#### ANATOMICAL SITES AND SEVERITIES OF INJURY IN UNPROTECTED ROAD USERS

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#### SUMMARY

The anatomical sites and severities of the injuries received by 932 motorcyclists, pedestrians and cyclists are described, using a sample consisting of all road accident casualties brought to one large accident hospital over a one year period in 1974/75.

Almost a third of these unprotected road users were detained in hospital. Pedestrians were detained most frequently but motorcyclists were detained for longer. No bicyclist stayed in hospital for more than three months.

The study shows that although there were differences in the distribution of injury for the three different road user groups, in all three the lower leg was the part of the body most commonly receiving severe injury.

The nature and location of injuries classified AIS 3 and above are discussed with reference to their clinical importance in terms of duration of stay in hospital; and for injuries to the head, neck, chest or abdomen of AIS 4 or above in relation to threat to life. These are the types of injury it would seem most worthwhile to attempt to mitigate or to prevent.

## 1. INTRODUCTION

The term unprotected road user covers pedestrians and users of two-wheeled vehicles. The latest national casualty figures (for 1975) in the United Kingdom<sup>(1)</sup> indicate that the number of motorcyclists (including riders of scooters and mopeds) killed or injured annually in this country has risen since 1972 as have the number of bicyclists but that the number of pedestrians (and vehicle occupants) killed or injured has decreased slightly. Despite this the number of pedestrians killed in Great Britain expressed as a proportion of all Road Traffic Accident fatalities remains high (38% in 1974,<sup>(2)</sup> compared with 12% for motorcyclists and 4% for bicyclists, the remaining 46% being vehicle occupants).

In order to consider protective measures which might lessen the overall incidence of injury, it is necessary to obtain an understanding of the patterns of injury existing amongst unprotected road users, the parts of the body involved, and the severity of injury sustained by the three different kinds of unprotected road user, motorcyclist, pedestrian and bicyclist. Of particular concern are those injuries involving threat to life and the probability of permanent disability.

The hospital sample upon which this paper is based includes all road traffic accident casualties brought to one hospital over a period of one year; it forms a part of a continuing two year study. The incidence and severity of injury have been presented for each of the three groups of unprotected road user, both for the body as a whole and for the different regions of the body. In addition length of stay in hospital has been recorded. As in earlier papers (3)(4) a substantial proportion of the casualties seen in this sample, mainly those with slight injuries, were not reported to the Police and consequently would not reflect in the published national statistics on road traffic accidents; this was particularly noticeable amongst bicyclists.

### 2. METHODS

Injury data were collected for all road traffic accident casualties brought to one large accident hospital in Southern England, the Battle Hospital in Reading, Berkshire, together with police data for the catchment area of that hospital which amounts to 900 square kilometres. The period covered by the investigation was between July 1974 and June 1975. All injuries were recorded and most of the more seriously injured casualties were seen and medically examined. The casualties were then traced to police records and, if reported to the police, details of the corresponding accidents were obtained. Length of stay in hospital, including transference to other hospitals, was also recorded together with age and sex.

In this paper we have examined in detail the unprotected road users in this sample. A total of 932 such casualties (348 motorcyclists, 302 pedestrians and 282 bicyclists) were investigated during the period under review; 284 were in-patients, of whom 7 died, 638 were out-patients and 10 were brought in dead; 692 were male and 240 were female. Of the 932 casualties 505 (54%) were

reported to the Police. Thirty-nine per cent of the motorcycle casualties, 32% of pedestrian casualties and 68% of the bicycle casualties were not notified to the Police. During the same period over 1000 vehicle occupant casualties were seen in this sample.

Severity of injury is coded using the Abbreviated Injury Scale (AIS)<sup>(5)</sup> with some refinements. This is an internationally recognised clinical classification of injury severity in which each casualty is classified by region of the body and on an overall basis. Injuries are coded as minor-AIS 1, moderate-AIS 2, severe (not life threatening) - AIS 3, serious (life threatening but survival probable)- AIS 4, critical (survival uncertain)-AIS 5, or maximum (currently untreatable)-AIS 6. When employing this classification for overall assessment of injury the most serious injury sustained has been used to indicate the overall severity.

