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BMJ Open

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)

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To cite: 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. doi:10.1136/bmjopen-2022-061076

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2022-061076).

Received 14 January 2022
Accepted 06 April 2022

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ABSTRACT

Objectives To identify the differences between women and men in the probability of entrapment, frequency of injury and outcomes following a motor vehicle collision. Publishing sex-disaggregated data, understanding differential patterns and exploring the reasons for these will assist with ensuring equity of outcomes especially in respect to triage, rescue and treatment of all patients.

Design We examined data from the Trauma Audit and Research Network (TARN) registry to explore sex differences in entrapment, injuries and outcomes. We explored the relationship between age, sex and trapped status using multivariate logistical regression.

Setting TARN is a UK-based trauma registry covering England and Wales.

Participants We examined data for 450 357 patients submitted to TARN during the study period (2012–2019), of which 70 027 met the inclusion criteria. There were 18 175 (26%) female and 51 852 (74%) male patients.

Primary and secondary outcome measures We report difference in entrapment status, injury and outcome between female and male patients. For trapped patients, we examined the effect of sex and age on death from any cause.

Results Female patients were more frequently trapped than male patients (female patients (F) 15.8%, male patients (M) 9.4%; p<0.0001). Trapped male patients more frequently suffered head (M 1318 (27.0%), F 578 (20.1%)), face, (M 46 (0.9%), F 6 (0.2%)), thoracic (M 2721 (55.8%), F 1438 (49.9%)) and limb injuries (M 1744 (35.8%), F 778 (27.0%); all p<0.0001). Female patients had more injuries to the pelvis (F 420 (14.6%), M 475 (9.7%); p<0.0001) and spine (F 359 (12.5%), M 485 (9.9%); p=0.001). Following adjustment for the interaction between age and sex, injury severity score, Glasgow Coma Scale and the Charlson Comorbidity Index, no difference in mortality was found between female and male patients.

Conclusions There are significant differences between female and male patients in the frequency at which patients are trapped and the injuries these patients sustain. This sex-disaggregated data may help vehicle manufacturers, road safety organisations and emergency services to tailor responses with the aim of equitable outcomes by targeting equal performance of safety measures and reducing excessive risk to one sex or gender.

Strengths and limitations of this study

- ⇒ We include data from 70 027 patients over an 8-year time period.
- ⇒ The source data set, the Trauma Audit and Research Network (TARN), is of high quality.
- ⇒ The data set does not allow clear differentiation between patients who are 'medically trapped' (eg, due to pain) or 'physically trapped' (eg, due to intrusion into the vehicle).
- ⇒ We prespecified outcome measures to minimise bias, but the inherent concerns of a retrospective cohort analysis remain.
- ⇒ Our analysis only includes patients who met the threshold for inclusion in TARN; therefore, motor vehicle collisions where severe injury did not occur were not included.

INTRODUCTION

Sex refers to the biological attributes of humans and animals associated with physical and physiological characteristics such as reproductive anatomy, gene expression, chromosomes and hormone profiles. It is usually categorised as male or female, although there are other variations in sex characteristics.[1]

Gender refers to the societal overlay of roles, behaviours and identities ascribed to individuals. It influences how people see themselves, how they are perceived by others; societal bias affects distribution of power and resources. Gender identity refers to individual's deeply felt internal and individual experience of gender. Gender identity is a spectrum and is not restricted to man and woman. An individual's gender identity may differ from their sex assigned at birth.[1]

Research outcomes may depend on patient sex (such as medication trials, where sex hormones may affect efficacy), gender (eg, in trials where actual or perceived behavioural differences may be important) or both. The Trauma Audit and Research Network (TARN) data set includes sex as recorded on the hospital notes and may represent either sex assigned at birth or gender.

