MOTORCYCLE ACCIDENTS

THE LEG INJURY PROBLEM IN PERSPECTIVE

Esther M. DUFFY
Research Officer
Department of Neuropathology
Institute of Neurological Sciences
Southern General Hospital
GLASGOW G51 4TF

Allison BLAIR
Research Assistant
Department of Neuropathology
Institute of Neurological Sciences
Southern General Hospital
GLASGOW G51 4TF

It is widely acknowledged that, as a road user, the motorcyclist is less visible, less well protected, and therefore generally at greater risk of injury than the car occupant in the accident situation. The lower limb is particularly vulnerable to injury. Although in itself a leg injury is seldom a life-threatening event, it frequently has long term repercussions for the rider, and the cost to society is high.

This retrospective study examines in detail the injuries of all motorcycle riders passing through 5 major accident and emergency departments in Strathclyde Region in the calendar year from 1st January 1988. The aim was to provide a current and realistic view of both the nature and the extent of the leg injury problem, in relation to the incidence of other body injuries. Two hundred and seventeen individuals were studied (201 drivers, 16 passengers) of which 134 sustained some degree of leg trauma, but a surprising proportion required only minimal treatment. For those hospitalised, treatment given, time spent in treatment, and predicted outcome were noted.

Data was gathered from medical records only, and accident details were obtained from the same source where possible. Some suggestions are made for improved leg protection and for general injury reduction in motorcycle accidents.

INTRODUCTION

Government statistics indicate that the motorycle accident rate in Great Britain has been falling steadily since 1982. However it is still the case both in Great Britain and elsewhere that a very high proportion of this class of accident involves young riders below the age of 24 years. (1,2,3,4)

The injury consequences for the motorcyclist are potentially much more serious than for the car ocupant who is relatively protected from the hostile highway environment by the shell of his vehicle. Although the most frequent cause of, or contributory factory to, death in two wheeler accidents is head trauma (2,4) this is not the most common injury sustained: lower limb injuries are much more common. Accounts of the incidence of lower limb damage vary from around 40% (5) to 65% (3). The leg is reported to be more frequently injured than the thigh (3,5,6), although thigh injuries tend to be more severe (3,5,6,7,8).

Given the general youth of the motorcycling fraternity, the cost to the taxpayer of motorcycling accidents is proportionally higher than for other classes of road traffic accidents: injury severity is greater leading to more protracted periods of hospitalisation, and frequently to expensive surgery and lengthy rehabilitation. Recent information from Scottish health In-Patient Statistics indicates that almost half of all lower limb injured motorcyclists are still receiving in-patient treatment 11 days after admission.

AIM

The aim of this study was to investigate the incidence, distribution and severity of leg injuries in relation to general body injuries. It was hoped that this work, funded by the Department of Transport, through the Transport and Road Research Laboratory (TRRL) might provide information which would lead to the improvement of leg protection for motorcyclists.

METHODOLOGY

Medical information was gathered retrospectively on all motorcyclists who passed through the accident and emergency departments of 6 major hospitals, in the Strathclyde Region of Scotland, for the period of one calender year from January 1st 1988. In the event, data from one of the hospitals was gathered for a shorter and different time period, and this hospital was therefore dropped from the study.

All injury details were obtained from casualty department records in the first instance and the detailed medical record was available for each case admitted for inpatient treatment. And initial forms were completed by the medical staff at the admitting unit. Details were gathered on the nature and extent of all recorded injuries, on treatment type and time

spent in treatment, and on discharge type and follow up or transfer. Clinicians were asked to make a prediction of disability whenever possible based on the extent to which the injury or its consequences prohibited (or made more difficult) daily living activities. In cases of fatality, cause of death and survival time were also established. Lower limb injuries were noted in great detail for each case.

Inconsistencies in recording of data by different hospitals were referred back to clinicians at source hospitals prior to injury coding using AIS 85. This injury coding was carried out by a single member of the research staff at the Institute of Neurological Sciences, to ensure consistency of scoring.

General information on the accident circumstances was gathered from the medical and casualty record whenever possible, but obviously scene of accident investigations were not feasible, given the time lapse between the accident and the data collection.

RESULTS

The Sample

Full information on the injuries of 217 riders was available (201 drivers and 16 pillions)*. Typically the vast majority of drivers were male and the proportion of passengers who were female (31%) was higher than the proportion who were drivers (9%). Table I below shows sex of rider and rider position.

