 1% of all road users and account for 19% of all deaths.[5] This group of road users was selected as they most frequently sustain lower-limb injuries that tend not to be associated with death unless multiple injuries are sustained, most notably traumatic brain injury.[6] In the UK, helmets are the only form of mandatory personal protection. An open lower-limb injury should meet the criteria of referral and transfer to a MTC according to prehospital triage that includes distance (< 45 minutes away), the presence of a crushed, degloved or an open fracture warranting joint orthopaedic and plastic surgery involvement. Where these criteria are not met, the patient is taken to the nearest trauma unit. If the patient still warrants referral to a MTC, they may require stabilisation (optimisation in intensive care and/or operative stabilisation with an external fixator) prior to transfer.

In 1991, the BOA and the British Association of Plastic Reconstructive and Aesthetic Surgeons (BAPRAS) proposed combined guidelines on the management of open fractures. These guidelines have undergone multiple revisions, the most recent in 2009, when they were rebranded as 'standards' in line with evidence-based practice: BOA/BAPRAS joint standards for the management of open fractures of the

lower limb (BOAST 4).[7–8] The most significant change was the elimination of the six-hour rule that stated 'all open high energy tibial fractures should be classified as a surgical emergency and the first orthopaedic procedure should be undertaken within 6 hours of injury'.[7] Instead, the aim is for surgery to be performed by the most appropriate specialists (senior orthopaedic and plastic surgeons; standards 6 and 11), in the most appropriate place (centres providing joint orthoplastics care or at a specialist centre; standard 9) and at an appropriate time (on a scheduled trauma list; standard 11), unless specific criteria are met which warrant immediate surgery.[9] These criteria include the presence of vascular injury, compartment syndrome, severe contamination and multiple injuries (standards 3,4 and 5).[9]

The Trauma Audit and Research Network (TARN) was established in 1989 as a nonprofit organisation funded by participation fees. Hospitals in England, Wales and Northern Ireland were initially invited to submit their data for analysis. Since 2013, all trauma receiving hospitals in England and Wales have submitted data. At the time of this study, TARN contained the largest European trauma registry, with data collected on 475,000 injured patients. Data obtained comprise a vital audit tool for feedback and, thereby, a means of improving patient care and guiding future service delivery. Since the implementation of the trauma network, TARN identified a 30% increased rate of risk-adjusted survival; that is, the equivalent of 600 more patients are surviving trauma.[10]

The aims of this study were to identify population demographics of adult motorcyclists and pillion passengers with isolated open lower-limb fractures, to determine the impact of BOAST 4: time to skeletal stabilisation and soft tissue coverage (standard 13: 'Definitive skeletal stabilisation and wound cover are achieved within 72 hours and should not exceed 7 days') and to observe the combined impact of BOAST 4 and the trauma network on patient movement to trauma centres.[9]

Methods and Materials

This is a retrospective cohort study comparing adult motorcyclists and pillion passengers with open lower-limb fractures in England during two timeframes: I January 2007 to 31 December 2009 and I January 2010 to 14 April 2014. For the purpose of the longitudinal analysis, the two timeframes were referred to as 2007–2009 and 2010–2014. There is a deliberate discrepancy in the length of the two timeframes, which differ by two years. This is to allow for uptake of the revised guidance (2009) and to facilitate analysis of patient movement in the context of the trauma network.

The TARN definition of an open fracture is: 'where there is lack of continuity/breach in skin overlying a fracture; also called compound'.[11] Patients were identified in the TARN database using the abbreviated injury scale (AIS) codes assigned to them, which identify open lower-limb fractures and, from that, the injury severity score (ISS) was determined. Data collected included age, sex, whether they were the rider or pillion passenger, mechanism of injury, behaviour (the presence of alcohol, drugs, if a helmet was worn), ISS, 30-day mortality, time from injury to skeletal stabilisation, time from injury to soft-tissue coverage and patient movement. Patient movement refers to whether patients were taken to a MTC or trauma unit (in the earlier, 2007–2009 pre-trauma network period, the hospital was deemed to be equivalent to a MTC according to today's categorisation).