Historical epidemiological data describe major trauma secondary to injury in the UK as predominantly a disease of young men.[2] More recent analysis demonstrates that this paradigm no longer applies, with particular, focus on the burden of trauma in the older population.[3 4] Despite increasing awareness of these changing demographics, trauma systems remain tuned to recognising and treating historical perceived norms.[4 5]

Motor vehicle collisions (MVCs) are a significant cause of morbidity and mortality throughout the world accounting for 1.35 million deaths and between 20 and 50 million injuries worldwide per annum.[5] To our knowledge, no studies have considered the differences in injury patterns, entrapment status and morbidity and mortality outcomes between female and male patients. Failure to collect and analyse sex-disaggregated data is a common concern in research; while most studies present baseline demographic data by sex, far fewer report outcome data by sex or conduct sex and gender-based analysis (SGBA).[1 6] Failure to carry out SGBA can have serious consequences for patient outcome. As an example, female patients are 50% more likely to be misdiagnosed when experiencing a myocardial infarction due to persistent gender-blind research, which overlooked different presentation of symptoms in women compared with men. Women's symptoms have been labelled 'atypical' despite being experienced by half of the population.[7]

Following an MVC, some occupants will be trapped and be unable to exit the vehicle without assistance.[8] Those who are physically trapped will require the assistance of fire and rescue services to perform a mechanical intervention to the vehicle to create space for extrication.[9] Patients who are medically trapped due to pain or disability will require physical assistance, analgesia and the application of spinal precautions or reassurance that such precautions are not required. Patients who are trapped have worse outcomes than those who are not trapped.[8]

We could find no previous sex-disaggregated data, which report injury patterns for patients trapped following an MVC. This information would be useful for those triaging, rescuing or treating patients. There may be additional value of sex-disaggregated data to target public health interventions and the design of safety systems such as restraint devices and airbags.

The aims of this study were to define the probability of entrapment, frequency of injury and outcomes by the sex of the casualty.

METHODS

A retrospective review of the UK TARN database was carried out, including patients injured between 1 January 2012 and 31 December 2019. TARN collects data from Major Trauma Centres and Trauma Units in the UK. Eligibility criteria for inclusion in the TARN database include patients with trauma who are admitted to hospital for ≥72 hours or are admitted to a critical care unit or die in hospital or are transferred to another hospital for specialist care. Prehospital deaths, isolated closed fractures of the limbs and hip fractures in patients over the age of 65 are not included. TARN includes routine data on patient demographics, physiology, interventions, injuries and in some circumstances (including MVCs) the trapped status of the patient.

Inclusion criteria were patients aged 16 years or older, with mechanism coded as 'vehicle incident/collision', directly admitted to a TARN participating hospital in England and with complete documented outcomes. To ensure data quality, patients were excluded if they underwent secondary transfer from another hospital or when the trapped status was not documented on the database.

For patients who met the inclusion criteria, data fields including sex, age, trapped status, injury severity score (ISS), abbreviated injury scale for each body region, any details of spinal injury and significant time-dependent injuries as described in previous work were made available for analysis.[8]

Simple descriptive analysis was used to define the characteristics of the female and male groups. Levene's test was used to assess equality of variances and a two-tailed t test to compare means and Mann-Whitney test for comparing medians. χ^2 test was used for categorical variables. P values of less than 0.01 were considered significant due to multiple analyses being performed. The relationship between age, sex and trapped status was explored further using multivariate logistical regression. SPSS (IBM Corp V.23 Armonk, New York) and Stata (StataCorp. V.2015. Stata Statistical Software: Release V.14. College Station, Texas) were used for the analyses. Additional analyses which were not prespecified: injuries of patients who were excluded for incomplete entrapment data, injuries sustained by year over time and a passenger/driver analysis. Analyses that are not prespecified are included in online supplemental file 1.

Patient and public involvement

TARN has patient and public involvement on the TARN Board, which has oversight of the research portfolio. For this specific analysis, we sought the opinions of the advocacy group GENDRO.

