BMJ Open

Comparison of injury patterns and interventions between adolescent, adult and paediatric trauma cases: a cross-sectional review of TARN data

Stephen Mullen [iD],[1,2] Amy Tolson,[3] Omar Bouamra [iD],[4] Ben Watson,[3] Mark David Lyttle [iD],[5,6] Damian Roland,[7,8] David James[9]

For numbered affiliations see end of article.

Correspondence to
Dr Stephen Mullen;
smullen001@googlemail.com

ABSTRACT

Objectives The aim is to compare adolescent (10–24.99 years) trauma patterns and interventions to adult (≥25) and paediatric cases (<10) and to identify any transition points.

Design and setting Data were collected from the Trauma and Audit Research Network (TARN) over a 10-year period. We conducted a retrospective cross-sectional analysis.

Participants After exclusions there were 505 162 TARN eligible cases.

Primary and secondary outcome measures To compare adolescent trauma patterns and interventions to those in paediatric and adult cohorts. Identify transition points for mechanism of injury (MOI) and interventions by individual year over the adolescent age range (10–24.99).

Results Road traffic accidents are the most common MOI in the adolescent group, in contrast to both the paediatric and adult group where falls <2 m are most common. Violence-related injury (shootings and stabbings) are more common in the adolescent group, 9.4% compared with 0.3% and 1.5% in the paediatric and adult groups, respectively. The adolescent grouping had the highest median Injury Severity Score (ISS) and the highest proportion of interventions. The proportion of cases due to stabbing peaked at age 17 (11.8%) becoming the second most common MOI. The median ISS peaked at 13 at age 18. The percentage of cases that fulfil the definition of polytrauma enters double figures (11.8%) at age 15 reaching a peak of 17.6% at age 18. The use of blood products within the first 6 hours remains around 2% (1.6%–2.8%) until age 15 (3.4%), increasing to 4.7% at age 16.

Conclusions Trauma patterns are more closely aligned between adult and paediatric cohorts than adolescence. The highest proportion of trauma interventions occur in the adolescent population. Analysing the adolescent cohort by year of age identified some common points for when descriptors or outcomes altered in frequency, predominantly between the ages of 15–17 years.

INTRODUCTION

Adolescence is defined as the transition from childhood into adulthood. Healthcare systems must provide for the physiological, psychological and social changes that characterise this period reflected by the term

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Trauma and Audit Research Network, a UK trauma database, records trauma demographics, Injury Severity Score and patient outcomes, it, however, does not collect data on those who died at scene, therefore, it is not fully representative of all trauma cases.

⇒ The definition of adolescence (10–24.99 years) was adopted to reflect the current literature appreciating that some may find the age range too extensive, but this potential concern is addressed within the yearly analysis.

⇒ Comparison of trauma patterns and interventions between paediatric, adolescent and adult groups is an area of research with little evidence to date.

⇒ By analysing the adolescent cohort by individual year of age, there may be an identifiable common point for when trauma descriptors or outcomes alter in frequency.

developmentally appropriate care.[1–3] As with medical presentations adolescent trauma patients present across services and, dependent on age, may be managed in either paediatric, adult or mixed trauma departments. In the UK, adolescents predominantly transition from paediatric to adult care at the age of 16. There is national and international variation when defining adolescence by age with recent studies recommending the range 10–24 years.[4–6]

In recognition of the importance of developmentally appropriate care, clinicians can be faced with the dilemma of choosing when to follow adult or paediatric trauma principles. While there are many similarities, some subtle differences exist. There is variation regarding mechanism of injury (MOI) (non-accidental injury in infancy and 'silver-trauma' in the geriatric population) and physiological response to trauma. Paediatric resuscitation adheres to weight-based calculations[7] for

medication with changes in physiological parameters correlating to age, whereas adults have a more 'one-size-fits all' approach that may be adapted if required. For paediatric trauma cases, a more conservative strategy is adhered to for imaging[8–10] and in the management of abdominal visceral injury, and paediatric trauma algorithms omit the role of permissive hypotension.[10]