Death, which can of course result from a range of severities of injury, and from complications arising from a relatively minor injury, does not have a separate category within this scale of injury classification. Therefore the term "fatal" is not used but would correspond to AIS 6 or to any lower AIS category which, in this country, resulted in death within 30 days of an accident. In this sample there were 17 casualties (6 motorcyclists and 11 pedestrians) who died from their injuries. Of the motorcyclists two were AIS 6 and four AIS 5; of the pedestrians seven were AIS 6, two AIS 5 and two were AIS 3.

# 3. RESULTS

The results obtained can most conveniently be examined under four separate headings.

## 3.1 Proportion of casualties detained or not detained in hospital

Thirty one per cent of the unprotected road user casualties brought to the hospital were detained; pedestrians were more likely to be detained than motorcyclists or bicyclists (see Table 1). Amongst the vehicle occupant casualties brought to the hospital during the same period the proportion of casualties detained was 22%.

There was no statistical difference between the proportion of vehicle occupants, motorcyclists or bicyclists detained in hospital but the proportion of pedestrians detained was significantly higher.

Detained or not detained Category of road user	Detained	Not detained	Total	Percentage detained
Motorcyclist	91	252	343 (+ 5*)	27
Pedestrian	132	165	297 (+ 5°)	44
Bicyclist	61	221	282	22
All unprotected road users	284	638	922 (+10*)	31

TABLE 1NUMBER OF UNPROTECTED ROAD USERS DETAINED OR NOT<br/>DETAINED IN HOSPITAL BY CATEGORY OF ROAD USER.

\* Five motorcyclists and five pedestrians brought in dead are not included in these figures

# 3.2 Overall severity of injury

The overall AIS ratings for each of the three unprotected road user categories, including those brought in dead, are shown in Table 2.

AIS Rating Category of Road User	No Injury O	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Maximum 6
Motorcyclist (348 cases)	3	173	103	57	5	5	2
Pedestrian (302 cases)	3	134	97	54	1	6	7
Bicyclist (282 cases)	2	181	82	16	1		

TABLE 2 NUMBER OF UNPROTECTED ROAD USERS BY OVERALL SEVERITY OF INJURY AND BY CATEGORY OF ROAD USER

It will be seen that bicyclists in the sample received fewer injuries of AIS 3 and above than motorcyclists or pedestrians; this difference was

statistically significant. No bicyclist sustained an injury greater in severity than AIS 4. The difference in the pattern of overall AIS severity between the other two road user groups was not statistically significant. Only a comparatively small proportion (17%) of the unprotected road users as a whole sustained injury of AIS 3 or above.

#### 3.3 Distribution of injury

Table 3 shows the incidence of injury of any severity for the different regions of the body for each of the three categories of unprotected road user. It will be seen that for motorcyclists the head, knees, arms and lower leg were the regions of the body most commonly sustaining injury of any severity, for pedestrians the head, arms, knees, lower leg and thighs and for the bicyclists the head, arms and knees. The detailed figures on which Table 3 is based are given in the Appendix.

If only those injuries of AIS 3 and above are considered for the three groups of road user a different pattern of injury for the different regions of the body is discernible.

In the sample (see Table 4) the regions of the body most commonly sustaining these more serious injuries were: in motorcyclists, the lower legs, the upper limbs, the head or thigh; in pedestrians, the lower leg, the head, thigh or pelvis; and in bicyclists, the lower leg, upper limbs or pelvis. For the latter category it has to be remembered that the numbers are small; for example 18% in the case of the pelvis represents only three cases. The nature of this table in which one case can occur in several columns because of multiple injury makes it unsuitable for standard statistical treatment. However from the table it may be inferred that the region of the body most likely to receive serious injury was the lower leg whether for motorcyclists, for pedestrians or for bicyclists.

Amongst the pedestrians there were four cases of bilateral fracture of the tibia and fibula, a pattern of injury not seen amongst riders of two wheeled vehicles.