RESULTS

Between 2012 and 2019, there were 450 437 cases identified in total on the TARN database. Following exclusions, data for 71 719 patients from an MVC were identified, of

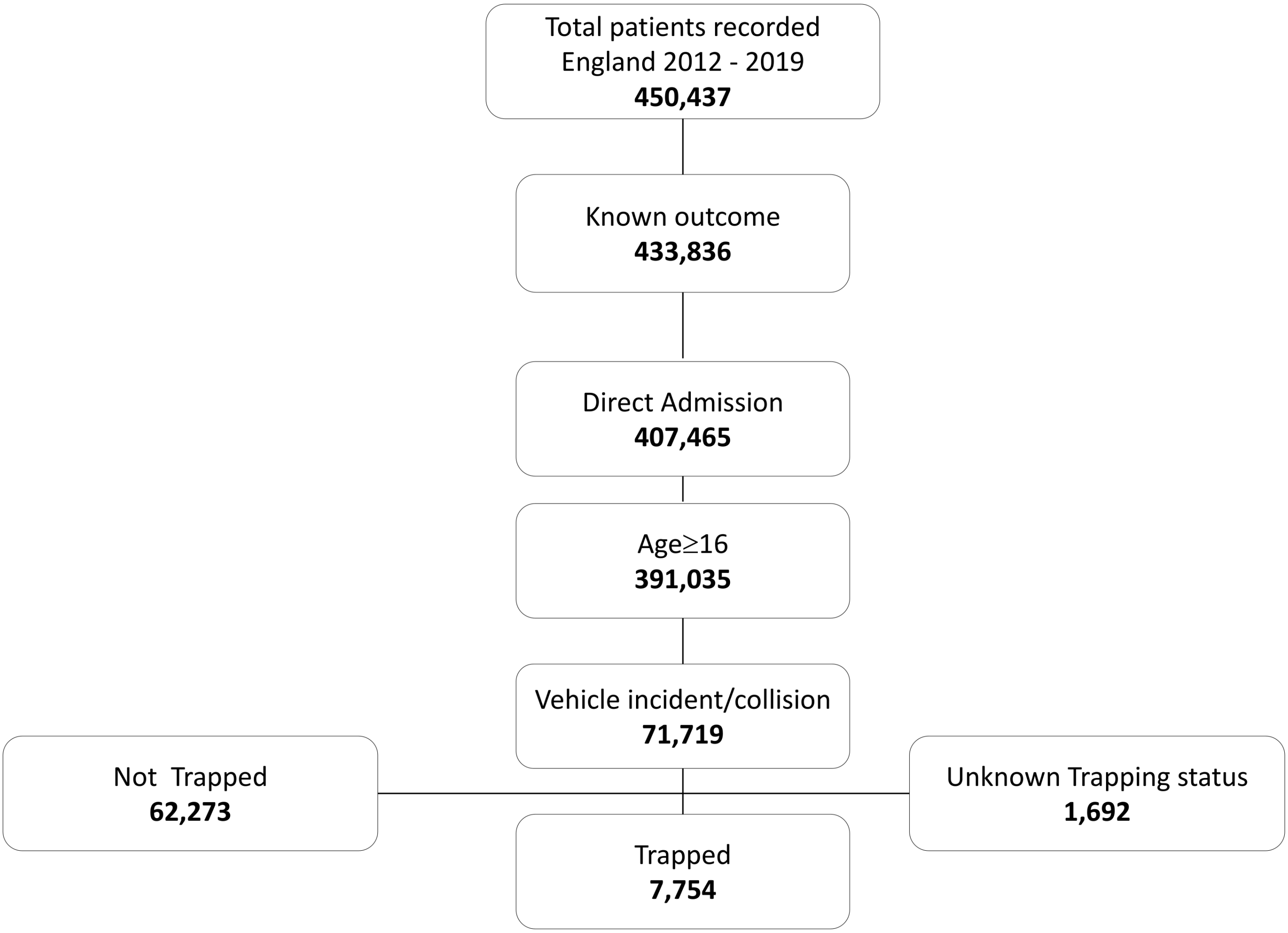

Figure 1 Study profile.

which 70027 patients had a known trapped status were analysed (figure 1).