Within the adolescent cohort (10–24.99 years), there are differences between younger (10–15.99) and older adolescent (16–24.99) trauma. Those who attend a paediatric MTC (major trauma centre) have a lower Injury Severity Score (ISS), but with no clinical variation in Abbreviated Injury Scale (AIS) or initial observations.[11] Road traffic accidents are the most common mechanism, but young adolescents are more likely to be a pedestrian and older adolescents a driver or passenger. Older adolescents are more likely to suffer trauma from violence, self-harm and to be intoxicated, with a higher overall mortality,[12] while those attending paediatric MTCs have a lower crude and adjusted mortality.[11]

There are currently no papers published that compare adolescent trauma patterns to paediatric (0–10) and adult trauma (≥25). The primary aim of this study is to analyse adolescent trauma patterns and interventions recorded by Trauma and Audit Research Network (TARN), assessing how these compare to paediatric or adult trauma populations. The hope is that this information would provide units with data to improve the service and outcomes for adolescent trauma.

METHODS
Study design and setting
In this cross-sectional study, we analysed data collected in the TARN database.

Study population
The TARN database is a UK trauma database and includes patients of any age who sustain severe injury resulting in hospital admission for 3 days or greater, critical care admission, transfer to a tertiary/specialist centre or in-hospital death within 30 days. TARN data are available on request. Injuries are assigned an AIS score, ranging from 1 (minor injury) to 6 ('incompatible with life'). The ISS, derived by adding the squares of the 3 highest scoring body regions, ranges from 1 to 75 with major trauma defined as ISS>15.[13 14] Data are entered into the TARN database by local coordinators who receive bespoke training, utilising retrospective chart review methodology. Multiple publications have accessed TARN data.[15–19]

Datasets were included for all adolescent trauma episodes recorded in TARN in England, Wales and Northern Ireland over a 10-year period (January 2010–December 2019). Scottish trauma data are captured elsewhere (Scottish Trauma Audit Group) and are, therefore, not included in this analysis. Adolescence was defined as 10–24.99 years in line with international guidance.

Suspected self-harm is included although prehospital deaths are not recorded by TARN.

Outcomes
The primary outcome measures are:
1. Comparison of adolescent trauma patterns to paediatric (<10 years) and adult (≥25 years) cohorts, including MOI, mode of transport, ISS, AIS, percentage of cases defined as polytrauma, length of stay (LOS), rehabilitation script and mortality.
2. Comparison of adolescent trauma interventions (10–24.99) to paediatric (<10) and adult (≥25) cohorts, including chest drain insertion, thoracotomy, surgical airway (cricothyroidotomy), use of blood products and number of operations.
3. Determine whether transition points exist between paediatric, adolescent and adult trauma patterns. Data analysed by individual year over the adolescent age range (10–24.99), using variables described in outcomes 1 and 2.

Statistical analysis
Descriptive statistics were used to compare demographic features, injury characteristics and crude mortality. For continuous variables hypothesis testing between subgroups was performed using K-sample equality-of-median test (Mood's test), which tests the null hypothesis that the K samples were drawn from populations with the same median. For categorical variables, the χ^2 tests or Fisher's exact test were used, followed by an adjusted residuals analysis (which tests cells for significance and contribution for χ2). A two-sided p value of 0.05 was considered statistically significant. Statistical analysis was performed using Stata V.16.1 (StataCorp. 2019. Stata Statistical Software: Release 16, StataCorp).[20]

Patient and public involvement
Patients or the public were not involved in the design, conduct, reporting or dissemination plans of this study.

RESULTS
Over the 10-year period, 614 787 cases were recorded by TARN. Of these 44 836 were in non-British hospitals and were excluded as this study was limited to a UK setting. A further 64 789 patients had unknown final outcomes. After excluding these cases, there were 505 162 TARN eligible cases (online supplemental appendix: figure 1, appendix table 1).

