Forensic Science International 237 (2014) e6–e10

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

Case report

Occupant accelerations and injury potential during an ambulance-to-curb impact

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ARTICLE INFO

Article history:
Received 11 December 2013
Received in revised form 7 January 2014
Accepted 30 January 2014
Available online 12 February 2014

Keywords:
Ambulance
Curb
Acceleration
Injury

ABSTRACT

This paper presents real world acceleration data for an ambulance driving up and over a curb. A full scale reenactment was performed for a litigated case in which a patient on a gurney in an ambulance claimed a variety of bodily injuries after the ambulance struck a curb. A height and weight matched surrogate rode on the gurney during the tests. Results demonstrated that peak vehicle and occupant accelerations never exceeded 1.1 g's. To address the claimed injuries, the accelerations likely sustained by the patient were compared to those experienced during daily life. Since ambulances are wide vehicles that travel fast on potentially narrow arterial, collector or local roadways, curb or median impacts may occur during the normal course of driving. Thus, these results may be useful for forensic experts in dealing with similar cases involving claimed injuries following curb impacts.

1. Introduction

Ambulances are unusual vehicles in that they are wide and heavy compared with passenger vehicles and they carry passengers in a number of positions and orientations, including patients on gurneys and EMS personnel, who are often unrestrained when riding in the rear compartment. Furthermore, although ambulances are associated with high crash fatality and injury rates per mile traveled [1], they are also largely exempt from the USA Federal Motor Vehicle Safety Standards (FMVSS).

To address injury potential in vehicle-to-vehicle crashes, anthropometric test dummies have been used in sled and full scale crash tests of ambulances in frontal and side impacts [2–4]. However, the biomechanical responses and injury potential of curb impact in an ambulance are unknown. Curbs and center medians are common features of roadway design. For wide and heavy vehicles such as ambulances, curb or median impacts may occur during the normal course of driving, particularly on narrow arterial, collector or local roadways. The question of injury potential during a curb impact arose in a case in which a 63-year-old woman, being transported by ambulance for chest pains, claimed multiple injuries after the ambulance traversed a curb in the center of the roadway.

Previously, the occupant kinematics associated with traversing curbs in passenger cars have been determined [5]. The resulting occupant accelerations indicated a low risk of significant contact with interior vehicle components and a corresponding low risk of injury. However, given the unique suspension characteristics and occupant seating arrangements in ambulances, accelerations measured in passenger vehicles are not applicable to an ambulance that strikes or mounts a curb. The purpose of this analysis was therefore to recreate the vehicle and occupant accelerations during a curb impact in an ambulance. Such full scale reenactments, when feasible, can provide valuable insight into the forensic analysis of an injury or claimed injury.

2. Methods

2.1. Case description

In October of 2010, a 63-year-old female (1.65 m; 61 kg) was picked up at her home, having called 911 for chest pains. Two EMTs loaded her onto a Stryker gurney and into the ambulance (a 2009 International 4400 LP, with VIN 1HTMRAAMX9H102650), and proceeded towards the hospital. Throughout the patient was strapped to her gurney and the gurney was secured to the floor of the ambulance. The patient's husband drove his vehicle behind the ambulance to the hospital. It was undisputed that while driving 32–50 kph straight through an intersection (Fig. 1), the ambulance mounted a concrete center median, or curb (Fig. 2). The height of the curb was 10 cm at the leading edge, and sloped upwards to a

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http://dx.doi.org/10.1016/j.forsciint.2014.01.023
0379-0738/

Fig. 1. The ambulance was traveling southbound, straight through an intersection (direction of red arrow). The tire(s) of the ambulance mounted the center concrete median.

Fig. 2. Concrete median/curb struck by the 2009 International ambulance. The initial height is 10 cm and the full height is 19 cm.

maximum height of 19 cm. The patient's husband later testified that the left rear dual tires of the ambulance went up onto the curb. Ambulance personnel indicated that only the left front tire that mounted the curb. Following the incident, there was no damage to the tire, wheel rim or undercarriage of the ambulance Fig. 3. The patient claimed a variety of injuries as a result of this incident, including disc injuries to her lower back and neck Fig. 4.

2.2. Incident reenactment

The ambulance was weighed and measured. The roadway width was measured for comparison to the ambulance width. A reenactment was conducted to directly measure motions comparable to those the patient sustained during the event in question. For the vehicle reenactment, the actual ambulance and gurney were used. The gurney was positioned in the correct semi-recline position by the EMT who rode with the patient that day. The backrest angle was 42° (as measured at the reenactment). In addition, the ambulance was operated by the EMT who drove the ambulance on the day of the incident.

After providing informed consent, a height and weight matched surrogate (1.65 m; 59 kg) was strapped onto the gurney using both the hip and knee restraints (Fig. 5). The vehicle and occupant acceleration during impact with the curb was measured using two ±10 G triaxial accelerometers (S2-10G-MF, NexGen Ergonomics, Pointe Claire, Quebec). The signal was sent to a Biometrics data logger (Type P3X8, Biometrics Ltd.) that recorded the data at a rate of 100 Hz, using DataLog PC Software 3.00 (Biometrics Ltd). One accelerometer was mounted to the vehicle floor, directly under the center of the gurney. One accelerometer was housed in a semi-rigid rubber disc specifically designed to record acceleration transmitted from seat surfaces to an occupant. This "seat pad" was positioned directly under the surrogate's buttocks. For each accelerometer, resultant accelerations were calculated to combine the three axes of data.

Two trials were performed in which the vehicle was driven southbound through the intersection and intentionally up onto the curb. Both trials were executed at approximately 32 kph. During Trial 1, both the left front and left rear tires mounted the curb. During Trial 2, only the left front wheel mounted the curb. Following Trial 2, the EMT driver indicated that, from his perspective in the cab, the impact felt identical to the curb impact on the day of the incident. Although the surrogate occupant was aware that a curb impact was going to occur, the precise timing of impact was unknown to her, thus preserving some element of unawareness that would be expected during the actual incident. Following the reenactment, a mechanical inspection of the ambulance was conducted. No tire, rim or undercarriage damage occurred during the reenactment.

2.3. Injury potential

As an indicator of injury potential, occupant accelerations measured during the reenactment were directly compared against published accelerations of activities of daily living (ADLs). In addition, the lumbar (L5/S1) and cervical (C7/T1) spine forces were estimated using the measured accelerations, the patient's weight above these spinal levels, and Newton's second law of motion, which holds that the acceleration of a body is directly proportional to the net force acting on the body and inversely proportional to its mass ($F = ma$).

To assess the likelihood of injury, we define a Factor of Risk [6] as the ratio (Φ) of each predicted load to the respective injury tolerance limit. When this ratio exceeds 1.0, injury is more likely than not (i.e. at least 51% probable). This metric is the simplest, and

Fig. 3. There was no damage to the front left wheel, tire or undercarriage of the 2009 International ambulance following impact with the center median.