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Major trauma and urban cyclists: physiological status and injury profile

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ABSTRACT

Introduction Pedal cycling in cities has the potential to deliver significant health and economic benefits for individuals and society. Safety is the main concern for potential cyclists although the statistical risk of death is low. Little is known about the severity of injuries sustained by city cyclists and their outcome.

Aim The aim of this study was to characterise the physiological status and injury profile of cyclists admitted to our urban major trauma centre (MTC).

Methods Database analysis of cyclist casualties between 2004 and 2009. The physiological parameters examined were admission systolic blood pressure (SBP), admission base deficit and prehospital Glasgow Coma Scale.

Results 265 cyclists required full trauma-team activation. 82% were injured during a collision with a motorised vehicle. The majority (73%) had collided with a car or a heavy goods vehicle (HGV). These casualties formed the cohort for further analysis. Cyclists who collided with an HGV were more severely injured and had a higher mortality rate. Low SBP and high base deficit indicate that haemorrhagic shock is a key feature of HGV casualties.

Conclusion Collision with any vehicle can result in death or serious injury to a cyclist. Injury patterns vary with the type of vehicle involved. HGVs were associated with severe injuries and death as a result of uncontrollable haemorrhage. Awareness of this injury profile may aid prehospital management and expedite transfer to MTC care. Rapid haemorrhage control may salvage some, but not all, of these casualties. The need for continued collision prevention strategies and long-term outcome data collection in trauma patients is highlighted.

INTRODUCTION

Pedal cycling in cities has the potential to deliver significant health and economic benefits for individuals and society.[1] An increasing number of people cycle as a means of urban transportation.[2 3] Pedal cyclists are however considered to be vulnerable road users.[4] Vulnerable road users currently account for 46% of global road traffic deaths.[4] WHO estimate that, by 2020, road traffic incidents will be the leading cause of death worldwide.[4 5] Reducing these incidents is a key priority in many countries.[4 5] Promotion of cycling is an important part of this strategy. Safety should improve as the cyclist population grows; however, the absolute number of urban cyclist casualties may increase.[1]

From a national perspective, cycling in Great Britain is a low risk activity with lower casualty rates than motorcyclists or pedestrians (an average of 34 cyclists are killed and 646 are seriously injured per billion kilometres travelled per year).[6 7] Cyclist injury patterns, however, vary between seasons and are influenced by the road environment.[8 9] In London, the relative risk per individual journey is falling but evidence still suggests that it presents a hostile environment for cyclists.[2 3 10 11] In 2009, 13 fatalities, 398 serious injuries and 2998 slight injuries were reported for cyclists following collision with a motor vehicle on London's roads.[3] London cyclists represented around 13% of all deaths and 15% of all 'killed or seriously injured' cyclist casualties reported in Great Britain during that year.[3 7] The majority of cyclist collisions in London occur during commuting times (08:00–09:00), within 20 m of a junction and on roads with a 30 mph speed limit.[3] Heavy goods vehicles (HGVs) have consistently been implicated as a cause of death for cyclists in London, particularly when turning left at a junction.[2 3 10 11]

Collision between cyclists and motor vehicles is a preventable cause of morbidity and premature mortality. In London, the annual casualty figures have been considered in previous reports but the relatively small number of fatalities do not fully illustrate the risks for London's cyclists.[2 3 7 10–12] A wide spectrum of injury severity may be encompassed within a description of 'seriously injured'. This larger group of cyclist casualties has not previously been considered due to the limitations of available datasets.[2 3 7 10–12] The safety and survival of cyclists involved in collisions may be improved by a greater understanding of their injury profile. In addition, survival after traumatic injury does not always guarantee return to full function. Greater understanding of the outcomes for cyclists who survive motor vehicle collisions may alter the perspective of cyclist risk in London and aid injury prevention strategies. The purpose of this study was to characterise the injury profile of adult cyclists admitted to our urban major trauma centre (MTC). Our primary objective was to describe the physiological status of cyclist casualties at admission. We then wished to examine the spectrum and severity of injury in this population and their outcome. A retrospective database analysis was conducted.