The characteristics of each group are summarised in table 1. Twenty-six per cent of patients were women. The average age (SD) across all eligible patients was 46.2 (20.1); female patients were older than male patients (52.4 (SD 22.0) vs 44.1 (SD 18.9), p=<0.0001). Female patients had less severe injury (p<0.0001). Mean (median for Glasgow Coma Scale (GCS)) physiological variables were similar for female and male patients. Small differences in heart rate, respiratory rate and oxygen saturations demonstrated statistical but not clinically significant differences.

Of patients who survived to hospital, 3868 (5.5%) died within 30 days of initial injury. Female patients had statistically worse survival although the difference was small (94.0% vs 94.6%, p=0.001). A higher proportion of female patients was trapped than male patients (p=<0.0001). Of the population of patients who were trapped, female patients had better outcomes (92.3% alive at 30 days compared with 90.0% of males, p=0.01).

Tables 2 and 3 show that trapped female and male patients demonstrated significant differences in the incidence of thoracic and spinal injuries. Tension pneumothorax was more common in male patients and dens fractures were more common in female patients (both p<0.0001). Spinal cord injuries were also more common in female patients (p=0.038). When trapped, male patients were more likely to suffer from head, face, thoracic and limb injuries (all p<0.0001, table 3), while female patients were more likely to have pelvic (p<0.0001) and spinal injuries (p<0.001). The incidence of abdominal injuries was similar in female and male patients.

Figure 2 demonstrates the interaction between adjusted mortality, trapped status and age. This analysis adjusts for the interaction between age and sex, ISS, GCS and the Charlson Comorbidity Index. In this adjusted analysis, trapped male patients were more likely to die, but the 95% CIs overlapped between the male and female groups for all age categories.

Figure 3 displays the interaction between probability of entrapment, sex and age. Female patients were more likely to be trapped in all the age groups considered except in patients aged 80 and over.

Table 1 Demographics, outcomes and physiology

	All trapped and not trapped				Only trapped		
	Total	Female	Male	P value	Female	Male	P value
Number (%)	70 027	18 175 (26.0)	51 852 (74.0)	<0.0001	2879 (37.1)	4875 (62.9)	<0.0001
Age (mean, SD)	46.2 (20.1)	52.4 (22.0)	44.1 (18.9)	<0.0001	50.1 (21.8)	42.9 (19.7)	<0.0001
ISS (median, IQR)	13 (9–22)	13 (9–22)	13 (9–24)	<0.0001	17 (9–27)	19 (10–29)	<0.0001
Driver of vehicle (%)	16 600	5132 (30.9)	11 468 (69.1)	<0.0001	1623 (31.9)	3471 (68.1)	<0.0001
Systolic blood pressure (mean, SD)	133.3 (28.0)	133.1 (30.2)	133.4 (27.2)	0.361	128.7 (30.7)	129.5 (30.9)	0.309
Heart rate (mean, SD)	86.7 (22.2)	87.9 (21.9)	86.2 (22.3)	<0.001	91.2 (24.2)	92.1 (26.3)	0.185
Respiratory rate (mean, SD)	20.3 (6.9)	20.3 (6.7)	20.3 (7.0)	0.833	21.3 (7.3)	21.5 (8.2)	0.207
Oxygen saturation (mean, SD)	96.1 (7.9)	96.2 (7.3)	96.0 (8.0)	0.001	97.4 (5.9)	97.3 (5.9)	0.544
GCS (median, IQR)	15 (15–15)	15 (15–15)	15 (15–15)	n/a	15 (1415)	15 (14–15)	n/a
Alive at 30 days (n,%)	66 159 (94.5)	17 084 (94.0)	49 075 (94.6)	0.001	2657 (92.3)	4396 (90.0)	0.01

GCS, Glasgow Coma Scale; IQR, Interquartile range; ISS, injury severity score; SD, Standard Deviation.

DISCUSSION

This is the largest analysis to date of sex-disaggregated data for patients with trauma following an MVC and confirms significant differences in injury patterns and trapped status between female and male patients.

