EFFECT OF SEAT BELT USE AND AIRBAGS DEPLOYMENT ON CLINICAL OUTCOMES IN ROAD TRAFFIC INJURY PATIENTS

SHORT TITLE: **EFFECT OF SAFETY DEVICES**

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ABSTRACT

Objective: Seat belts and airbags are safety devices designed to prevent road traffic injuries (RTI). They reduce fatal outcomes in patients with RTI. This study aimed to compare their effectiveness on the clinical outcomes of injured patients with RTI.

Methods and Data sources: A multicenter cross-sectional study was conducted using the Emergency Department-based Injury In-depth Surveillance (EDIIS) registry between Jan 2011 and Dec 2020. All patients who sustained RTI in a vehicle with fewer than 10 seats were eligible. The target population was categorized into four groups: seat belt use and airbag deployment, seat belt use only, airbag deployment only, and non-use. The primary outcome was intracranial injury. The secondary and tertiary outcomes were intensive care unit (ICU) admission and in-hospital mortality. The adjusted odds ratios (AORs) (95% confidence intervals [Cis]) of the safety device for related outcomes were calculated.

Results: Among 82,262 patients, 13,929 (16.9%) were classified as seatbelt and airbag deployment; 47,123 (57.4%) as seatbelt use only; 1,820 (2.2%) as airbag deployment only; and 19,300 (23.5%) as the non-use group. Compared to the non-use group, AORs (95% CIs) for intracranial injury were 0.49 (0.42-0.56) in the seat belt use and airbag deployment groups, 0.39 (0.35-0.44) in the seat belt use only group, and 1.34 (1.08-1.67) in the airbag deployment only group. For in-hospital mortality, AORs were 0.29 (0.22-0.36) in the seat belt use and airbag deployment groups, 0.17 (0.14-0.21) in the seat belt use only group, and 1.74 (1.30-2.32) in the airbag deployment only group.

Conclusion: Seat belt use had a significant preventive effect on intracranial injury and in-hospital mortality. The airbag deployment only group had worse outcomes. Public efforts to increase the proper use of safety devices are needed to reduce the RTI burden.

Keywords: Accidents, Traffic, Seat Belts, Air Bags, Brain Injuries

INTRODUCTION

Death from road traffic injury (RTI) increased to 1.35 million annually in 2016 and is now the eighth leading cause among all age groups.[1] In Korea, the number of deaths from RTI in 2020 was 3,081, and the overall trend over the decade has been decreasing since 2012.[2] However, it is considered the leading cause of death for children and young adults aged 5-29 years, and low- and middle-income countries bear the greatest burden of road traffic fatalities and injuries.[1,3] Most patients who survive RTI suffer from severe disabilities and economic costs, resulting in a public health burden.[4] Several strategies have been implemented to reduce RTI: road safety campaigns such as seatbelt use, reducing alcohol-impaired driving, various safety technologies such as seatbelts, airbags, child safety seats, electronic stability control, and strong law enforcement.[5-7]

Seat belt use is considered the most effective modality to save lives. When properly used, it can reduce the risk of fatal injury by 45% and moderate-to-critical injury by 50%.[6.8] However, seat belt use rates varied widely across countries. Seat belt use increased to 89.6% in 2018 in the United States, but in developing countries, it remained low at less than 60%.[8-10] According to the 2021 Report on the Transport Culture Index of Korea, seatbelt use rates increased from 73% in 2011 to 87% in 2017, but remained at a standstill of 84% in 2021.[11]

Airbags have been introduced to provide further protection from RTI in severe collisions.[12,13] Frontal airbags saved 50,457 lives from 1987 to 2017 in the United States and reduced fatalities by 14% when seat belts were not used.[8] However, severe studies reported that, regarding air-bag-related injuries, unstrained drivers in frontal collisions were more likely to sustain more severe injuries.[13-15]

Each device is well known to reduce fatal outcomes in patients with RTI and has been implemented with a safety device designed to prevent injuries. However, studies comparing the preventive effects of seat belts and airbags on clinical outcomes are limited. This study aimed to compare the effectiveness of these safety devices on the clinical outcomes of injured patients with RTI.

