THE CAUSES OF PEDESTRIANS' HEAD INJURIES FOLLOWING COLLISIONS WITH CARS REGISTERED IN 2000 OR LATER

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ABSTRACT

Injury and collision data from London's Helicopter Emergency Medical Service (HEMS) and the UK's Police fatal files were used to quantify and describe the nature of pedestrian head injury and investigate the causes.

The HEMS data relating to all pedestrian accidents since 2000 was analysed with respect to their injuries, and the cost of these injuries was estimated using the time they spent on the ward and/or in intensive care. In addition to the HEMS data, Police fatal files containing details of fatal pedestrian impacts with the front of cars registered in 2000 or newer were analysed. These included post-mortems, which were coded using the Abbreviated Injury Scale. Although the fatal file sample was limited in size, it had the advantage of containing photographs of the accident and many other pertinent details. This enabled the causes of individual injuries to be determined. The head injuries seen in the HEMS data were then compared to the injuries in the fatal files .

The HEMS dataset contained 746 pedestrians struck by motor vehicles, with 2,974 recorded injuries. 34 fatal pedestrian accidents were analysed using the Police fatal files.

The analysis of the HEMS data showed that the most frequent and costly injuries were to the head and legs. Head injuries of fatally injured adults were found to be principally caused by contact with the windscreen and surrounding structure.

This research highlights the potential of hospital data to be an important tool in accident research, as the injury information can provide evidence of the effects of the changing vehicle fleet, and what injuries should be prioritised in the future. The paper also begins to quantify the proportion of the most serious head injuries (suffered by fatalities) which are caused directly by the vehicle, compared with secondary impacts with the ground or other objects.

INTRODUCTION

Pedestrian injuries

In 2007 in Great Britain there were 646 pedestrian deaths and 6,924 seriously injured pedestrian casualties in traffic accidents [1]. The majority of pedestrian impacts are with the front of the car. Pedestrians are usually hit from the side, and are 3 to 4 times more likely to be crossing the path of the vehicle than travelling in a parallel direction to it. Cases where the vehicle runs over the pedestrian (where the wheels travel over the pedestrian) are rare, with estimates varying between 2 % and 10 % [2] of pedestrian casualties.

Previous studies have seen that the body parts with the highest risk of injury for a pedestrian struck by a vehicle are the head, followed by the lower extremities, the thorax, and the pelvis [2]. For non-fatal injuries, the lower extremities have been seen as the most frequently injured.

The head is often subject to two impacts, the first with the car itself, and the second with the ground as the pedestrian is thrown from the car. In relation to the relative severity of these two impacts, the literature is divided. Some observe that the primary impact (with the car) is the most severe impact [2]. This is in line with papers suggesting that the injuries caused by secondary impact are fewer and less serious than those caused by primary impact [3]. However, others claim that the secondary impact is often a source of injury comparable to the primary impact [4].

At-the-scene studies [5] have shown that contact with the vehicle was responsible for more life-threatening or fatal head injuries than contact with the ground, and also that the windscreen frame was more likely to give a serious head injury than contact with the windscreen glass or the bonnet. There were other trends in the type of injuries suffered: head injuries were the most frequent injury sustained by those having non-minor injuries, with leg injuries being the second most common. As the overall injury severity of the pedestrians increased, the likelihood of injury for the individual body regions also increased: more severely injured pedestrians had more injuries in more regions.

Supported by the European Commission (EC), the European Enhanced Vehicle-safety Committee Working Group 10 (EEVC WG10) and 11 developed testing methods and standards for pedestrian protection in frontal impacts with cars. These new standards have been introduced in a 2-stage approach, the first of which was the EC Directive 2003/102/EC [6]. This directive introduced a number of tests, including limits on the results of impacts between a lower leg form and the bumper and a head form to the bonnet top.

In addition to the pedestrian regulation, Euro NCAP undertakes pedestrian sub-system impactor tests. Leg forms impact with the bumper and the bonnet leading edge and the head forms strike the bonnet at a variety of locations. As of 2009, the pedestrian tests have become an integral part of the new overall score given by Euro NCAP for any new car [7].

Much of the previous accident research performed in the area of pedestrian injury has been based on pedestrian impacts with relatively old cars. Since these studies car geometry, stiffness and mass has altered such that previous conclusions may no longer be valid for the modern car fleet. The purpose of this paper is to explore how a new source of data, collected by medical professionals, can add to the knowledge of the injuries received by pedestrians in traffic accidents. The causes of these injuries in pedestrian impacts with new cars (registered in 2000 or later) will also be explored for a selection of fatally injured pedestrians using Police fatal files.

