

ASSESSMENT OF THE MECHANISM OF LIMB AMPUTATION IN CAR-TO-PEDESTRIAN ACCIDENT VICTIMS

Grzegorz TERESIŃSKI

Department of Forensic Medicine, Medical University of Lublin
ul. Jaczewskiego 8, 20-090 Lublin, Poland

ABSTRACT

Limb amputations are believed to be the markers of high speed (>90 km/h) pedestrian hits caused by sharp edges of a car body. The analysis of the circumstances of such accidents shows, however, that amputations are also produced at much lower velocities (60+ km/h) when the lower limb gets under the front bumper (especially when the car is not braked) and therefore the wrapping of the upper body part around the hood causes stretching and disrupting of the entrapped limb leading to amputation (in the majority of “incomplete” amputation cases, the “tissue bridge” remains paradoxically on the impact side or laterally to the impact side).

Keywords: amputations, biomechanics, injury severity, legs, pedestrians

Lower limb amputations are rare consequences of car-to-pedestrian hits - according to the Pedestrian Crash Data Study database by NHTSA, they account for less than 5% of all AIS3+ lower extremity injuries in pedestrians (Takahashi et al., 2000). In the patients admitted to the trauma centres, surgical primary limb amputation is often necessary (11% according to Burgess et al., 1987) in cases of complicated fractures with vessel injuries. The lower limb amputations above the knee and major femoral artery lacerations are the only lower limb injuries classified as AIS 4 injuries.

To date no reliable methods of determining the collision speed of a vehicle based on widely used methods of injury scaling have been worked out as the majority of injuries are poorly correlated with the real collision velocity (Teresiński, 2005). Limb amputations and trunk disruptions are believed to be the exceptions, which, according to literature data are caused when pedestrians are hit by vehicles travelling at the speed of >90-100 km/h (Zivot and Di Maio, 1993, Karger et al., 2000, Bellion, 1999). Therefore in the present study the circumstances of such injuries were analysed and possible mechanisms of their occurrence were assessed.

MATERIAL AND METHODS

The initial material consisted of the results of autopsies of traffic accident victims carried out at the Department of Forensic Medicine, Medical University of Lublin in the years 1996-2004. The material included only those cases in which the autopsy was extended by preparation of soft tissues of the back and limbs with evaluation of the osteoarticular system of the lower limbs (Teresiński and Mądro, 2003). From the group of 846 pedestrians, 36 typical hits in standing position were selected in whom at least one limb was severed and the circumstances of accidents could be explicitly defined on the basis of the files from the Offices of Public Prosecutors and Courts. This group contained 20 “complete” amputations and 26 “incomplete” or “partial” amputations, i.e. those in which only a shred of tissues joining the limb with the body was left (Fig. 1).



Fig. 1 – Left: examples of „incomplete” amputations (arrows indicate tissue bridges). Right: partly severed limbs connected with the rest of the body by clothes

RESULTS AND DISCUSSION

IMPACT CIRCUMSTANCES: About 3/4 of amputations were localized at the shin level. The frequency of amputations was similar in hits to the back, left and right surface of the victim’s body (a relatively high percentage of amputations was observed in frontal hits although the frequency of such

hits was the lowest one in the whole group of analysed cases). Limb amputations were most frequently caused by older models of passenger cars with pontoon bodies, which were not braked on impact.

The average collision speed was 92 km/h (max. 115 km/h) in the “complete” amputation group and 84 km/h (max. 125 km/h) in “partial” amputation group. Both the “partial” and “complete” amputations were found in victims hit at the speed of only 60+ km/h.

MECHANISM OF AMPUTATION: It is generally thought that limb amputations in pedestrians and cyclists are caused by sharp edges of the front body of a car (Fig. 2 left), which cut limbs like an axe blade (Spitz, 1993, Karger et al., 2000, Zaba et al., 2003). However, in the analysed group only a few amputation cases could have been caused by such a mechanism. Moreover, in the other cases there was strong evidence against the mentioned above “blade cut” mechanism, which will be discussed below (the schematic figures in this chapter are not simulations but reconstructions according to the medical findings).

Amputation edges: In all but one of the cases, even when the skin disruption was relatively straight, the edges of separated muscles were irregular and ragged (Fig. 2 right).



Fig. 2 – Trunk severance by the sharp edge of Audi 80’s roof and both shins amputation by Volvo 440

Vehicle damage and marks: In the majority of vehicles no sharp bends were found and blood marks were located mainly at the level of and below the front bumper (Fig. 2 right).

Types of clothes’ damage: In several cases the severed part of the limb was joined to the rest of the body by clothes which were not torn at the side of hit (Fig. 1 right).

