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MOTOR-CYCLISTS, CRASH HELMETS, AND HEAD INJURIES

BY

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In 1941 crash helmets for Army motor-cyclists on duty became compulsory, and since 1953 an increasing number of civilian riders have been wearing them. In this paper an attempt is made to evaluate their use and to comment on the present situation. The difficulties of trying to present this statistically will be appreciated. The use of crash helmets is only one aspect of the whole accident problem and it is all too easy to relate accident statistics incorrectly to the particular problem under review. Moreover, the assessment has to take into consideration the fact that traffic on the roads is increasing year by year, and only a proportion of motor-cyclists are wearing helmets. When considering the effects of a protective measure on the mortality rate it has to be remembered, too, that the main reasons for the general reduction of accident mortality which has taken place in recent years have been the advances in medicine and the improvements in organization of accident work. Above all, it should be noted that hospital figures alone will not reflect what should be one of the main uses of a helmet—that is, so to modify the effects of a blow that injury is prevented or is trivial. Nevertheless, from a consideration of cases severe enough to be admitted to hospital it is believed that some conclusions may be drawn. In this series the number of patients admitted who were wearing crash helmets at the time of the accident was not large, but in view of the importance of the problem it was felt that some comment on the present position was pertinent.

Our material is drawn from two sources. At the Radcliffe Infirmary, Oxford, all accident cases are admitted to the Accident Service. As this hospital is the only one in the district to admit such cases it provides an unselected series. Table I shows that in the six years

although the analysis for 1955 is not yet complete, those motor-cyclists admitted in that year who were wearing crash helmets have also been included to illustrate particular points. The other source is the Army. At the Military Hospital (Head Injuries), Wheatley, Oxford, is the Army Neurosurgical Unit, and in addition to receiving Service patients from the immediate vicinity patients with head injuries come from other hospitals for special treatment and review. These cases therefore comprise a selected series, but are very valuable when considering the use of crash helmets, because of the compulsory rule. In the three years 1952–4 there were 135 consecutive admissions of Army motor-cyclists suffering from head injury.

The Motor-cyclist at Risk

In 1954 there were estimated to be 1,071,000 motor-cycles on the roads of Great Britain, comprising nearly one-fifth of the motorized traffic. In that year 967 motor-cyclists and 181 pillion passengers, a total of 1,148, were killed. During 1954 also, the production of motor-cycles was a record, 63% going to the home market.

There is no doubt that head injury accounts for the great majority of the deaths. Indeed, over 70% of all fatal road accidents are associated with head injury, and the proportion in motor-cyclists is even higher. Cairns (1941) found the incidence of head injury among fatal motor-cycle injuries to be 92%, and Pike (1949) quoted a similar figure. We can confirm this. At the Radcliffe Infirmary in the last two years, 1954–5, for example, there were 19 deaths among motor-cyclists, of which no fewer than 17 were due to head injury. If it should be thought that the motor-cyclist is being singled out unduly from other road users, two further points in connexion with the accident problem as a whole should be borne in mind.

Firstly, a survey made of the accident details of 1,000 consecutive cases of head injury (Lewin, 1954) showed that road accidents accounted for 74.5%. Of those involved in road accidents, 31.2% were pedal-cyclists (perhaps betraying the city of origin of these figures); motor-cyclists including pillion riders comprised 30%, pedestrians 21.8%, and car drivers or passengers 16.7%. When one bears in mind the small proportion of motor-cyclists on the roads compared with pedal-cyclists and pedestrians, their special risk of head injury stands out prominently. Secondly, although there has been a considerable improvement in the mortality rate from head

TABLE I.—Head Injury Statistics, 1949–54

Year	Total Head Injuries	Deaths	Motor-cyclists	Deaths
1949	203	25	46	5
1950	333	37	81	12
1951	393	23	93	6
1952	354	19	83	4
1953	559	33	112	11
1954	636	27	140	10
Total	2,478	164	555	48

1949–54, 2,478 patients with non-missile head injuries from all causes were admitted, of whom 555 (22.4%) were motor-cyclists. These form the main civilian series on which this paper is based. In addition,

injury (over the last seven years the mortality from head injury in the Accident Service at the Radcliffe Infirmary has fallen from 12.3% to 4.3%), the more severe injury sustained by the motor-cyclist is shown by the fact that, during this period when the overall mortality from head injury was falling, the proportion of deaths among motor-cyclists was increasing. Thus in 1949-52, of 104 deaths from head injury, 26% were motor-cyclists; in 1953, 11 out of 33 (33%), and in 1954, 10 out of 27 (37%).