London's Helicopter Emergency Medical Service

A report was produced in the 1980s by the Royal College of Surgeons which documented cases of patients dying unnecessarily because of the delay in receiving prompt and appropriate medical care. London's Air Ambulance was established to address the findings of this report and to find a way to respond quickly in London's increasingly congested roads. London's Air Ambulance began operations in 1989 from a temporary base at Biggin Hill Airport and in 1990 moved to a permanent base in central London. This is at the Royal London hospital, which was the only multidisciplinary hospital with a site where it would be safe to build a rooftop helipad. The Helicopter Emergency Medical Service (HEMS) began to fly from the rooftop at the Royal London on 30 August 1990 and to date has flown over 17,000 missions.

Two trauma teams are available to attend major trauma incidents seven days a week from 7am to sunset. At night the poor visibility makes flying around the city dangerous, therefore the teams are grounded and rapid response cars are used instead. These cars can also be used if the emergency occurs whilst the helicopter is away on another mission.

The HEMS primarily deals with major trauma accidents of all varieties including serious road traffic accidents. The patient is then seen as quickly as possible by a specialist trauma doctor and paramedic team to provide the greatest chance of survival. The paramedic team at the London Ambulance Service control room decides which of the 3,500 calls they receive a day are appropriate for the HEMS to attend. The paramedic team can also request for the HEMS to attend if they require further medical resources in the field. The helicopter's medical team are equipped with a substantial range of drugs, emergency surgical kits, monitors and other equipment so that they can begin treatment straightaway. A doctor is part of the HEMS team and is able to perform life saving medical procedures that a paramedic is not qualified to undertake. They can also take the patients to the hospital best suited for the patient's needs rather than the closest Accident and Emergency (A&E) department.

Police fatal files

Police fatal file accident reports are recognised as an important source of information for accident research. They can provide detailed information on the events leading up to an accident, as well as giving details of driver errors and/or vehicle defects which may have contributed to the accident and to the injuries that resulted in the fatality.

These fatal accident reports cost a great deal to produce both in terms of police and pathologists' time. The reports are produced, even where no criminal prosecution is envisaged, for presentation in evidence at the Coroner's inquest.

In 1992, TRL was commissioned by the UK's Department for Transport (DfT) to set up and manage the police fatal road traffic accident reports project. The purpose of this project was to institute a scheme whereby police forces in England and Wales would routinely send fatal road traffic accident reports to

TRL when they were no longer of use for legal purposes.

The fatal reports provide a valuable insight into how and why fatal accidents occur and offer an opportunity to learn from these tragic accidents, so that future incidents may be prevented. The current archive contains over 34,000 police fatal accident reports.

METHOD

The types of injuries sustained by pedestrians in traffic accidents were explored using data collected by HEMS. This data was also used to estimate the cost of these pedestrian casualties to the hospital. The causes of the head injuries of a sample of fatally injured pedestrians were determined using information present in Police fatal files.

HEMS pedestrian data

The data from the accidents attended by the HEMS team is entered into a database which is then primarily used for various analyses aimed at improving patient care and trauma management. This database holds information on the age and gender of the patient as well as their injuries and the treatment they received both on route to the hospital and during their stay. This includes information on operations, who treated them, outcome (i.e. whether they lived and if not then the area of the hospital in which they died) and their length of stay in hospital (both on wards and in Intensive Care Unit).

The HEMS database is a medical database, and as such it has detailed information on the injuries sustained by pedestrian casualties. Each injury is coded using the International Statistical Classification of Diseases and Related Health Problems, Ninth Revision (ICD-9). This is a coding system developed by the World Health Organisation, where each possible injury has a unique four character ICD-9 code associated with it. There are dictionaries of ICD-9 codes freely available on the internet [8]. This code describes what the injury is, but does not include a measure of the severity of the injury.

The severity of the injuries is recorded by the HEMS team using the Abbreviated Injury Scale (AIS 1998). Each injury description is assigned a unique six digit numerical code in addition to the AIS severity score. The AIS severity score is a consensus-derived anatomically-based system that classifies individual injuries by body region on a six point ordinal severity scale ranging from AIS 1 (minor) to AIS 6 (practically untreatable), shown in Table 3 [9]. This paper concentrates on injuries with an AIS score of 2 or greater.

Table 1.
Possible values of AIS.

AIS Score	Description
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Maximum
9	Unknown

MAIS denotes the maximum AIS score of all injuries sustained by a particular occupant. It is a single number that attempts to describe the seriousness of the injuries suffered by that occupant.

