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The Impact of Seat belts and Airbags on High Grade Renal Injuries and Nephrectomy Rates in Motor Vehicle Collisions

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Abstract

Purpose—Motor vehicle collisions (MVCs) are the most common cause of blunt genitourinary trauma. We compared renal injuries with no protective device to those with seat belts and/or airbags utilizing the National Trauma Data Bank (NTDB). Our primary endpoint was a reduction in high-grade renal injuries (grades III–V) with a secondary endpoint of reduction in nephrectomy rate.

Materials and Methods—The NTDB research datasets, admission year 2010, 2011, and 2012, were queried for MVC occupants with renal injury. Subjects were stratified by protective device and airbag deployment. Abbreviated Injury Score was converted to American Association for the Surgery of Trauma renal injury grade and nephrectomy rates were evaluated. Intergroup comparisons were analyzed for renal injury grades, nephrectomy, length of stay, and mortality with chi-square or one-way ANOVA. Protective device relative risk reduction was determined.

Results—A review of 466,028 MVCs revealed 3,846 renal injuries. Injured occupants without a protective device had a higher rate of high grade renal injury (45.1%) compared to those with seat belts (39.9%, $p=0.008$), airbags (42.3%, $p=0.317$), and seat belts with airbags (34.7%, $p<0.001$). Seat belts (20.0%, $p<0.001$), airbags (10.5% $p<0.001$), and seat belts with airbags (13.3%, $p<0.001$) reduced the rate of nephrectomy compared to no protective device (56.2%). The combination of seatbelts and airbags also reduced total hospital length of stay ($p<0.001$) and ICU

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days ($p=0.005$). Relative risk reduction of high-grade renal injuries (23.1%) and nephrectomy (39.9%) were highest for combined protective devices.

Conclusions—Occupants of MVCs with protective devices have reduced rates of high-grade renal injury and nephrectomy. Reduction appears most pronounced with the combination of seat belts and airbags.

INTRODUCTION

Motor vehicle–related injuries kill more children and young adults than any other single cause in the United States.¹⁻³ The U.S. Census Bureau estimates there were 77 million motor vehicle collisions (MVCs) in the last decade⁴ resulting in more than 34,000 deaths annually.⁵ In addition, another 3.6 million drivers and passengers were treated in emergency departments yearly as the result of being injured in MVCs.⁶ The economic burden to society is tremendous; lifetime costs of crash-related deaths and injuries among drivers and passengers were \$70 billion in 2005.⁷

Seat belts, which reduce the risk for fatal injuries from MVCs by 45% and serious injuries by 50%⁸, are the most effective intervention for protecting motor vehicle occupants.⁹ Air bag deployment during MVCs has been shown to reduce occupant mortality by 63%.¹⁰ Wearing both a lap and shoulder belt has reduced mortality by 72% and the combined use of an air bag and seat belt by more than 80%.¹⁰

MVCs are the most common mechanism of injury resulting in renal trauma, accounting for 48% to 66% of all renal injuries.^{11, 12} However, there exists a paucity of data on the role of MVC protective devices in the reduction of renal injuries. We compared renal injuries and nephrectomies of MVC occupants with no protective device to those with seat belts and airbags utilizing the National Trauma Data Bank (NTDB). The primary endpoint of our study was a reduction in high-grade renal injuries (American Association for the Surgery of Trauma (AAST) organ injury scale (OIS) grades III-V), with a secondary endpoint of reduction in nephrectomy rate. As MVCs are the leading cause of unintentional injury in the US, understanding the impact of protective devices on solid organ injury becomes increasingly important. **We hypothesized that the** combination of protective devices could reduce high-grade renal injury and potentially the resultant nephrectomy rate compared to using a single protective device or no device at all. Furthermore, protective device research may provide evidence for public health decision-making regarding motor vehicle-related injury prevention.

MATERIALS AND METHODS

Study Design

A retrospective cohort study was performed to determine the impact of seat belts and airbags on renal injuries and nephrectomy rates in MVCs. This study was determined to be exempt from review by our institutional review board.