These facts seem to show clearly that not only is the motor-cyclist much more liable to head injury than any other road user and to run a high chance of severe injury, but also that anything that can be done to lessen the risks or severity of head injury in motor-cyclists would considerably lower the mortality rate of road accidents as a whole.

Crash Helmets in Army Motor-cyclists

Miners and racing drivers have worn protective helmets for many years, but it was the Army experience in the second world war that focused attention on the value of crash helmets for motor-cyclists on the roads. They were made compulsory in the Army in November, 1941, and were

FIG. 1.—Effect of a severe blow to an Army steel helmet. The scalp and skull were uninjured (Case 1).

believed by Cairns (1946) to have been one of the factors which contributed to the fall in fatal motor-cycle accidents that followed for the next five years. Pike (1949), in a later survey of 559 motor-cycle accidents among Army personnel, noted that head wounds accounted for a quarter of all the serious cases, yet less than one-seventh of the slight cases, suggesting, therefore, that blows sufficient to cause slight injury elsewhere in the body had no effect on a head protected by a helmet.

We think that we can give collateral evidence of their value in another way. In the three years 1952-4, 135 Army motor-cyclists were admitted to Wheatley with head injury. It would be anticipated that among these Service patients the majority would have been wearing helmets, but the reverse was true: 76 were not wearing a helmet at the time of the accident, and in a further 16 the evidence was uncertain. In other words, in an Army hospital and in circumstances where a crash helmet is compulsory on duty, two-thirds of our motor-cyclists had been injured when off duty and not wearing helmets. There are quite possibly some other factors at work as well, for S. Rosenbaum (1955, personal communication) noted some decrease in injuries involving drivers of all kinds of vehicles when on duty as compared with off duty. Since these observations, the Army has encouraged its riders to wear their helmets when riding off duty.

The present Army helmet is, of course, designed not only against road accidents but also against missile wounds, and has an outer steel shell with a smooth surface and a generous thick rubber lining about $\frac{1}{4}$ in. (1.6 cm.) thick. It clearly prevents many minor accidents. However, no helmet will protect against all injury, and the following case of a severe blow illustrates this point and also the way a helmet may modify the type of injury sustained.

Case 1.—A soldier was said to have been overtaking at 75 miles (120 km.) an hour when he came off his motor-cycle. He was wearing a regulation steel helmet. From the outset he was deeply unconscious, with bilateral ptosis, fixed pupils, and spastic limbs with decerebrate spasms. The only other injury was a small surface wound of the right knee. There was no mark on the head and no skull fracture. The helmet (Fig. 1) showed a pronounced depression 3 in. (7.5 cm.) in diameter and $\frac{1}{4}$ in. (1.3 cm.) deep in the left frontal region, evidence of the severe blow sustained. Burr-hole exploration 26 hours after the injury showed no surface bleeding over the brain, but the brain was tight and the ventricular fluid heavily blood-stained. The patient died 36 hours after injury. *Necropsy.*—No fracture of the skull was seen. The surface of the brain was intact, with no surface bleeding and only minor bruising at the tip of the right temporal pole and the adjacent undersurface of the frontal lobe. Bilateral uncinate and tonsillar herniation was found. On coronal section, however, there were extensive mid-brain haemorrhages and a large haemorrhage in the right basal ganglia measuring 8 by 4 cm. The pituitary stalk was ruptured.

Here the helmet had given considerable protection against surface injury to the scalp, skull, and brain despite its being severely deformed. However, the severe general shaking given to the brain by such a blow had led to deep haemorrhages and presumably to microscopical injury as well.

Civilian Experience

Before 1953 few civilian motor-cyclists wore crash helmets. A road survey in 1952 showed that only 2% did so. In the spring of 1953 the Metropolitan Police introduced a light-weight helmet for their patrols, and this undoubtedly stimulated civilians to use them. By August, 1953, 10% of motor-cyclists were wearing helmets, and by the end of that year 16%. During 1954 various surveys by road organizations and by ourselves gave figures of 19-22%. This figure had increased during 1955 to about 30%, the tendency being for the percentage to be higher in urban than in rural communities and higher on main roads than on secondary roads. But the fact remains that at the present time not more than a third of our motor-cyclists, at the most, are wearing helmets, despite the publicity over the past year.