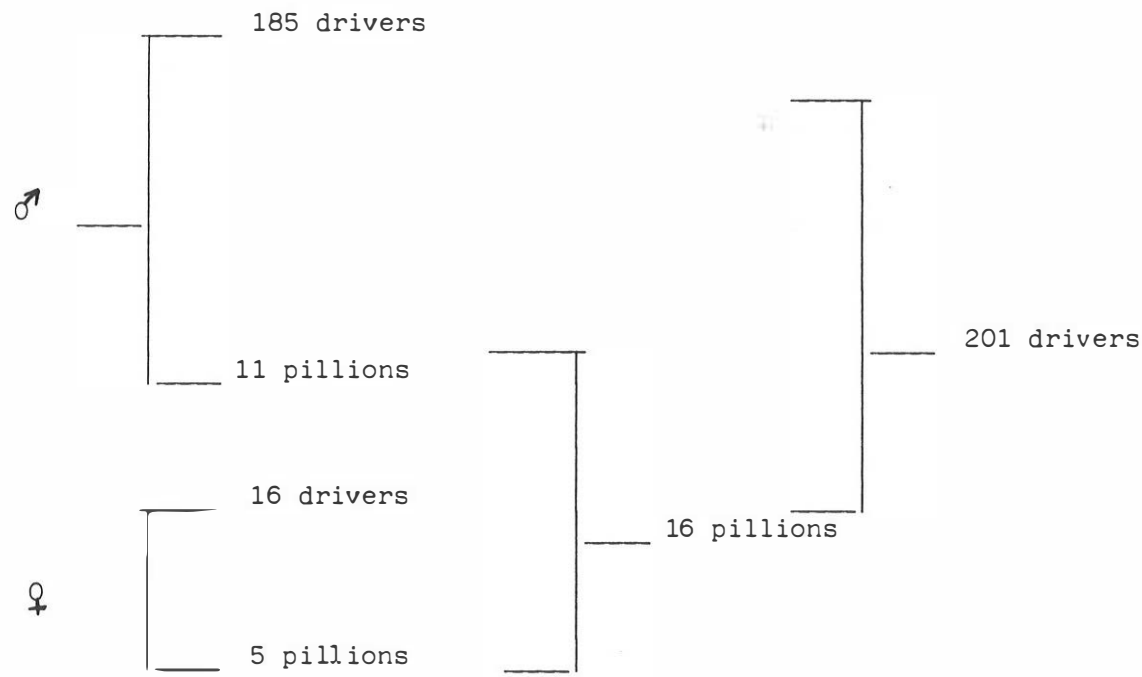

Table I: Position of Rider, and Sex of Rider

The age distribution for drivers and pillions was heavily biased towards the younger age group, as seen in Table II.

*Throughout this paper, the term "riders" is used to describe collectively motorcycle drivers and pillion passengers.

	Age (years)			
	≤18	18≤ 22	23≤ 35	>35
Drivers	29	88	61	23
Pillions	4	6	4	2
Total	33 (15%)	94 (43%)	65 (30%)	25 (12%)

Table II: Rider Age

These figures support the observations of, amongst others, Pedder, Newman and Mackay (1990) (2), Mukai (1987)(3) and Petrucelli and Mortimer (1985) (4) that in excess of half motorcycle casualties are to young people under the age of 22 years (in this case, 58%)

INJURY SEVERITY

There were only 3 fatalities in this sample: all were drivers, and all were reported by the hospital as "death from head injuries". However the total number of deaths among drivers and pillions in Strathclyde Region during the study period was 12, and a large proportion of these occurred within the catchment areas of the 5 participating hospitals. Further investigation revealed that in these fatal motorcyclists, death occurred instantly (or later at the scene of the collision), and the corpses were transferred directly to the mortuary. Only one of the 3 fatal cases taken to hospital died in transit, and was brought to the casualty department for certification. The remaining 2 were transferred to the regional neurosurgical unit for management of brain trauma and died 2 and 4 days later respectively.

A wide range of injuries of all severities were sustained, the vast majority of which were minor, requiring only minimal treatment. One

hundred and seventy one motorcyclists were discharged from the casualty department and required no further follow up, 3 were discharged to the care of their general practitioners and one refused treatment. Thirty nine riders were admitted as in-patients for varying periods of treatment, as summarised in Table III below.