METHODS

The Royal London Hospital (RLH) is an urban MTC and the base for the London Helicopter Emergency Medical Service (HEMS). Over 2000 adult patients require full trauma-team activation per annum, of which a quarter are graded as injury severity score (ISS) >15.[13] A contemporaneous trauma registry of all trauma-team activations is used to facilitate quality improvement. Patients who independently present to the accident and emergency department with minor injuries are not included in this dataset. Details from the whole patient pathway are recorded including prehospital data, admission physiology, abbreviated injury scores (AISs), interventions, processes of care and outcomes. Quality improvement infrastructure includes fortnightly multidisciplinary trauma Mortality and Morbidity meetings and monthly, consultant-based peer-review. A retrospective analysis of the trauma registry was conducted. All adult cyclists admitted between 1 January 2004 and 31 December 2009 were identified. Information omitted from the database was obtained from the medical notes.

A cyclist injured during a collision with an HGV is a criterion for automatic deployment at The London HEMS. Cyclist casualties following car collisions are attended if the injuries are severe or the London Ambulance Service crew request assistance. Data were sought from the HEMS database concerning the transfer destination for their cyclist missions during the study period.

The physiological parameters selected for analysis were the admission systolic blood pressure (SBP) measurement, the admission base deficit (BD) and the prehospital Glasgow Coma Scale (GCS). Admission vitals were selected because scene times are influenced by the need for medical intervention or extrication; they are, in the main, already minimised. Surgical intervention can only be provided in hospital; therefore, the physiological status of patients at admission influences their outcome. Prehospital GCS was selected to describe early neurological status and indicate the presence of traumatic brain injury because many of the severely injured patients were given a general anaesthetic at the scene. BD was used to define hypoperfusion and circulatory shock.[14 15] The normal range of BD in our laboratory is −2 to 2 mmol/l. The ISS and AIS were used to describe the severity of cyclist injuries.[13] Where SBP measurements were documented as ‘unrecordable’, ‘<90’ or ‘radial’, proxy values of 10 mm Hg, 60 mm Hg and 90 mm Hg were assigned, respectively. Unless stated, data are presented as median with IQR. Statistical significance was tested using Mann−Whitney U test, Students t test, Wilcoxon, Fishers or χ^2 tests as appropriate and $p<0.05$ denoted significance.

RESULTS

During the 6-year study period, a total of 281 cyclists were admitted to the RLH. The annual workload increased year on year but cyclist casualties consistently represented about 4% of the total number of patients requiring full trauma-team activation (281/7003 patients). During the same period, London HEMS attended 305 cyclists, which represented 3% of their deployed missions (305/8852). Twenty-one (7%) cyclists were declared dead at the scene. Of those alive at scene, 133 (47%) cyclist casualties were transferred to the RLH and 151 (53%) were transferred to one of eight other London hospitals. In addition, 148 cyclist casualties were transported to the RLH by the London Ambulance Service.

Within the RLH cohort, 265 casualties were received directly from the scene and 16 were transferred to us from other hospitals. The 265 primary admissions formed our cohort for this analysis (figure 1, table 1). The average (SD) age was 35 (11) and 77% were male subjects. The most frequent times of admission were 10:00 h and 18:00 h, consistent with the recognised peak of casualties during times of commuter travel.[3] The median time from injury to admission was 76 min (54−86).

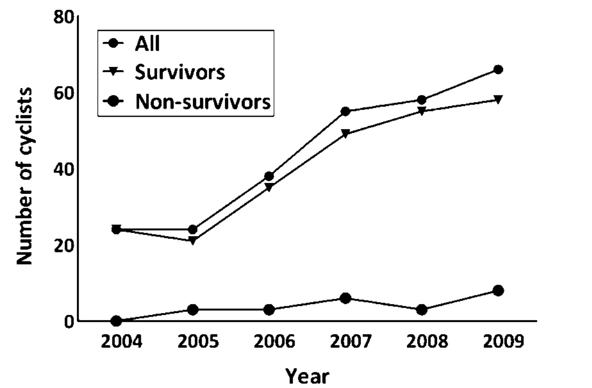

Figure 1 Annual totals for cyclist casualties requiring full trauma-team activation and the outcome. The total number of cyclists admitted to our hospital increased year on year. A small proportion of cyclists die as a result of their injuries. Casualty numbers per year (total, survivors, non-survivors): 2004 (24, 24, 0), 2005 (24, 21, 3), 2006 (38, 35, 3), 2007 (55, 49, 6), 2008 (58, 55, 3) and 2009 (69, 58, 8).