The analysis of the HEMS data was carried out at two levels: the casualty level (of 746 pedestrians), and the injury level (of 2,974 injuries). To investigate injuries at the more meaningful casualty level, the maximum AIS in different body regions was calculated for each pedestrian. The body regions were:

H – Head (includes Neck)
L – Lower limb
U – Upper limb
A – Abdominal region (includes abdomen, lower back, lumbar spine and pelvis)
T – Thorax (includes thoracic spine)
M – Multiple and Not specified regions

The "Multiple and Not specified regions" category was used for injuries such as external burns, which are a single injury but affect more than one region.

The cost of these pedestrian casualties to the hospital was estimated, by considering the different cost of a day on a normal ward and a day in an intensive care unit (ICU). The Intensive Care Society state that the cost of a day in an ICU is approximately six times as costly to the hospital as a day spent on a ward [10]. Christensen et al [11] cites the Department of Health statistics [12] which say that the mean cost per patient per day on a general ward is £281, and the mean cost per patient per day in a critical care unit is £1,328 (approximately 4.7 times more costly than the ward). The information in the HEMS database includes the number of days spent by each patient on the ward and in the ICU, so this was used to calculate a cost of each patient to the hospital.

It should be noted that this cost only accounts for the length of time each pedestrian was in hospital, and does not account for the differing costs of surgical operations and procedures carried out during their stay or other pertinent factors. This is partially because this information could not readily be provided by the HEMS for this study, but also because the length of stay in hospital makes up a large proportion of the cost for each patient. In a study of blunt trauma patients, Christensen et al [11] calculated that approximately 75% of the total costs were accounted for by the length of stay in hospital.

The distributions of some variables, for example the body regions injured for different age groups, were compared using a chi-squared test of significance to determine whether any differences were statistically significant. Where this was performed the p-value given by the test has been quoted. For example, a p-value of 0.05 means that the probability that the distributions being compared are different is 95 %.

Police fatal files

The fatal file archive was searched to find and extract any files containing fatal pedestrian accidents involving a car registered in 2000 or later. These files were then searched through in order to identify whether they included photographs of the vehicle damage and a post mortem. This was required as the aim of looking at the files was to correlate the damage on the vehicles to the injuries the pedestrians received.

In the time available, 34 fatal files were analysed with details obtained on the circumstances of the accident (i.e. the location, time, date, contributory factors etc.), the driver of the vehicle, the vehicle itself and its damage, and the pedestrian and their injuries. The details were filled out on forms and input into a database for analysis. The injuries detailed in the post mortems were coded into AIS 2005 codes [13].

The location of damage on the cars which were involved in collisions with pedestrians was described using a 70 zone grid, shown in Figure 1. The AIS 2+ injuries received by each pedestrian were attributed to the various zones on the vehicle that were damaged or to other causation factors such as the ground, walls or acceleration injuries. This was done using a combination of the evidence from the photographs, scene plans, the post-mortems, and other aspects of the Police report (e.g. the direction of travel of the pedestrian, the speed and action of the car and the rest position of the pedestrian).

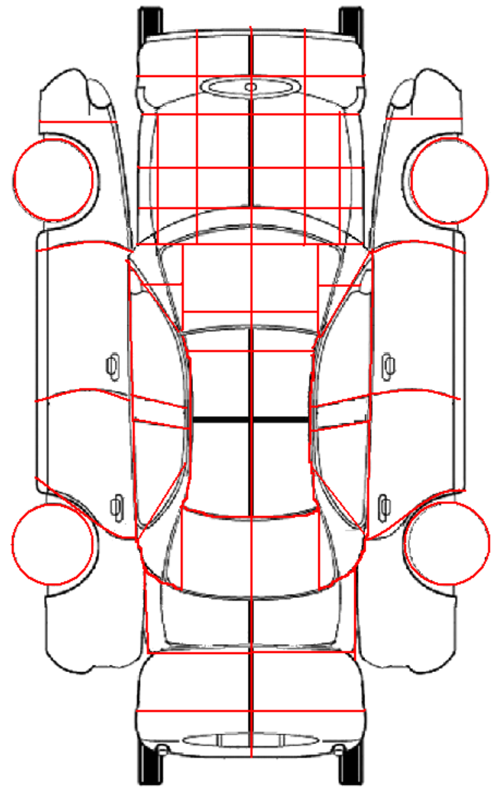

Figure 1. Zones on vehicle used for injury causation

RESULTS

An overview of the injuries received by pedestrians, and the costs associated with these injuries, was provided using the data recorded in the HEMS dataset. This also provided an overview of the head injuries received by pedestrians. The causes of pedestrian head injuries in impacts with cars registered in 2000 or later were investigated using the information present in Police fatal files.

Overview of HEMS pedestrian injuries

In total, the HEMS dataset used in this paper consisted of 746 pedestrians struck by motor vehicles between 2000 and 2007; with 2,974 injuries received in total. Of the 746 pedestrians, 616 survived (83%).