The number of fatalities was too small to allow comparison of distribution of fatal injuries for the different classes of road user to be made; such

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CATEGORY OF BODY ROAD REGION USER	MOTORCYCLIST (348 cases)	PEDESTRIAN (302 cases)	BICYCLIST (282 cases)
HEAD	26	54	48
NECK	3	1	2
BACK	3	1	2
LEFT SHOULDER	4	4	3
RIGHT SHOULDER	9	6	5
LEFT ARM	20	22	24
RIGHT ARM	24	22	23
CHEST	7	9	4
ABDOMEN	5	8	6
PELVIS	<1	5	1
LEFT HIP JOINT	0	< 1	< 1
RIGHT HIP JOINT	<1	<1	<1
LEFT THIGH	10	12	7
RIGHT THIGH	7	14	6
LEFT KNEE	25	15	14
RIGHT KNEE	25	16	12
LEFT LOWER LEG	16	15	6
RIGHT LOWER LEG	11	15	5
LEFT ANKLE & FOOT	13	10	5
RIGHT ANKLE & FOOT	7	8	6

# TABLE 3. Percentage distribution of injury of all severities by region of the body and by category of road user.

Note: The percentages shown in the Table are not additive for the different regions of the body because injuries were often multiple.

USER AND BY REGION OF THE BODY, EXPRESSED AS A PERCENTAGE OF THE TOTAL NUMBER OF CASUALTIES IN EACH CATEGORY. THE DISTRIBUTION OF INJURY OF AIS 3 OR ABOVE BY CATEGORY OF ROAD TABLE 4

		-	
Ankle and Foot	(†) 9	(L)	6 (1)
Lower Leg	38 (26)	34 (23)	41 (7)
Knee	6 (4)	3 (2)	1
Thigh	15 (10)	22 (15)	12 (2)
Pelvis and Hip Joint	3 (2)	15 (10)	18 (3)
Abdomen	3 (2)	4 (3)	6 (1)
Chest	4 (3)	12 (8)	1
Upper Limbs	22 (15)	7 (5)	24 (4)
Back	3 (2)	(L)	t
Neck	4 (3)	1	6 (1)
Head	19 (13)	32 (22)	12 (2)
Region of body Category of road user	Motorcyclist % (69 cases)	Pedestrian % (68 cases)	Bicyclist % (17 cases)

- Only those cases with an overall AIS of 3 or above are included in this table. ~ Note:
- 2 The percentages are not additive because injuries were often multiple.
- 3 The numbers of cases are shown in brackets ( ).

comparisons have been made elsewhere  ${}^{(6)}$ . However, if only those categories of injury which are regarded as life threatening (AIS 4 - 6) are considered, for the regions of the body most commonly receiving such injuries, some indication can be gained from the sample of the patterns of threat to life amongst the different classes of road user studied. These results are shown in Table 5.

TABLE 5	NUMBE	R OF	LU	THRE	TE	NING	INJU	RTDS	(AIS	4-6)	BY	CATEGO	)RY	OF	ROAD
	USER.	AND	BY	REGION	OF	THE	BODY	LIKE	LY TO	STR	TAIN	STICH	TN.	JUR	[

Region of the body Category of Road User	Head	Neck	Chest	Abdomen
Motorcyclist (12 cases)	7	1	3	1
Pedestrian (14 cases)	12	-	2	2
Bicyclist (1 case)	-	4		1

As in the previous table containing multiple injuries standard tests for significance cannot be made. Nevertheless, the head would seem to be the area of the body most commonly receiving life threatening injury, both for pedestrians and for motorcyclists.

## 3.4 Length of stay in hospital

Length of stay in hospital might be expected to relate broadly to severity of injury and it has been shown to be related to the likelihood of sustaining permanent disability<sup>(4)</sup> amongst unprotected road users.

Length of stay for the different categories of road user in the current sample is shown arbitrarily divided in Table 6. Fig 1 further illustrates some differences in the characteristics by showing the percentage of detained casualties remaining in hospital after a given number of days.

Pedestrians show a smoothly falling rate of discharge with a number of long stay patients.

Half as many bicyclists were detained (see Table 1); they had the highest rate of discharge and none was detained for more than 12 weeks.

