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A prospective study of children aged <16 years in motor vehicle collisions in Norway: Severe injuries are observed predominantly in older children and are associated with restraint misuse

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ABSTRACT

Objective: The implementation of the compulsory wearing of seat belts (SBs) for children and improvements in child restraint systems have reduced the number of deaths and severe injuries among children involved in motor vehicle (MV) collisions (MVCs). Establishing the characteristics predictive of such injuries may provide the basis for targeted safety campaigns and lead to a further reduction in mortality and morbidity among children involved in MVCs. This study performed a multidisciplinary investigation among child occupants involved in MVCs to elucidate injury mechanisms, evaluate the safety measures used and determine the characteristics that are predictive of injury.
Methods: A prospective study was conducted of all child occupants aged <16 years involved in severe MVCs in south-eastern Norway during 2009–2013. The exterior and interior of the MVs were investigated and the injured children were medically examined. Supplementary information was obtained from witnesses, the crash victims, police reports, medical records and reconstructions. Each case was reviewed by a multidisciplinary team to assess the mechanism of injury.
Results: In total, 158 child occupants involved in 100 MVCs were investigated, of which 27 (17%) exhibited Abbreviated Injury Scale (AIS) scores of 2+ injuries and 15 (9%) exhibited AIS 3+ injuries. None of the children died. Of those with AIS 2+ injuries ($n = 27$), 89% ($n = 24$) were involved in frontal impact collisions and 11% (3/27) were involved in side impacts. Multivariate analysis revealed that restraint misuse, age, the prevailing lighting conditions and ΔV were all independently correlated with AIS 2+ injuries. Safety errors were found in 74% (20/27) of those with AIS 2+ injuries and 93% (14/15) of those with AIS 3+ injuries. The most common safety error was misuse of restraints, and in particular loose and/or improperly positioned SBs.
Conclusion: The risk of injury among child occupants is significantly higher when the child occupants are exposed to safety errors within the interior of the vehicle. Future campaigns should focus on the prevention of restraint misuse and unsecured objects in the passenger compartment or boot.

1. Introduction

More than 1.2 million persons are killed in road traffic accidents every year (WHO, 2013a), and up to 50 million persons suffer from non-fatal injuries as a result of road traffic accidents worldwide (WHO, 2013b). For a long time any passenger deaths due to airplane or train crashes have been considered unacceptable, with all such incidents being investigated with the aim of reducing the probability of future deaths, whereas deaths due to car accidents

Abbreviations: CRS, child restraint system; EMCC, emergency medical communication centre; HS, harness strap; MV, motor vehicle; MVC, motor vehicle collision; SB, seat belt; AIS, Abbreviated Injury Scale; IQR, interquartile range; GEE, generalized estimation equation; ΔV, instantaneous change in velocity.

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have been treated as if they are an unavoidable aspect of that mode of transportation. In 2010 the United Nations General Assembly proclaimed a decade of action for road safety (WHO, 2013b), and the World Health Organization and the European Union have concomitantly developed comprehensive traffic safety plans. The Norwegian government has implemented the vision zero road traffic safety project as the basis for national traffic safety activities. The ambition of this project is for no one to be killed or permanently disabled due to road traffic accidents in the future. The first step toward this goal is to reduce the number of severe and fatal injuries associated with road traffic accidents by one-third by 2019 (The Norwegian Ministry of Transportation, 2009).

Norway is a sparsely populated country with 5 million inhabitants. During the last decade between 2 and 10 child occupants of motor vehicles (MVs) aged <16 years have been killed in MV collisions (MVCs) annually, with 20–30 children being severely injured every year (Statistics Norway, 2013). In a recently published study we found that 38% of the child occupants on Norwegian high-speed roads were improperly restrained, with the errors being severe in 23% of the child occupants.

The present study was designed to elucidate the injury mechanisms, evaluate the safety measures used and determine the accident characteristics predictive of injury, by carrying out an in-depth crash investigation of the vehicles and evaluating the medical examinations of the children involved in major MVCs that occurred in south-eastern Norway during a 39-month period (2009–2013).

