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Are Airbags Effective in Decreasing Trauma in Auto Accidents?

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Airbags were initially developed in the 1950s as a passive restraint system for the millions of people who would not use active restraint systems. The original design consisted of a nylon bag that triggered to inflate with a change in velocity analogous to hitting a brick wall at 10 to 15 mph. Initially considered as a substitute for seatbelts, it was soon realized that their protective effect when used alone was inferior to seatbelts. Airbags provide protection in frontal collisions only, leaving persons vulnerable to side collisions, rollovers, and secondary impacts. Airbags were reintroduced in the 1980s as a supplemental restraint to be used in conjunction with seatbelts. Mercedes Benz was the first automobile company to offer airbags as an option on their high-end vehicles in 1980, whereas Porsche was the first company to make dual airbags standard in 1987. Passive restraints, airbags, or automatic seatbelts were mandated by the National Highway Traffic and Safety Association in 1989, whereas dual side (driver and passenger) airbags became mandatory in cars manufactured after 1998.

As airbags became more widely used, injuries caused by airbag deployment were discovered. These injuries typically occurred in children and adults of small stature secondary to the large force required to deploy an airbag in a few seconds [1–5]. Injuries caused by first-generation airbags included closed head injuries, cervical spine injuries, facial fractures, and ocular injuries. In 1997, the National Highway Traffic and Safety Association allowed car manufacturers to install depowered, "second-generation" airbags to decrease the risk of injury associated with airbag deployment. The use of second-generation airbags and campaigns to educate parents on the dangers of placing children in the front seat with an airbag have decreased injuries attributed to airbags.

AIRBAG-SPECIFIC INJURIES

Airbag-associated injuries were discovered initially in unrestrained drivers or passengers because of out-of-position contact with the nylon bag. An increase in facial fractures, ocular injuries, odontoid fractures, and flexion cervical spinal

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injuries was described in several case series [1–4]. Airbag use also has been related to an increase in minor and moderate head injury [5]. A study conducted by Transport Canada in the 1990s evaluated all motor vehicle collisions in which an airbag deployed (800 cases). Fifty-three fatalities were associated with airbag deployment, with victims suffering severe head, cervical spine, and chest injuries [6]. When crash data from vehicles before 1998 were compared with those after 1998, first-generation airbags were associated with more severe neck injuries and more severe injuries overall [7]. The most recent literature on injuries and airbags revealed no association between airbag deployment and injury to the head, face, spine, chest, or abdomen [8]. In fact, airbag use alone was associated with a decrease in injuries to the brain, face, and cervical spine by nearly one half. Another study that evaluated overall crash fatalities in cars equipped with first- or second-generation airbags found a decrease in overall mortality when second-generation airbags were used [9].

Fatal injuries associated with airbag deployment in pediatric, front seat passengers were documented in the early 1990s and evoked laws prohibiting small children and rear-facing car seats in the front seat [10]. Injuries seen in pediatric patients secondary to airbag deployment are often related to the head and cervical spine; however, these injuries have been decreasing since 1998 and are generally attributable to improper restraint or seat position [11]. In a study from 2006, airbags were protective in older children (ages 15–18), but younger children had a trend toward more severe injury [12].

CRASH FATALITY

The Fatality Analysis Reporting System includes data on all crashes on US highways that result in a death within 30 days. A study using the Fatality Analysis Reporting System database (1992–1997) shows that airbags are associated with a decrease in crash fatality with an adjusted odds ratio of 0.71, whereas the combination of airbags and seatbelts is associated with a larger protective effect (adjusted odds ratio = 0.18) [13]. The authors adjusted for vehicle weight, vehicle year, and driver age. A more recent study using Fatality Analysis Reporting System data from 1990 to 2000 that demonstrated a significant reduction in the 30-day risk of death when airbags are used alone supports the findings from the earlier study [14].

The National Automotive Sampling System is another large population-based database in which police-reported crashes that occur on roadways in the United States are randomly sampled in detail to determine the effectiveness of safety features implemented by the National Highway Traffic and Safety Association. An early study using this database supported the Fatality Analysis Reporting System data. In more than 5000 patients, airbags were associated with a decrease in crash fatality with an adjusted odds ratio of 0.58 [15]. When airbags are analyzed over variable crash impacts, they are associated with an increase in injuries at lower speeds and a decrease in injuries at higher speeds. Another large study using the National Automotive Sampling System database showed discordant results. Over a 10-year period, no difference in

severe injury or death was found when airbag-restrained persons were compared to unrestrained persons [16]. All of these studies included a substantial number of cars with first-generation airbags, so the effect of airbags may be clouded by mortality related to airbag deployment itself. When in-hospital mortality of patients admitted to a level I trauma center was assessed, patients in vehicles with airbag deployment (either with or without a seatbelt) were less likely to die from their injuries compared to unrestrained persons [8].

INJURY PATTERNS

The decrease in mortality is most likely related to a decrease in injuries and injury severity; however, several studies associated airbags with an increase in injury. Sutyak and colleagues [17] reported an increase in injury severity, hospital length of stay, and intensive care unit stay. They also reported an increase in chest and abdominal injuries. A study using the National Automotive Sampling System database reported an increase in injury severity, whereas a more recent study using the same database showed no protective effect against injury and an increase in lower extremity fractures in all crash victims [16,18]. The National Automotive Sampling System database includes injuries in patients who do not survive to reach the hospital, however; therefore, their data may not extrapolate to persons who present to trauma centers.