METHODS

Study design and setting, data source

This was a multicenter cross-sectional observational study using the Emergency Department-based Injury In-depth Surveillance (EDIIS) database in Korea. The EDIIS is a nationwide prospective database of injured patients visiting the ED, supported by the Korea Centers for Disease Control and Prevention (CDC). It was established in five hospitals in 2006, and currently, 23 EDs gather injury-related information for injury prevention. EDIIS was constructed based on the core dataset of the International Classification of External Causes of Injuries by the World Health Organization. The database comprises 58 items, including the patient's demographics, injury-related information, emergency medical service (EMS) records, clinical findings, diagnosis and medical treatment in the ED, and clinical outcomes. Primary surveillance data were collected by general physicians in each ED, and the recorded data were regularly supervised and revised by emergency physicians and trained research coordinators. All research coordinators were required to complete training before participation and upload the surveillance data into a web-based database system of the KOREA CDC. For quality assurance, the data were reviewed monthly by a quality management committee.[16]

Study population

The study population included all injured patients who sustained RTI in the vehicle and visited the ED between January 2011 and December 2020. We excluded cases resulting from out-of-vehicle RTI, 10 or more passenger vehicles, children aged six years (they are obliged to use safety car seats in Korean law), or had unknown information on seat belt use, airbag deployment, and clinical outcomes.

Main outcomes

The primary outcome was intracranial injury, which was defined as the diagnosis code of the ICD-10 from S06.1 to S06.9. The diagnosis code is recorded on a discharge summary after an ED or hospital admission. The secondary and tertiary outcomes were intensive care unit (ICU) admission and in-hospital mortality. The latter was defined as death in the ED or during admission for injury care determined at discharge from the ED or hospital.

Variables and measurements

The main exposure variables were seat belt use and airbag deployment, as indicated in the EDIIS registry. The study population was categorized into four groups: seat belt use and airbag deployment, seat belt use only, airbag deployment only, and non-use. We collected information on demographic variables (age, sex, and past medical history), day of injury (weekend and weekday), time of injury (day [06:00–18:00]), alcohol use, EMS use, injury-related variables (driving status, type of road [expressway, national way, alleyway, and others], collision direction (frontal, lateral, rear, rollover, complex, and others), anatomical location of injury), excess mortality ratio-based injury severity score (EMR-ISS), and hospital-related variables (time interval from injury to ED arrival, initial mental status and vital signs at the ED, length of ED stay, ED outcome, and in-hospital mortality).

Statistical analysis

Counts and proportions were used for categorical variables, and medians and interquartile ranges (IQR) for continuous variables. We used the Kruskal-Wallis test for continuous variables and Pearson's χ^2 test for categorical variables. Adjusted odds ratios (AORs) (95% confidence intervals [Cis]) of seat belt use and airbag deployment for related outcomes were calculated using multivariable logistic regression analysis. A two-sided P value of < 0.05 was defined as significant. All statistical analyses were performed using the SAS software (version 9.4; SAS Institute Inc., Cary, NC, USA).

Ethics statement

This study was approved by the Institutional Review Board (IRB) of the Chungbuk National University Hospital (IRB No. 2022-10-013). The requirement for informed consent was waived, and patient information was anonymized before analysis**.**

RESULTS

Of the 2,627,450 injured patients, 429,501 visited the ED because of road traffic injuries. A total of 82,262 patients were included in the analysis, excluding out-of-vehicle injuries (n=88,576), in-vehicle injuries with more than 10 seats (n=161,041), children aged below six years (n=8,209), unknown outcomes (n=41), seat belt use (n=22,742), and airbag deployment (Figure 1).