Demographics
Of the 505 162 TARN eligible cases, 14 668 (3%) were aged under 10 years (paediatric), 45 527 (9%) were between the ages of 10–24.99 (adolescent) and 444 967 (88%) were aged 25 and over (adult). Males accounted for more cases in the paediatric and adolescent cohorts (65% and 77%, respectively) with an even gender split in adults (table 1).

Table 1 Demographics, mechanism of injury and mode of arrival in paediatric, adolescent and adult trauma cases

			Paediatric	Adolescent	Adult
Gender					
Male		No	9565	35216	232981
		%	65.2	77.4	52.4
Female		No	5103	10311	211986
		%	34.8	22.6	47.6
Mechanism of injury					
RTC		No	2769	22420	73876
		%	18.9	49.2	16.6
Fall >2 m		No	1249	5111	51793
		%	8.5	11.2	11.6
Fall <2 m		No	7558	5868	283950
		%	51.5	12.9	63.8
Shooting		No	17	481	640
		%	0.1	1.1	0.1
Stabbing		No	25	3760	6204
		%	0.2	8.3	1.4
Other (blast, blow, burn, crush, amputation)		No	3050	7887	28504
		%	20.8	17.3	6.4
Mode of arrival					
Ambulance		No	5450	26354	317313
		%	37.2	57.9	71.3
Air ambulance		No	722	3953	15794
		%	4.9	8.7	3.5
Car/personal vehicle		No	2464	1962	19702
		%	16.8	4.3	4.4
Other (public transport, walking, police)		No	1437	3441	25208
		%	9.8	7.6	5.7
Not recorded		No	4595	9817	66950
		%	31.3	21.6	15.0

RTC, road traffic collision.

Mechanism of injury

Falls under 2 m were the most common MOI in paediatric and adult cohorts (table 1). Road traffic collisions (RTCs) were the most common MOI in adolescents (49.2%) and was the second most common in the other cohorts. Injuries related to personal violence (shootings, stabbings) were more common in adolescents (table 1). The 'other' category is an amalgamation of MOI with smaller numbers and is not viewed as a stand-alone entity.

Mode of arrival

Road transport via ambulance was the most frequently recorded mode of arrival for all groups, although the proportion of patients arriving in private transport was largest in paediatrics (table 1).

Injury pattern

The highest median ISS was reported in adolescents (ISS 10: IQR 9–21; table 2), while paediatric and adult cohorts

had an ISS of 9 and similar IQRs (IQR 9–16; IQR 9–17, respectively). There was no difference in the median AIS constituents, although variation was noted in the IQR. The highest proportion of polytrauma was seen in the adolescent cohort (14.5%); table 2).

Interventions

A higher proportion of adolescents received blood within 6 hours (table 3) and had chest drains inserted. Cricothyroidotomy was an infrequent event in all groups (range 0.1%–0.2%; table 3). While rare, thoracotomy was more frequent in the adolescent group (1% vs 0.1% vs 0.4% for adolescents, paediatrics and adults, respectively). The median number of operations was 1 for all groups.

Mortality and LOS

The longest LOS was in adults (median 10 days; IQR 5–19), followed by paediatrics (6 days; IQR 4–14) and adolescents (6 days; IQR 4–11; table 3). The median

Table 2 Variation in injury pattern between paediatric, adolescent and adult trauma cases

	Paediatric (<10 years) Median (IQR)	Adolescent (10–24) Median (IQR)	Adult (≥25) Median (IQR)
ISS	9 (9–16)	10 (9–21)	9 (9–17)
GCS	15 (15–15)	15 (14–15)	15 (15–15)
Polytrauma	4.8%	14.5%	6.8%
AIS			
Head	4 (3–5)	4 (3–5)	4 (3–5)
Thorax	3 (3–4)	3 (3–4)	3 (3–4)
Abdo	3 (2–4)	3 (2–3)	3 (2–3)
Pelvis	2 (2–4)	2 (2–4)	2 (2–2)
Limb	3 (3–3)	3 (2–3)	3 (2–3)

AIS, Abbreviated Injury Scale; GCS, Glasgow Coma Scale; ISS, Injury Severity Score.