	In-Patient Treatment Period				
	1 day	2≤7 days	8≤30 days	1 m≤3 months	>3 months
Driver	9	16	6	4	0
Pillion	2	1	0	0	1
Total	11	17	6	4	1

Table III: In-Patient Treatment Period (all injuries)

Twenty eight percent of all admissions were for one day only and were, in the main, for routine observations, tests and x-rays, wound debridement and setting of minor fractures. Of those who required longer periods of treatment, 39% (ie. 28% of all those hospitalised) were still in hospital after 7 days. The mean in-patient treatment period was shorter for drivers than for pillions: 10 days (range from 1 - 56 days) versus 36 days (range 1 - 141 days). This average for pillion passengers was heavily influenced by one case requiring a protracted treatment period due to vascular damage to the lower limb. The medians for drivers and pillions were 2 and 1.5 days respectively. Overall, 17% of all drivers received in-patient treatment, compared to 25% of pillion passengers. This should not be taken to imply greater vulnerability to injury or higher injury severity in motorcycle passengers as the calculations are based on a small number of pillions only. Following the initial period of treatment at the source hospital, 5 were discharged home with no follow up, 3 were discharged with follow up by the casualty department, and 8 were referred to other hospitals. No discharge information was given for the remainder.

GENERAL INJURY DISTRIBUTION

The distribution of significant injuries was examined for all riders (Table IV). For the purposes of this particular analysis, all skin and soft tissue, (or superficial) injuries (AIS 1 or 2) were discounted and "significant injury" in this case was termed to be any injury of AIS 3 or above severity, or any injury of AIS 2 severity which was other than superficial. In Table IV, only one injury for each individual is shown (ie their highest scoring injury).

Numbers in brackets denote pillion passengers.

	A I S					TOTAL
	2	3	4	5	6	
Head	7	1	4	0	0	12
Face	1 (+1)	0	0	0	0	2
Neck (not spine	1	0	0	0	0	1
Thorax	0	0	0	1	0	1
Abdomen	1	0	0	0	0	1
Upper limb	17(+3)	5	0	0	0	25
Lower limb	20	10	0	0	0	30
TOTAL	51	16	4	1	0	72

Table IV: Maximum AIS per Injured Rider, by Body Region

Although skin soft tissue injuries were excluded from this table it is worthy of note that a total of 145 riders had this type of injury as their most severe from the accident. Seventy two individuals sustained at least one significant injury. The number who received serious (AIS 4) head injuries is surprisingly small in comparison to that observed by other authors,(4) and indeed compared to the number expected on the basis of the author's ongoing involvement in the field of head injuries in this population. It was not possible in this retrospective study, to establish with certainty whether or not a helmet was in use in each case. It is undoubtedly true that the incidence and severity of head trauma has been reduced by the introduction of mandatory helmet wearing (14). Nevertheless the very low incidence of serious head injury in this sample is remarkable.

For comparative purposes, information on head injury status was sought on the 12 fatalities from motorcycle accidents in the Strathclyde Region in 1988, and details were released in 11 cases. There were 6 fatalities where cause of death was reported as "head injury", and the remaining 5, who had other stated causes of death, all sustained at least one AIS 3 head injury.

Generally, the majority of significant injuries were at the lower end of the severity scale; moderate as opposed to severe. The most commonly injured area was as expected, the lower limb, followed by the upper limb. Lower limb injuries will be discussed in more detail shortly. Of

upper limb injuries the majority were closed fractures and shoulder, wrist or finger dislocations.

LEG INJURIES: SUPERFICIAL

Skin and soft tissue injuries to the lower limbs were very common amongst drivers and pillions. Table V below illustrates the topographical distribution of AIS 1/2 external injuries for each individual for whom this was their most severe lower limb injury. No distinction has been made between injuries to the left or right sides as there was no remarkable difference in incidence between the two.

Where a rider sustained two injuries of the same severity to different parts of the lower limb, both are shown. Thus the number of actual injuries recorded (107) exceeds the number of people who sustained such an injury. (86).