Figure 2 shows the proportion of the pedestrians in each of three age groups who received at least one

AIS 2+ injury to one of the six different body regions.

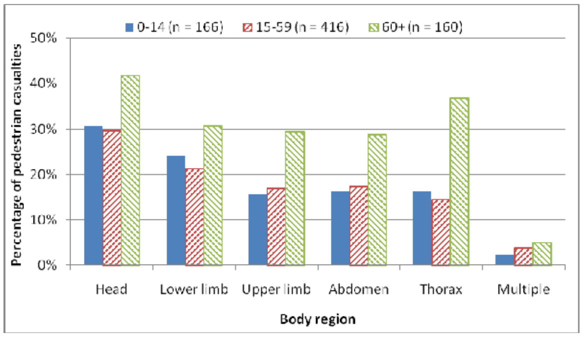

Figure 2. Injury regions by age group.

Head injuries were the most frequent AIS 2+ injuries for pedestrians in all age groups. Like all injury regions, head injuries were proportionally more frequent in pedestrian casualties aged 60 or older. The differences in the injury distributions for the different age groups were statistically significant ($p < 0.01$).

Selecting only fatally injured pedestrians gave a different injury distribution, shown in Figure 3. In this figure, head injuries are no longer the most frequently injured region: the abdomen and thorax both received more AIS 2+ injuries. Also, thorax and injuries to multiple or non specified body regions were most frequent for the youngest age group. The differences in the injury distributions for the different age groups for these fatalities are significant ($p < 0.1$).

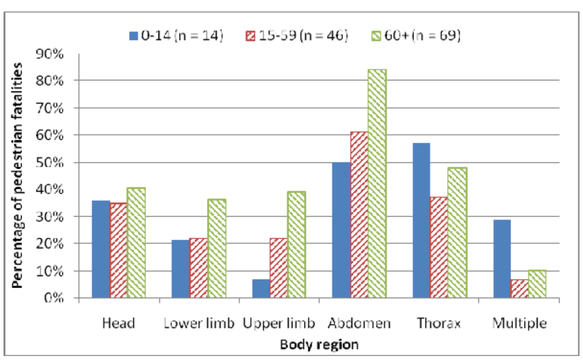

Figure 3. Injury regions by age group for fatally injured pedestrians

Table 2 shows the most frequent combinations of AIS 2+ injuries received by the pedestrians in the HEMS dataset, where 'H' is head, 'L' is lower limb, 'U' is upper limb, 'A' is abdomen, 'T' is thorax and 'M' is injury to multiple or non specific regions. There were 330 pedestrians who had injuries recorded, and for whom the highest AIS in each of these body regions were known. This table shows the injury combinations received by at least 10 pedestrians.

Table 2.
Most frequent combinations of AIS 2+ injuries

H	L	U	A	T	M	Freq.
X						92
	X					40
X				X		16
		X				14
X	X					13
	X		X			12
X		X				10
X	X			X		10
X	X		X	X		10

The most frequent combination of serious injuries was an AIS 2+ injury to the head only, a combination received by 28% of the pedestrians in the dataset. AIS 2+ injuries to the lower extremities only were the next most frequent, accounting for 12% of the pedestrians. Other combinations of injuries made up the remaining 60%, although no other single combination accounted for more than 5% of the casualties.

Of the 2,974 recorded injuries to the pedestrians in the HEMS dataset, 1,857 were known to be AIS 2+ injuries. Table 3 shows the ten most frequent AIS 2+ injuries received by the pedestrian casualties.

Table 3.
Most frequent AIS 2+ injuries

Injury description	Freq.
Cerebral contusion closed	158
Generalized SAH IVH	133
Cerebral subdural haematoma	93
Fracture of ribs closed	92
Fracture of base of skull, closed with intracranial injury	81
Pneumothorax, without wound into thorax	73
Injury to lung without wound into thorax	70
Fracture of malar and maxillary bones closed	67
Fracture of pelvis, pubis closed	54
Fracture of clavicle, closed	53

The list of the most frequent AIS 2+ injuries is dominated by head injuries. The three most frequent AIS 2+ injuries were head injuries, which made up five of the ten most frequent.

Cost of pedestrian injuries (HEMS dataset)

Figure 4 shows the mean cost of the pedestrian injuries in the HEMS dataset, calculated using the method based on the duration of stay of the casualties in hospital. Figure 5 shows the cumulative annual cost for these pedestrians by body region injured. These figures show the cost of the pedestrians who had AIS 2+ injuries in the given body region.