The 555 motor-cyclists admitted over the six years 1949-54 have been divided into three groups (Table II): 1949-52, the period when helmets were rarely worn; 1953, the transitional period when perhaps 10% of motor-cyclists wore helmets; and 1954, when the figure had risen to about 20%. As indicated above, we are dealing only with that

TABLE II.—Head Injuries in Motor-cyclists (555 Cases)

Years	Number	Wearing Crash Helmet	No Crash Helmet
1949-52 ..	303 (27 deaths)	1	302 (27 deaths)
1953 ..	112 (11 ..)	3	109 (11 ..)
1954 ..	140 (10 ..)	23 (3 deaths)	117 (7 ..)

group of motor-cyclists with head injuries severe enough for admission to hospital. We have no information on the other two groups of motor-cyclists—those in whom the injury is so slight that in-patient treatment is not required, and the fatal cases where death occurs on the road before reaching hospital. The evidence from the hospital figures suggests, however, that the value of wearing a crash helmet would be well shown if these two latter groups could be analysed as well, and a pilot survey along these lines is urgently needed. A crash helmet will not prevent an accident; but if it can convert what would have been a major injury

requiring hospital admission into a minor one it will have earned its place, quite apart from any modification it may have on the more severe hospital cases.

When comparing helmet and non-helmet cases it should be borne in mind that the presence of concussion is usually the criterion for inclusion in the head injury series and commonly the reason for admission, so that if a helmet has an effect then the two groups are not comparable as regards the severity of the blow sustained. It may be postulated that a severer blow will be required to cause an equivalent degree of concussion when a helmet is worn. Reports of accidents are difficult to analyse, but if we accept the contention that injuries elsewhere in the body in addition to a head injury indicate in general a more severe accident, then the postulate is correct. Thus in Table III the incidence of

TABLE III.—*Other Injuries Sustained by 277 Motor-cyclists with Head Injuries*

Other Injuries	Without Crash Helmet (227)	With Crash Helmet (50)
Total No. (155)	119 (52.4%)	36 (72%)
Fractures:		
Face	38	9
Upper limb	48	17
Lower "	25	8
Spine	2	1
Thorax and pelvis	13	8
Chest	3	3
Abdomen	5	3
Eyes	2	—
Major lacerations and soft-tissue injuries	22	10

major injuries elsewhere in the body is set out, comparing the first 227 in this series of motor-cyclists with head injuries not wearing crash helmets, with a series of 50 similar patients wearing crash helmets admitted in 1954 and 1955. The differences are striking: 72% of the crash-helmet cases had sustained multiple injuries as against 52.4% of the non-helmet cases. When the details are considered there is a very obvious increased risk of injury to the chest and abdomen, there being six examples in the crash-helmet group as against only three in the non-helmet group, which is over four times as large. It should be noted, also, that both figures are well above the incidence of multiple injuries in an unselected series of head injuries from all causes, which in a previous paper (Lewin, 1953) was estimated to be 32.7%. This is a further illustration of the additional risks of injury a motor-cyclist runs.

Mortality

Table II shows how the motor-cyclist shares in the rising tide of road accidents. It is salutary to note that in the single year 1954 there were nearly half as many admissions as for the four-year period 1949–52. It is encouraging that whereas in the earlier years 1 in every 7.5 motor-cyclists who were admitted died, in 1954 the proportion had fallen to 1 in 14. Nevertheless it is a worrying thought that motor-cyclists should account for one-third of all deaths from head injuries.

During 1954 there were three deaths among motor-cyclists wearing crash helmets; details of these cases are instructive.

Case 2.—A man aged 26 was wearing a crash helmet at the time of the accident. From all accounts he was driving at speed at night and crashed head on into a brick wall. He lay unconscious in the snow for some time, and when admitted to the Radcliffe Infirmary some two hours later was comatose and *in extremis*, with a systolic blood pressure of 50 mm. Hg. He was bleeding from the nose and both ears, and cerebrospinal fluid was discharging from the left ear. There was an obviously fractured mandible, several ribs on the left side were broken, and the lungs were congested. On these signs there was a presumptive diagnosis of a fractured base of skull, but there was no bruise or laceration over the head. Despite resuscitation the patient died six hours after injury. X-ray films of the skull were not taken and necropsy was not performed. The crash helmet (pulp type) was well made, but had fractured on the left side

with very mild deformity, and surrounding it was a wide area of skid marks. The front of the helmet was relatively unmarked, and this suggested that the patient had turned his head to the left to avoid a frontal impact.

This case again illustrates the fact that a helmet will not protect against all head injury, and from what we know of the accident here it was similar in severity to Case 1. Again the head was unmarked.