The explanations for these differences are likely to include both reasons pertaining to biological sex, for example, physical size, muscle mass, hormonal differences and reasons pertaining to gender such as driving behaviours, postcollision behaviours and responses by emergency responders such as decisions related to extrication.

Female patients in this analysis had a lower ISS and tended to be older than male patients. These differences were more apparent in those patients who were trapped. The recorded physiological observations are broadly similar between sexes.

There are gender-related differences that may contribute to the observed differences. Men drive more miles, faster, in a riskier manner and more frequently have accidents, resulting in the higher injury burden and mortality as seen in this analysis and elsewhere.[10–13] Women make up a higher proportion of older drivers.[14] Older women are more likely than men of equivalent age to be killed or seriously injured in collisions, after controlling for miles driven; whereas young men have the highest risk of serious injury or death per million miles driven.[11]

Trapped male patients were more likely to have severe injuries of the head, face, chest (including tension pneumothorax) and limbs, with female patients more likely to have injuries of the vertebrae, spinal cord and pelvis. No statistically significant differences were found between trapped female and male patients in relation to pelvic ring injuries with blood loss, multiple spinal fractures or abdominal injuries.

Differences in injuries may be accounted for by (1) differences in car usage, kinematics and mechanism of injury (MOI) and (2) differences in effectiveness and availability of safety systems and (iii) differences in biological propensity to certain injury types.

Difference in kinematics and resultant MOI

An analysis of the UK-based STATS V.19 MVC registry demonstrates that male drivers are more likely to have MVCs while travelling forwards (64.2% vs 56.5%), whereas female drivers are more likely to have collisions while manoeuvring (16.1% vs 11.9%) or turning (10.7% vs 8.4%). Similar findings are reported in the USA, with female patients more likely to be involved in a side impact MVC and male patients more likely to have a frontal impact.[15] Side impact MVCs result in a transfer of energy to the patient who is more likely to cause significant spinal injury.[16] Side impacts are also a common cause of lateral compression fractures of the pelvis,[17 18] which may explain the finding of an increased prevalence of these injuries in female patients. It is rare for lateral compression fractures of the pelvis to be associated with significant

Table 2 Significant injuries by sex for trapped casualties

	Female	%	Male	%	P value
Pelvic ring fracture with blood loss >20%	23	0.8	48	1.0	0.394
Blood loss >20% (%)	114	4.0	161	3.3	0.139
Tension pneumothorax (%)	26	0.9	92	1.9	<0.0001
Multiple spinal fractures (%)	429	14.9	649	13.3	0.54
Dens fracture (%)	85	3.0	79	1.6	<0.0001
Spinal compression fracture grade 2/3 (%)	66	2.3	75	1.5	0.022
Unstable spinal fracture (%)	276	9.6	441	9.0	0.43
Spinal cord injury (%)	218	7.6	308	6.3	0.038

Injuries are not mutually exclusive; patients may have more than one qualifying injury.

bleeding, which perhaps accounts for the higher rate of pelvic fractures in female patients but not a high rate of pelvic fractures with significant blood loss.[19]

Male patients experience a higher rate of frontal collisions, which may account for the increased rate of head, face and chest injury found in this study, through interactions and resultant energy transfer with the steering wheel and/or air bag.[20 21] The higher rate of male drivers and their interactions with the pedals and the 'bracing' experienced by drivers precollision may explain the higher rate of limb injury seen in male patients in this study.[22 23]

Differences in availability and effectiveness of safety systems

Safety systems are less effective for passengers than drivers and are optimised to minimise energy transfer from frontal collisions.[22 24 25]

It has been previously demonstrated that women are more likely to be compliant with safety systems such as seat belts than men and as a result have less risk of multiple and severe injuries and their associated mortality.[26 27] However, the safety features incorporated in modern cars are less likely to be effective for women. Current mandatory crash testing uses a scaled down 50th centile male mannequin to represent 5th percentile females and are not modelled to account for anthropometric differences between women and men.[28–31] This systemic bias, with cars developed, tested and safety-rated using primarily an anatomically correct, weighted and biomechanically-matched male mannequin has led to the development of safety systems, which are likely to be more effective for men than women. For example, whiplash protection systems are significantly more effective at preventing injury in men than women.[29 32] Comparison of female and male dummies demonstrates higher biomechanical response in the female dummy in the neck region which may offer some explanation for the increased rate of spinal fractures in female patients found in our study.[33]