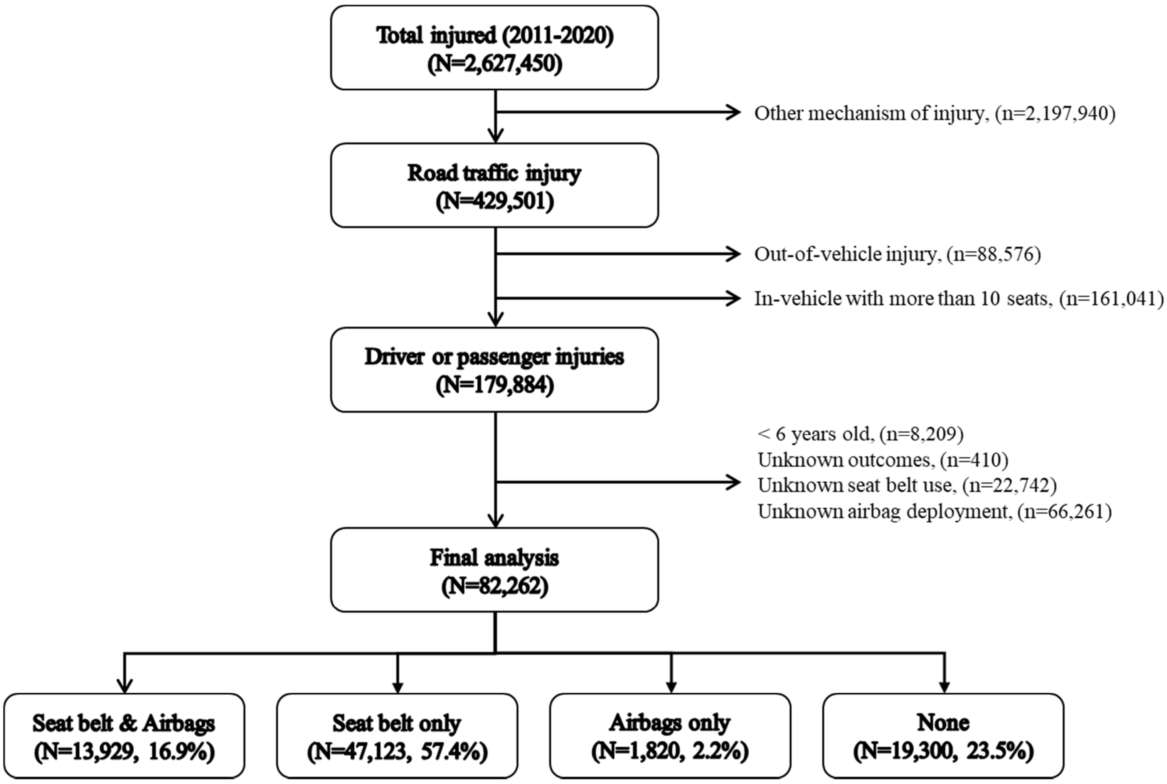

Figure 1. Study population.

Table 1 shows the demographic characteristics of the study population using safety devices. Among 82,262 eligible patients, there were 13,929 (16.9%) in the seat belt use and airbag deployment group, 47,213 (57.4%) in the seat belt use only group, 1,820 (2.2%) in the airbag deployment only group, and 19, 300 (23.5 %) in the non-use group. The airbag deployment only group was more likely to be younger (median age, 34 years), injured at night (18:00-06:00), drink more alcohol (20.8%), use more EMS (64.0%), and show a decreased mental status at the ED visit (all P<0.001).

Table 1.
Demographic findings of study population by safety devices

	Total		**Seat belt and airbag**		**Seat belt only**		**Airbag only**		**None**		
	N	%	N	%	N	%	N	%	N	%	p-value
All	82262		13929	16.9	47213	57.4	1820	2.2	19300	23.5	
Age											<0.001
<18	3616	4.4	230	1.7	1369	2.9	102	5.6	1915	9.9	
18-30	17610	21.4	2892	20.8	9099	19.3	589	32.4	5030	26.1	
30-45	26619	32.4	4398	31.6	16405	34.7	540	29.7	5276	27.3	
45-65	26582	32.3	5006	35.9	16089	34.1	458	25.2	5029	26.1	
>65	7835	9.5	1403	10.1	4251	9.0	131	7.2	2050	10.6	
Median (IQR), year	40 (29-54)		42 (31-55)		41 (31-53)		34 (25-49)		36 (25-53)		<0.001
Sex											<0.001
Male	42053	51.1	8129	58.4	23897	50.6	1107	60.8	8920	46.2	
Day of injury											<0.001
Weekend	29264	35.6	4911	35.3	16533	35.0	605	33.2	7215	37.4	
Time of injury											<0.001
06:00-18:00	50431	61.3	7955	57.1	30742	65.1	845	46.4	10889	56.4	