Data Source

We analyzed the NTDB admission years 2010, 2011, and 2012. The NTDB is a voluntary data repository that currently contains the trauma admissions of participating level I-V trauma centers throughout the United States. The NTDB is managed by the American College of Surgeons and has been utilized in multiple studies on trauma.^{3,4} To provide standardization of the population, the NTDB defines trauma patients as any patient with an International Classification of Disease, 9th revision, clinical modification code (ICD-9-CM) discharge diagnosis 800-959.9 excluding late effects of injuries (905-909), superficial injuries (910-924) and foreign body cases (930-939). All injury related deaths in the emergency department and deaths on arrival are included in the cohort for this study.

Study Cohort

The NDTB research datasets, admission year 2010, 2011, and 2012, were queried for MVC occupants by ICD-9-CM external cause of injury codes with renal injury by ICD-9 code (866). Subjects were stratified by protective device (no protective device, seat belt) and airbag deployment. Seat belt was defined as wearing either a lap-belt and/or a shoulder-belt. We utilized the methodology elucidated by Kuan et al. to convert abbreviated Injury Score (AIS) codes for renal injury to AAST-OIS renal injury grades, excluding codes that did not match.¹³ Surgical management was evaluated for nephrectomy by current procedural terminology code (55.5) or **angioembolization (38.86)**. A total of 252 patients who were categorized as MVC occupants did not have device data and were excluded from the analysis. Intergroup comparisons were analyzed for renal injury grades, nephrectomy, hospital length of stay, ICU length of stay, days on the ventilator, discharge disposition, and mortality. Relative risk reduction in high-grade renal injury and nephrectomy was determined for each occupant restraint device.

Statistical Analysis

Results were summarized with frequencies and percentages for dichotomous and categorical variables and with mean±standard deviation for continuous variables. Device between group analyses were performed with chi-square analysis for AAST-OIS renal injuries, nephrectomy and hospital discharge disposition. Device between group analyses were performed with one-way ANOVA analysis for hospital length of stay, ICU length of stay, and days on the ventilator. Analyses were performed using SPSS 18® (Chicago, IL) and statistical significance was determined at $p = 0.05$. Protective device relative risk reduction was calculated for high-grade renal injuries and nephrectomy.

RESULTS

NTDB research datasets, admission year 2010, 2011, and 2012 registered a total of 2,329,246 patient records. MVCs occurred in 466,028 patients (20.0%), which resulted in 3,846 cases with renal injuries and a calculable AAST scores (0.8%). Similar to prior renal trauma studies using the NTDB, a total of 52% of AIS scores mapped to AAST-OIS renal injury grades.¹⁴ Patient demographics and presenting injury status are presented in table 1.

AIS score was converted to the AAST-OIS to allow for direct comparison of grade of renal injury and rate of nephrectomy among protective devices. Grade III injuries were included in our analysis, as previous studies looking at the NTDB have shown that nephrectomies in this group are not uncommon.¹⁵ The distribution of high-grade renal injuries by protective device is shown in Table 2. Comparison of renal injury frequency demonstrated injured occupants without a protective device had a higher rate of high grade renal injury (45.1%) compared to those with seat belts (39.9%, $p=0.008$), airbags (42.3%, $p=0.317$), and seat belts with airbags (34.7%, $p<0.001$) Figure 1. The decrease in the rate of high-grade renal injury appears most pronounced with both a seat belt and airbag.

The rate of nephrectomy in high-grade renal injuries stratified by protective device is shown in Figure 2. More than half of high-grade renal trauma in MVC occupants with no protective device resulted in nephrectomy (56.1%), while those utilizing seat belts (20.0%, $p<0.001$), airbags (10.5% $p<0.001$), and seat belts with airbags (13.3%, $p<0.001$) had a lower rate of nephrectomy. There was no statistical difference in the rate of angioembolization between occupants with no protective device (3.2%) and those with seat belts (2.6%), airbags (3.1%), and seat belts with airbags (2.0%, $p=0.443$). In subset analysis evaluating nephrectomy rates by individual renal injury grade comparing no protective device to any protective device there was no statically significant differences for each grade (Grade III renal injuries $p=0.192$, Grade IV renal injuries $p=0.319$, Grade V renal injuries $p=0.123$).