Statistical analysis was conducted using a chi-squared test to compare the two timeframes for categorical variables. Where the distribution was not found to follow a normal distribution, a Mann-Whitney U test was conducted. All patients with a previous matched submission were excluded, so that there was only one submission per patient and no duplication in patient numbers. Only patients with a final outcome (dead or alive) at discharge were included.

Results

There were 1564 motorcyclists and 64 pillion passengers identified from the TARN database of 475,000 patients (Fig 1). Of these, 93% (1521/1628) were male (mean age 33.8 years); 7% (107/1628) were female (mean age 35.4 years). Males constituted 95% (1491/1564) of motorcyclists and 47% (30/64) of pillion passengers. The gender difference between motorcyclists and pillion passengers was found to be statistically significant ($P < 0.001$). There was no statistically significant difference in gender distribution between the two timeframes.

A blunt mechanism of injury predominated, with a statistically significant increase in the latter period (92% vs 97%, $P < 0.001$). There was no significant difference in associated alcohol or drug use in either period ($P > 0.05$). Helmet usage did not vary at 8% compared with 6% (27/356 vs 73/1156, $P > 0.05$). Mean ISS (14.01 vs 14.23) and 30-day mortality (3.4% vs 2.2%) remained unchanged ($P > 0.05$).

Time to skeletal stabilisation

The number of patients requiring skeletal stabilisation was 215/439 (49%) in the earlier timeframe and 774/1189 (65%) in the later group. This increase was highly statistically significant ($P < 0.0001$). The median time from injury to skeletal stabilisation for 2007–2009 was 7.33 hours (range 2 hours to 119 days, interquartile range, IQR, 15.1 hours) and for 2010–2014 median time was 14.3 hours (range 0.42 hours to 35 days, IQR 18.8 hours). A Mann-Whitney U test comparing time taken from injury to stabilisation between the two timeframes confirmed a highly statistically significant difference (U = 69197.500, asymptotic two-tailed $P = 0.000$). There was a demonstrable increase in the time from injury to skeletal stabilisation between the two timeframes.

Time to soft-tissue coverage

The number of patients requiring soft tissue coverage was 113/439 (26%) in the earlier timeframe and 508/1189(43%) in the later one. This increase in coverage was found to be statistically significant ($P < 0.0001$). In 2007–2009, the median time from injury to soft tissue coverage was 62.3

hours (range 2 hours to 119 days, IQR 95.6 hours) and for 2010–2014 was 63.7 hours (range 1.65 hours to 35 days, IQR 107 hours). When time from injury to soft-tissue coverage was compared, there was no statistically significant difference (62.3 hours vs 63.7 hours, $P = 0.726$). A Mann-Whitney U test comparing time taken from injury to soft tissue coverage between the two timeframes confirmed no statistically significant difference between the groups (U = 16631.5, asymptotic two-tailed $P = 0.726$). There was a reduction in the number of patients who had skeletal stabilisation and later went on to soft-tissue coverage (215 vs 113 and 774 vs 439). The results are summarised in Table 1.

Patient movement

In the overall group, 54% (873/1628) were taken to a MTC in the first instance: 204/1628 (12.5%) were taken to a MTC in 2007–2009 and 669/1628 (41%) in 2010–2014. This increase was found to be a highly statistically significant ($P < 0.001$). A breakdown of patient movement during the timeframes is summarised in Table 2.

Discussion

In common with other studies, we have shown support for an orthoplastics service following the introduction of the trauma network.[12–19] Plastic surgical involvement is an integral factor in major trauma service planning and provision from postgraduate training to the provision of joint orthoplastics operating lists. The reduction we identified in the number of patients undergoing skeletal stabilisation and who later underwent soft-tissue coverage suggests a coordinated orthoplastic service. There is evidence of a lower rate of infection for patients who undergo combined single-stage orthoplastic fixation and soft-tissue coverage within 72 hours.[12,17] One study by Stammers et al examined pre- and post-MTC open fracture workload during two eight-month timeframes at St George's Hospital, London.[19] In the post-MTC period, they report a time to definitive skeletal stabilisation of 4.7 days compared with 2.2 days ($P = 0.06$), time to skin coverage 8.3 compared with 3.7 days ($P = 0.06$); results were not statistically significant. In another study of nearly 50% of cases involving motocyclists, there was a reduction

Table 1 Results from the two cohorts, 2007–2009 and 2010–2014 and comparison between the two groups.