Two hundred and seventeen cyclists (82%) were admitted with injuries sustained during a collision with a motor vehicle; 194 (73%) of these collisions involved a car or an HGV. We therefore elected to focus on these categories for further analysis stratifying the characteristics of physiology and injury severity by survival (tables 2 and 3).

Physiology

Cyclists injured by a collision with an HGV had significantly lower SBP on admission than casualties injured by a car (HGV: 118 mm Hg (90−139), car (C): 135 mm Hg (120−150) $p<0.001$). In the car cohort, there was no demonstrable difference in admission SBP between survivors (S) and non-survivors (NS) (figure 2A). By contrast, non-survivors, in the HGV cohort, had significantly lower blood pressure than survivors (S: 120 mm Hg (98−141), NS: 10 mm Hg (10−78), $p<0.001$). An ‘unrecordable’ SBP was reported for two patients (<1%) in the car cohort and seven patients (10%) in the HGV cohort (table 4).

A raised admission BD was found in 16 (11%) of the car casualties and 28 (54%) of the HGV casualties. The severity of shock was more pronounced in the HGV cohort (HGV: 6.5 mmol/l (1.9−10.4), C: 0.3 mmol/l (−1.2 to 1.7), $p<0.001$).

Table 1 Demographics of all cyclist casualties requiring full trauma-team activation at The Royal London Hospital during the 6-year study period

	Total
Number	265
Age*	35 (11)
% Male	77
Mortality n (%)	23 (9)
% Injured by motor vehicle collision	82
Mode of injury n (%)	
Car or small van	142 (54%)
HGV	52 (20%)
No second party involved	41 (15%)
Bus or tram	15 (6%)
Motorcycle	8 (3%)
Other cyclist	5 (2%)
Pedestrian	2 (<1%)

*Average (SD), n = number, % percentage of total cohort.
HGV, heavy.

Table 2 Cyclists involved in collisions with a car or heavy goods vehicle (HGV)

	Car	HGV	p Value
Number	142	52	–
Age*	35 (11)	34 (11)	0.38
% Male	85	52	<0.001
Physiology†			
SBP	135 (120 to 150)	118 (90 to 139)	<0.001
Base deficit	0.3 (−1.2 to 1.7)	6.5 (1.9 to 10.4)	<0.001
GCS	15 (14 to 15)	15 (14 to 15)	0.61
Injury severity			
% ISS≥15	20	42	<0.001
ISS†	5 (1 to 10)	9 (4 to 28)	<0.001
Outcome			
LOS†	1 (0 to 6)	8 (1 to 24)	<0.001
Mortality n (%)	8 (6%)	11 (21%)	<0.001

*Average (SD).
†Median (IQR), % of the injury category, p values determined by Mann–Whitney U tests or χ^2 tests.
GCS, Glasgow Coma Scale; ISS, injury severity score; LOS, length of stay; SBP, systolic blood pressure.

Survivors in the HGV group had higher BDs than survivors from the car group (HGV: 4 mmol/l (1.4–7.6), C: −0.4 mmol/l (−1.3 to 1.1), p<0.001). An elevated BD was a feature in 18 (95%) of the non-survivors, regardless of the vehicle involved (figure 2B and table 4).

No statistical difference in scene GCS was found between the two cohorts (table 2). Among the survivors, a scene GCS of ≤12 occurred in 16 patients (11%) following car collision and two (4%) following HGV collision. Non-survivors in both cohorts had a lower prehospital GCS than survivors (figure 2C) (C: S=15 (14–15), NS=6 (3–10); HGV: S=15 (15–15), NS=13 (5–15), p<0.001).

