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INJURY PATTERNS IN TRAFFIC ACCIDENTS AND SUGGESTED PREVENTIVE MEASURES

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The increasing motorization of recent decades has resulted in increasing numbers of road accidents. An attempt must be made to reduce the numbers and effects of accidents. The task of traumatological research is not and cannot be the prevention of accidents, but rather to investigate, in collaboration with technologists, the question of how injuries in road traffic accidents can be prevented or reduced. It is car occupants, however, who have received most attention in research projects. These efforts received great support from the American National Traffic Safety Act of 1966. Since then there has been a revolution in what is called the inner safety of vehicle construction, a development which is certainly not yet concluded.

The first result of the American legislation that was obvious even to the layman was brought about by the ordinance concerning safety locks in vehicle doors. While up to 1966 in Sweden about 35 per cent of occupant fatalities in vehicle accidents were the result of ejection, today in modern cars this is a rare occurrence.

The car maker needs data on the tolerance of the human body in order to improve his vehicles; he has to know how the different injuries arise and thus which parts of the vehicles are to be regarded as being particularly dangerous. Attempts have been made to ascertain the necessary facts by analysing traffic accidents in detail and correlating the victims' injuries with the damages to the vehicles. In addition, comprehensive statistical evaluations were made of the data arrived at by investigating traffic accidents. Through experiments carried out on cadavers, attempts were made to determine the tolerances of certain regions of the body to dynamic loads, the main interest being centred on the skeleton. By means of collision experiments with living test persons or human cadavers, attempts were made to determine the course of movement and the tolerances of the human

body; this was after the realization that the dummy, however sophisticated it may be, is only a poor substitute for the human body.

Today much is known concerning the skeleton's tolerance to dynamic and static loads, while our knowledge about the tolerances of the soft parts is limited. In an accident situation, certain injury patterns may be expected, as will be briefly shown in the following.

OCCUPANTS OF PASSENGER VEHICLES

Head-on collision

Driver: As far as the second collision is concerned, i.e. the impact of a driver not protected by a restraint system, it is decisive whether the front part of the vehicle is raised at collision (1), is unchanged in the vertical plane (2), or is pressed downward (3). In the first case, the driver is thrown forward and downward in relation to the vehicle; in the second case he moves forward horizontally in relation to the vehicle; and in the third case he is thrown forward and upward. From this follow the differences to be expected.

If the driver is thrown forward and downward, the head may strike the steering wheel, the chin frequently striking the steering-wheel hub. This can result in a traction in the cranio-cervical junction, since the trunk is thrown under the instrument panel, especially if the latter is placed high, whereas the chin remains caught on the steering wheel. Complete or incomplete ring fractures of the base of the skull or hangman's fractures of the axis can result. (This also occurs when the steering assembly is pushed into the vehicle and strikes the driver's chin.)

If the driver is thrown forward horizontally in the vehicle, the anterior chest wall strikes the steering wheel. This situation is particularly dangerous when, as is often the case in older vehicles, the steering wheel spokes break off or bend. If this happens the trauma is transmitted to a relatively small portion of the anterior chest wall, which is deeply impressed into the interior of the thorax, causing severe intrathoracic and intra-abdominal injuries. Conditions are rather different today, however, since many modern steering wheels do not usually deform in such a way as to constitute a danger to the driver on impact, and in certain vehicle models they are so constructed as to absorb energy as they come to lie against the whole of the anterior chest wall.

Cadaver experiments have shown that in a collision at 50 km/h, when the anterior chest wall strikes the steering wheel it can be subjected for about 20 msec to a force of approximately 2000 kp. (Coermann et al. 1972). If the impact is against a small part of the steering wheel in the region of the lower half of the anterior chest wall, then the so-called shoveling effect (Voigt 1968) can cause not only ruptures of the liver and sometimes heart damage but also an aortic rupture at the classical site (i.e. just below the insertion of the lig. arteriosum Botalli or just below the exit of the a. subclavia sin.); in such cases, the lower part of the anterior chest wall is impressed from in front and below, causing the intra-aortic soft parts to be "shoveled" cranially into the arcus aortae. This causes a cranially directed displacement of the arcus aortae, its deflection and thus an overstretching in the area of the insertion of the lig. arteriosum Botalli. Furthermore, the compression of the intrathoracic organs leads to a raised intraaortic pressure which, together with the deformation of the aorta, seems to lead to rupture. Aortic ruptures have been caused experimentally in cadavers by a blow to the lower part of the anterior chest wall, and it has been shown that the aorta tolerates an intra-aortic pressure of about 1200 mmHg under dynamic conditions (Voigt et al. 1973). If the pleura mediastinale is not injured in conjunction with the aortic rupture, the patient can survive the aortic rupture long enough to make surgery possible. If no such steps are taken, the wall of the resultant pseudoaneurysm of the aorta may later rupture into the left pleura and occasionally even into the oesophagus.