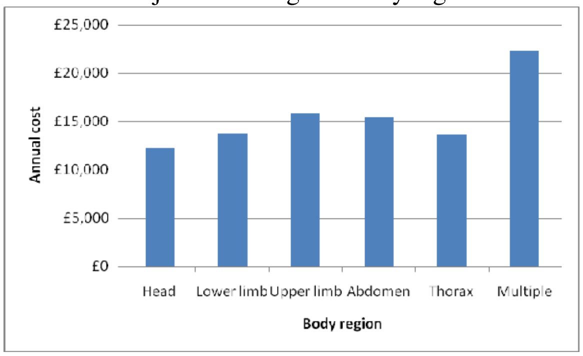

Figure 4. Mean cost per patient in HEMS dataset by injury region.

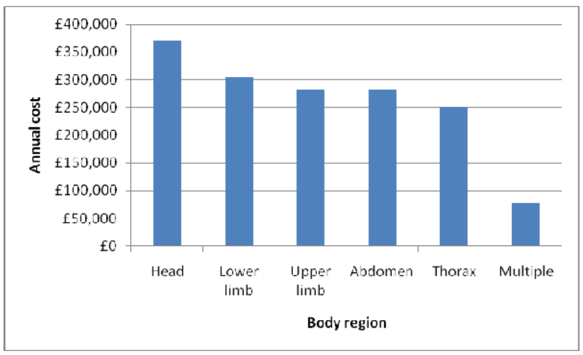

Figure 5. Annual cost of pedestrian casualties in HEMS dataset by injured region.

Although the average cost of head injuries was relatively low compared to other body regions, the large number of head injuries meant that pedestrians with AIS 2+ head injuries had a larger cumulative cost than pedestrians with AIS 2+ injuries in other regions.

Pedestrian head injuries

The analysis of the HEMS dataset has shown that head injuries were the most frequent serious injuries received by these pedestrians. Table 4 shows the ten most frequent AIS 2+ head injuries received by the pedestrians in the HEMS dataset.

Table 4.
Most frequent head injuries in HEMS dataset

Injury description	Freq.
Cerebral contusion closed	158
Generalized SAH IVH	133
Cerebral subdural haematoma	93
Fracture of base of skull, closed with intracranial injury	81
Fracture of malar and maxillary bones closed	67
Intracranial injury of unspecified nature closed	39
Fracture of other facial bones, closed	36
Cerebral haemorrhage extradural closed	35
Fracture of vault of skull, closed with intracranial injury	30
Fracture of base of skull, closed without intracranial injury	29

These injuries are split between injuries involving the brain, and fractures of the surrounding bones. Brain injuries dominated, especially the two most frequent AIS 2+ head injuries: cerebral contusion, and generalised SAH IVH (subarachnoid haemorrhage and intraventricular haemorrhage).

In comparison, Table 5 shows the most frequent AIS 2+ head injuries received by the fatalities in the HEMS pedestrian dataset.

Table 5.
Most frequent head injuries of fatally injured pedestrians in HEMS dataset

Injury description	Freq.
Generalized SAH IVH	64
Cerebral contusion closed	44
Cerebral subdural haematoma	41
Fracture of base of skull, closed with intracranial injury	33
Intracranial injury of unspecified nature closed	26
Fracture of malar and maxillary bones closed	12
Fracture of vault of skull, closed with intracranial injury	11
Other or unspec. intracranial haem.	8
Fracture of other facial bones, closed	6
Cerebral haemorrhage extradural closed	5

The types of head injuries received by the fatalities were very similar to the head injuries received by the pedestrian dataset as a whole: nine of the ten most frequent pedestrian head injuries for all casualties were also present in the ten most frequent pedestrian head injuries of fatalities.

Causes of pedestrian head injuries (In-depth review of Police fatal files)

Figure 6 shows the causes of the AIS 2+ head injuries sustained by the 27 pedestrians in the Police fatal files who received at least one AIS 2+ head injury. This figure is at the pedestrian level.

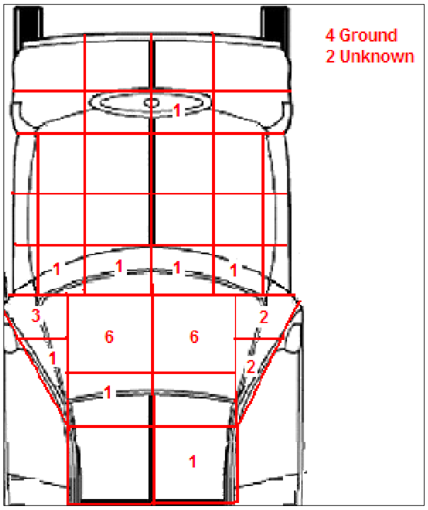

Figure 6. Causes of pedestrian head injuries.