Lower limb Leg Region	AIS 1	AIS 2	TOTAL
Hip	6	-	6
Thigh	14	-	14
Knee	46	1	47
Calf	6	-	6
Ankle	10	-	10
Foot	9	-	9
Generalised	15	-	15
TOTAL	106	1	107

Table V: Superficial Injuries to Lower Limbs

It is readily apparent that the most common site of external injuries to the lower limb is the knee (43%). It should also be noted that the only other obvious difference between the distribution of driver and passenger lower limb injuries is that there are no calf injuries at all in the latter group. Six of the 40 below the knee injuries were to passengers as opposed to 34 to drivers. It is unfortunate that, due to incomplete or unclear data, it was not possible to compare the lower limb injuries of pillion passengers with their respective drivers.

LEG INJURIES: FRACTURES AND INTERNAL

The consequences of lower limb fractures, joint disruptions or internal, vascular injuries are much more serious than those of external injuries, albeit that the latter are important purely from a numerical standpoint. In this particular study, there were no fractures among passengers but the distribution of driver fractures is illustrated in Figure I. Again there was no great difference in incidence between right and left lower limbs. Where a driver fractured bones in more than one area, both are recorded. Nineteen drivers sustained a total of 23 fractures (2 of the 8 leg fractures involved both tibia and fibula). Once more, the leg is shown to be more vulnerable than the thigh (13 fractures v 5).

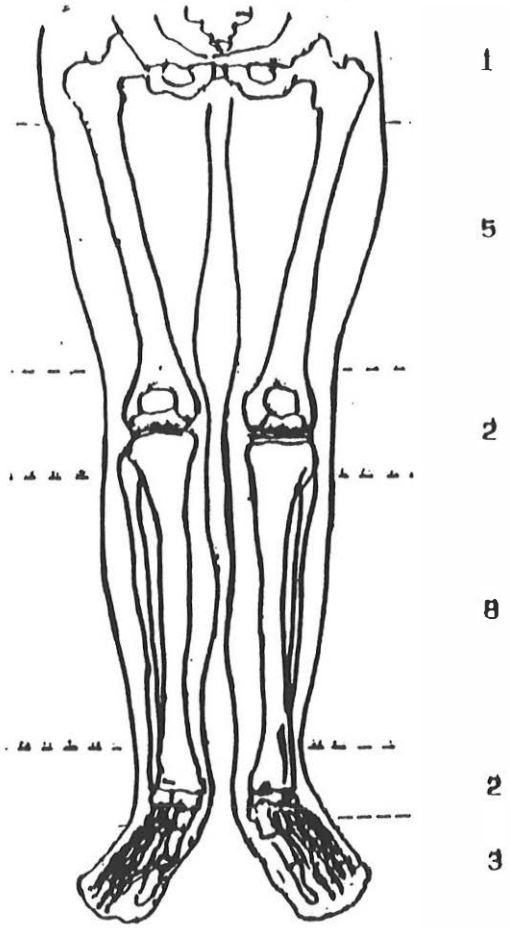

Figure I. Distribution of Lower Limb Fractures

There were relatively few cases of damage to the joints. The ankle and knee were equally vulnerable in the six drivers and 2 pillion who

received strains/sprains or dislocations to those joints. Injuries to muscles or vascular supply were rare, but severe when they occurred. Of 4 such cases, 3 involved the thigh and, one (the most severe) the leg.

The lower limb injury pattern for all riders is shown in Figure II overleaf. The maximum AIS for lower limb trauma for each rider is shown. The 134 riders who sustained lower limb damage (ie 119 plus 15 generalised SST injuries of AIS 1 severity (Table V)) represent 62% of all riders included in the study. Of these 79% are very minor (AIS 1): only 21% were of greater significance. Nevertheless, although so many of the lower limb injuries are minor, their sheer number makes them important to note.

INJURY CAUSATION

In any attempt to protect the two wheeled "occupant" from damage to the lower limb, it is obviously vital to consider the cause of this injury. Although no examination of vehicles involved, or scene of accident investigations, were routine in this study, some information was available from casualty departments and ambulance crews. The details are summarised in Table VII below. Where a rider was in contact with more than one object, all are included as it was not possible to ascertain reliably which of the possible contacts was the cause of the injury. The maximum number of contacts was two, and this applied in 6 cases. Again, contacts for pillions are added in brackets.