Motorcyclists showed a special characteristic. The proportion detained was 40% lower than for pedestrians but the curve is consistently above the others showing that as a class they can be expected to stay longer in hospital on average. In the 10 to 20 day period the rate of discharge is significantly increased although no outstanding reason for this is currently discernible. Subsequently in the long stay regime there is little or no difference in the rate of discharge compared with pedestrians.

Of the very long stay cases, five out of twelve casualties sustained severe leg injuries, usually fractures of the femur or compound fractures of the tibia and fibula, and four received a severe brain lesion; two received some other lesion with neurological involvement, a fracture dislocation of the cervical spine with quadriplegia (one case) and a brachial plexus injury (one case). There was also one case with an unstable fracture of the lumbar spine without cord involvement. It is too soon to determine the proportion of these cases sustaining permanent disability, although from such follow-up as has so far been possible, about a half would appear to have been severely or very severely disabled.

Length of stay Category of road user	0 - 7 days	8 - 28 days	29 – 84 days	More than 84 days
Motorcyclist (91 cases)	48	34	11	7
Pedestrian (132 cases)	70	17	9	4
Bicyclist (61 cases)	79	13	8	-

TABLE 6 THE DISTRIBUTION OF CASUALTIES BY LENGTH OF STAY IN HOSPITAL EXPRESSED AS A PERCENTAGE OF THE TOTAL NUMBER OF DETAINED CASUALTIES IN EACH CATEGORY.





Undischarged patients (percent)

PA 231.1

## 5. DISCUSSION

We have been unable to find any references in the literature which compare the patterns and severity of injury amongst the different classes of unprotected road user and in which the body as a whole as well as its regions are considered.

The data in our sample, which covered all casualties brought to the hospital used for our investigation, show that the numbers of unprotected road users injured were about equally divided between motorcyclists, pedestrians and bicyclists. Despite their apparent vulnerability out of the total of 932 casualties only a comparatively small proportion (17%) sustained injury of AIS 3 or above. Of these, motorcyclists and pedestrians were the most frequent recipients of the more severe injuries. Pedestrians were detained more often (see Table 1), but motorcyclists stayed longer in hospital (see Fig 1 and Table 6). Very few bicyclists received injury more severe than AIS 3 or above (see Table 2). In the whole sample there were 17 deaths (6 motorcyclists and 11 pedestrians), 10 of whom were brought in dead.

Siegal et al<sup>(7)</sup> state that nearly 25% of the motorcyclist casualties studied by them received one or more fatal lesions and that approximately 60% sustained severe to critical injuries (AIS 3 - AIS 5); however they do not say how their sample was selected. Ashton<sup>(8)</sup> in an on the spot investigation of pedestrian accidents reported that out of 177 pedestrian casualties seen 23 died and 42 sustained injury of AIS 3 - AIS 5. Both of these studies show a much higher proportion of the more severe injuries than our own. This inevitably occurs in studies in which a sample is determined solely by the police alerting an investigator to the occurrence of an accident because lesser accidents will attract less attention.

A hospital sample, such as the present one, is likely to bring in a wider spectrum of injury, particularly at the minor end and to give a more representative picture of injury in any geographical area under investigation. However it could be expected that a total injury sample for the catchment area would contain an even greater number with minor injuries, because a proportion of the casualties would not attend hospital.

The areas of the body requiring protection in non-vehicle occupant casualties are those regions which are most liable to sustain injury of AIS 3 or above. Hight et al<sup>(9)</sup> in an earlier version of the paper by Siegal et al<sup>(7)</sup> on motorcyclists states that the lower limbs (as a whole) were the part of the body most frequently receiving injury of AIS 3 or above, followed by the head. In Ashton's paper on pedestrians the regions of the body most frequently receiving injury of AIS 3 or above were the lower limbs (as a whole) and then the head.

In our sample of unprotected road users the body areas most often receiving injury of AIS 3 or above were as follows: in motorcyclists the lower leg, the upper limb, the head and the thigh, in pedestrians the lower leg, the head, the thigh or the pelvis, and amongst the small number of bicyclists with severe injuries, the lower leg, the upper limb or the pelvis (see Table 4). Although there were differences in injury distribution for the different categories, for all three the lower leg was the region of the body most likely to receive serious injury, and for pedestrians also the head.