Moreover, female patients are more likely to drive and be injured in smaller cars, with less efficient safety systems. Smaller cars are associated with a greater injury burden and may account for some of the sex-related differences seen in this study.[34]

Table 3 Injury site by sex for trapped casualties

	Female	%	Male	%	P value
Head AIS 3+	578	20.1	1318	27.0	<0.0001
Face AIS 3+	6	0.2	46	0.9	<0.0001
Thoracic AIS 3+	1438	49.9	2721	55.8	<0.0001
Abdomen AIS 3+	355	12.3	595	12.2	0.87
Spine AIS3+	359	12.5	485	9.9	0.001
Pelvic AIS 3+	420	14.6	475	9.7	<0.0001
Limb AIS 3+	778	27.0	1744	35.8	<0.0001

Injuries are not mutually exclusive; patients may have more than one qualifying injury.
AIS, abbreviated injury scale.

Female patients are biologically prone to certain injury types

The intersection of age, biological differences, female propensity to injury and medical conditions such as osteoporosis may further account for some of the differences in injuries seen in this analysis.[35] Women and men differ physically in ways that are pertinent to injury and entrapment in RTCs. They each have unique anthropometry for example: women have wider pelvic measurements and shorter torsos, even controlled for height difference.[36] As such, female pelvic geometry may be more prone to injury following a side impact.[37] A combination of these factors may explain the differences seen in injury patterns in this study; we found a greater proportion of pelvic fractures in women and a higher rate of head and chest injury in male patients.

Sex hormones affect body composition. Testosterone contributes significantly greater skeletal muscle mass (8% greater, after correcting for Body Mass Index) in men, which does not start to fall until the fifth decade.[38] Female sex hormones are responsible for ligaments in women being more lax, which combined with women's cervical vertebrae being smaller than men of equivalent head size, which may explain the greater rate of spinal cord injury in women.[39 40] Postmenopausal changes in bone composition mean that women have a 50% greater loss of bone in