Table 3 Survivor demographics

	Car	HGV	p Value
Number	134	41 (79%)	–
Age*	35 (11)	34 (10)	0.45
Physiology			
SBP			
≥90	131 (94%)	37 (71%)	0.053
<90	3 (2%)	4 (8%)	0.053
Unrecordable	0	0	–
Base deficit			
All†	−0.4 (−1.3 to 1.1)	4 (1.4 to 7.6)	<0.001
≤2 mmol/l (n)	126	23	<0.001
2.1–6 mmol/l (n)	6	11	<0.001
>6 mmol/l (n)	2	7	<0.001
GCS			
15–13	118	39	0.08
12–10	3	2	0.08
9–6	6	0	0.08
<6	7	0	0.08
Injury severity			
% ISS≥15	17	29	0.29
ISS†	4 (1 to 9)	9 (4 to 18)	0.03
AIS head	0 (0 to 2)	0 (0)	0.03
AIS face	0 (0 to 1)	0 (0)	0.34
AIS chest	0 (0)	0 (0 to 2)	0.33
AIS abdo pelvis	0 (0)	0 (0 to 2)	0.01
AIS extremity	1 (0-2)	2 (1 to 3)	<0.001
AIS external	0 (0)	0 (0)	0.94
Outcome			
Length of stay†	1 (0 to 7)	12 (6 to 26)	<0.001
Home	126 (89%)	33 (63%)	0.01
Transferred	8 (6%)	8 (15%)	0.01

*Average (SD).
†Median (IQR), % percentage of the total cohort, p values determined by MWU, χ^2, Fishers or Wilcoxon Rank.
AIS, abbreviated injury score; GCS, Glasgow Coma Scale; HGV, heavy goods vehicle; ISS, injury severity score; MWU, Mann–Whitney U test; SBP, systolic blood pressure.

Injury severity and regions of injury

Cyclists involved in a collision with an HGV were more severely injured than cyclists who collided with a car (ISS HGV: 9 (4–28), C: 5 (1–10), p<0.001). ISS between 0 and 3, implying no injury or relatively minor injury, were reported for six (12%) of the HGV cohort and 52 (37%) of the car cohort. ISS >15, denoting severe to critical injury, was reported for 23 (42%) patients in the HGV cohort and 29 (20%) patients in the car cohort. Non-survivors had higher injury severity regardless of mode of injury (figure 3).

Analysis of the anatomical regions of injury (AIS) suggested that the vehicle involved influenced the injuries sustained by cyclists. Survivors in the HGV cohort had more severe injuries to the abdomen, while survivors in the car cohort had more severe head injuries. The most substantial difference between the two cohorts, however, was the severity of injuries to the extremities and bony pelvis (AIS extremity) (table 3). For non-survivors, the injuries to the chest and bony pelvis (extremity) were more severe in the HGV cohort than the car although this did not reach statistical significance (table 4).

Outcome

The number of fatalities within the whole cyclist cohort was 23 (9%). During the study period, the mortality for our entire trauma patient population was 7% (485/7003). Cyclist casualties comprised 5% of our total mortality (23/485). A higher mortality rate was observed in the cyclists injured by HGV collision (11 patients, 21%) compared with those injured by car collision (eight patients, 6%). Of the non-survivors in the HGV cohort, nine out of 11 died shortly after admission. In the car non-survivors, four of the eight also died on the day of admission, four spent 1–8 days in intensive care before death. Mortality and Morbidity review determined that most deaths were unpreventable due to the severity of injuries sustained. For two patients, following HGV collision, the injuries would have been amenable to surgical control. Peer review questioned whether expedited delivery to theatre may have potentially altered outcome.

Outcome for survivors varied with the vehicle involved. In the car cohort, 134 patients (94%) survived and 126 (94%) were sent home from our hospital. The remaining eight (6%) survivors required transfer to another medical facility. In the HGV cohort, 41 (79%) survived but only 33 (80%) patients in the HGV group were discharged home. Eight (20%) required transfer to another medical facility for further medical care or rehabilitation (table 3).