Case 3.—A youth aged 18 was believed to have collided with a car while riding his motor-cycle. He was wearing a crash helmet, but this came off during the impact and was afterwards found near the hedge. Initially the patient was unconscious, but on admission to hospital 40 minutes later he was conscious and alert. He had a right parietal scalp laceration and both pupils were equal and reacting. The principal injury was to the chest. He was shocked, pale, and sweating, and was thought to have a haemopneumothorax. There was also a fracture of the right humerus. Blood transfusion was given, but he died three and a half hours after the accident. *Necropsy.*—There were numerous fractured ribs on the right side, with rupture of the right lung and several pints of blood in the pleural cavity; the air passages were full of frothy blood, which was the immediate cause of death. A fissure was present in the right parietal region of the skull extending to the base, and there was slight bruising of the left temporal lobe.

Here clearly the cause of death was extracranial. From all accounts the head injury itself was not fatal, and indeed the evidence is that the crash helmet came off before the impact. We have seen other cases where the helmet has come off at the time of the accident, because of a bad fit or an incomplete fastening.

Case 4.—A youth aged 19 was admitted to hospital one hour after a road accident in which he was riding a motor-cycle and wearing a crash helmet. The engine suddenly stalled and he was thrown clear. From the outset he was deeply comatose and decerebrate, with signs indicating a brain-stem lesion. There was some left temporal bruising, the lower jaw was fractured, and there was a good deal of bleeding into the pharynx with inhalation. The following day the neurological state had improved a little, but there was increasing difficulty with the airway, and a tracheotomy was performed. This did not, however, improve him, and he died 23 hours after the accident. *Necropsy.*—Both lungs were collapsed, with blood in the alveoli and bronchi. There was no fracture of the skull, and the external surface of the brain appeared to be normal and without evidence of increased intracranial pressure. On section, however, several haemorrhages were found in the brain stem and basal ganglia (Fig. 2). The crash helmet shell, which was made of cork, was intact (Fig. 3), but had a rigid peak which had been torn from the main helmet. The left ear strap was partly torn off and skid marks were present on the left side. There was internal rubber padding $\frac{1}{4}$ in. (6 mm.) thick with additional frontal protection. The goggles were also broken.

FIG. 2.—Coronal section of the brain to show bilateral haemorrhages in the basal ganglia. There is also a haemorrhage deep in the white matter of the left temporal lobe (Case 4).

FIG. 3.—Helmet (cork) worn in fatal case (No. 4). Note that the peak and the left ear flap have been torn from the main shell.

This was a severe head injury but without skull fracture, and was complicated by a fractured jaw with severe bleeding into the air passages. There had been some improvement in the patient's neurological state after the early hours; the chest complication was the immediate cause of death, although the head injury alone carried a very unfavourable prognosis.

It should be noted that all these three cases had multiple injuries, and, so far as we can judge from the circumstances, they were very severe accidents. During 1955 there were two further deaths among civilian motor-cyclists wearing crash helmets, and references to both these patients are recorded to illustrate other points (Case 9 and Fig. 4). In Case 9 the head injury was mild and the cause of death was extracranial. Fig. 4 shows the type of helmet, partly home-made, which was used in the other case where death was

FIG. 4.—Plastic helmet, partly home-made, worn in a fatal case, with death from head injury.

of the 14 deaths in 1954 and 1955 from all causes among motor-cyclists not wearing crash helmets. All but two of these motor-cyclists died from head injury, and in nine it was the sole injury. These figures are small, but they strongly suggest that if an efficient crash helmet is worn the likelihood of a fatal head injury from a blow of ordinary severity is greatly reduced.

Fracture

Table IV shows no significant difference, in the 1954 series, between the incidence of a fracture of the skull with a helmet and that without, although, as mentioned earlier, it is questionable whether the actual severity of the blow

TABLE IV.—Skull Fracture in 140 Motor-cyclists Admitted with Head Injury in 1954

Type	Cases	Fracture		
		Nil	Fissure	Depressed
Wearing helmet ..	23*	15	6	1
No helmet ..	117	82	27	8

* Details of Case 2 not known.

sustained in the two groups is comparable. What is important, however, is the type of fracture sustained. In 22 of the 23 patients in 1954 who wore crash helmets, and the fracture details of whose cases are known, only 1 sustained a compound or a depressed fracture, whereas among the 117 non-helmet patients 11 had compound fractures, 6 of which were depressed, and 2 others had closed depressed fractures. Moreover, in the solitary example of compound fracture where the patient was wearing a crash helmet, the helmet had a plastic shell which had fractured easily and had been driven into the frontal region.