18:00-06:00	31831	38.7	5974	42.9	16471	34.9	975	53.6	8411	43.6	
Past medical history											
Hypertension	2400	2.9	435	3.1	1358	2.9	55	3.0	552	2.9	0.448
Diabetes mellitus	1225	1.5	232	1.7	719	1.5	28	1.5	246	1.3	0.024
Chronic liver disease	151	0.2	32	0.2	77	0.2	5	0.3	37	0.2	0.309
Cerebrovascular disease	192	0.2	32	0.2	115	0.2	4	0.2	41	0.2	0.897
Alcohol consumption											<0.001
Yes	4325	5.3	820	5.9	1229	2.6	378	20.8	1898	9.8	
EMS use											
Yes	32579	39.6	7408	53.2	15586	33.0	1164	64.0	8421	43.6	<0.001
Mental status at the ED											<0.001
Alert	79074	96.1	13355	95.9	45908	97.2	1600	87.9	18211	94.4	
Verbal	873	1.1	191	1.4	264	0.6	77	4.2	341	1.8	
Painful stimuli	453	0.6	103	0.7	103	0.2	44	2.4	203	1.1	
Unresponsive	454	0.6	82	0.6	97	0.2	63	3.5	212	1.1	
Unknown	1408	1.7	198	1.4	841	1.8	36	2.0	333	1.7	
Vital signs											
SBP, Median (IQR)	133 (120-150)		136 (120-151)		135 (120-150)		130 (114-147)		130 (118-146)		<0.001
HR, Median (IQR)	82 (74-91)		83 (75-93)		81 (74-90)		86 (76-97)		82 (75-93)		<0.001
RR, Median (IQR)	20 (18-20)		20 (18-20)		20 (18-20)		20 (18-20)		20 (18-20)		<0.001

IQR, interquartile range; EMS, emergency medical services; ED, emergency department; SBP, systolic blood pressure; HR, heart rate; RR, respiratory rate.

The proportion of passengers was highest in the non-use group (70.1%). Frontal collision was the most common in the seat belt use and airbag deployment and airbag deployment only groups (19.8% and 24.8%, respectively). Regarding the anatomical classification of injury, the proportion of head and face injuries was higher in the airbag deployment only group and the non-use group (57.0% and 50.6%, respectively). However, a neck injury was most common in the seat belt use alone group (42.6%). The airbag deployment only group had a higher proportion of injury severity score, intracranial injury, ICU admission, and in-hospital mortality (all P<0.001; Table 2).

Table 2.
Injury-related characteristics by safety devices

	Total		**Seat belt and airbag**		**Seat belt only**		**Airbag only**		**None**		
	N	%	N	%	N	%	N	%	N	%	p-value
All	82262		13929	16.9	47213	57.4	1820	2.2	19300	23.5	
Driving status											<0.001
Driver	49759	60.5	10804	77.6	32115	68.0	1073	59.0	5767	29.9	
Passenger	32503	39.5	3125	22.4	15098	32.0	747	41.0	13533	70.1	
Type of road											<0.001
Expressway	14143	17.2	2991	21.5	8228	17.4	264	14.5	2660	13.8	
National way	64073	77.9	10363	74.4	37131	78.6	1430	78.6	15149	78.5	
Alleyway	1381	1.7	205	1.5	681	1.4	42	2.3	453	2.3	
Others	2665	3.2	370	2.7	1173	2.5	84	4.6	1038	5.4	
Collision direction											<0.001
Frontal	10712	13.0	2760	19.8	4603	9.7	451	24.8	2898	15.0	
Lateral	7431	9.0	1021	7.3	4163	8.8	132	7.3	2115	11.0	
Rear	13121	16.0	433	3.1	9432	20.0	44	2.4	3212	16.6	