Figure 1 Variation in mechanism of injury throughout adolescence (10–24) compared with paediatric and adult cases. RTC, road traffic collision.

intensive care unit (ICU) LOS was highest in adults (3 days). Rehabilitation prescriptions were documented for 45.1% of adolescent cases, 36.6% of adults and 34.5% of paediatrics. Adults had the highest mortality (7.8%), followed by adolescents (4.3%; table 3).

Adolescent trauma patterns compared by yearly age, and to adult and paediatric datasets

Demographics

Males remain the most common gender to have a TARN recorded case (online supplemental appendix table 1). In those under 10, males account for 65.2% of cases rising from the age of 12 to a peak of 80% in 23 years.

Conveyance by ambulance rises through adolescence, coinciding with a decrease in private vehicle use.

Mechanism of injury

RTCs were the most common MOI through the majority of adolescence. This rises sharply in young adolescence, peaking at 55.2% and 55.8% at the ages of 11 and 17, respectively. This is maintained above 43.0% throughout other adolescent years, before dropping sharply (figure 1).

Falls under 2 m are the second most common MOI until 17, with a decreasing trend noted until late adolescence (30.2% at 10 to 8.9% at aged 17; figure 1). At the age of 17 stabbings become the second most common MOI. There are relatively few cases of stabbing in 10–13 years (range 0.1%–1.0%) but this rises at 14 years to 4.2%, peaking at 17 years at 11.8%; this remains above 8% through to

Table 3 A comparison of interventions and outcomes between paediatric, adolescent and adult trauma cases

		Paediatric (<10 years)	Adolescent (10–24)	Adult (25+)	P value
Blood products	%	0.9	4.3	1.5	<0.0001
	No	127	1957	6610	
Chest drain insertion	%	0.6	7.6	4.3	<0.0001
	No	89	3476	19044	
Thoracotomy	%	0.1	1.0	0.4	<0.0001
	No	20	476	1643	
Cricothyroidotomy	%	0.1	0.2	0.1	0.187
	No	1	5	10	
No of operations (median+IQR)		1 (1–1)	1 (1–1)	1 (1–1)	<0.0001*
LOS (days; median+IQR)		6 (4–14)	6 (4–11)	10 (5–19)	0.0001
ICU LOS (days; median+IQR)		2 (1–4)	2 (1–6)	3 (1–8)	0.0001
Rehab prescription		34.5%	45.1%	36.6%	<0.0001
Mortality		2.7%	4.3%	7.8%	<0.0001

*Similar medians but clinically significant difference noted. This is due to the different distributions of the variable with the three groups, with different and large sample sizes, allowing the detection of small differences.
ICU, intensive care unit; LOS, length of stay.
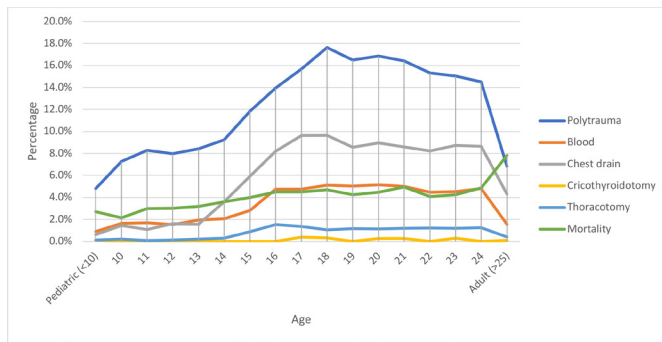
Figure 2 Variation in trauma interventions throughout adolescence (10–24) compared with paediatric and adult cases.

24. In comparison the number of shootings remains relatively low, rising from 10 years (0.1%) to 1.3% in 17 years and peaking at 1.4% in 24.

Injury pattern

The median ISS remains 9 until aged 15, peaking at 13 in 18 years, then subsequently decreasing to 10 in 24 years. There is no difference in median AIS for any region (head, thorax, abdomen, pelvis, limb; online supplemental appendix table 1).

The percentage of cases that fulfil the definition of polytrauma increase from 7.3% at aged 10, reaching a peak of 17.6% at age 18. This decreases to 14.5% by age 24.