Mechanism of shoe sole scratches: The criminological examinations of shoes were conducted only in 7 victims, sole scratches were found in 5 of them, however in 4 scratches ran the contralateral shoe edge – contrary to the majority of other hits caused by passenger cars, which generally braked on impact (Teresiński, 2005). This indicated that the limbs moved in the way similar to that presented in Fig. 3 (note: small and compact car types are dominant in Poland).

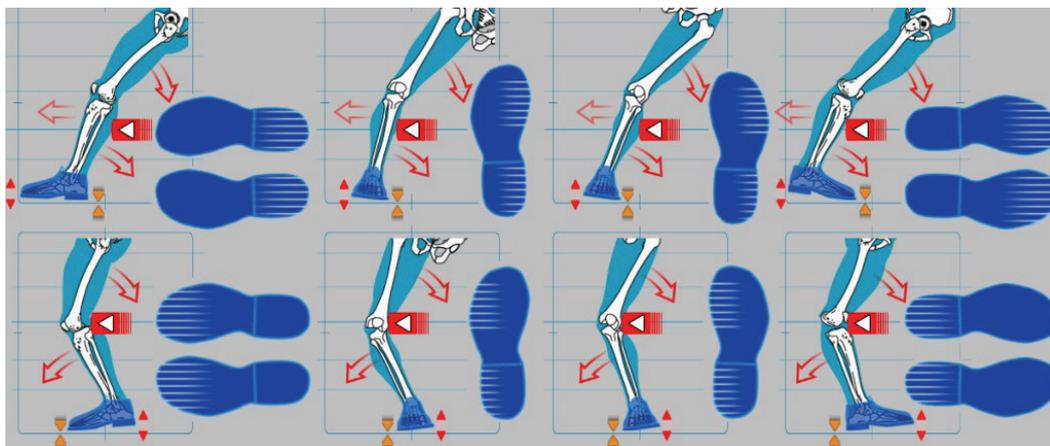


Fig. 3 – A possible mechanism of formation of shoe sole scratches located contralaterally to the impact site (bottom) found in analysed amputation cases compared to ipsilateral scratches (top) usually found in typical pedestrian hits by intensely braking passenger cars – comp. Fig. 7

Mechanism of long bone fractures: In 14 victims the tibial, fibular and femoral bones were preserved, which after maceration were carefully examined to assess the course of slits and additional cracks (Teresiński and Mądro, 2004). Despite high impact speeds the multi-fragment fractures were detected in fewer than half of cases (43%), almost equally common (41%) were various bending fractures, and the bases of so-called Messerer’s wedges were equally often turned to the impact side and to the opposite side (Fig. 4).

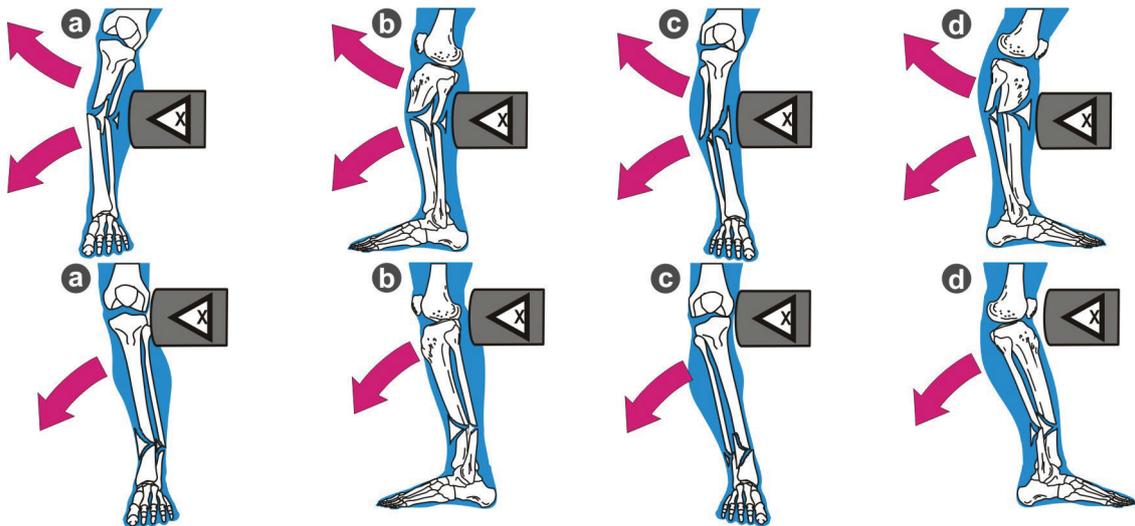


Fig. 4 – A possible mechanism of formation of „reversed” (bottom) bending fractures compared to „classical” Messerer’s fractures (top)

Localisation of tissue bridge: In “incomplete” amputations (N=26) the location of the “tissue bridge” was rarely (N=3) found on the opposite side of the limb in relation to the impact site (1 upper extremity amputation and 2 hits to the front of the shins, where there are no muscles, which favours open fractures from that side). In the majority of cases “the tissue bridge” remained paradoxically on the impact side (N=7) or laterally to the impact side (N=10), or only fragments of the deeper layer of muscles without lateralisation (N=6) were preserved.