Hospital status and discharge disposition were analyzed to determine the immediate level of post-injury care as well as the functional capacity at the completion of the hospital stay. Hospital status of MVC occupants with renal high-grade renal injury stratified by protective device is demonstrated in Table 3. MVC occupants with a protective device had a statistically shorter mean ICU length of stay ($p=0.005$) as well as shorter overall hospital length of stay ($p<0.001$). There was no statistical difference in mean number of days requiring ventilator support ($p=0.843$) between the protective device groups. Discharge disposition, including home, acute care, and nursing home was similar among all protective devices ($p = 0.821$). Mortality rates were lower among MVC occupants **wearing protective devices**, but this did not reach statistical significance ($p=0.079$).

In order to evaluate the extent protective devices were associated with a decrease in the incidence of high-grade renal injuries and nephrectomy; we determined the relative risk reduction. Occupants of MVCs with an airbag only had the lowest relative risk reduction in high-grade renal injuries (6.2%) and nephrectomy (16.3%). Those with airbags had a increased reduction in while those with both airbags and seat belts experienced the largest relative risk reduction (23.2% and 39.9%, respectively).

DISCUSSION

Using a large national trauma database, we report the impact of seat belts and airbags on high-grade renal injuries and nephrectomy rates in MVC's. High-grade renal injuries of MVC occupants decreased with the use of seat belts, airbags, and a combination of both protective devices, although only the cohort with both seat belts and airbags was statistically significant. This protective effect translates into a significantly lower rate of subsequent

nephrectomy. The relative risk reduction in high-grade renal injury and nephrectomy is also substantial, with similar increasing trends when combining protective devices, as compared to no device and a single protective device.

The findings of our study are consistent with a previous study utilizing data from the Crash Injury Research and Engineering Network database, which showed passengers in automobiles with frontal and side airbags have a reduced rate of renal injury compared with those without airbags.¹⁶ Our study expands upon these findings, showing that the combination of seat belt and airbags are associated with a decrease in not only the rate of high-grade renal injury (from 45.1% without a protective device to 34.7% with a seat belt and airbag) but also are associated with a decrease in the rate of subsequent nephrectomy (from 56.1% with no protective device to 13.3% with a seat belt and airbag).

When compared to no protective device, occupants with seat belts, airbags, and seat belts with airbags demonstrated a significantly shorter ICU and hospital length of stay while no statistical differences were noted in days on the ventilator. The decrease in mortality rate seen among MVC occupants trended toward statistical significance. Williams et al. who showed a statistically higher rate of ventilator-associated pneumonia, bacteremia, ICU and hospital days, and mortality in unrestrained MVC occupants when compared to those with restraint devices.¹⁷ This significance held for all three groups (seat belts, airbags, seat belts with airbags). Their cohort, however, included all MVC patients and did not specifically analyze high-grade renal injury, which makes direct comparison to our study difficult.

We demonstrated a substantial relative risk reduction in high-grade renal injuries and nephrectomy rates with the use of motor vehicle protective devices. In a prior study evaluating the operative management of renal injuries, Wessells et al. reported the relative risk of nephrectomy in MVC was 0.83 (95% CI 0.39-01.79), which occurred in 3.6% of MVCs while the vast majority of renal trauma was managed nonoperatively (95.9%).¹¹ This study included all grades of renal trauma where the majority were hematoma/contusions and lacerations. The nephrectomy rate in the current study was considerably higher which likely reflects our higher-grade injuries. The success rate of angioembolization for the management of renal trauma is low and may reflect the low use in our study. Of patients who are initially managed by angioembolization, up to 88% require some type of secondary intervention.¹⁴ While reductions in renal trauma specifically with seat belts compared to airbags have not previously been described, role of protective devices in mortality reduction has been well documented. Cummins et al. demonstrated that compared with no protective device, occupants with seat belt and airbags had a 67% reduction in mortality, seat belt alone had a 51% mortality reduction, and airbag only had a 32% mortality reduction.¹⁸ This additive protective trend seen with the combination of seat belt and airbags was also observed in our study.