Interventions

The use of blood products within the first 6 hours remains around 2% (1.6%–2.8%) until 15 (3.4%), increasing to 4.7% at age 16 and peaking at 5.1% at 18 and 20 years (figure 2). Chest drain insertion follows a similar trend, ranging from 1.4% to 1.6% until the age of 14 (3.6%) and increasing yearly until a peak of 9.6% at age 17.

Mortality and LOS

The median (LOS) varies between 5 and 6 days. The median ICU LOS increases at age 18 from 2 to 3. The percentage requiring rehabilitation prescriptions remains relatively constant throughout (range 44.0%–47.0%; online supplemental appendix table 1). Mortality increases from 2.1% at 10 years to 5.0% at 20 years of age.

DISCUSSION

Using national trauma registry data, we have demonstrated that closer correlation exists between paediatric and adult cohorts than between either and adolescence. This pattern was apparent across MOI, median ISS and interventions. Analysing the adolescent cohort by year of age identified some common points for when descriptors or outcomes altered in frequency, predominantly between the ages of 15 and 17 years.

Some of these differences are predictable. For example, the adolescent group had the highest biological sex imbalance (77.4% male) compared with the paediatric (65.2%) and adult (52.4%) groups. This is consistent

with existing literature, reflecting increased risk-taking behaviour in adolescent males.[21] The MOI notes a higher proportion of road traffic accidents and stabbing, both of which are more commonly associated with males.[22–24] For the almost 50:50 split in the adult population, we would hypothesise that this reflects the MOI with a higher proportion resulting from falls under 2 m, a mechanism that is not associated with risk taking behaviours but potentially a consequence of mechanical or pathological falls.[22 25]

In terms of high acuity, low frequency interventions (ie, chest drain), a higher proportion are performed in the adolescent and adult cohorts than in paediatrics. The increase in the percentage of cases classified as polytrauma may help explain this rise in interventions. However, paediatric trauma resuscitation and management is known to be more conservative than in adult practice, with less surgical interventions and a reduction in the number of CT scans or proportion of whole body CTs.[26 27] This more conservative approach may have a role in the lower frequency of interventions within the ED, opting for closer observation and admission. Furthermore, as paediatric physiology can withstand a larger drop in circulating blood volume than adult cases they may be perceived as clinically more stable, allowing a more conservative approach to be followed.

In the individual yearly analysis, there are various transition points when the variables change with age. For MOI, there is a decrease in the proportion attributed to RTC from 11 to 15, before rising at 17. This may correlate with increasing independent travel and the commencement of driving motor vehicles. At the age of 17, stabbings become the second most common MOI. The proportion of cases defined as polytrauma enters double figures at age 15, with a notable increase in the use of blood products at this age.

These findings may influence how we manage and resource adolescent trauma. Instead of identifying which trauma model adolescents best fit, the results would suggest that they are a unique entity and should be resourced accordingly. The higher ISS, increased number of interventions, longer total and ICU LOS identify adolescent trauma as the most severely injured cohort. Although mortality is higher in the ≥25s, they have more comorbidities which impacts on this outcome. As adolescence spans both paediatric and adult services, there is a tendency for neither to fully address their needs, hence the undesirable title of the 'forgotten tribe'. Recent adult trauma publications focus on the importance of silver trauma while the paediatric literature highlights the role of NAI.[22 28] Neither have clear strategies to address adolescent trauma. Other Western healthcare systems, most notably in Australia and the USA, have recognised the unique needs of the adolescent cohort. They have developed clinical teams, wards and training programmes specific to adolescent health.[29]

There is currently not a concept of adolescent trauma care. Given the yearly analysis notes between the age of

15–17, there are alterations in frequency and outcome of key variables this would imply that the current model of care offered is fit for purpose. However, we would highlight that these 'transition' points do not correlate with the adolescent population becoming more closely matched to adult data but more of a change from paediatric parameters. All trauma services, therefore, need to consider the clinical needs of adolescents and address these, including the provision of targeted youth work-led interventions.