	2007–2009	2010–2014	2007–2009 vs 2010–2014
Male gender	412/439 (93.9%)	1109/1189 (93.3%)	$\chi 2$ 0.174, $P = 0.676$
Mean age (years)[a]	33.9 (range 14.6–82.9)	34 (range 5–80.3)	Mann Whitney test U = 260698, asymptotic two-tailed $P = 0.973$
Mean injury severity score	14.01	14.23	Independent samples t test –0.395, $P = 0.676$
Blunt vs penetrating	405/439 (92.3%)	1148/1189 (96.6%)	$\chi 2$ 13.468, $P < 0.001$ (0.000)
Alcohol consumption	21/439 (5%)	51/1189 (4%)	$\chi 2$ 0.185, $P > 0.05$ (0.667)
Drug use	4/439 (0.9%)	12/1189 (1%)	$\chi 2$ 0.032, $P > 0.05$ (0.859)
Helmet use[b]	324/439 (73.8%)	854/1189 (71.8%)	$\chi 2$ 0.012, $P > 0.05$
Proportion of patients requiring skeletal stabilisation	215/439 (49%)	774/1189 (65%)	$\chi 2$ 308.149, $P < 0.0001$
Median time from injury to skeletal stabilisation	7.33 hours (range 2 hours to 119 days), IQR 15.1 hours	14.3 hours (range 0.42 hours to 35 days), IQR 18.8 hours	Mann Whitney test, U = 69197.500, asymptotic two-tailed $P = 0.000$
Proportion of patients that then went on to require definitive soft-tissue reconstruction	113/215 (52.6%)	439/774 (56.7%)	$\chi 2$ 251, $P < 0.0001$
Median time from injury to soft tissue reconstruction	62.3 hours (range: 2 hours to 119 days), IQR 95.6 hours	63.7 hours (range: 1.65 hours to 35 days), IQR 107 hours	Mann-Whitney test, U = 16631.5, asymptotic two-tailed $P = 0.726$
Patient primary transfer to a major trauma centre	204/1628 (12.5%)	669/1628 (41%)	$P < 0.001$
30-day outcome	15/439 (3.4%)	26/1189 (2.2%)	$\chi 2$ 1.507, $P > 0.05$

IQR, interquartile range.
[a] Male and female.
[b] Where helmet use was not known these were excluded from the analysis.

Table 2 Breakdown of patient movement during the two timeframes, 2007–2009 and 2010–2014.

Transfer type	2007–2009			2010–2014			Overall (2007–2014)		
	MTC	Trauma unit	Total	MTC	Trauma unit	Total	MTC	Trauma unit	Total
1 (no transfer)	163	205	368	531	362	893	694	567	1261
2 (transfer in)	32	17	49	89	26	115	121	43	164
3 (transfer out)	8	13	21	44	129	173	52	142	194
4 (transfer in and out)	1	0	1	5	3	8	6	3	9
Total	204	235	439	669	520	1189	873	755	1628

in time from fixation to soft-tissue coverage ($P = 0.003$) and from injury to soft-tissue coverage ($P = 0.051$).[16] In this study, the increased workload was paralleled by the increase in the number of consultant appointments in plastic surgery, participating in the trauma rota and providing a free flap service. One trust identified the increase in plastic surgical workload to be as high as seven times since the trauma network was introduced.[18] There is no directly comparative data with our study as this is a highly selective group with specific inclusion criteria. Unlike other published studies, our study is a longitudinal analysis conducted over a seven-year period examining motorcyclists and pillion passengers with isolated open lower-limb fracture from 148 trauma receiving units in England.