If the front part of the vehicle is pressed downward in the collision, the driver's forehead may strike the windshield or, even more dangerous, the upper frame of the windshield. If the forehead strikes the upper frame of the windshield, ring fractures of the base of the skull (traction) or fractures of the dens axis may occur, caused by backward dislocation of the dens (shearing effect). If, in this situation, an angular acceleration of the head occurs, i.e. rotation about a transverse axis, there is a danger of rupture of sagittal bridging veins (vv. cerebri sup.) or of gliding contusions in the brain. The rupture of all or numerous bridging veins indicates the simultaneous presence of microscopically detectable bleedings in the brain stem (Voigt & Saldeen 1968). Such patients immediately become deeply unconscious, dying later, or else they die at once. There is no evidence of any subdural bleeding worth mentioning. The rupture of only one or some few sagittal bridging veins leads to subdural hematoma. Gliding contusions are characterized by parasagittal subcortical and subarachnoidal bleedings in the region of the caudal part of the gyrus frontalis sup. or sometimes of the central gyri and later lead to deep-seated local necroses (Voigt & Löwenhielm 1973). Experimental investigations have shown that ruptures of bridging veins are to be expected in conjunction with angular accelerations of more than 4000–5000 rad/sec^2 (Löwenhielm 1975). In head-on collisions the driver may sustain a posterior

fracture-luxation of the acetabulum or fractures of the femur and patella as a result of the impact on the instrument panel or—what is even more dangerous—against the fire wall (dashboard injury) (Breton & Blondeau 1927).

Front-seat passenger. Unrestrained front-seat passengers generally strike their heads against the windshield or—when the front of the vehicle is pressed downwards on collision—against its upper frame. Ring fractures of the base of the skull, ruptures of bridging veins, and gliding contusions of the brain may result, and also fractures of the dens axis caused by backward dislocation of the dens. Fractures of the dens axis may also occur, however, when the front of the vehicle is raised on collision and the upper portion of the anterior chest wall or the lower portion of the neck strikes the instrument panel, the head continuing forward. The dens fracture in this case is the result of a shearing effect due to forward dislocation of the dens (Sköld). Occasionally the upper jaw strikes the instrument panel, sometimes giving rise to Le Fort fractures. As far as the windshield is concerned, it has been shown that the impact of the head against toughened glass is more dangerous than that against laminated glass (Mackay et al. 1970).

The impact of the chest against the instrument panel may lead to a sagittal compression of the thorax, possibly resulting in a dislocation of the heart caudally to the left and consequent overstretching and rupture of the aorta ascendens or to a rupture of the truncus brachiocephalicus. Aortic ruptures at the classical site are also possible, particularly when the lower part of the trunk is thrown under the instrument panel and the trauma directed toward the lower region of the anterior chest wall (Voigt 1968).

Just as is the case with drivers, the impact of the knee joint against the instrument panel or fire wall leads to so-called dashboard injuries. If the passenger was sitting with his legs crossed when the accident occurred (or if it was an oblique head-on collision), the outside of the knee joint may strike the instrument panel, causing the thigh to be pressed diagonally against the anterior pelvic wall, with resultant impression fractures, producing a butterfly-shaped fragment of the anterior pelvic wall or vertical fractures of the hip bone behind the acetabulum, generally accompanied by fractures of the femur (dashboard injury Type 2) (Voigt 1965).

Driver and passenger can be protected in cases of head-on collision by restraint systems. The choice today is between belts and the air bag. Three-point belts are

superior to the other types of belt. With diagonal belts there is always the danger of sliding under, particularly when the occupant is thrown out of the vehicle or under the instrument panel. The chin may remain caught by the belt, which can even lead to decapitation (Saldeen 1967, Voigt 1968). The use of lap belts alone offers no protection against the impact of the head against the instrument panel, possibly with hangman's fracture of the cervical spine as a result (Schneider et al. 1965). When the three-point belts are used, neck injuries or ruptures of the parasagittal bridging veins occasioned by angular acceleration of the head are not likely, as experience has shown in Sweden (Sköld). Stretchability of the belts is a prerequisite for their affording proper protection. Cadaver experiments by Schmidt & Kallieris (1974) have shown that belts which stretch only up to 6 or 18 per cent can cause severe thoracic injuries. The belts normally in use in Sweden stretch about 25–35 per cent, and experiments have shown that under static loads up to 65 per cent stretching can be obtained. This means that the driver protected by a belt can move a very long way forward in a head-on collision and strike the steering wheel. This is especially likely when unrestrained back-seat passengers are thrown against the front-seat occupants, thus causing the belts to be doubly strained. In many vehicles, increased attention should be given to this fact when new models of steering are designed. Air bags are considerably more expensive than belts and offer no protection when the vehicle suffers from further collision effects (roll over) after the primary impact, and also one must expect the head to be retroflected after the impact with the air bag. Ruptures of the parasagittal bridging veins and injuries to the cervical column are to be expected, as cadaver experiments have shown.

The restraint systems offer protection, in oblique head-on collisions, against the head striking the side pillars of the windshield, an impact which quite often leads to extremely serious skull injuries.