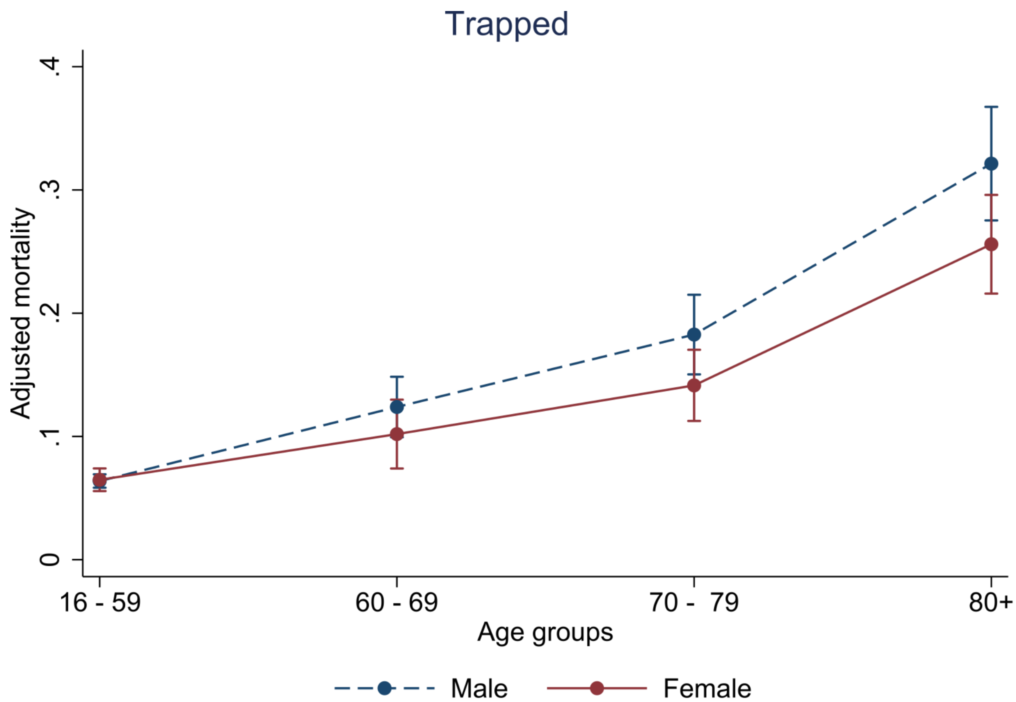

Figure 2 Adjusted mortality and age. Error bars=95% CIs.

old age compared with men, again making them susceptible to fractures as a result of MVC.[35]

Female patients were more likely than male patients to be trapped (15.8 vs 9.4%, p<0.0001). The mean age of trapped female patients was significantly higher than trapped male patients; this may influence their own ability to self-extricate due to frailty or relative immobility.[41] An additional possible explanation may include different treatment by rescuers, for example, perhaps being less likely to recommend or facilitate self-extrication for older women. Females are more likely to sit closer to the steering wheel, meaning that less movement intrusion of the dashboard and steering wheel is required to cause entrapment.[42] Furthermore, this study found that female patients are more likely to have injuries of the pelvis and spine, and these injuries may prevent self-extrication and increase the frequency of entrapment.

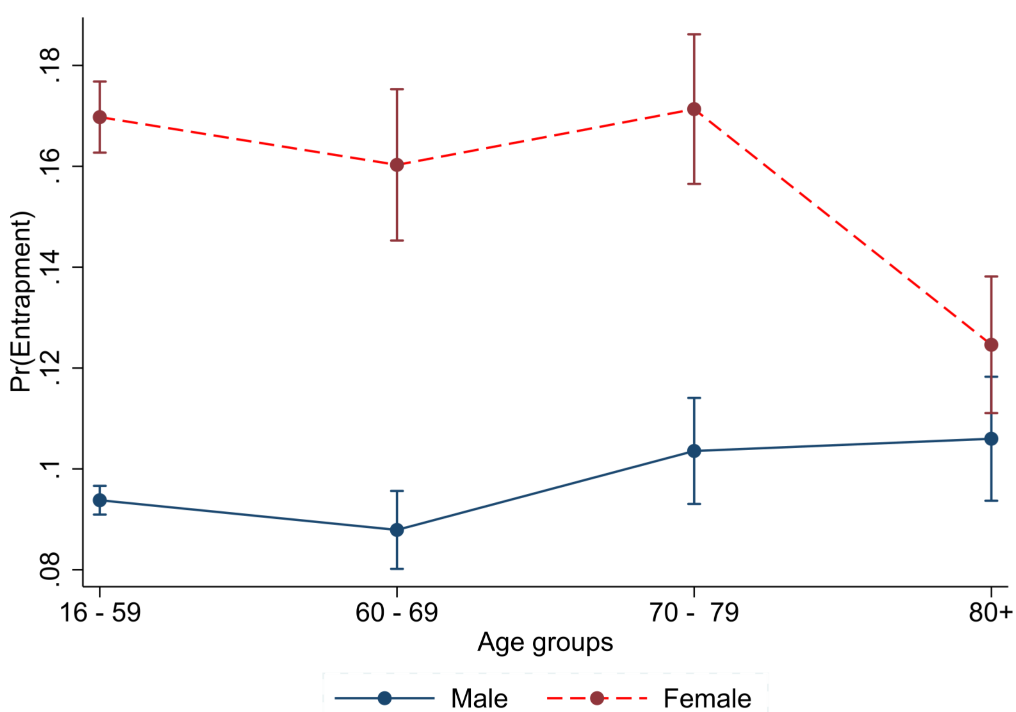

Figure 3 Probability of entrapment and age. Error bars=95% CIs.