Case 5.—A young man was found in the road unconscious, lying near his motor-cycle. By the time he was admitted to hospital some two hours later he had improved to a state of confusion, and subsequently had a post-traumatic amnesia of about

FIG. 5.—Helmet (plastic type) in Case 5 which was fractured and deformed. The patient sustained a severe compound depressed left frontal fracture.

three days. Locally he had sustained a compound depressed fracture of the left supraorbital region and left orbital roof with considerable displacement of the left eye. X-ray examination confirmed the fracture, together with an extension over to the right frontal sinus, and the presence of air in the subarachnoid space. There was severe damage to the optic chiasm, only the vision in the nasal field of the left eye remaining. Bilateral anosmia and palsy of the right sixth cranial nerve were present. At operation 18 days after injury, through a left frontal flap, the depressed bone was raised and the dura in relation to the air sinus repaired. Subsequently the patient made a good recovery, although the visual defect remained. The helmet remained on after the accident. It had a very light plastic shell with a superficial felt covering and a rigid peak, and was greatly deformed (Fig. 5). It was fractured on the left side upwards and inwards from the peak margin, and was bent at the site of the main fracture of the skull.

It would appear, therefore, that an efficient helmet lessens the chances of a compound or a depressed fracture, with their attendant immediate and later complications.

Brain Injury

Among the survivors we have not found any appreciable differences in the degrees of concussion sustained by those wearing crash helmets and those not, as judged by the duration of post-traumatic amnesia (P.T.A.). The reason for this among hospital figures has already been set out. If a

helmet is effective, in addition to preventing a concussion in some minor injuries and excluding such cases from a hospital series, it may be expected also to convert some otherwise fatal cases into those with long amnesia. There is little doubt that a survey of all motor-cycle accidents would show a favourable effect on concussion when a helmet is worn, and an inquiry along these lines is needed. Cairns and Holbourn (1943) attempted this to some degree by collating various pieces of evidence, and estimated that a crash helmet reduced the incidence of severe P.T.A. (one day or more) to a third. Part of their material, however, was selected, and further information is required on this point.

We can, however, cite several examples of motor-cycle accidents where there is no doubt that a crash helmet prevented or modified favourably the effects of a head injury. The following four patients admitted in 1955 illustrate this point in various settings.

Examples of the Protective Value of a Crash Helmet

Case 6. Severe Multiple Injuries and Blow to Helmet, but No Head Injury.—A motor-cyclist aged 23 was wearing a crash helmet when he hit a stationary car, was thrown off his cycle, and landed on his head. There was, however, no loss of consciousness or any evidence of head injury. Yet the impact was severe enough to produce a compound fracture of the left femur, a severely comminuted supracondylar fracture of the left humerus, and a laceration in the perineum. The helmet was of the "corker" type but made of light metal, and was not deformed. A soft plastic peak had retained its shape and was intact. Heavy mud markings on the crown and right side confirmed that he had somersaulted over and landed partly on the top of his head.

Case 7. Blow to Head with Fracture of Crash Helmet and Minimal Evidence of Head Injury.—A lad aged 16 was riding on the pillion and wearing a crash helmet when he was involved in an accident. He was fully alert and rational when admitted to

FIG. 6.—Lightweight wood-pulp helmet worn in Case 7 which was fractured but undeformed, and had protected against a major injury.

hospital 35 minutes later, and on inquiry there was either no loss of consciousness at all or, at the most, a post-traumatic amnesia of a few seconds. There were no scalp marks or fracture of the skull, and no neurological symptoms or signs. The helmet (Fig. 6), however, which had a thin wood-pulp shell but with good rubber padding, was fractured for a length of 3 in. (7.5 cm.) in the right temporal region with a wide area of skid marks around it, evidence of quite a severe blow to the head. Moreover, the patient had sustained extensive injuries down the right side, including a fracture of the right tibia, fibula, and femoral condyle, and deep lacerations of the right thigh and foot, from which he made a satisfactory recovery.

Case 8. Severe Multiple Injuries with Major Head Injury and Ultimate Recovery.—A man aged 24 was riding his motor-cycle and wearing a crash helmet when he collided with a car and ricocheted against a bridge. He was deeply unconscious from the outset and was admitted to hospital severely shocked and with such a multiplicity of injuries that his survival was regarded as unlikely. The injuries included a compound fracture of the right leg with doubtful viability of the foot; a fracture of the right clavicle and scapula with a complete right brachial plexus

lesion; a closed fracture of the right forearm; a right haemo-pneumothorax; a compound fracture of the mandible; and a fissured fracture of the skull in the left fronto-parietal region. In the early stages he had a blood transfusion of 10 pints (5.7 litres), and seven days after the injury a tracheotomy was performed because of difficulty with the airway. It was four days before the patient spoke, and thereafter he made a gradual recovery and finally had a P.T.A. of about seven weeks. Lumbar puncture nine days after the accident showed that there had been some subarachnoid bleeding. The subsequent course was one of gradual improvement, the patient requiring prolonged hospital treatment for his various injuries. When seen eight months after the accident he was nearly ready for retraining. The crash helmet was well made, with a cork shell and inner padding. It was intact, and the only marks present were a few grazes in the left parietal region.