There were 1,354,400 licensed motorcycles, scooters and mopeds in the UK in 2014.[20] To calculate the population rate or risk of a motorcycle crash injury is not straightforward owing to the inclusion criteria: 175,000 patients were identified from within the TARN database of 475,000 patients (Fig 1). Of these, 1628 patients were included in this study who met our inclusion criteria and had a known outcome at discharge from hospital. It can be criticised that seven years is not long enough to monitor change, particularly as data collection was poor in the first timeframe. In 2014, all trauma receiving trusts in England were under mandate by the government to submit data to TARN. This was not the case throughout the duration of the study period and, therefore, we must interpret the data with caution as they are not a complete reflection of all injured motorcyclists and pillion passengers in England from 2007 to 2014. Neither does the data reflect an upsurge or epidemic in motorcycle accidents when comparing numbers of injured riders and pillion passengers between 2007–2009 (439) with numbers in 2010–2014 (1189). Furthermore, since 2013 TARN has provided hospitals with an additional data collection tool specifically for patients with BOAST 4 injuries, which has improved data capture for this patient group.

The trauma network was designed to ensure that patients with significant injuries are taken promptly to a MTC where there are specialist services available to treat these patients optimally, with plastics and neurosurgical support. This decision is often made in the prehospital setting using a triage tool based on physiological findings and suspected injury patterns. It is designed to identify, from limited prehospital information, patients with an ISS greater than 15. Prior to the trauma network, it had been predicted that a trauma divert policy might result in problems for regional ambulance services in the UK with an 'over-triage' of patients by prehospital personnel resulting in a longer journey to a MTC when a closer trauma unit might suffice.[21] Appropriate resources and training may help to avoid such situations, which echoes findings of international studies that quote the positive predictive value of prehospital triage systems being between 19–25%.[21–23] The London Ambulance Service is integrated as part of the trauma network and uses major trauma triage. This is not the case for satellite hospitals who feed into the MTCs. Their ambulance transfer protocols also relate to major trauma and not to open fractures. It is therefore not known as to whether open fractures were placed on an automatic divert.

It would have been interesting to further investigate patients transferred to MTCs and whether their outcomes were any better than those treated at their nearest centres (before and after 1 April 2012). The available TARN dataset did not permit analysis of the prehospital decision making so we were unable to identify whether an over- or underestimation of the severity of injuries had occurred. In any case, an open fracture is eligible for MTC transfer regardless of ISS (mean ISS 14.01 in the earlier timeframe vs 14.23 in the later one) provided that the transfer is within the current 45-minute isochrone. Since this study was conducted, the 2016 National Institute for Health and Care Excellence major trauma guidelines have stated that open long-bone fractures should be taken 'directly to a major trauma centre or specialist centre that can provide orthoplastic care'.[24]

Conclusions

Our study has shown that males in their 30s who are motorcyclists (rather than pillion passengers), tend to suffer isolated open lower-limb fractures. Since BOAST 4 was revised in 2009, we have demonstrated that the time from injury to skeletal stabilisation is longer, suggesting that a more timely, staged approach has been adopted. There was no difference demonstrated in the time from injury to soft-tissue coverage. The shortfall in the number of patients who had skeletal stabilisation and who later underwent soft-tissue coverage may be the benefit of coordinated orthoplastics surgery. ISS and the 30-day mortality of this population was stable. We have also demonstrated an increase in patient movement to