CONTACT	SST	#	JOINT	INTERNAL	TOTAL
Hard Ground	55(+3)	13	3(+1)	0	75
Car/Van	15(+2)	4	1	0	22
HGV/PSV	2	0	0	0	2
Own Vehicle	3	0	1(+1)	0	5
Roadside Furniture	4	1	1	0	6
Other	1	0	0	0	1
Not Known	20(+2)	5	(1)	(1)	30
TOTAL	107	23	9	1	140

Table VII: Leg Injuries v. Contact Points

Although this table lists recorded contact points against lower limb injuries, medical records note only that the rider collided with these objects, rather than that a specific part of the body contacted the object named. It must be emphasised that the intention is to suggest

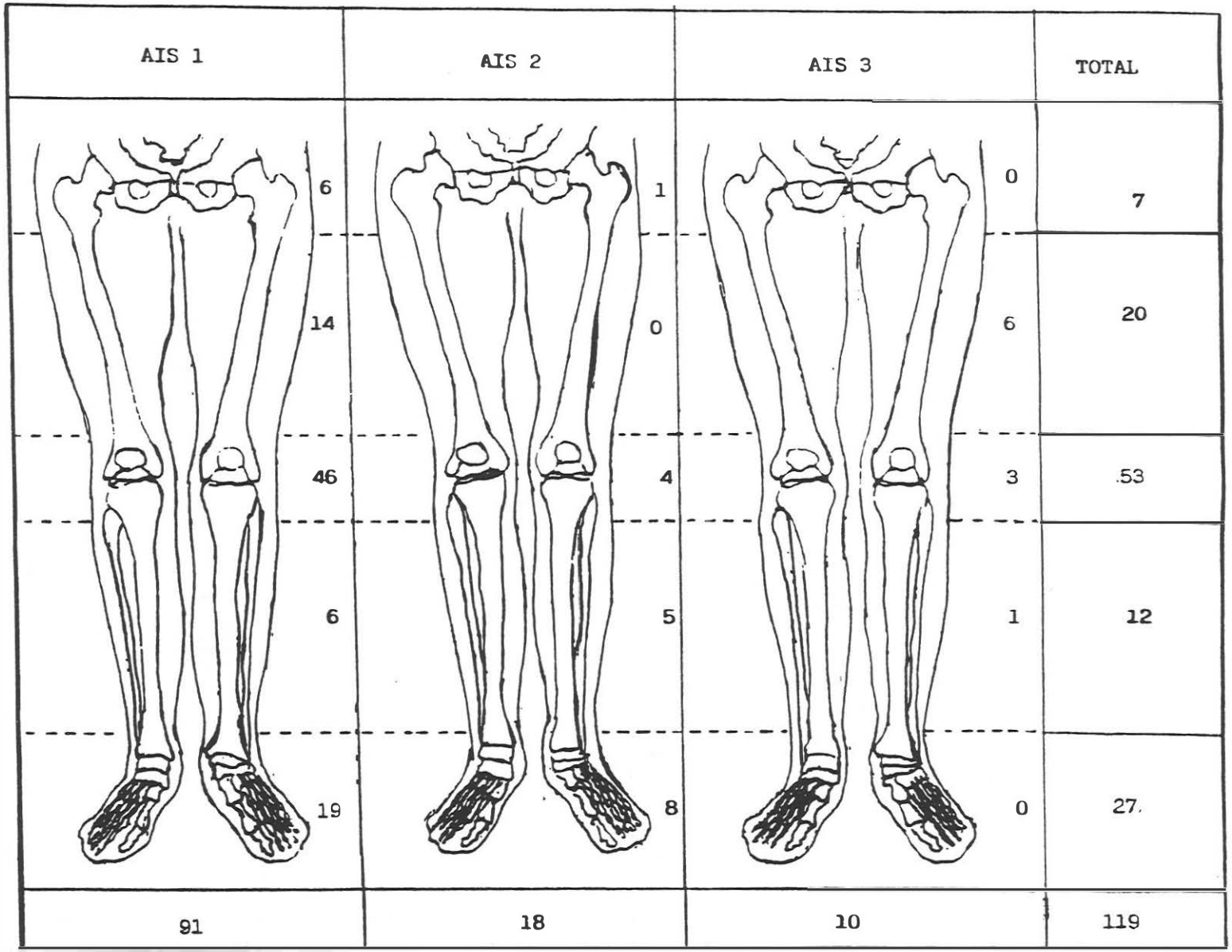

Figure II : Location of Maximum Lower Limb Injury

possible causes of lower limb injuries in these cases.

