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Injury Severity Score based estimation of height of fall in bus rolling down the cliff

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ABSTRACT

A case of bus rollover into the canyon, 40 m down the road, with 47 occupants out of which 18 were fatally injured, was used to compute the Injury Severity Score (ISS) for each passengers as well as the equivalent free fall for this particular accident, to be compared to the height of fall as estimated by the Lau's model based on ISS, resulting the conclusion whether Lau's model and the computation of ISS can be considered reliable to estimate the height of fall in any other case. Dealing with this, we would be also able to assess a protective potential of the bus on occupants while it falls from the height. By using classic energy-related mechanical formulas the presented rollover down the cliff has been transferred into a corresponding free fall from the height (10 m). ISS for each passenger has been used to establish height bands of the corresponding free fall. The analysis of the presented case showed that only 30% of bus passengers sustained injuries similar to the injuries expected in the fall from height in the range of 10–20 m. The chances to be non-severely injured as a consequence of the fall in a bus is 43%, but still remains a very high chance (27%) to sustain injures more severe than expected for the equivalent free fall from height out of a vehicle. Moreover, eight passengers sustained pulmonary detraction which is characteristic of the fall above 40 m. The conclusion is that this mathematical computing for transferring one way of motion into another one may be useful for any other event similar to the fall from height and further usage of Lau's modules. Also, estimated severity of the injuries expressed through ISS can be merely an approximating indicator of the height of the fall of the bus, so ISS is not able to estimate the exact height. Finally, in majority of cases the protective potential of the bus may preserve from severe body damage, but the mortality rate still stands on a very high level.

1. Introduction

In traffic trauma, bus rollover accidents are the rarest, but this type of accident is the most serious with the highest mortality rate.[1,2] There are various ways a bus rollover accident can play out. It could be with one or more impacts with another vehicle or an object, or the rollover may be the only event. Also, a rollover accident may include only a fall from height – down the slope without previous contact with a moving, or a stationary object, and without rotation.[1,2] In that case bus passenger injuries could have certain similarities to the injuries occurring in falls from heights.

Differences of the mechanism and severity of the injuries occurring due to falls from heights and ones occurring when bus impacts the surface are known. A fall from height is associated with more severe blunt injuries when compared to a motor vehicle crash or other mechanisms of blunt trauma.[3,4] In falls from heights body is exposed to contact with the surface without any protection and with nothing to help absorb the energy of the impact to the human body. Besides height severity of the injuries is determined by the type of surface, the way body impacts the surface and numerous other factors.[4–6] Frequencies of different body parts injuries differ in relation to the height of the fall.[4,6,7] On the other hand, in injuries occurring due to bus falls from heights and impacting the surface,

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the body is relatively protected (with seats, padding, etc) and weight of the bus, velocity, number of impacts, etc, are of significant importance to the intensity of the force and the mechanism of injury.[1,2,8]

Having in mind all of the above listed similarities and differences we have tried to compute the Injury Severity Score (ISS)[9] and Abbreviated Injury Scale (AIS) for each of 47 occupants injured during the presented bus fall (without significant collision with any movable or stationary object) as well as the equivalent free fall for this particular accident, to be compared to the height of fall as estimated by the Lau's model based on ISS, resulting the conclusion whether Lau's model and the computation of ISS can be considered reliable to estimate the height of fall in any other case. According to this, we would be also able to estimate a protective potential of bus construction on occupants while it falls from the height, and to discuss differences from free falls.

2. Material and methods

On June, 2013 in Montenegro, a Romanian bus with 45 tourists and two crew members fell in the canyon, rolling down the cliff by the angle of circa 75°, and stopped at a linear distance of approximately 40 m from the edge of the road (Fig. 1, video link[10]). The place where the bus fell is a right strong curve located between a tunnel and a bridge, 100 m above the river (Fig. 2). Getting out of the tunnel, the driver is supposed to adjust the speed and turn strongly right for almost 90°, but he missed the curve and his bus went out from the left side of the road down the canyon. Potential long fall stopped after 40 m by the trees and a huge rock on the cliff (Fig. 1). The speed limit on that part of the road is 40 km/h, but the bus doubled it (on the basis of the tachograph data). Before the fall, the bus hit a metal handrail, but it's protective potential in comparison with the high-speed running bus was absolutely negligible.

Fig. 1. The place where the bus went off the road.

Fig. 2. The curve between the tunnel and the bridge where the bus went out from the road.

2.1. The free fall assumptions and its computation

Since the presented fall of the bus was not a free fall, but the fall with an initial velocity and deceleration due to friction between the bus and the ground, the classic energy-related mechanical formulas were used to establish a height of corresponding free fall without initial velocity:

$$E = E_k + E_p = ½\, m \cdot v^2 + m \cdot g \cdot H$$

(E – energy; E_k – kinetic energy; E_p – potential energy; m – mass; v – velocity; g – gravity coefficient; H – height.)

The force of friction (F_f) was also present during the fall, so the following formula was also included:

$$F_f = m \cdot g \cdot \sin 75° \cdot u_s$$

with the approximate coefficient of friction (u_s) between the ground surface and rubber of 0.8.[11]

2.2. The Lau's model – ISS/AIS explanations

All of the previously stated calculations were needed to check the ISS based mathematical model for estimation of the height of fall. We used a mathematical model by Lau et al.[9] which classifies ISS bands in seven height bands at intervals of 10 m.

The ISS is an established medical score system to assess trauma severity, and it is based upon the Abbreviated Injury Scale (AIS). The body is divided in six ISS body regions: head and neck; face; chest; abdomen and pelvic contents; extremities and pelvic girdle; external. According to the severity of injured ISS body regions, using six point scale (1 minor, 2 moderate, 3 serious, 4 severe,