Fig. 5 - Possible mechanisms of shin amputation in car-to-pedestrian high-speed collision

Conclusions: The evidence listed above indicated that the lower limb got under the front bumper and therefore the wrapping of the upper body part around the car body caused stretching and disrupting of the entrapped limb (Fig. 5-1) leading to complete amputation in this phase (then the severed part remained on the road - Fig. 5-2). In some other cases incompletely severed part of the limb remained connected with the rest of the body by the tissue bridge (Fig. 5-3) or got disrupted in the somersault phase as the amputated fragment was often found at some distance, even several dozen meters away from the crash site (Fig. 5-4).

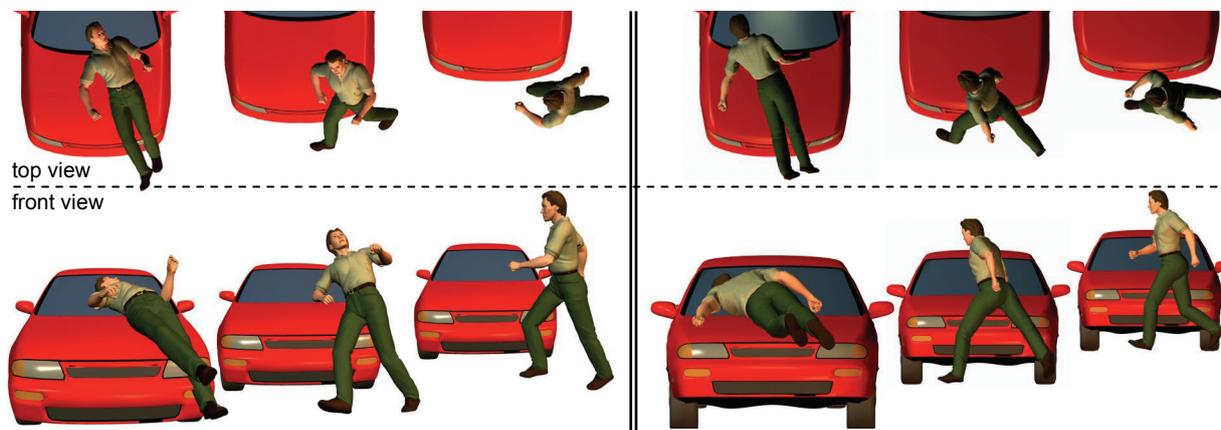


Fig. 6 – The effect of gait cycle on the rotation of pedestrian body in wrapping phase



Fig. 7 - Comparison of pedestrian dummy kinematics during the initial phase of car-to-pedestrian crash tests: left - car is not braking (note the entrapment of the lower extremity under the front bumper); right - car is intensely braking (screen shots have been captured from the Pedestrian/Bicycle Crash Test DVD prepared by Forensic Reconstruction Specialists Inc. - <http://www.frsi.ca>)

A number of incomplete amputations with tissue bridges lateral to the impact direction may be explained by the influence of the movement phase on the rotation of the pedestrian's body (Fig. 6).

The results of available crash tests (Fig. 7) confirmed the possibility of pulling the fractured lower limb under the front bumper in the case of passenger car hits, especially when the car was not braked (no effect of lowering the front car part).

CONCLUSIONS

Although the majority of amputations concerned the hits caused by old, big passenger cars with pontoon bodies, the problem holds as in the group examined there were also hits by newer vehicles, including small city and family cars. Contrary to common opinions, the limb amputations were also caused at impact speed much lower than 100 km/h (not only in the elderly). The "partial" amputations were found in victims hit at the speed of only 60-64 km/h. The lowest collision speeds which resulted in complete amputations were approximately 60 km/h and 77 km/h.

The majority of studies on passive safety of the vehicle in relation to vulnerable traffic participants are carried out at relatively low collision speeds (about 40 km/h). The results of the present study may be found useful for indicating the construction changes needed to limit the risk of more severe injuries to the lower limbs in hits at higher speeds. However, this issue requires further studies based on high-speed (>60km/h) crash tests using post-mortem human subjects.

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