Case 9. Severe Multiple Injuries with Death. Evidence of a Major Blow to Head, but Mild Brain Damage.—A young man was riding his motor-cycle and wearing a crash helmet when he collided with a car. He received very severe injuries, was profoundly shocked on admission, and died 21 hours later. The injuries included a compound fracture of the pelvis with disruption of the pubic symphysis, a compound fracture of the left forearm, closed fractures of the right forearm and of the left leg, and extensive lacerations over the right thigh with a massive haematoma. At necropsy it was found that the major branches of the internal iliac arteries on each side had been torn and there was about a litre of blood in the peritoneal cavity. The patient had clearly sustained a major blow on the back of the head, for his helmet was fractured in the occipital region for a length of 2 in. (5 cm.). Around it were abrasions to the helmet for a diameter of 3 in. (7.5 cm.). The shell was thin plastic, but with inner sponge-rubber lining $\frac{1}{4}$ in. (1 cm.) thick. Despite his severe injuries, the patient was conscious on admission and at the most only slightly confused, and, so far as tests could be made, there were no neurological abnormalities. There were no marks on the head, and at necropsy no skull fracture was found and the brain showed slight oedema only.

Site of Brain Injury

As wearing a crash helmet modifies the severity of fracture and the concussive effect, we should consider also whether there are differences in the nature of the brain damage sustained between the helmet and non-helmet cases. Although the figures are small, the following observations may be significant. In the two cases which so far have come to necropsy and in which it is known that an efficient helmet was worn at the time of the accident, the findings are strikingly similar (Cases 1 and 4). Neither had scalp marks or skull fracture, and the surface of the brain was intact and without surface bleeding. Mild surface bruising of the brain was apparent in one case in the region of the temporal pole (Case 1). Coronal sections, however, showed that brain-stem haemorrhages and major haemorrhages in the basal ganglia were present in both cases, massive in Case 1. By contrast, the necropsy findings in the seven fatal cases in 1954 where no crash helmet was worn showed fracture of the skull in six; surface bleeding, subarachnoid or subdural, in all; and major surface contusion, frequently lacerations, principally at the frontal and temporal pole, in six. Haemorrhages in the brain stem basal ganglia were found in only one case.

These findings suggest that an efficient helmet, and particularly a good shell, will minimize severe fracture and surface injury to the brain. Generous inner padding of the right material is, however, also required to absorb the energy of the blow and reduce the general concussive effect. Even though the helmet shell was fractured in Cases 7 and 9, good inner padding protected against severe brain injury. This of course has a limit, and Case 1 may well illustrate a blow excessive for even a well-padded steel helmet.

If these observations on brain injury in crash-helmet cases are confirmed, they indicate that in helmet construction both the shell and the inner padding have functions which are complementary. In fatal cases where an efficient helmet is worn the common finding may be deep brain injury and presumably also diffuse microscopical damage, from the concussive effect of a severe blow which cannot be sufficiently dissipated.

Type of Helmet

Helmet construction is still in its developmental stage, and it is not sufficiently realized by the public that, although some protection to the head is better than none, it does not follow that just any type of helmet gives efficient protection. Indeed, some may do harm not only by giving a false sense of security, but also, if they are brittle, by fracturing easily and damaging the underlying scalp and skull. Vulcanite and some plastic helmets may do this. Thus in Case 5 the sharp broken ends of the helmet were driven into the frontal region.

Criteria of an Effective Helmet

From observations of these patients we believe that the outer shell of a good helmet should be tough, not easily deformed, and not brittle so as to render it liable to fracture. Coupled with this, the surface should be smooth and free from excrescences so that the helmet can glide over the area struck and thus reduce friction. This has the effect of "lengthening" the blow and lowering the rate of deceleration of the head, with consequent lessening of the concussive effect. It also decreases the rotational effect. The steel helmet is very efficient for military personnel but too heavy and cumbersome for ordinary civilian use. There are, however, possibilities of lightweight metal helmets which may be satisfactory. Impregnated wood pulp seems to be about the best among the present materials for ordinary purposes. Cork is reasonably satisfactory, but has the disadvantage of friction unless it can be covered by other material.