DISCUSSION

In this single centre study, over a 6-year period, we have demonstrated that cyclist casualties form a consistent proportion of our adult trauma admissions. The number of cyclist admissions is increasing annually and this may be related, in part, to the increasing population of cyclists in London.[1 3] Injury following collision with a motor vehicle was the reason for admission in 82% of cases. Cars and HGVs were the vehicles most frequently involved. Our cyclist admissions were a heterogeneous group of young trauma patients with a wide

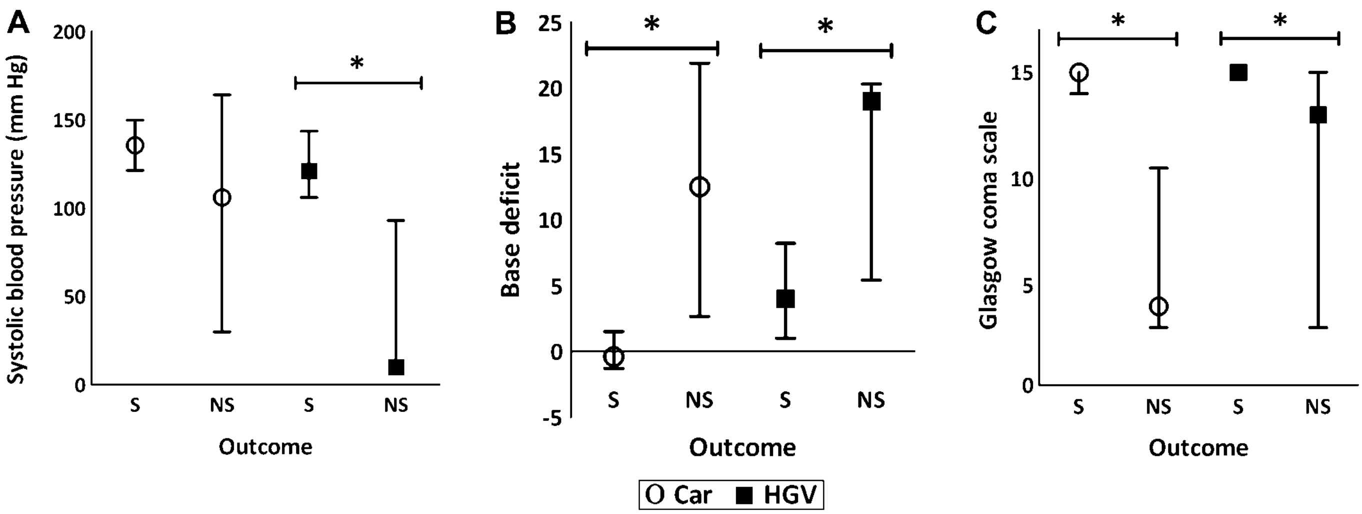

Figure 2 Admission physiology of cyclist casualties. Admission physiology and scene Glasgow Coma Scale (GCS) were examined according to mode of injury. Data presented are medians with IQR and * denotes $p<0.05$. Survivor (S) vs non-survivor (NS) in the same injury category using Mann–Whitney U test. A: Systolic blood pressure (SBP) on admission to the emergency department. SBP for cyclists injured after collision with a car did not differ between survivors and non-survivors. Low blood pressure was a significant feature of non-surviving cyclists hit by heavy goods vehicles (HGVs). Car: S=132 mm Hg (116–146), NS=83 mm Hg (48–122); HGV: S=120 mm Hg (98–141), NS=10 mm Hg (10–78). B: Base deficit (BD) on admission to the emergency department. Most survivors in the car cohort had a normal BD. Non-survivors had a significantly raised BD indicative of hypoperfusion. Most HGV casualties had a raised BD suggesting that shock was a prominent feature in this cohort. Non-survivors in both groups had more severe shock at admission. Car: S=−0.4 mmol/l (−1.3 to 1.1), NS=12.5 mmol/l (4.6 to 20.3); HGV: S=4.0 mmol/l (1.4 to 7.6), NS=19.0 mmol/l (11.0 to 19.9). C: GCS at the scene of collision. Survivors from both groups had a normal GCS at scene. Non-survivors in both groups had significantly reduced GCS at scene. Car: S=15 (14–15), NS=6 (3–10); HGV: S=15 (15–15), NS=13 (5–15).