If lower limb injuries were due to the contacts listed, the pattern displayed is very different to others reported in the literature (eg Harms (1989)(3)) who have found the most common source of lower limb injury to be cars at 73% compared to 16% in the present study. Road surface (54% in this study) was reported to be the cause of only 3% of all lower limb injuries. The percentages for this study were calculated including the "contact not known" group. If these are excluded, the percentages increase to 68% for ground as reported contact and 20% for cars as reported contact. The discrepancy between this study and the previous study may be explained by the differences in the two samples: the present study deals only with details obtained from medical sources, whereas the other incorporated scene of accident and vehicle examination data, which obviously provides more comprehensive information.

Skin and soft tissue or superficial injuries in this study group were apparently most commonly associated with ground contact (as were fractures). Protecting the rider from contacts with other vehicles, roadside furniture etc would prevent a reasonable proportion of fractures and joint injuries but only a small proportion of surface injuries which may require alternative protective measures.

IN-PATIENT TREATMENT

Any assessment of lower limb severity must go beyond the initial description of the injury to consider the time spent in treatment, which is directly proportional to the degree of trauma. 82% of hospitalised motorcyclists in this study sustained some degree of lower limb trauma; of a total of 39 hospitalised riders only 7 who were admitted had no such injuries. Generally however the number of motorcyclists who required in patient treatment was surprisingly small at 18%.

Treatment Period	INJURY TYPE			
	SST	#	Internal	None
1 day	5(+2)	1	1	2
2 $\leq$ 7 days	5(+1)	4	2	5
8 $\leq$ 14 days	1	2	-	-
15 $\leq$ 30 days	-	2	-	1
1 month $\leq$ 3 months	-	4	-	-
$>$ 3 months	-	-	(1)	-

Table VIII: In-Patient Treatment Time: Leg Injuries

A lower proportion of drivers than passengers sustained lower limb injuries (27/201 v 4/16). Once again it should be remembered that the sample contains only a small number of passengers.

Hospitalisation period is obviously affected by the type of treatment required, and is most commonly increased the necessity for surgery, which was carried out on 32 drivers and 6 passengers, not only to the legs (21 cases) but also to other areas of the body. (see Table IX).

Surgery To	Drivers	Pillions
Upper limb	10	2
Lower Limb	17	4
Abdomen	1	-
Head	2	-
Face	2	-

Table IX Surgical Intervention at Hospital of First Admission

The nature of leg surgery ranged from simple wound debridement and/or saturing (11), aspiration of fluid from the knee (3) to patellectomy/patellar reduction (3), external fixation of fractures (1) and internal reduction of fractures (7). Vascular surgery was performed in one case and there were 2 skin grafts. It should be noted that several individuals underwent multiple procedures. Details on those surgically managed in hospitals of second referral are not known.

The average treatment period for surgical cases (all injuries) was 20 days; for lower limb cases the average was 24 days (only 6 days for non-lower limb surgical cases).

Estimates of disability were given in 10 cases only. In 4 cases of upper limb injury, 2 predictions of moderate and one of severe disability were made (the latter due to surgical amputation). One back injury was thought likely to lead to moderate disability. There were only 5 predictions of disability following lower limb trauma (3 slight, 1 moderate, 1 severe).

This low number in no way reflects the prediction rate which was expected, and is not consistent with other reported findings.

It may be that few predictions were made because of doubts as to the eventual outcome of injuries, or because minor disabilities were considered too insignificant to mention, or because junior medical staff (who were largely responsible for form completion) felt inexperienced to make such predictions. Alternatively, the low response rate to this item may simply be due to there being little time, in departments which administer acute care, for form completion.

DISCUSSION

Given the volume of traffic on the roads today, accidents and injuries are inevitable and means of reducing injury severity to the motorcyclist, who is a vulnerable road user, must be sought. This study clearly shows the high incidence of lower limb trauma and supports the need for integral protection on the machine. Leg damage, particularly to the knee, was the most frequently occurring injury, and the majority of lesions were superficial only. By far the most common reported contact associated with these superficial injuries is road surface (Table VII). These, and indeed many of the joint injuries, could be reduced or even eliminated by the wearing of protective clothing. Ideally, such attire should possess several important features: it should be fluorescent, so as to improve the motorcyclists visibility to other road users, and should be made of strong but lightweight fabric; extra padding over the spine, elbows and knees should be incorporated and gloves should be worn; stitching of all clothing must of course be secure; strong leather boots, preferably to just below the knee (with padding) should also be worn. The question of head/facial protection is outwith the remit of this particular study, but it is reasonable to suggest that the full face helmet has an advantage over its open face counterpart in terms of protection.