Although our study demonstrated a renal protective role of seat belts and airbags, other solid abdominal organs do not appear to receive the same protection. This may be partially explained by renal anatomy and collision forces. Anatomically the kidney is protected in the retroperitoneum by the perinephric fat, lateral and posterior abdominal wall musculature, in addition to adjacent visceral organs. Renal injury is related to the direct transmission of

kinetic energy and it is commonly associated with other organ injuries. In addition, deceleration forces during an MVC occur at points of anatomical fixation, such as the renal hilum or ureteropelvic junction, which can also result in renal injury. Siegal et al. demonstrated that seat belt use did not protect against hepatic or splenic injuries, which seem to be more of a function of crash direction.¹⁹ Williams et al. found that seat belt use appeared to have no influence on abdominal injuries as the odds ratio of their analysis approached one.¹⁷ However, patients with airbag deployment were less likely to have abdominal injuries (adjusted OR = 0.70; 95% CI, 0.56-0.87), as were patients who were maximally restrained with both seat belts and airbags (adjusted OR = 0.76; 95% CI, 0.63-0.92).

While protective devices reduce motor vehicle occupant trauma, they have also been reported as a source of injury.²⁰ Overt abdominal injury, including renal trauma,²¹ as well as occult abdominal injuries have been described as a result of airbag deployment.²² Thor et al. found the risk of moderate (AIS2+, OR 2.14 95% CI, 1.06-4.33) or serious abdominal injury (AIS3+, OR 3.48 95% CI, 1.27-9.62) is higher for belted drivers in frontal crashes with a deployed airbag than for belted drivers not exposed to a deployed airbag. The liver and spleen were not found to have statistically significant higher odds of injury with airbag deployment. These authors hypothesize that an increase in abdominal injury potential may be related to a change in occupant kinematics as a result of the occupant engaging the deployed airbag, consequently forcing the occupant to submarine under the lap belt.²³

Seat belts have also been cited as a possible etiology of renal trauma, particularly at the point where the lap/shoulder belt connects with clasp mechanism as it relates to an occupant's torso and costal margin. In a study of collision patterns and vehicle interior components following motor vehicle collisions, Kuan et al. reported renal injury in frontal and side impact collisions appears to occur after direct impact from objects within the vehicle compartment. Specifically, acceleration into the seat belt or steering wheel seems to result in renal injuries.²⁴ The authors found that drivers injured by the seat belt more commonly have right renal injuries while passengers more commonly have left renal injuries, although this was not found to be statistically significant due to the low power of the study.

Motor vehicle injury reduction remains a formidable public health challenge, despite the impressive declines in motor vehicle-related death rates over the last century.²⁵ Protective devices such as seat belts and airbags are among the most important measures to further reduce motor vehicle occupant injuries and deaths. With the continued risk of organ injury during MVCs, understanding the impact of seat belts and airbags on renal injuries and nephrectomy rates provides additional evidence to support the role of these protective devices.

Limitations

Although this is one of the largest studies examining the impact of motor vehicle protective devices on renal trauma, there are several limitations. The NTDB is not a population-based sample of hospitalized patients. It includes a disproportionate number of larger hospitals with younger and more severely injured patients. There exists both a selection and an

information bias. Not all trauma centers submitting data to the NTDB use the same version of the AIS and not all AIS scores correspond to AAST renal grades. However, this method of conversion to AAST renal grade has been successfully employed in prior studies evaluating renal trauma.^{13, 26} The NTDB lacks specific crash data, such as speed, direction of impact, as well as occupant position (driver vs passenger). Despite these limitations, this study includes the largest population of MVC related renal trauma demonstrating the renal protective effects of seat belts and airbags.

CONCLUSIONS

Occupants of MVCs with protective devices have reduced rates of high-grade renal injury and nephrectomy. Reduction in both appears most pronounced with the combination of seat belts and airbags.