Roll over	1262	1.5	206	1.5	580	1.2	28	1.5	448	2.3	
Complex	2658	3.2	422	3.0	1630	3.5	47	2.6	559	2.9	
Others	47078	57.2	9087	65.2	26805	56.8	1118	61.4	10068	52.2	
Anatomical classification of injury											
Head and face	33676	40.9	5311	38.1	17556	37.2	1037	57.0	9772	50.6	<0.001
Neck	29767	36.2	3509	25.2	20122	42.6	351	19.3	5785	30.0	<0.001
Chest	14729	17.9	4134	29.7	7197	15.2	476	26.2	2922	15.1	<0.001
Abdomen	19887	24.2	3146	22.6	12523	26.5	364	20.0	3854	20.0	<0.001
Upper extremity	14720	17.9	3150	22.6	7741	16.4	421	23.1	3408	17.7	<0.001
Lower extremity	13110	15.9	2866	20.6	6226	13.2	499	27.4	3519	18.2	<0.001
Injury severity											
EMR-ISS ≥ 9	49035	59.6	9030	64.8	25772	54.6	1409	77.4	12824	66.4	<0.001
EMR-ISS ≥ 16	18403	22.4	4194	30.1	8007	17.0	856	47.0	5346	27.7	<0.001
Median (IQR)	9 (4-14)		9 (4-17)		9 (4-12)		13 (9-25)		9 (4-17)		<0.001
ED disposition											<0.001
Discharge	66827	81.2	10101	72.5	40780	86.4	1085	59.6	14861	77.0	
Transfer to other hospital	3504	4.3	780	5.6	1520	3.2	172	9.5	1032	5.3	
Admission	11592	14.1	2991	21.5	4845	10.3	518	28.5	3238	16.8	
Death	339	0.4	57	0.4	68	0.1	45	2.5	169	0.9	
Time interval from injury to ED arrival											
Median (IQR), hour	1.1 (0.6-3.7)		1.0 (0.6-2.8)		1.2 (0.7-4.3)		1.0 (0.5-2.1)		1.0 (0.6-3.0)		<0.001
ED length of stay											
Median (IQR), hour	1.9 (1.1-3.6)		2.5 (1.4-4.5)		1.7 (1.1-3.1)		3.1 (1.7-5.9)		2.1 (1.2-4.2)		<0.001
Clinical outcomes											
Intracranial injury	1902	2.3	334	2.4	731	1.5	107	5.9	730	3.8	<0.001
ICU admission	3287	4.0	960	6.9	1119	2.4	222	12.2	986	5.1	<0.001
In-hospital mortality	566	0.7	108	0.8	137	0.3	65	3.6	256	1.3	<0.001

EMR-ISS, excess mortality ratio-adjusted injury severity score; IQR, interquartile range; ED, emergency department; ICU, intensive care unit.

Figure 2 shows the trends in the applied safety devices by year. In the non-use group, it decreased from 29.3% in 2011 to 15.1% in 2020. The seat belt use rate reached approximately 82% by 2020. Compared to the non-use group, AORs (95% CIs) for intracranial injury were 0.49 (0.42-0.56) in the seat belt use and airbag deployment group, 0.39 (0.35-0.44) in the seat belt use only group, and 1.34 (1.08-1.67) in the airbag deployment only group. For ICU admission, AORs were 0.44 (0.40-0.48) in the seat belt use only group, and 2.02 (1.72-2.37) in the airbag deployment only group. For in-hospital mortality, AORs were 0.29 (0.22-0.36) in the seat belt use and airbag deployment group, 0.17 (0.14-0.21) in the seat belt use only group, and 1.74 (1.30-2.32) in the airbag deployment only group (Table 3).