Side collisions

If, in a side collision, the region of the temple is struck, this can result in a ring fracture of the base of the skull due to torsion effect (Voigt & Sköld 1974). In other cases the blow from the side can cause impression fractures and/or transverse fractures of the base of the skull and intracranial injuries.

The trunk is in particular danger. Here it must be noted that in side collisions the trauma is mainly directed at unrestrained car occupants from ahead and from the side towards the thorax and only seldom directly from the side, since as a result of the original movement (direction of travel) the occupant is thrown forwards and to the side and strikes the inside of the door. Apart from rib fractures, ruptures of the spleen and liver as well as lung injuries are frequent. Especially when the trauma comes from the left, aortic ruptures at the classical site may occur. Characteristic here are column fractures of the first

two ribs (Voigt 1968). The surrounding injuries to the soft parts suggest that the anterior chest wall has been displaced to the right, probably causing the arcus aortae to be pulled to the right as well.

Displacement of the heart may lead to ruptures of the pericardium and heart injuries, primarily in the region of the atrial septum.

The trauma affecting the occupants sitting on the collision side and directed towards the pelvic region occasionally leads to Duverney's fracture, and more often to fractures of the pelvic ring. The most serious form is the central fracture-luxation of the acetabulum. The ramus superior of the pubis is the weakest region of the pelvis. A trauma from the side can lead to a flattening-out of the hip bone and result in a fracture either just in front of the eminentia ileopectinea or closer to the symphysis. Pelvic ring fractures usually are multiple, due to the anatomical form of the pelvis. As the pelvic ring proper is pentagon-shaped on the outside, the flattening-out of one hip bone reduces the angle between the sacrum and the os ileum, or alternatively the angle of the symphysis. The result is thus vertical fractures in the region of the apexes of the angles. This is the explanation of the well-known vertical fractures of the massa lat. of the sacrum and also of the parasymphysial fractures. The symphysis itself is often protected from injury by the strong presymphysial aponeurosis (Voigt 1965).

Rear-end collision

In rear-end collisions, the greatest danger for the front-seat occupants is that the backrests of these seats may be bent backwards. If this happens, the occupant is thrown backwards and the head strikes structures at the back of the vehicle, or may even strike the other vehicle through the rear window. The results may be impression fractures of the skull and injuries to the cervical vertebrae. If the backrest is not bent backwards, whiplash injuries of the neck may occur, particularly if the upper edge of the backrest is at neck level. Such injuries, however, are seldom fatal. Headrests offer protection against this type of injury, as long as they reach up to eye level and cannot be bent backwards by the impact of the head. Three-point belts offer no protection in rear-end collisions.

Injuries to unprotected road users

When pedestrians, cyclists and moped riders are struck by a motor vehicle and thus subjected to a high rate of acceleration, deformations

result at the point where the vehicle hits the body, further deformations are caused by violent movements of the parts of the body not submitted to the direct trauma, and finally deformations are caused by the secondary impact with the road surface. This leads to multiple injuries where it is often difficult or impossible to say in which phase of the complicated process the different injuries arose.

First of all, at the moment of impact of the motor vehicle there occur fractures of the lower legs, which are to be regarded as flexion fractures pure and simple. When the thigh or buttocks strike the radiator surround of a passenger car, this can cause very considerable décollements, to which little attention has been paid clinically up to now. What occurs is a laceration of the subcutaneous fatty tissue, resulting in large hollows with blood and lacerated subcutaneous tissue. The danger of a fat embolism as a result of such injuries is obvious. Injections inadvertently given in such décollements can lead to infection. After absorption of the blood, the décollements result in seromas.

If the back side of one of the legs of a pedestrian is not caught by the front part of the vehicle it may be thrown violently backwards, with a pelvic luxation as the result. The reason for this is that the thigh that is thrown back draws the ipsilateral hip bone with it, which results in a rotation of the hip bone about a transverse axis through the sacrum (Voigt 1965). If the symphysis is not torn apart by this, then the surround of the contralateral foramen obturatorium may be deformed and fractured. The deformation of the vertebral column and thorax brought about by the violent movement of the trunk may lead to multiple fractures. According to the speed of impact and the design of the front part of the vehicle, the head of the pedestrian or cyclist may strike either the motor hood, the windshield or its side pillars, or the front of the vehicle roof. Impression fractures of the skull are possible, as are fractures of the cervical vertebral column.

Concerning the origin of injuries to pedestrians struck by vehicles, investigations are currently being carried out in various research centres. So far, little is known about how the design of the front parts of vehicles influences the injury pattern of pedestrians and cyclists hit by them.

As far as the injuries resulting from high-speed motor cycle accidents are concerned, it can only be emphasized that the injuries of riders and passengers who have been thrown off are severe and multiple. The only protection that can be offered is the abolition of the motor cycle.

SUMMARY

A short survey is given of the main patterns of injuries sustained in traffic accidents. The following injuries are accounted for: ruptures of the parasagittal bridging veins and gliding contusions of the brain, axis fractures, and aortic and pelvic injuries.

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