Table 4 Non-survivor demographics

	Car	HGV	p Value
Number (%)	8 (6%)	11 (21%)	–
Age*	41 (12)	35 (15)	0.38
Physiology			
SBP mm Hg			
≥90	4	3	0.38
<90	2	1	0.38
Unrecordable	2	7	0.38
Base deficit			
All†	12.5 (4.6–20.3)	19 (11.0–19.9)	0.68
≤2 mmol/l n (%)	0	1	0.90
2.1–6 mmol/l n (%)	2	1	0.90
>6 mmol/l n (%)	6	9	0.90
GCS			
15–13	1	6	0.06
12–10	2	0	0.06
9–6	1	2	0.06
<6	4	3	0.06
Injury severity			
% ISS≥15	88	100	0.16
ISS†	33 (23–45)	36 (33–40)	0.56
AIS head	3 (1–4)	0 (0–3)	0.42
AIS face	0 (0)	0 (0)	1.0
AIS chest	4 (0–5)	5 (0–5)	0.76
AIS abdo pelvis	0 (0–1)	2 (0–2)	0.77
AIS extremity	2 (0–4)	5 (3–5)	0.13
AIS external	0 (0)	0 (0)	–
Outcome			
Length of stay†	1 (0–1)	0 (0)	0.38

*Average (SD).
†Median (IQR), p values determined by MWU, χ^2, Fishers or Wilcoxon Rank.
AIS, abbreviated injury score; GCS, Glasgow Coma Scale; HGV, heavy goods vehicle; ISS, injury severity score; MWU, Mann–Whitney U test; SBP, systolic blood pressure.

spectrum of injury severity. In keeping with previous reports, female patients appear to be over-represented in our cohort of HGV casualties (male subjects 27, female subjects 25) but the reasons for this remain unclear.[2 10 11] During the study period, the RLH was the principal trauma centre for London, as the London regional trauma system was not implemented until 2010. It can be assumed that, as a single institution, the RLH received the greatest volume of cyclist casualties in the area. We therefore have a unique dataset from which we can describe the injury profile of cyclist casualties.

Through the analysis of admission physiology and injury severity of cyclists following collision with a car or an HGV, characteristic patterns emerged. Cyclist casualties following collision with a car were more numerous. The higher AIS head scores suggest that traumatic brain injury may be more commonly associated with car collision. Most cyclists admitted after collision with a car survived. A few needed longer term medical care. Collision with an HGV was characteristically associated with severe torso injuries coupled with severe haemorrhage. Six of the 11 (55%) HGV non-survivors had a GCS of 13–15 at the scene suggesting that head injury was not the main cause of death in this cohort. Death was frequently attributed to exsanguination and survival was dependent upon the ability to gain surgical haemorrhage control. The mortality rate of our cyclists injured by HGVs (21%) suggests that these cyclist casualties comprise some of our most severely injured admissions. In the HGV survivors, the longer length of stay and higher rate of transfer suggest that this cohort can have complex medical problems requiring longer term care. Our study suggests that the injury profile of a cyclist casualty is influenced by the motor vehicle involved in the collision. Further investigation of this finding is warranted, as results may inform urban transport strategies.

Injuries to pedal cyclists have been reported in several countries with some variation between settings.[16–19] Within the UK,

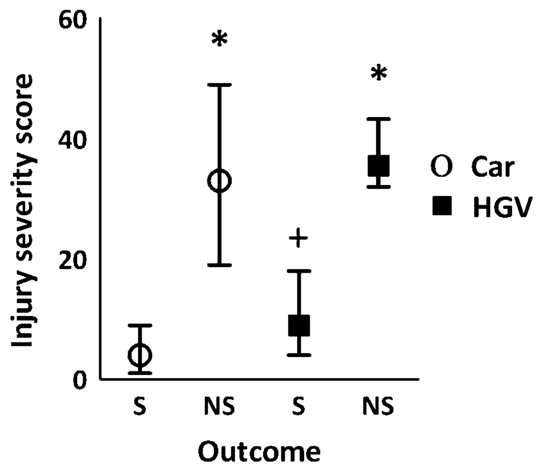

Figure 3 Injury severity of cyclists injured by collision with a car or a heavy goods vehicle (HGV). Injury severity scores for each mode of injury were compared. Most of the cyclists injured by a collision with a car sustained minor or moderate injuries. HGV survivors (S) had more severe injuries than car survivors. Non-survivors (NS) were more seriously injured than survivors in both categories. Data are presented as median with IQR. Car: S=4 (1–9), NS=33 (23–45); HGV: S=9 (4–18), NS=36 (33–40). * Denotes $p<0.05$ S vs NS, + denotes $p<0.05$ S vs S using Mann–Whitney U tests.

previous reports have used large datasets such as Hospital Episode Statistics, police collision statistics (STAT19) and coroners' reports.[2 3 7 8 10–12] All have recognised limitations but document the numbers of casualties robustly. HGVs in particular have been consistently identified as a significant cause of mortality to cyclists but the reasons for this remain unclear.[2 10 11] Our study demonstrates that the cause of death following collision with an HGV is frequently exsanguination.