Impacts to the windscreen caused AIS 2+ head injuries for 12 of the pedestrians, more than any other area of the vehicle. Impacts to the A-pillars caused 8 pedestrians' AIS 2+ head injuries, and impacts at the base of the windscreen caused 4 pedestrians' AIS 2+ head injuries. The remaining head injuries were caused by the header rail, the roof, the leading edge of the bonnet, the ground, or had an unknown cause. It should be noted that the head injury caused by the leading edge of the bonnet was to a 7 year old child, in an impact with a large 4x4 vehicle. With the exception of this impact, no head injuries were caused by any point of the bonnet below the base of the windscreen.

The severity of the head injuries caused by these different parts of the vehicle are summarised in Figure 7.

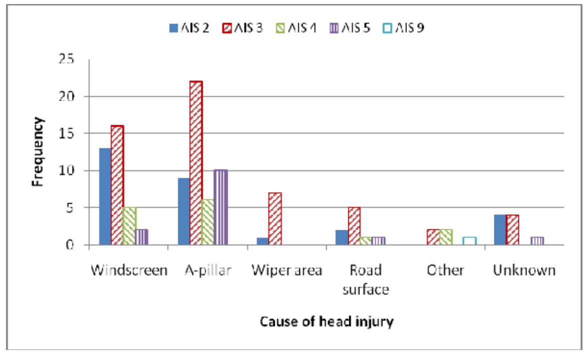

Figure 7. Severity of head injuries by cause.

Although more pedestrians (at a casualty level) had head injuries caused by the windscreen, the greatest number of serious head injuries (at an injury level) was caused by impacts with the A-pillar. Impacts with the A-pillar also caused proportionally more AIS 4+ head injuries than the windscreen.

Table 6, Table 7, Table 8, Table 9, Table 10, and Table 11 list the AIS 2+ injuries which were recorded for pedestrian impacts with the windscreen, A-pillars, wiper area, other parts of the vehicle, the road surface, and those with an unknown cause respectively. The injury descriptions are abbreviated versions of those recorded using the AIS injury coding system.

Table 6.
AIS 2+ head injuries caused by impacts with windscreen

AIS	Description	Freq
5	Brain stem compression	1
	Cerebellum: haematoma, epidural or extradural, large	1
4	Cerebellum: haematoma, subdural, small	1
	Cerebrum: haematoma, subdural, small, bilateral	1
	Cerebrum, brain swelling, moderate	1
	Base (basilar) fracture, complex	1
	Vault fracture, complex	1
3	Cerebrum: brain swelling NFS	4
	Base (basilar) fracture NFS	3
	Cerebrum: contusion, multiple, at least one on each side but NFS	2
	Cerebrum: haematoma, subdural NFS	2
	Cerebrum, contusion, single NFS	1
	Cerebrum: contusion, multiple NFS	1
	Cerebrum: contusion, multiple, on same side but NFS	1
	Cerebrum: brain oedema NFS	1
	Cerebrum: NFS	1
2	Cerebrum: subarachnoid haemorrhage	4
	Cerebellum: subarachnoid haemorrhage	3
	Vault fracture NFS	3
	Cerebrum: intraventricular haemorrhage	1
	Vault fracture, closed	1
	Maxilla fracture	1
Total		36

Table 7.
AIS 2+ head injuries caused by impacts with A-pillars

AIS	Description	Freq.
5	Brain stem NFS	3
	Brain stem compression	2
	Brain stem: injury involving haemorrhage	2
	Cerebrum: contusion, single, extensive	1
	Cerebrum: contusion, multiple, extensive	1
	Diffuse axonal injury LOC > 24 hours NFS	1
4	Base (basilar) fracture, complex	2
	Sinus: sigmoid sinus, thrombosis, occlusion	1
	Sinus, transverse sinus, thrombosis. Occlusion	1
	Cerebrum: intraventrivular haemorrhage, associated with coma > 6 hours	1
	Vault fracture, complex	1
3	Cerebrum: contusion, multiple, at least one on each side, small	3
	Cerebrum, haematoma, NFS	3
	Cerebrum, brain swelling NFS	3
	Cerebellum: brain swelling/oedema NFS	2
	Intracranial vascular injury	1
	Cerebellum: haematoma NFS	1
	Cerebellum, haematoma, subdural NFS	1
	Cerebellum NFS	1
	Cerebrum: contusion NFS	1
	Cerebrum: brain oedema NFS	1
	Cerebrum: laceration NFS	1
	Cerebrum: subarachnoid haemorrhage, associated with come > 6 hours	1
	Cerebrum: NFS	1
	Base (basilar) fracture NFS	1
	Vault fracture comminuted	1
2	Cerebrum: subarachnoid haemorrhage	3
	Vault fracture NFS	2
	Orbit, fracture, closed or NFS	2
	Cerebellum: subarachnoid haemorrhage	1
	Vault fracture, closed	1
Total		47