It is of interest to note that pedestrians were detained more frequently than motorcyclists or bicyclists. This tendency to receive serious injury more often is almost certainly related to differences in the mechanism of injury. Pedestrian casualties are always struck by some moving vehicle; motorcyclists or bicyclists are frequently injured by falling off their machines without other vehicle involvement; and, in the case of bicyclists, at relatively low speeds.

Prolonged stay in hospital may be expected to be associated with the possibility of permanent disability<sup>(4)</sup>. Prolonged stay, i.e. detention for more than 12 weeks, was not seen amongst the bicyclists in the sample. It was however seen amongst motorcyclists and pedestrians. (See Table 6).

In our earlier paper<sup>(4)</sup> using a hospital sample of road users based upon casualties occurring in 1973, it was shown that severe permanent disability in unprotected road users occurred only amongst those casualties who were detained for more than 3 months and that the lower leg was the part of the body most frequently giving rise to severe permanent disability, mainly amongst motorcyclists.

In the sample which forms the basis for this paper we have not as yet been able to follow up a sufficient number of cases to ascertain permanent disability for all those receiving it. However, it seems likely, because of the nature of the injuries sustained by those staying in hospital for more than 12 weeks, that severe disability occurred mainly to the lower leg and to the central nervous system. If both samples were taken together the regions of the body appearing to require the greatest protection against the possibility of receiving severe permanent disability whether amongst motorcyclists or pedestrians, would seem to be the lower leg and the head.

For injuries involving threat to life, the head for pedestrians and the head and possibly to a lesser extent the chest for motorcyclists were the most vulnerable areas of the body in the present sample. Amongst the 282 bicyclists in the sample none received an injury greater than AIS 4, and no deaths were seen but there were three deaths in our earlier sample  $\binom{4}{}$ . In a recent American study  $\binom{10}{}$  there were 3 fatalities in a hospital sample of 613 bicyclist casualties studied.

The cause of death in all 3 fatalities in our earlier sample was injury to the head as was the case in most of the fatalities in the American sample. These results tend to confirm earlier findings<sup>(6)</sup> in which head injury was found to be the leading clinical cause of death amongst bicyclists and amongst pedestrians.

## 6. CONCLUSIONS

The following conclusions can be drawn from the data analysed in this hospital sample of 932 unprotected road user casualties (348 motorcyclists, 302 pedes-trians and 282 bicyclists).

1. Amongst the three categories of unprotected road users investigated pedestrians were most likely to be detained in hospital.

Of those detained, motorcyclists stayed longer on average in hospital than pedestrians or bicyclists. No bicyclist was detained for more than 12 weeks.
 Amongst the 932 casualties only 12 stayed in hospital for more than 12 weeks.

4. For injuries of AIS 3 and above (mainly AIS 3) the lower leg was part of the body having the highest frequency of injury in all the categories studied.

For other regions of the body there were differences in injury patterns for the different categories.

5. The head was the region of the body most commonly receiving life threatening injury amongst motorcyclists and pedestrians.

6. The proportion of bicyclists in the sample was substantially higher than that recorded in the national figures but the overall severity of injury received was much less than for motorcyclists or pedestrians.

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# APPENDIX:

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TABLE 7. Distribution of injury for all categories of A.I.S. by region of the body amongst 348 motorcyclist casualties