Although the optimal fabric has not yet been developed, Kavlar and leathers specially selected for motorcycle clothing manufacture have been recommended elsewhere (13). Leather is particularly expensive, and it must be remembered that young motorcyclists (who form the majority) may find the financial outlay for such clothing prohibitive, and therefore opt for a lower standard. This may in part explain the high incidence of surface injuries in motorcycle accidents. Additionally there are complaints of discomfort and heat fatigue from wearing leather clothing in the summer. Comfort and cost should be borne in mind when investigating new fabrics for protective clothing. Meantime, leather clothing remains the most suitable option, and its more widespread use would reduce the incidence not only of leg injuries, but also of upper limb injuries.

It is the opinion of the authors that formal recommendations, and possibly ultimately legislation, should be considered regarding clothing for motorcyclists. Given that there are some difficulties (such as the cost/comfort issues) with current materials, legislation would be unpopular and difficult to impose at the present time, but may become a realistic option at a later date. At the very least, education of motorcyclists, highlighting the advantages of wearing proper clothing, should be undertaken. Ongoing textile research is also recommended.

Some measure of protection against superficial injuries may also be afforded by a built in safety leg fairing, such as that proposed by Chinn, Hopes and Finnis (1989)(7). More importantly such a feature has

potential to protect against skeletal injuries. It is not the purpose of this paper to discuss the constituent materials of leg protectors (or indeed of protective clothing) but rather to suggest what benefits might be gained from the optimum in these items.

Padding in the knee area of a safety fairing is seen as having two major benefits: firstly to the knee itself, in minimising both skin and patellar damage; and secondly in reducing the forces transferred up the femur, which may lead to fractures of this bone (5). Otherwise the femur/thigh area is more difficult to protect directly than the tibia/fibula area.

Two separate schools of thought exist regarding the value of the safety fairing. Tadakoro et al (1985) (9) report that rider trajectory is altered and that the resulting injury pattern in accidents would be more life threatening than is currently the case. However Chinn et al (1989) (7), and Chinn and Macaulay (1984)(11) have produced contrary results, suggesting that the only change in injury pattern would be a reduction in the frequency and severity of lower limb trauma.

There has always been a problem in convincing the motorcyclist of the merits of safety features and equipment, for example there was considerable resistance to the introduction of the helmet wearing law in Great Britain in 1973. Likewise any legislation relating to safety fairings or clothing would be similarly received. Education and publicity may go some way towards popularising safer motorcycling. Failing this, the evidence provided by this and other papers suggests that there may be sufficient justification for considering legislative changes.

CONCLUSIONS AND RECOMMENDATIONS

1. The lower limb is the body region most vulnerable to injury in a motorcycle accident, followed by the upper limb. The knee is the most frequently injured part of the lower limb.

2. The vast majority of lower limb injuries are superficial only. These have no great long term consequences for the rider, nor do they generally require lengthy treatment periods, but their

   frequency of occurrence means that they should not be dismissed as insignificant.

3. The most common reported contact associated with lower limb injury, particularly to the soft tissues, is with the ground.

4. Use of proper protective clothing might reduce or even prevent such injuries. The best materials currently available appear to be Kevlar based fabrics and leathers, but these are expensive and uncomfortable to wear in certain circumstances. Further

textile research is recommended to develop the optimal fabric for protective clothing for motorcycles.

5. Longer term disabilities and protracted treatment times are a result of skeletal or internal injuries to the lower limb. The most common reason for surgical intervention in this study was lower limb trauma, (again followed by upper limb trauma) and the in-patient treatment period is longer for lower limb damage than for damage to any other area of the body (although attention is drawn to the very low incidence of head injury in the sample). Other work has shown the benefits of a motorcycle safety fairing in preventing or minimising lower limb injury. Safety fairings may be a valuable addition to the machine.

6. Until such time as legislation relating to protective clothing and lower limb protection becomes viable, motorcyclists must be made more aware of their advantages in even the simplest accident situation.

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