2. Methods

2.1. Materials and subjects

Data from a prospective cohort study of child occupants involved in severe MVCs form the basis of this study. The data were collected between November 1 2009 and January 31 2013 in south-eastern Norway, which has a population of 2.8 million people covering an area of 136,000 km^2 that includes both rural and urban environments. The crash investigators were two specifically trained paramedics. After an MVC, witnesses on the scene or the occupants in the involved MVs normally alert an emergency medical communication centre (EMCC). Based on the criterion "MVC – possible severe injury or death", the crash investigator on call was alerted by one of the region's five EMCCs. An accident was included in the study if at least one of the passengers was aged <16 years and one of the occupants was met by a trauma team in the admitting hospital.

2.2. The investigation protocol, supplementary information and medical examination

Detailed descriptions of the investigation protocol, reconstructions and the retrieval of the supplementary information are previously published (Skjerven-Martinsen et al., 2011). For each MVC, a detailed accident report including photographic documentation of the MV exterior, interior and the accident environment was made by the crash investigators. The exterior examination focused on intrusions and movement of the passenger compartment, the point of first contact and the end point of the MV. The interior investigation paid attention to the occupants' use of restraints and child restraint systems (CRSs), additional safety equipment such as airbags, seat belt (SB) pretensioners and load limiters, the presence of unsecured cargo, friction marks on SBs and harness straps (HSs), and evidence of contact points between the child and the interior of the MV such as deformations or deposited biological material (i.e., blood, skin and hair).

Reconstructions were conducted subsequent to the technical inspections and collection of relevant information regarding the seating of the child. A child or a dummy of the same height and weight as the involved child occupant was placed into the same restraints or CRS in order to detect in what way the restraints and CRS were used, the occupant's movements and contact points in the passenger compartment. Reports generated from the on-scene investigation were supplemented by information provided by the involved occupants, emergency medical service personnel, witnesses, EMCC reports, police records from all 13 different police districts in the region and reports from the regional accident analysis groups of the Norwegian Public Roads Administration (in cases of fatal injuries within the vehicle). The medical records of the involved children were obtained after informed consent had been obtained from their guardians.

Finally, all cases were reviewed by a multidisciplinary team consisting of physicians with expertise in traumatology, pediatric surgery and forensic medicine, as well as research technicians. All of the information was evaluated to determine the likely mechanisms of injury for each child occupant.

2.3. Definition of variables

Injuries were coded based on all available information using the Abbreviated Injury Scale (AIS) 2005 manual (Association for the Advancement of Automotive Medicine, 2008). The AIS is an anatomically based injury scoring system that classifies each body region into a 6-point ordinal severity scale: 1, minor; 2, moderate; 3, serious; 4, severe; 5, critical; and 6, maximum (currently untreatable). The AIS score was used to calculate the Maximum Abbreviated Injury Severity Score and the Injury Severity Score. A child with an AIS score of ≥2 (AIS2+) in at least one body region was defined as injured. Children not admitted to hospital were not coded as injured.

A child was registered with safety errors if any restraint misuse was present or the child was exposed to unsecured objects (fellow unrestrained passengers or unsecured cargo). Restraint misuse was defined as any use of a CRS or SB deviated from the manufacturers specifications (e.g., improper routing, twisting or tightness of the SBs or harness straps) as well as the use of size-inappropriate restraints (e.g., children <135 cm or <36 kg seated in SB-only) and CRS installation errors (e.g., too loose or otherwise incorrect installation). The evaluation of safety errors was based on knowledge from a previous study (Skjerven-Martinsen et al., 2013), and the concrete errors found in this study are shown in Table 3.

All types of safety errors were graded as follows: grade 1, minor errors; grade 2, major errors; and grade 3, critical errors (as described (Skjerven-Martinsen et al., 2013)). This system was developed in order to classify the severity of the restraint misuse based on the likelihood of potential injury resulting from a high-energy MVC. In the present study this system was extended to include heavy, unsecured cargo in either the boot or the passenger compartment as a safety error.

The instantaneous change in velocity (ΔV), the principal direction of force and the rotation were calculated manually for all included MVs. The collision impact was categorized into frontal (−45° to +45°), side (−46° to 134°, +46° to +134°), rear (−135° to +135°), rollover (at least 180° on its horizontal axis) and sideswipe; the last categorized when the first contact between an MV and a crash partner driving in the same direction caused loss of control and a second impact for the MV. One impact did not mutually exclude another impact (e.g., a collision could involve both a frontal impact and a rollover). The MV type was categorized into sedan/hatchback/station wagons, sport utility vehicle, minibus/minivan or truck/bus/tractor.