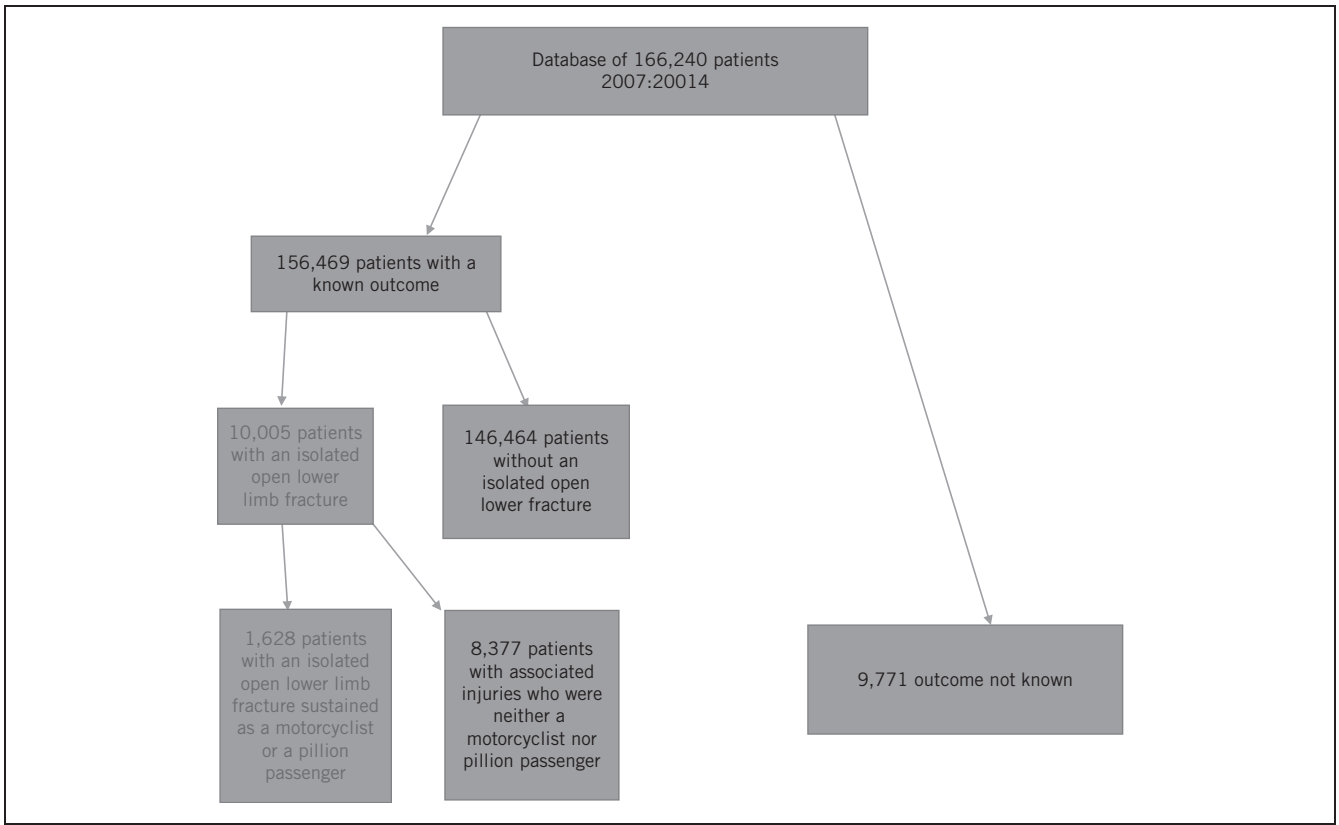

Figure 1 Motorcyclists and pillion passengers identified from the TARN database of 475,000 patients

MTCs suggesting the influence of BOAST 4 standards of care and the impact of the introduction of the trauma network. We acknowledge that there are regions that lack MTCs and we therefore advocate that these patients should be taken to centres offering a joint orthoplastics service, as advocated by BOAST 4.