Several other studies examined the effect of airbags on injury patterns with a different result. A study from Maryland used the trauma registry in the late 1990s to determine the effect of airbags on injuries. Airbags increased upper extremity injuries but decreased shock and injuries to blood vessels [19]. A small, prospective study evaluated 200 patients and found a decrease in shock as well as a decrease in injuries to the head, face, and lower extremities [20]. A retrospective study from Germany supported these findings with a decrease in the severity of head, cervical spine, and thoracic injuries [21]. When examining only patients admitted to a level I trauma center, airbags were associated with a decrease in injuries in all body regions except the extremities [8].

HEAD AND NECK INJURIES

Although airbags intuitively protect persons against serious head and neck injury by providing a barrier between the driver or passenger and the windshield, some studies have found an increase in head and neck injuries with airbag deployment. When assessing maxillofacial injuries only, seatbelts and airbags were associated with a decrease in injuries, whereas airbags alone increased total injuries but decreased severe injuries [22]. Another study reported opposing effects on drivers and passengers restrained with airbags. Drivers had a decrease in facial fractures with no effect on facial lacerations, whereas passengers incurred an increase in facial fractures with no change in lacerations [23]. There have been case reports of eye injuries related to airbag deployment; however, airbags decrease the incidence and severity of orbital injuries, as noted in a study on a large population using the National Automotive Sampling System database [24].

Table 1
Studies addressing mortality and injury patterns with airbags

Authors	Year	Study design	N	Mortality	Injury patterns
Loo et al [20]	1996	Prospective	200	*NR*	Decreased ISS, shock, severe brain injury, facial fractures and laceration, and lower extremity fractures
Kuner et al [21]	1996	Retrospective	122	*NR*	Decreased severe injury to head, cervical spine and thorax Increased severe lower extremity fractures
Sutyak et al [17]	1997	Retrospective	38	*NR*	Increased ISS, ICU stay, LOS, AIS of chest and abdomen No change in extremity fractures
Stucki et al [16]	2000	Retrospective, NASS database	*NR*	1.07% fatality rate with AB vs 1.21% unrestrained	No change in severe injuries
Segui-Gomez [15]	2000	Retrospective, NASS database	5003	aOR = 0.58	Decreased injuries at high speed and increased injuries at low speed
Segui-Gomez et al [19]	2000	Prospective, Trauma Registry	1065	2% with AB and 0.6% without AB	Increase in upper extremity fractures in females
Crandall et al [13]	2001	Retrospective, FARS database	19,718	aOR = 0.71; AB+SB = 0.18	*NR*
Cummings et al [14]	2002	Retrospective, FARS database	51,031	RR = 0.92; AB + SB = 0.32	*NR*
Schneider [7]	2003	Retrospective	667	*NR*	Decreased head, neck, face, chest, and abdominal injuries Increased upper and lower extremity injuries
McGwin et al [18]	2003	Retrospective, NASS database	32,058	*NR*	Increased lower extremity fractures
Williams et al [8]	2008	Retrospective, Trauma Registry	14,390	aOR = 0.52, AB + SB = 0.29	Decreased brain, face, cervical spine, thorax, and abdomen injuriesIncreased extremity injuries

Abbreviations: AB, airbag; AIS, abbreviated injury score; aOR, adjusted odds ratio; FARS, Fatality Analysis Reporting System; ICU, intensive care unit; ISS, injury severity score; LOS, length of stay; NASS, National Automotive Sampling System; NR, not reported; RR, relative risk; SB, seatbelt.

Traumatic brain injury has been associated with isolated cases of airbag deployment, mostly in out-of-position drivers and passengers [25,26]. Most recent studies report an overall decrease in head injuries, with the greatest effect seen when seatbelts and airbags are used in conjunction [8,20,27,28]. A recent study that evaluated minor to moderate head injury (abbreviated injury score of 1-2) showed an increase in minor head injury with depowered airbags, although an equivalent decrease in severe injuries was seen [5]. Blunt cerebrovascular injuries have been associated with seatbelt and airbag restraints, with 83% of these injuries occurring in patients with airbag deployment [29]. Cervical spine injuries have been reported in children and adults of small stature; however, when used in conjunction with seatbelts, airbags decreased cervical spine injuries [30,31].

THORACOABDOMINAL INJURIES

Because an airbag must expand in a short amount of time, a large amount of force is necessary for deployment. This force is often exerted on the chest, which may lead to an increase in thoracic injuries, as reported in several studies [32]. When examining aortic injuries alone, however, which are known to be caused by deceleration upon crash impact, airbags were protective in frontal collisions [33]. Sternal fractures are more commonly associated with seatbelts (92%) than with airbags (13%) [34]. Abdominal injuries have been attributed to seatbelt use secondary to compression on the abdominal viscera against the spinal column. Airbags are protective against abdominal injuries and pelvic fractures, however [8,35]. Uterine trauma may be associated with preterm labor or fetal demise, although airbags were not associated with uterine injury after motor vehicle collision [36].

EXTREMITY INJURIES

The association between airbags and extremity injuries has been reported in large, population-based studies [18,19,37,38]. A mechanism for the increase in lower extremity injuries was described by Crandall in a cadaver-based study [39]. When an airbag deploys in an unbelted individual, the pelvis and lower extremities are unrestrained, which allows for forward motion and contact with the knee-bolster. Upper extremity fractures tend to occur in female passengers or small adults secondary to proximity to the airbag and steering column [19].

SUMMARY

Multiple studies have addressed the effect of airbags on injury and mortality after motor vehicle collision with discrepant results (Table 1). Although large, population-based studies have minimized the protective effect of airbags, the most recent studies examining airbags have shown a decrease in injury and death, with the greatest protective effect seen when they are used in conjunction with seatbelts. Optimal restraint use is also associated with a decrease in infectious morbidity and hospital resource utilization. The widespread use of

seatbelts and airbags will continue to save lives and decrease morbidity after motor vehicle collision.

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