There are several limitations to this study. This is a retrospective analysis of data collected by TARN with no regression models performed. In retrospective analysis, potential limitations include missing data and misclassification bias. As TARN has prespecified inclusion criteria and does not collect data on those who died at scene it is not fully representative of all trauma cases within the UK. However, these limitations are consistent for all cohorts (paediatric, adult and adolescent) within the study. The definition of adolescent (10–24) was adopted to reflect the current literature, appreciating that some may find the age range too extensive, but this potential concern is addressed within the yearly analysis. Similarly the breakdown into paediatric (<10s) and adult (≥25s) may be too broad given the difference between infant (<1s) and silver (>60s) trauma presentations. A considerable number of cases (10.5%) had incomplete data with no mortality outcome recorded in the database. This is often due to transfer of patients between centres. These were excluded from the analysis and may have influenced our findings (online supplemental appendix table 2).

CONCLUSION

As far as the authors can identify this is the first paper to compare adolescent trauma patterns and interventions to paediatric and adult cases. Adolescent cases have the highest percentage of trauma interventions performed with a higher ISS and greater proportion of rehabilitation scripts. Surprisingly, in terms of MOI and intervention, there are greater similarities between adult and paediatric presentation than to adolescent cases. In yearly analysis, transition points are identified between the ages of 15 and 17. Our hope is that these data can be used to further develop the care provided by all trauma receiving units.

Author affiliations
[1]Paediatric Emergency Department, Royal Belfast Children's Hospital, Belfast, UK
[2]School of Medicine, Queen's University Belfast, Belfast, UK
[3]Emergency Department, Royal Belfast Hospital for Sick Children, Belfast, UK
[4]Institute of Population Health, Trauma Audit & Research Network, Salford, UK
[5]Emergency Department, Bristol Royal Hospital for Children, Bristol, UK
[6]Faculty of Health and Applied Science, University of the West of England, Bristol, UK
[7]Emergency Department, Paediatric Emergency Medicine Leicester Academic (PEMLA) Group, Leicester, UK
[8]SAPPHIRE group, University of Leicester Department of Health Sciences, Leicester, UK
[9]Children's Emergency Department, University Hospital Southampton NHS Foundation Trust, Southampton, UK

ORCID iDs
Stephen Mullen http://orcid.org/0000-0001-7115-980X
Omar Bouamra http://orcid.org/0000-0002-3155-4634
Mark David Lyttle http://orcid.org/0000-0002-8634-7210

REFERENCES

1 RCPCH. Health transition resources. Available: https://www.rcpch.ac.uk/resources/health-transition-resources [Accessed 1 Jun 2021].
2 RCPCH. Facing the future: standards for ongoing health needs 2018. Available: https://www.rcpch.ac.uk/resources/facing-future-standards-ongoing-health-needs [Accessed 8 Jun 2021].
3 NICE. Transition from children's to adults' services for young people using health or social care services 2016. Available: https://www.nice.org.uk/guidance/ng43/chapter/Recommendations#overarching-principles [Accessed 8 Jun 2021].
4 SCIE. The care act: transition from childhood to adulthood. 2014. Available: https://www.scie.org.uk/care-act-2014/transition-from-childhood-to-adulthood/ [Accessed 1 Jun 2021].
5 White PH, Cooley WC, Boudreau ADA, *et al*. Supporting the health care transition from adolescence to adulthood in the medical home. *Pediatrics* 2018;142:e20182587.
6 Sawyer SM, Azzopardi PS, Wickremarathne D, *et al*. The age of adolescence. *Lancet Child Adolesc Health* 2018;2:223–8.
7 Skellett S, Maconochie I, Bingham B, *et al*. *Paediatric advanced life support guidelines*. Resuscitation Council UK, 2021.
8 The Royal College of Radiologists. *Paediatric trauma protocols*. London, 2014.
9 The Trauma Audit Research Network. Severe injury in children. Available: https://www.tarn.ac.uk/content/downloads/3572/Severe%20Injury%20in%20Children%202017-2018.pdf [Accessed 23 Aug 2022].
10 National Institute for Health and Care Excellence. Major trauma: assessment and initial management. In: *NICE guideline NG39*. 2016.