AIS BODY CATEGORY REGION	NO INJURY AIS O	MINOR AIS 1	MODERATE AIS 2	SEVERE AIS 3	SERIOUS AIS 4	CRITICAL AIS 5	MAXIMUM AIS 6
HEAD	256	28	51	6	2	4	1
NECK	338	7	-	2	-	1	-
BACK	336	10	-	2	-	-	-
LEFT SHOULDER	333	8	7	-	-	-	-
RIGHT SHOULDER	318	17	11	2	-	-	-
LEFT ARM	278	49	14	7	-		-
RIGHT ARM	265	61	14	8	-	-	-
CHEST	324	16	5	-	2	-	1
ABDOMEN	331	14	1	1	1	-	-
PELVIS	346	-	1	1	-	-	-
LEFT HIP JOINT	348	-	-	-	-	-	-
RIGHT HIP JOINT	347	-	-	1	-	-	-
LEFT THIGH	314	25	2	7	- 1	-	-
RIGHT THIGH	323	21	-	4	-	-	-
LEFT KNEE	260	75	10	3	-	-	-
RIGHT KNEE	261	82	3	2	-	-	-
LEFT LOWER LEG	293	33	7	15	-	-	-
RIGHT LOWER LEG	310	25	2	11	-	-	-
LEFT ANKLE & FOOT	304	38	3	3	-	-	-
RIGHT ANKLE & FOOT	323	19	5	1	-	-	-

# APPENDIX:

TABLE 8.	Distribution of	of injury	for all	categories	of A.I.S.	by region of
	the boo	ly amongs	t 302 pe	destrian ca	sualties	

AIS BODY CATEGORY REGION	NO INJURY AIS O	MINOR AIS 1	MODERATE AIS 2	SEVERE AIS 3	SERIOUS AIS 4	CRITICAL AIS 5	MAXIMUM AIS 6
HEAD	139	60	81	10	1	6	5
NECK	299	3	-	-	-	-	-
BACK	298	3	-	1	-	-	-
LEFT SHOULDER	290	8	4	-	-	-	-
RIGHT SHOULDER	283	7	12	-	-	-	-
LEFT ARM	235	58	б	3	-	-	-
RIGHT ARM	236	55	9	2	-	-	-
CHEST	276	14	Ĺ4	6	-	1	1
ABDOMEN	279	15	5	1	1	-	1
PELVIS	288	2	3	9	-	-	-
LEFT HIP JOINT	301		-	1	- 1	-	-
RIGHT HIP JOINT	301	-	-	1	-	-	-
LEFT THIGH	266	27	1	8	-	-	-
RIGHT THIGH	261	32	1	8	-	-	-
LEFT KNEE	258	38	4	2	-	-	-
RIGHT KNEE	254	44	4	-	-	-	-
LEFT LOWER LEG	258	29	2	13	-	-	-
RIGHT LOWER LEG	257	27	4	14	-	-	-
LEFT ANKLE & FOOT	273	23	6	-	-	-	-
RIGHT ANKLE & FOOT	279	22	-	1	-	-	-

# **APPENDIX:**

AIS BODY CATEGORY	NO INJURY	MINOR	MODERATE	SEVERE	SERIOUS	CRITICAL	MAXIMUM
REGION	AIS O	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5	AIS 6
HEAD	145	82 ·	53	-	-	-	-
NECK	275	5	1	1	-	-	-
BACK	276	6	-		-	-	-
LEFT SHOULDER	274	6	2	-	-	-	-
RIGHT SHOULDER	267	12	3	-	-	-	-
LEFT ARM	213	58	10	1	-	-	-
RIGHT ARM	216	55	8	3	-	-	-
CHEST	271	11	-	-	-	-	-
ABDOMEN	264	17	-	-	1	-	-
PELVIS	279	-	2	1	-	-	-
LEFT HIP JOINT	281	-	-	1	-	-	-
RIGHT HIP JOINT	281	-	-	1	-	-	-
LEFT THIGH	262	17	2	1	-	-	-
RIGHT THIGH	265	15	1	1	-	-	-
LEFT KNEE	242	34	6	-	-	-	-
RIGHT KNEE	249	33	-11 <u>-1</u> -17	( <u> </u>	200 <u>-</u> 111		-
LEFT LOWER LEG	264	14	2	2	- 11	-	aft = 17
RIGHT LOWER LEG	267	9	1	5	-	-	-
LEFT ANKLE & FOOT	267	11	4	-	-	-	-
RIGHT ANKLE & FOOT	266	13	2	1	-	-	-

TABLE 9. Distribution of injury for all categories of A.I.S. by region of the body amongst 282 bicyclist casualties