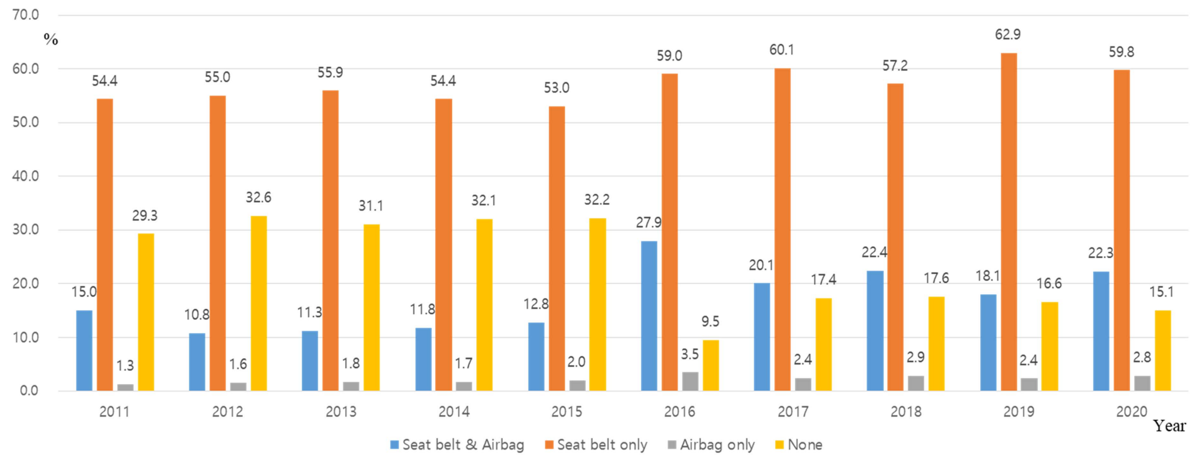

Figure 2. Trends in the applied safety devices by the year.

Table 3. Multivariable logistic regression analysis on study outcomes by safety devices

	Total	Positive outcomes		Unadjusted	Adjusted
	N	N	%	OR (95% CI)	OR (95% CI)
Primary outcome: Intracranial injury					
Total	82262	1902	2.3		
Seat belt and airbag	13929	334	2.4	0.63 (0.55-0.71)	0.49 (0.42-0.56)
Seat belt only	47213	731	1.5	0.40 (0.36-0.44)	0.39 (0.35-0.44)
Airbag only	1820	107	5.9	1.59 (1.29-1.96)	1.34 (1.08-1.67)
None	19300	730	3.8	1.00	1.00
Secondary outcome: ICU admission					
Total	82262	3287	4.0		
Seat belt and airbag	13929	960	6.9	1.38 (1.25-1.51)	1.08 (0.97-1.19)
Seat belt only	47213	1119	2.4	0.45 (0.41-0.49)	0.44 (0.40-0.48)
Airbag only	1820	222	12.2	2.58 (2.21-3.01)	2.02 (1.72-2.37)
None	19300	986	5.1	1.00	1.00
Tertiary outcome: In-hospital mortality					
Total	82262	566	0.7		
Seat belt and airbag	13929	108	0.8	0.58 (0.46-0.73)	0.29 (0.22-0.36)
Seat belt only	47213	137	0.3	0.22 (0.18-0.27)	0.17 (0.14-0.21)
Airbag only	1820	65	3.6	2.76 (2.09-3.63)	1.74 (1.30-2.32)
None	19300	256	1.3	1.00	1.00

Adjusted for age, sex, time of injury, diabetes mellitus, driving status, type of road, collision direction, alcohol consumption, and EMS use.

OR: odds ratio; CI: confidence interval; ICU: intensive care unit.

DISCUSSION

Through this injury surveillance data, we found that seat belt use and airbag deployment and seat belt use only had significant preventive effects on intracranial injury and in-hospital mortality because of RTI.