Key of Definitions for Abbreviations

NTDB	National Trauma Data Bank
MVC	Motor vehicle collision
AAST	American Association for the Surgery of Trauma
LOS	Length of stay
AIS	Abbreviated Injury Score

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Figure 1. High-grade renal injury rate by protective device

Comparisons represent each protective device group in comparison to the no protective device group. The seatbelt group and seatbelt+airbag had lower rates of high-grade renal injury than the no protective device group ($p = 0.008$ and <0.001 , respectively) while the airbag group's rate of injury did not differ statistically from the no protective device group ($= 0.317$).

Figure 2. Nephrectomy rate of high-grade renal injury by protective device

Comparisons represent each protective device group in comparison to the no protective device group. All protective device groups had lower rates of nephrectomy than the no protective device group ($p < 0.001$ for all comparisons).

Table 1

Baseline characteristics, demographics, and presenting abbreviated injury scale score (AIS). SBP, systolic blood pressure, ED, emergency department.

	Patients (%) n=3846	No protective device (%) n=1752	Seat belt (%) n=1012	Airbag (%) n=390	Seat belt + Airbag (%) n=692	p-value
Age (mean±SD)	36.5±17.8	33.1±15.2	39.2±19.0	33.9±16.0	42.7±20.7	< 0.001
White race	1741 (45.2)	804 (45.9)	429 (42.4)	155 (39.7)	323 (46.7)	0.087
Male	2300 (59.8)	1155 (65.9)	556 (54.9)	237 (60.8)	352 (50.9)	< 0.001
SBP <90 in ED	388 (10.1)	195 (11.1)	92 (9.1)	42 (10.8)	59 (8.5)	0.148
Comorbidities (none present)	3228 (83.9)	1433 (81.8)	864 (85.4)	324 (83.1)	607 (87.7)	0.002
Injury Severity Score						
<9	252 (6.6)	76 (4.3)	91 (9.0)	17 (4.4)	68 (9.8)	
9-15	585 (15.2)	217 (12.4)	164 (16.2)	64 (16.4)	140 (20.2)	
16-24	1079 (28.1)	470 (26.8)	297 (29.3)	99 (25.4)	213 (30.8)	
25-47	1598 (41.5)	802 (45.8)	387 (38.2)	173 (44.4)	236 (34.1)	
48	332 (8.6)	187 (10.7)	73 (7.2)	37 (9.5)	35 (5.1)	
Head AIS >3	550 (14.3)	304 (17.4)	127 (12.5)	59 (15.1)	60 (8.7)	
Abdomen AIS >3	1155 (30.0)	574 (32.8)	288 (28.5)	130 (33.3)	163 (23.6)	

Table 2

AAST organ injury scale grading of renal injuries by protective device

	No protective device (%) n= 790	Seat belt (%) n= 404	Airbag (%) n= 165	Seat belt + Airbag (%) n= 240
Grade III	440 (55.7)	247 (61.1)	101 (61.2)	151 (62.9)
Grade IV	267 (33.8)	133 (32.9)	48 (29.1)	73 (30.4)
Grade V	83 (10.5)	24 (5.9)	16 (9.7)	16 (6.7)

Table 3

Hospital and discharge status of patients with high-grade renal injuries. LOS, length of stay.

	No protective device	Seat belt	Airbag	Seat belt + Airbag	p-value
ICU LOS (days)	8.7±10.0	7.9±9.0	7.6±9.6	6.9±8.9	0.005
Ventilator (days)	9.1±10.3	9.4±10.0	9.0±11.2	8.6±11.2	0.843
Hospital LOS (days)	12.6±14.7	10.8±12.1	11.2±12.2	9.6±11.2	< 0.001
Discharge disposition					
Home	1049 (59.9)	616 (60.9)	228 (58.5)	433 (62.6)	
Acute care	119 (6.8)	79 (7.8)	30 (7.7)	57 (8.2)	0.821
Nursing home	376 (21.5)	212 (20.9)	80 (20.5)	136 (19.7)	
Mortality	124 (7.1)	70 (6.9)	38 (9.7)	38 (5.5)	0.079