Postcollision behaviour and patient experience differences between female and male patients may contribute to the increased rate of entrapment in women, who are more likely to experience multiregion and widespread pain following an MVC, which may prevent them leaving the vehicle without assistance.[43] TARN does not record whether a patient was physically trapped by vehicle deformation or medically trapped (eg, by pain), which prevents further analysis within this dataset.

Trapped female patients had a lower ISS than trapped male patients and were less likely to die (7.7% vs 10.0%). However, once the factors in our model were considered (age, sex, ISS, GCS and Charlson Comorbidity Index), no difference in mortality was found between female and male patients (figure 2).

This study shows that men and women experience different rates of entrapment and different injury patterns when involved in MVCs. This may have implications for the design of car safety systems, so as to protect men and women equally. Likewise, for prehospital clinicians, this work highlights the differences seen in clinical practice when attending MVCs.

The higher rate of female entrapment seen may in part be explained by this cohort being older and having greater comorbidity. Current UK extrication dogma still prioritises ‘spinal precaution’ methods of extrication that involve the patient being passive in the process. A greater focus on self-extrication as a safe alternative to rescue service-assisted extrication may in future reduce the number of medically trapped patients.

Not all patients trapped in an MVC were included in this study due to the TARN inclusion criteria. Of note, prehospital deaths from the most severe MVCs are not included, nor were patients who received minor injuries but were physically trapped by mechanical deformation of the vehicle. This study was unable to distinguish entrapment due to medical causes (eg, pain or relative immobility) from physical entrapment due to vehicle deformity, which implies a greater energy transfer collision. This analysis did not discriminate between the type of vehicle (eg, car or bus/coach or light/heavy goods vehicle) and includes all occupants of vehicles involved in an MVC, which is a heterogeneous group. The ‘trapped’ status recorded on TARN has high data completeness with only 2.4% of patients having this element missing; the route of completion varies between centres but is normally taken from the ambulance service patient report form. The ‘trapped’ definition is open to interpretation and cannot distinguish between type and mode of entrapment. These limitations may hinder our interpretation of trapped status.

CONCLUSIONS

Male patients are more severely injured and more likely to die as a result of MVC than female patients. Female patients under 80 are more frequently trapped than male patients. Female patients are more likely to have spinal and pelvic injuries and male patients are more likely to have head, face, thoracic and limb injuries. Differences in driving behaviours, kinematics, collision type, position in vehicle, the efficacy of safety systems, biological vulnerability to certain injury types and postinjury behaviour may all have influence on these patterns.

Sex-disaggregated data on mortality, entrapment and injury patterns in motor vehicle collisions may help to inform vehicle manufacturers, emergency services personnel and road-safety organisations to tailor responses with the aim of equitable outcomes by targeting equal performance of safety measures and reducing excessive risk to one sex or gender. Future work should include appropriate sex-based and gender-based analyses designed to shed light on the biological and sociocultural factors that create differential experience and outcomes for women and men involved in MVCs.

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Acknowledgements We would like to thank TARN and the TARN research committee for their support. Thank you to Caroline Leech who provided feedback on an early draft of the manuscript.

Contributors TN, LW, SH, RF, JS and WS contributed to the conception and study design, analysis and interpretation of data, drafting and revising the manuscript. OB contributed to the analysis and interpretation of the data and critically revised the manuscript. All authors read and approved the final manuscript. TN is the guarantor of this paper.

Funding Publication costs were funded by a charitable grant from the Road Safety Trust (award/grant number NA). The Road Safety Trust had no role in the design, data collection, analysis or writing of this manuscript.

Competing interests None declared.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not applicable.

Ethics approval TARN data analyses are conducted using anonymised data, which are governed by a code of practice approved by the Confidentiality Advisory Group who are appointed by the Health Research Authority. Additional individual ethical approval was not required for this analysis.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information. Additional data relevant to this study are available in the supplementary file. The original dataset used in this study is available from TARN.

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those

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