Table 8.
AIS 2+ head injuries caused by impacts with wiper area

AIS	Description	Freq.
3	Cerebrum: haematoma, subdural NFS	2
	Cerebrum: brain oedema NFS	2
	Cerebrum: contusion, multiple, at least one on each side but NFS	1
	Cerebrum, haematoma, NFS	1
	Cerebrum: brain swelling NFS	1
2	Cerebrum: subarachnoid haemorrhage	1
Total		8

Table 9.
AIS 2+ head injuries caused by impacts with other parts of vehicle

AIS	Description	Freq.
Unknown	Unknown	1
4	Base (basilar) fracture, complex	1
3	Base (basilar) fracture, complex	1
	Cerebrum: contusion, single, small	1
	Cerebrum: brain swelling NFS	1
Total		5

Table 10.
AIS 2+ head injuries caused by impacts with road surface

AIS	Description	Freq.
5	Brain stem: injury involving haemorrhage	1
4	Base (basilar) fracture, complex	1
3	Cerebrum: contusion NFS	1
	Cerebrum: laceration, <2cm	1
	Cerebrum: laceration NFS	1
	Base (basilar) fracture NFS	1
	Vault fracture comminuted	1
2	Cerebrum: subarachnoid haemorrhage	1
	Vault fracture NFS	1
Total		9

Table 11.
AIS 2+ head injuries with unknown cause

AIS	Description	Freq.
5	Cerebrum: haematoma, subdural, large	1
3	Cerebrum: haematoma, subdural NFS	1
	Cerebrum: brain swelling NFS	1
	Base (basilar) fracture NFS	1
	Vault fracture comminuted	1
2	Cerebellum: subarachnoid haemorrhage	1
	Cerebrum: intraventricular haemorrhage	1
	Cerebrum: subarachnoid haemorrhage	1
	Vault fracture NFS	1
Total		9

The 12 pedestrians who received AIS 2+ head injuries caused by impacts with the windscreen received a total of 36 AIS 2+ injuries - an average of 3 injuries each. The 8 pedestrians who received AIS 2+ head injuries from impacts with the A-pillars received a total of 47 AIS 2+ head injuries – an average of almost 6 per pedestrian. So although more pedestrians received fatal injuries caused by the windscreen, the total number of injuries was greater for the pedestrians in impacts with the A-pillars.

The head injuries received by the pedestrians were largely made up of haematomas, haemorrhages, and contusions of various areas of the brain. Of the 113 known head injuries, 74 % were various brain injuries, while the other 26 % were fractures to various parts of the skull. The proportion of fractures compared to other injuries caused by the windscreen was 28 %. This proportion for the A-pillar was 21 %.

DISCUSSION

This project has set out the nature and pattern of the injuries received by pedestrian road traffic casualties attended by London's HEMS team between 2000 and 2007. It is recognised that this dataset typically represents the most seriously injured pedestrians, but nonetheless the sample size presents a useful overview of the types of injuries received. Injuries to the head were identified as the most costly based on an annual summation of the cost to the treating hospital, calculated from length of stay multiplied by injury frequency.

Injuries to the head were also seen to be the most frequent. A single AIS 2+ head injury was found to be the most frequent combination of serious injuries, and the list of the most frequent injuries (as recorded using ICD-9) was dominated by head injuries. The cumulative cost of head injuries was also seen to be greater than the cost of injuries to any other body region.

The nature of the injuries to the head recorded in the HEMS dataset were investigated and compared with injuries observed in the Police fatal files. Similar trauma was noted. Forensic investigation of the evidence available in the Police fatal files allowed the AIS 2+ head injury mechanisms to be investigated.

Head injuries have been seen to be the most frequent type of pedestrian injury in other studies of pedestrian casualties [2,5]. Head injuries may also be expected to be more frequent in the HEMS dataset, as these pedestrians are likely to have been involved in relatively serious crashes compared to the population of pedestrian casualties as a whole. However, comparing the most frequently injured body regions of all casualties and fatalities only shows that the pedestrians who were killed suffered a higher proportion of abdomen and thorax injuries than head injuries, for all age groups. The analysis of the cost of injuries also showed that, although head injuries were the most frequent in the HEMS dataset, they accounted for the lowest average cost of all the body regions. Assuming that the cost (based on the duration of stay) is related to the severity of the injury, this suggests that serious head injuries are not as severe for pedestrians as severe injuries to other parts of the body.