Acknowledgement

TARN Research Committee, Ms Antoinette Edwards, Professor Fiona Lecky, Dr Kym Thorne. The trauma receiving units that contributed data to TARN: Addenbrooke's Hospital, Airedale General, Barnet Hospital, Barnsley District General Hospital, Bassetlaw District General Hospital, Bedford Hospital, Birmingham Children's Hospital, Birmingham Heartlands Hospital, Blackpool Victoria Hospital, Bradford Royal Infirmary, Bristol Royal Infirmary, Broomfield Hospital, Charing Cross Hospital, Chase Farm Hospital, Chesterfield Royal Hospital, City Hospital Birmingham, Colchester General Hospital, Conquest Hospital, Countess of Chester Hospital, Croydon University Hospital, Cumberland Infirmary, Darent Valley Hospital, Derbyshire Royal Infirmary (old site), Derriford Hospital, Dewsbury and District Hospital, Diana Princess of Wales Hospital, Doncaster Royal Infirmary, Dorset County Hospital, East Surrey Hospital, Eastbourne District General Hospital, Fairfield General Hospital, Frenchay Hospital, Frimley Park Hospital, Furness General Hospital, Great Western Hospital, Hereford County Hospital, Hillingdon Hospital, Homerton University Hospital, Huddersfield Royal Infirmary, Hull Royal Infirmary, Ipswich Hospital, James Cook University Hospital, James Paget Hospital, John Radcliffe Hospital, Kent and Sussex Hospital, Kettering General Hospital, King's College Hospital, King's Mill Hospital, Leeds General Infirmary, Leicester Royal Infirmary, Leighton Hospital, Lincoln County Hospital, Lister Hospital, Luton & Dunstable Hospital, Macclesfield District General Hospital, Manchester Royal Infirmary, Manor Hospital, Medway Maritime Hospital, Milton Keynes General Hospital, Musgrove Park Hospital, Newcastle General Hospital, Newham General Hospital, Norfolk and Norwich University Hospital, North Devon District Hospital, North Hampshire Hospital (Basingstoke), North Manchester General Hospital, North Middlesex Hospital, North Tyneside General Hospital, Northampton General Hospital, Northwick Park Hospital, Nottingham University Hospital, Peterborough City Hospital, Pilgrim Hospital, Pinderfields General Hospital, Poole Hospital, Queen Alexandra Hospital, Queen Elizabeth Hospital (Gateshead), Queen Elizabeth Hospital Birmingham, Queen Elizabeth Hospital Kings Lynn, Queen Elizabeth Hospital London, Queen Elizabeth Queen Mother Hospital, Queen's Hospital Essex, Rochdale Infirmary, Rotherham General Hospital, Royal Albert Edward Infirmary, Royal Berkshire

Hospital, Royal Blackburn Hospital, Royal Bolton Hospital, Royal Cornwall Hospital, Royal Derby Hospital, Royal Devon & Exeter Hospital, Royal Free Hospital, Royal Lancaster Infirmary, Royal Liverpool University Hospital, Royal London Hospital, Royal Oldham Hospital, Royal Preston Hospital, Royal Shrewsbury Hospital, Royal Surrey County Hospital, Royal Sussex County Hospital, Royal United Hospital, Royal Victoria Infirmary Newcastle, Russells Hall Hospital, Salford Royal Hospital, Salisbury District Hospital, Sandwell General Hospital, Scarborough Hospital, Scunthorpe General Hospital, Sheffield Children's Hospital, Sheffield Teaching Hospitals NHS Foundation Trust, Southampton University Hospital, Southend Hospital, Southport and Formby District General Hospital, St George's Hospital, St Helier Hospital, St Mary's Hospital, St Mary's Hospital Isle of Wight, St Peter's Hospital Chertsey, St Thomas' Hospital, St. James' University Hospital (Leeds), St. Richard's Hospital, Stepping Hill Hospital, Stoke Mandeville Hospital, Sunderland Royal Hospital, Tameside General Hospital, Torbay Hospital, Tunbridge Wells Hospital, University Hospital Aintree, University Hospital Lewisham, University Hospital of Coventry and Warwickshire, University Hospital of North Durham, University Hospital of North Staffordshire, University Hospital of North Tees, University Hospital of South Manchester, Wansbeck General Hospital, Warrington Hospital, Watford General Hospital, West Cumberland Hospital, West Suffolk Hospital, Wexham Park Hospital, Whipps Cross University Hospital, Whiston Hospital, Whittington Hospital, William Harvey Hospital, Wirral University Teaching Hospital, Worthing Hospital, Yeovil District Hospital, York Hospital.