It is fashionable at present to have a *peak*. Originally introduced to add smartness to the helmet, it has undoubtedly helped to popularize them, but it has its own dangers. We have seen several helmets where the peak has been ripped from the main body. The risk, therefore, is that it may prevent the helmet sliding over the ground, and in head-on collisions a rigid peak may also act as a fulcrum and increase the rotational effect to the head and neck. However, a possible advantage of a peak, apart from smartness, could be in protection to the eyes and upper face. Provided, therefore, a material can be developed which is firm enough to retain its shape against the wind, but flexible enough to bend over at a mild blow and protect the eyes, then the peak may be helpful. Nevertheless, it is safer to have no peak than one that is rigid or poorly attached.

The *internal padding* to a helmet is highly important. The material used should absorb the maximum amount of energy and reduce the maximum force to the head. From an examination of a large number of helmets following injury we think that good quality sorbo rubber which does not collapse easily, or cork, at least $\frac{1}{4}$ in. (1 cm.) thick, should be incorporated all round. Some of the newer foam materials may be better still.

In the past a good deal of attention has been paid to the crown of the helmet and the internal slings. This is important for particular problems, such as protection for miners where falls on the crown are common, but less so for civilian motor-cyclists, who rarely sustain injuries to the

helmet for the ordinary motor-cyclist, although the shell must be rigid enough not to collapse on to the head from moderate blows to the crown. Extra padding, however, should always be added to the frontal region, and, as mentioned above, a flexible peak might diminish facial injury.

The problem of the temporal region is more difficult. This is a dangerous area for a head injury, and many blows are sustained on the rim of the helmet and in the region of the ear where the flap is attached, which is a natural weak spot. Fig. 7 illustrates such a situation that arose with a helmet which finished too high above the right ear, and a blow here resulted in a right temporal injury. It may be that this part of the flap could be further padded or, alternatively, some of the newer synthetic materials used in place of leather, which might help to deaden the blow.

There are several types of helmet on the market at present and many different materials are being tried. Some helmets incorporate many of the points mentioned above, but in others the materials are unsuitable. These helmets have to comply with the British Standards Institution's requirements, but it should be remembered that these are at present based on the breaking power of a blow delivered to the crown of the helmet—a fact that is of limited value, for, as pointed out above, this is not the common direction of force in motor-cycle accidents, and fresh standards for the particular circumstances should be sought.

For the racing motor-cyclist and for those who intend travelling at speed, the present evidence suggests that a steel helmet, or a high-quality smooth-surfaced impregnated wood-pulp helmet with full padding, is advisable. But some riders find these cumbersome for local everyday purposes, and the special requirements of those riding light motorized machines, who also should have some protection, suggest the need for an alternative. For these users it should be possible now to consider the construction, for limited purposes, of a hat with a firm but thin shell and good padding which would afford some protection, and which would be popular.

Discussion

In focusing attention on crash helmets it should be emphasized that this is only one facet of the accident problem in motor-cyclists. A helmet will not prevent an accident, and the recent Ministry of Transport booklet *Sense and Safety* brings out very clearly the degree to which many accidents could be prevented by the better judgment and road sense of every road user. Improved training schemes for motor-cyclists are surely among the basic essentials. The question whether the speed and capacity of machines should be limited for ordinary road use also merits further consideration. Again, head injury is by no means the only risk the motor-cyclist runs. The frequency of other injuries has already been mentioned. The invalidism from major leg fractures, for example, might well be lessened by fitting leg-protection bars to all machines. On the hospital side there is room for improved organization of accident services, in view of the increasing number of accidents and the importance of early and effective treatment.

FIG. 7.—Problem of protecting the temporal region. This patient sustained concussion and the scalp injury shown. The helmet did not fit well in this region.

TABLE V.—Site of Scalp Injury in 181 Motor-cyclists Not Wearing Crash Helmets

Site	No.	Site	No.
Frontal	48	Occipital	5
Facial	48	Multiple	12
Parieto-temporal and ear	40	Unspecified	2
Vertex	4	None	22

crown, or for that matter to the occiput. Thus Table V shows that in a consecutive series of 181 motor-cyclists with head injuries not wearing helmets only nine had scalp injuries to the vertex or occiput. Motor-cyclists ride close to the ground, and the fall is usually forward or forward and to one side, the rider hitting the surface before there has been further rotation. Table V shows, further, that more than half the injuries are to the frontal and facial regions. There is therefore no necessity to have a high-crowned

The reasons for singling out the motor-cyclist from among other road users have been given. He rides unprotected and runs a particular risk of injury. The importance of head injury in the mortality rate is obvious, and it is clear from the present trend of figures that any reduction in the mortality rate from head injury among motor-cyclists would not only benefit the group but have a very favourable effect on accident mortality as a whole. One further point which should be mentioned is the economic loss to the country of these young men. In this series of motor-cyclists with head injuries, 56% were between 16 and 25 years of age and 95% were between 16 and 45. This may be compared with an incidence of 27.9% in the 16-25 year group and 55.8% in the 16-45 year group among an unselected consecutive series of 1,000 closed head injuries from all causes. The country can ill afford the injury to and loss of life among these vigorous young men, many of whom are skilled or in training. During 1955, for example, 149 motor-cyclists were admitted to the male accident ward of the Radcliffe Infirmary alone with injuries of all kinds. There were nine deaths. All had head injury, which was the cause of death in seven.