Severe haemorrhage is a common cause of death after traumatic injury.[20] It carries a high mortality but death is frequently preventable if appropriate treatment is delivered.[21–24] In the event of serious injury, survival can be maximised by the provision of excellent trauma care.[25] In our sample, the median time to admission was 76 min. Recognition of the high risk of haemorrhage in severely injured cyclists and expedited transfer to a MTC for surgical haemorrhage control may increase survival in some cases. Survival, in itself, however, does not equate to insignificant injury and a return to normal function. Cyclist casualties are young and in order to determine the full impact of cyclist injury on London we need to consider their long-term outcome.[22] Outcome data are currently unavailable but, the staff in the Trauma Outcomes Core, at the RLH, are working to address this deficit.[22] A large number of cyclists are 'seriously injured' in London every year.[3 7] Improved outcome data about the quality of life for survivors may alter our perspective of what 'seriously injured' means on an individual level. When combined with loss of earnings and the cost of medical care, the overall impact of cyclist casualties on society can be better calculated.

This study carries the inevitable limitations of a single centre, retrospective study. Our cyclist population may be biased towards a severe minority. Alternatively, the RLH may be the only UK hospital with sufficiently robust trauma data collection to be able to describe this casualty population in any detail. Our cyclist population had a wide spectrum of injury severity and most cyclists (90%) survived their collision. In this study, we have illustrated that the injuries sustained by cyclists and their physiological state on admission to hospital are influenced by the vehicle with which they collide. It is highly likely that these findings are applicable to any busy city where cyclists and motor vehicles share road space. ISS, a composite anatomical score, was used to describe injury severity, but it can be misleading. It correlates with the risk of death, not tissue damage; therefore, injuries with low scores can still result in long-term disability. The study period of 2004–2009 was chosen because the system delivering trauma care in London was restructured in 2010. It therefore does not take account of the initiatives implemented by Transport for London aimed at improving cyclist safety.[3] Absence of data on long-term outcomes is the greatest limitation, as our follow-up currently finishes at discharge. Despite these issues, our data go some way towards completing a gap in our knowledge and understanding of cyclist casualties. The risk of injury from motorised vehicles remains a major deterrent for potential cyclists.[1 3 26] This has sometimes been described as a perceived danger rather than an actual danger as statistically the risk of death is low.[3 12 26] Death, however, is not the only relevant outcome for this population of trauma patients. If urban residents in the UK are to be encouraged to cycle, then reducing the risk of collision with motorised vehicles remains an urgent priority. Infrastructure which separates bicycles and motorised vehicles is seen, by many, as the most effective way of reducing cyclist casualties.[27]

CONCLUSION

Annually, collision between cyclists and motor vehicles in London results in a small, but significant, number of preventable premature deaths and a larger number of serious injuries.[2 3] Pedal cyclists are a consistent feature of the adult admissions requiring full trauma-team activation at our MTC. They form a heterogeneous group of casualties with diverse injury patterns. Injury pattern, however, does appear to be influenced by the vehicle involved in the collision. Collision with an HGV results in a characteristic presentation of severe torso injuries, high levels of consciousness at scene and severe haemorrhagic shock. Survival depends upon the ability to obtain haemorrhage control in addition to the overall injury severity. Although the immediate management priorities for these severe casualties remain unchanged, awareness of the injury profile may expedite delivery to a MTC for haemorrhage control and potential salvage.[3 28 29] In many cases, however, injury severity was so severe that collision prevention is the only intervention which could alter outcome. Understanding the injury burden for cyclist casualties may lead to improved medical care, informed driver education and a renewed focus on collision prevention strategies. This study also highlights the necessity for prospective study of long-term outcomes in trauma patients to fully demonstrate the effects of trauma on society.

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Data sharing statement Further information can be obtained from Joanna Manson via joanna.manson@gmail.com.

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