References

1. National Audit Office. *Major Trauma Care in England. Report by the Comptroller and Auditor General. HC 213 Session 2009–2010.* London: The Stationery Office; 2010.
2. Royal College of Surgeons of England. *Better Care for the Severely Injured (UK). Report from the Royal College of Surgeons Severe Injuries Working Group.* London: RCS; 2000.
3. National Confidential Enquiry into Patient Outcome and Death. *Trauma: Who Cares?* London: NCEPOD; 2007.
4. NHS Confederation, Ambulance Service Network. Implementing Trauma Systems: Key Issues for the NHS. London: NHS Confederation; 2010.
5. Department for Transport. *Reported Road Casualties Great Britain: 2013 Annual Report.* London: Department for Transport; 2014.
6. Lin MR, Kraus JF. A review of risk factors and patterns of motorcycle injuries. *Acc Anal Prev* 2009; **41(4)**: 710–722.
7. Court-Brown CM, Cross AT, Hahn DM *et al.* A report by the British Orthopaedic Association/British Association of Plastic Surgeons Working Party on the Management of Open Tibial Fractures. *Br J Plast Surg* 1997; **50(8)**: 570–583.
8. Nanchahal J, Nayagam S, Khan U *et al. Standards for the Management of Open Fractures of the Lower Limb.* London: Royal Society of Medicine Press; 2009.
9. British Orthopaedic Association, British Association of Plastic Reconstructive and Aesthetic Surgeons. Standards for Trauma 2009. BOAST 4: The Management of Severe Open Lower Limb Fractures. https://www.boa.ac.uk/wp-content/uploads/2014/05/BOAST-4-The-Management-of-Sever-Open-Lower-Limb-Fractures.pdf (cited December 2017).
10. NHS England. Independent review of Major Trauma Networks reveals increase in patient survival rates. Press release, 25 June 2013. https://www.england.nhs.uk/2013/06/incr-pati-survi-rts (cited December 2017).
11. Trauma Audit and Research Network. TARN: Inclusion Criteria relating to Limbs. https://www.tarn.ac.uk/content/downloads/53/Fracture%20definitions.pdf (cited December 2017).
12. Mathews JA, Ward J, Chapman TW *et al.* Single-stage orthoplastic reconstruction of Gustilo-Anderson Grade III open tibial fractures greatly reduces infection rates. *Injury* 2015; **46(11)**: 2,263–2,266.
13. Chummun S, Wright TC, Chapman TW, Khan U. Outcome of the management of open ankle fractures in an ortho-plastic specialist centre. *Injury* 2015; **46(6)**: 1,112–1,125.
14. Trickett RW, Rahman S, Page P, Pallister I. From guidelines to standards of care for open tibial fractures. *Ann R Coll Surg Engl* 2015; **97(6)**: 469–475.
15. Ali AM, McMaster JM, Noyes D *et al.* Experience of managing open fractures of the lower limb at a major trauma centre. *Ann R Coll Surg Engl* 2015; **97**: 287–290.
16. Wordsworth M, Lawton G, Nathwani D *et al.* Improving the care of patients with severe open fractures of the tibia: the effect of the introduction of Major Trauma Networks and national guidelines. *Bone Joint J* 2016; **98B(3)**: 420–424.
17. Yarrow J, Rahman S, Marsden N *et al.* Management of open lower limb injuries in South West England and Wales. *Ann R Coll Surg Engl* 2015; **97(1)**: 35–39.
18. Hendrickson SA, Khan MA, Verjee LS *et al.* Plastic surgical operative workload in major trauma patients following establishment of the major trauma network in England: A retrospective cohort study. *J Plast Reconstr Aesthet Surg* 2016; **69 (7)**: 881–887.
19. Stammers J, Williams D, Hunter J *et al.* The impact of trauma centre designation on open tibial fracture management. *Ann R Coll Surg Engl* 2013; **95(3)**: 184–187.
20. Department for Transport. Statistical dataset: motorcycles. https://www.gov.uk/government/statistical-data-sets/veh03 (cited December 2017).
21. Moy R, Han K, Smith GD, Henning J. Trauma systems: the potential impact of a trauma divert policy on a regional ambulance service. *Emerg Med J* 2012; **29 (5)**: 404–408.
22. Esposito TJ, Offner PJ, Jurkovich GJ *et al.* Do prehospital trauma center triage criteria identify major trauma victims? *Arch Surg* 1995; **130**:171–176.
23. Kann SH, Hougaard K, Christensen EF. Evaluation of pre-hospital trauma triage criteria: a prospective study at a Danish level I trauma centre. *Acta Anaesthesiol Scand* 2007; **51**:1,172–1,177.
24. National Institute for Health and Care Excellence. *Fractures (Complex): Assessment and Management.* NICE guideline [NG37]. London: NICE; 2016 (updated September 2017).