Seat belt use is well known to be the most effective modality for reducing fatalities from RTI. Among the numerous efforts to increase the seat belt use rate, mandatory seat belt legislation is highly effective in promoting wearing seat belts and a cost-effective measure to reduce the severity and sequelae of traumatic brain injuries related to RTI.[17,18] Among them, 71% of all countries have adopted the best practice of mandating the use of seat belts by front and rear seat occupants.[1] However, seat belt use rates did not increase further from the late 80% in developed countries and were found to be less than 60% in developing countries.[8,9] Various efforts have been made to increase the seat belt use rate beyond legislation, such as public campaigns and the development of new technologies such as belt reminders or interlocks.[1,19,20]

Airbags are regarded as supplemental safety measures that reduce the risk of injury from RTI in combination with seat belts. Despite using seat belts, car occupants are injured when they hit the vehicle's interior parts, such as the steering wheel or dashboard, and airbags reduce the level of contact.[8] Fatalities in frontal collisions, specifically airbags, have been reduced by 22% among belted drivers.[21] The United States has implemented the mandatory installation of airbags, but in Korea, there is no such obligation. However, vehicle manufacturers voluntarily installed airbags, and the installation rate of airbags in manufactured vehicles in Korea was 88.3% in 2003.[22]

Despite the reduced risk of injury from airbags, our results found that the deployment only group had worse outcomes: a higher proportion of decreased mentality at the ED and injury severity score were observed. Moreover, the proportion of intracranial injuries, ICU admissions, and in-hospital mortality were higher. Airbags are generally designed to inflate moderate-to-severe car crashes according to the direction and severity of the impact.[8] Unrestrained occupants are more likely to be positioned in the deployment path of the airbag during a collision, leading to higher lethality from the airbags.[13,15]

Numerous studies have shown an overall reduction in the number of fatalities in frontal collisions, mainly due to the reduced risk of serious head and neck injuries.[15,23] However, most studies included only car occupants who wore their seat belts in airbag-equipped vehicles. In this study, the head and face injury rate was 57% in the airbag deployment only group, but those in the seat belt use and airbag deployment group and seatbelt use only group were significantly lower (38.1% and 37.2%, respectively). These results reinforce that airbags are a complementary safety device rather than an alternative to seat belts. Considering that they are designed to be deployed during serious RTI, we ensured that all occupants were properly seated and wearing seat belts to reduce the risk of injury.

Another point was to identify the characteristics of the airbag deployment only group. In our results, they are more likely to be younger, injured at night, drink more alcohol, and use more EMS. Previous studies have noted that a higher risk of injury is associated with the physique of occupants or specific positions of occupant seating, specifically those who were unrestrained or improperly restrained.[13,24] Unrestrained drivers were more likely to use a cell phone while driving, drive at excessive speed limits, attempt to pass other vehicles, have alcohol-impaired driving, and not follow traffic rules.[25] The driver has the greatest influence on passenger seat belt use, and driver restraint use is a significant predictor of restraint use, specifically among young passengers in RTI.[26] Therefore, public efforts are needed to prevent fatal RTIs by spreading traffic safety awareness and implementing a desirable driving culture for car occupants.

This study had several limitations. First, this was a retrospective observational study, and there might have been potential confounders that influenced the exposure and outcomes. Injury-related data, which can influence outcomes such as the speed at the time of collision, counterparts of the RTI, and passengers' seating positions, were not available from the EDIIS registry. Second, seat belt use and airbag deployment, which were the main exposure variables, were ascertained only through face-to-face interviews with the patient and guardians. This might be subject to over- and underestimation, which can also result in bias. Furthermore, we only had information on whether the airbags were deployed. Airbag-related data, such as the type, number, and location of airbags embedded in the vehicle, were limited, and could not be used for analysis.

CONCLUSION

Seat belt use showed preventive effects on intracranial injury and in-hospital mortality from RTI. Airbag deployment without seatbelt use had no preventive effect on the clinical outcomes. These results suggest that airbags are not a substitute for seatbelts but are an additional device to reduce RTI. Public health efforts are needed to increase the proper use of safety devices and implement a good driving culture for car occupants, which can help reduce the health burden of RTI.

Disclosure

The authors have no potential conflicts of interest to disclose.

Author Contributions

Conceptualization: Kim JH and Park GJ. Methodology: Park GJ. Formal analysis: Kim JH and Park GJ. Investigation: Kim JH, Shin IC, and Yong SM. Data curation: Kim JH and Park GJ. Writing – original draft preparation: Kim JH and Park GJ. Writing – reviewing and editing: Park GJ, Kim YM, Chai HS, Kim SC, Kim H, and Lee SW.

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