The evidence in this paper, together with earlier work on this subject, seems to leave little doubt that an efficient crash helmet will prevent many minor concussions and lessen the effect of severer injuries. The risks of severe and complicated skull fractures are considerably reduced. It is surely significant that among the number of civilian motor-cyclists admitted in the last two years there have been only two deaths from head injury where an efficient helmet has been worn, and in both cases there were multiple injuries and evidence of severe impact.

There are several lines for further study. The Road Research Laboratory is continuing its work on the design and construction of helmets, and the possibilities of many of the newer synthetic materials available for both the shell and the inner padding need testing. The standards of an efficient helmet for motor-cyclists also require review with their particular problems in mind. Starks (1952) made a useful survey of motor-cycle accidents based on statistics for the immediate preceding years, and a further field survey on the resultant injury to motor-cyclists when the head is struck would be particularly valuable at this period to estimate how useful a helmet is in preventing concussion altogether. In other cases, as suggested in this paper, a study of the brain injury sustained may also yield further useful information.

It is estimated that at the present time not more than a third of motor-cyclists over the country are wearing helmets. Every encouragement should be given to motor-cyclists to wear them. The Government could give a useful lead by removing the remaining purchase tax from these helmets. It should not be supposed, however, that this would be by any means the complete answer. The relief of a few shillings is unlikely to influence a young man who is prepared to pay a high price for a modern machine. Indeed, cost is rarely given as a reason for not wearing a helmet. The usual comment is that they are too hot or uncomfortable, or give rise to an unpleasant drumming in the ears. We rather suspect the real reason to be in many instances that a helmet detracts from the freedom and verve of riding an open machine. The motor-cyclist needs to be assured of the value of a crash helmet, and work should continue to produce a cheap, comfortable, and efficient helmet ready for his use. Parents and employers, motor-cycle clubs, and "ace" riders can all help to encourage and popularize their use.

Summary

The problem of head injuries in motor-cyclists and the use of crash helmets is discussed, based on 555 civilian motor-cyclists and 135 Army motor-cyclists admitted to two hospitals in recent years.

Of all head injuries due to road accidents, 30% occur in motor-cyclists. Although the mortality from head injury due to all causes has fallen in the last seven years

from 12.3 to 4.3%, the proportion of deaths among motor-cyclists has risen from 26 to 37%.

The findings among the injured motor-cyclists wearing crash helmets are described. The wearing of an efficient helmet leads to a significant reduction in the risks of severe and complicated skull fractures. Illustrative examples are given of the particular value of helmets in various circumstances and the criteria of an effective helmet are outlined.

Not more than one-third of motor-cyclists wear crash helmets at present—all should be encouraged to do so.

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MYASTHENIA GRAVIS

A PERSONAL STUDY OF 60 CASES

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Reference to standard textbooks provides contradictory statements about the early observations on myasthenia gravis. The first recorded example may well be that of Thomas Willis (1672). Gowers (1877), Erb (1879), and others recognized a form of bulbar palsy that clearly did not result from "progressive muscular atrophy" (motor neurone disease), and had noticed the absence of histological changes in the central nervous system; but of the earlier writers the greatest credit should perhaps be given to Jolly (1895), who first used the term "myasthenia gravis pseudoparalytica." He described two cases and referred to some 17 others in previous medical writings (11 of these 19 patients had died); he described the myasthenic reaction to electrical stimulation of muscles, and was the first to draw a parallel between the symptoms of this disease and those produced by certain alkaloids. He went further, and suggested the use of physostigmine in treatment, and, although regarding this as potentially dangerous, came within an ace of achieving the most important therapeutic advance, which was not to be made for another forty years (Walker, 1934). Prior to 1934 there was no treatment of value and the mortality was certainly very high.

Since 1895 very little has been added to the clinical picture, and the basic aetiology remains completely obscure, though some aspects of the underlying biochemical disturbance are now understood (Viets and Gammon, 1955). There have, moreover, been remarkably few studies of personally observed patients over a long period, and in Great Britain, excluding the