11 Evans J, Murch H, Begley R, *et al*. Mortality in adolescent trauma: a comparison of children's, mixed and adult major trauma centres. *Emerg Med J* 2021;38:488–94.

12 Roberts Z, Collins J-A, James D, *et al*. Epidemiology of adolescent trauma in England: a review of TARN data 2008-2017. *Emerg Med J* 2020;37:25–30.

13 Copes WS, Champion HR, Sacco WJ, *et al*. The injury severity score revisited. *The Journal of Trauma: Injury, Infection, and Critical Care* 1988;28:69–77.

14 Champion HR. Trauma scoring. *Scand J Surg* 2002;91:12–22.

15 Nutbeam T, Roberts I, Weekes L, *et al*. Use of tranexamic acid in major trauma: a sex-disaggregated analysis of the clinical randomisation of an antifibrinolytic in significant haemorrhage (crash-2 and crash-3) trials and UK trauma registry (trauma and audit research network) data. *Br J Anaesth* 2022;129:191–9.

16 O'Malley O, Ryan O, Wilson G, *et al*. Mortality and morbidity of stairlift injuries: analysis of the UK tarn database. *Injury* 2020;51:1306–11.

17 Nutbeam T, Weekes L, Heidari S, *et al*. Sex-disaggregated analysis of the injury patterns, outcome data and trapped status of major trauma patients injured in motor vehicle collisions: a prespecified analysis of the UK trauma registry (TARN). *BMJ Open* 2022;12:e061076.

18 Hay-David A, Stacey T, Pallister I, *et al*. Motorcyclists and pillion passengers with open lower-limb fractures: a study using TARN data 2007-2014. *Ann R Coll Surg Engl* 2018;100:203–8.

19 Hunt P, Bouamra O, Jenks T, *et al*. Early whole body versus focused computed tomography imaging following major trauma: existing evidence and analysis of 10 years of TARN data. *Emerg Med J* 2015;32:987–8.

20 StataCorp. *Stata Statistical Software: Release 16*. College Station, TX: StataCorp LLC, 2019.

21 Webman RB, Carter EA, Mittal S, *et al*. Association between trauma center type and mortality among injured adolescent patients. *JAMA Pediatr* 2016;170:780–6.

22 Kehoe A, Smith JE, Edwards A, *et al*. The changing face of major trauma in the UK. *Emerg Med J* 2015;32:911–5.

23 Vulliamy P, Faulkner M, Kirkwood G, *et al*. Temporal and geographic patterns of stab injuries in young people: a retrospective cohort study from a UK major trauma centre. *BMJ Open* 2018;8:e023114.

24 Haagsma JA, Graetz N, Bolliger I, *et al*. The global burden of injury: incidence, mortality, disability-adjusted life years and time trends from the global burden of disease study 2013. *Inj Prev* 2016;22:3–18.

25 Boyé NDA, Mattace-Raso FUS, Van der Velde N, *et al*. Circumstances leading to injurious falls in older men and women in the Netherlands. *Injury* 2014;45:1224–30.

26 Matsushima K, Kulaylat AN, Won EJ, *et al*. Variation in the management of adolescent patients with blunt abdominal solid organ injury between adult versus pediatric trauma centers: an analysis of a statewide trauma database. *J Surg Res* 2013;183:808–13.

27 Walther AE, Falcone RA, Pritts TA, *et al*. Pediatric and adult trauma centers differ in evaluation, treatment, and outcomes for severely injured adolescents. *J Pediatr Surg* 2016;51:1346–50.

28 Jones S, Tyson S, Young M, *et al*. Patterns of moderate and severe injury in children after the introduction of major trauma networks. *Arch Dis Child* 2019;104:366–71.

29 Golub SA, Arunakul J, Hassan A. A global perspective: training opportunities in adolescent medicine for healthcare professionals. *Curr Opin Pediatr* 2016;28:447–53.