When the causes of the pedestrians' head injuries were investigated in the sample of fatal casualties, the most frequent cause was an impact with the windscreen. The second most frequent cause was an impact with the A-pillar. However, a large number of injuries were caused by impacts with the A-pillar, suggesting that impacts to the A-pillar are more severe than impacts with the windscreen. The severity of the impacts with the A-pillar was also greater, making up the majority of the AIS 4+ head injuries.

Comparing the causes of these head injuries with the EuroNCAP and European pedestrian directive shows that, with the possible exception of the head impact of a small child with a large 4x4, not one of the impact zones are tested and acceptable limits applied. Testing of pedestrian head impacts currently focuses on impacts with the bonnet only. On the evidence of these fatally injured pedestrians, areas further up the car, especially the A-pillars and windscreen, should also be tested, or interventions applied to prevent head strikes to these areas.

The number of pedestrians with serious head injuries caused by secondary impacts was much fewer than the number whose head injuries were caused by the primary impact with the vehicle. Of the 32 pedestrians receiving AIS 2+ injuries, only four pedestrians had serious head injuries caused by secondary impacts with the ground. In comparison, Otte and Pohlemann [3] saw that 33 % of pedestrian injuries were caused by secondary impacts. The method used to determine the cause of the injuries – using photographs, statements and post mortems contained in Police fatal files – was perhaps more likely to attribute injuries to the vehicle rather than to secondary impacts. This is because the evidence of impacts to the vehicle is more obvious and more likely to be collected than evidence of secondary impacts. For example, a head may have struck a windscreen and the road surface, but the windscreen is the most visually obvious contact. Secondary impacts are likely to have been recorded as a cause when there was no evidence of an impact to the vehicle, or if the location of the injuries did not match the nature of the impact with the vehicle.

This study has looked at pedestrian impacts with the front of cars only. It is likely that other impact configurations, such as impacts with the side of cars, would produce different injuries and different causes of injury. For example, it might be expected that the proportion of the head injuries caused by secondary impacts with the ground would be larger for these types of accident, as the pedestrian would be less likely to contact the vehicle with their head before they were thrown to the ground.

Both of the datasets used in this paper contained more severely injured people than the national population of pedestrian accidents. For this reason, it is likely that the average costs of the pedestrian injuries calculated using the HEMS dataset is higher than the national average. However, it is likely that due to the rapid response provided by the HEMS and the specialized trauma care provided, that pedestrians suffering some of these serious injuries may have better outcomes than other pedestrians suffering the same injuries. However, there is data available which could be used to weight these costs – for example the national Hospital Episode Statistics – and performing this weighting would be a natural extension of this study.

With respect to the mechanisms of injury, the severity bias of the selection of fatally injured pedestrians is more pronounced, and it is likely that less severely injured pedestrians receive a different distribution of injuries from different causes.

Another limitation of the Police fatal files is that the post-mortems are often not consistent in the amount of information they record for the injuries. This may lead less specific, lower severity injuries to be recorded using AIS if the information was not available (e.g. amount of blood loss, exact location of fractures) to code a more severe injury. Further, the sample size is relatively small.

The costing model, based on the duration of stay of pedestrians on the ward and in intensive care, is an example of one method which can be used to prioritise injuries using medical information. The costs of individual injuries could be refined if other information was considered, such as the operations and procedures performed on the patient while they were in hospital. Costing road traffic injuries in a similar way is already carried out in the USA [14] and is used when considering the cost-benefit of countermeasures designed to increase road safety.

Finally, the analysis of pedestrian injuries using the HEMS dataset and Police fatal files is not limited to what has been presented here. For example, it is possible to focus on one particular cause of pedestrian injuries in more detail. The precise location of impacts on the windscreen could be investigated, and injuries caused by impacts near the edge of the screen could be compared with the impacts in the centre of the screen. The changes over time of the type of pedestrian injuries could be analysed using the HEMS dataset, to determine if changes in car design or other factors over time have changed the epidemiology of pedestrian injury. The costing model could also be developed, incorporating the cost of the operations and procedures carried out on the pedestrians in the hospital, and weighting the costs to be more representative of the national population of pedestrian casualties (using, for example, the nationally recorded Hospital Episode Statistics).

CONCLUSIONS

Using London's HEMS dataset, serious head injuries are more frequent, and have a higher total cost, than serious injuries to any other body region.

More fatally injured pedestrians had serious head injuries caused by impacts with the windscreen than any other part of the car. However, a greater number of injuries were caused by the A-pillars, and these tended to have a greater severity.

No fatally injured adult pedestrian head injuries were caused by any part of the car forward of the base of the windscreen. This is in contrast to current pedestrian impact legislation and consumer testing, which concentrate on head injuries caused by impacts with the bonnet.

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