Simple Criteria That Predict Major Injury of Front-Seat Passenger in Frontal Collision of Passenger Car

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감사의 글

2007년 이탈리아 소렌토 지중해 응급의학회를 참석했을 때, 인근 아말피 해변에서 이강현 교수님과 함께 시간을 했습니다. 응급의학과 교수의 생활과 연구자의 자세에 대해 상세한 이야기를 들을 수 있었던 계기를 통해 의과대학교수의 꿈을 꾸게 되었고, 그 다음 해 교수님 아래서 직접 지도를 받으며 임상강사로서 생활을 시작하였습니다. 진료와 교육을 병행하면서 연구를 하는 기본을 연마하고 지금 몸담고 있는 충주에서 의과대학 교수의 꿈을 이루게 되었지만, 지속적인 연구를 위한 연구 환경을 새롭게 마련하는 것이 여간 쉬운 일이 아니었습니다.

시행착오를 거듭하던 중 자동차의학을 소개해주셔서 응급의학과 접목을 위한 여러 시도 끝에 박사학위의 주제도 정해지게 되었습니다. 차량사고 한 예를 모아서 완성하는데 5-6시간 소요되는데, 관찰연구 기간인 3년 동안 200예 가까이 정리를 하고 분석하여 여러 단계의 작성을 거쳐 학위논문이 완성되었습니다.

감사의 글을 쓰면서 스승에 대한 존경과 감사의 말을 어떻게 표현할까 고민을 하다 보니 '군사부일체(君師父一體)'란 성어(成語)가 떠오릅니다. 저에게는 이강현 교수님께서 대통령이나 아버님과 같은 존재가 되었습니다. 박사학위 이전의 연구역량을 기르는데 도움을 주신 김영식, 하영록, 임현술 선생님 또한 저의 스승님이십니다. 그리고 6학기 박사과정에서 가르침을 주신 모든 교수님께 감사드리며, 자동차의학이라는 새로운 분야로 인도해 주신 홍익대 최형연 교수님께도 감사드리며 앞으로 지속적인 융합연구를 할 수 있기를 기대합니다.

마지막으로 대구에 계신 어머님, 서울에 계신 아버님, 어머님께도 아들이 받은 박사학위의 영광을 전해드리며, 아빠와 많은 시간을 함께하지 못해도 굳굳하게 잘 지내는 아들 스테파노에게 고마운 마음을 전하며, 가족들에게도 학위의 영광을 전해드립니다. 그리고, 사랑하는 아내 요안나에게도 감사의 마음을 전합니다.

2014년 6월 저자 씀

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ABSTRACT

Simple Criteria That Predict Major Injury of Front-Seat Passenger in Frontal Collision of Passenger Car

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Background: A frontal motor vehicle collision is the most common type of crash that results in fatalities. In this study, we suggested simple criteria that predict major injury to the frontseat occupant in the frontal collision of a passenger car.

Subjects and Methods: From January 2011 to December 2013, we collected data from front-seat occupants admitted to one of two emergency centers by ambulance following a frontal collision accident. We surveyed the cause of the accident, vehicle damage, information on the occupant, and severity of injury. Vehicle damage was assessed according to the collision deformation classification code through evaluation of photographs of the actual accident vehicle, and the patient's injury severity was evaluated by the injury severity score (ISS). Bivariate logistic regression models were formulated, and the cutoff point of deformation extent (DE) was inferred by receiver operating characteristic (ROC)

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curve analysis.

Results: Of the 192 subjects, 113 were males and 52 were major injury patients whose ISS exceeded 15. Gender, seat belt status, extent of vertical crash, and DE were significantly different between major and minor injuries ($p < 0.05$). After adjusting for confounds, not fastening the seat belt doubled the risk of major injury (OR = 2.2, 95% CI 1.061 - 4.390), and a cutoff value of three DE tripled the risk of major injury (OR = 3.2, 95% CI 1.382 - 7.343). In ROC curve analysis, DE 3 in the seat-belt-unfastened group and DE 5 in the seat-beltfastened group predicted major injury (area under the curve: 0.740 [95% CI, 0.627 - 0.834], sensitivity: 89.3%, specificity: 52.1%; and area under the curve: 0.696 [95% CI, 0.604 - 0.778], sensitivity: 41.7%, specificity: 94.6%, respectively).

Conclusions: At the scene of a frontal collision, emergency personnel can consider seat belt nonuse and DE ≥ 3 as criteria to transport front-seat occupants to trauma center.

Key words : Traffic accident, Motor vehicles, Trauma, Triage, Seat belts

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I. Introduction

A frontal motor vehicle collision is defined as having a crash direction between 1 o'clock and 11 o'clock. The National Automotive Sampling System of the National Highway Traffic Safety Administration analyzed all vehicle collisions from 2004 to 2012 and found that 62.0% (26716/43064) were frontal collisions (excluding rollover crashes) (1). Frontal collisions are also the most common type of crash that results in fatalities (2). Seat belts and front airbags are representative safety devices designed to protect front-seat occupants involved in frontal collisions with the aim of reducing fatalities (3, 4). Indeed, seat belt use and airbag deployment play an important role in decreasing fatal injury in frontal crashes (5 - 7), and triage using these factors can affect morbidity and mortality (8).

Information at the scene of an accident can predict the potential severity of occupant injuries (9). Motor vehicle crashes occur in various directions and types, and the severity of an occupant's injury varies depending on seating position and vehicle type. The higher the vehicle velocity is at the time of accident, the greater the deformation of the vehicle. Delta V—the change in velocity due to impact—affects the severity of a crash, and the amount of deformation is associated with the potential for occupant injury and mortality (10, 11). Other factors, such as the principal direction of force (PDOF: front, left, right, or rear), vehicle type (passenger car, sport utility vehicle, truck, van), crash mechanism (single vs. multiple crash event), seat belt use, airbag deployment, and extent of occupant space intrusion can influence the severity of the occupant's injury (7, 12). Unfortunately, the definitive factor(s) among these is (are) not used to triage the front-seat occupants injured at scenes of frontal car crashes.

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The 2011 Centers for Disease Control and Prevention field triage guidelines provided criteria for high-risk auto crashes in terms of the mechanism of injury (13). Intrusion criteria are difficult to measure at a rescue scene, and the use of vehicle telemetry data also has limitations due to the supplement problem of technology and device. Because delta V, a measure of crash energy, is calculated by detailed vehicle crash investigations, it is also impossible to use in the field (7). Therefore, criteria to facilitate triage in the field by emergency personnel need to be developed.

The objective of this study was to suggest simple criteria that predict major injury of the front-seat occupant at the scene of a frontal collision of a passenger car. We hypothesized that information about the occupant, safety devices, and vehicle deformation could predict injury severity in frontal crashes.

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II. Subjects and Methods

This investigation was a prospective observational study carried out at two institutions.

1. Subjects

We collected data on injured occupants who were admitted to the emergency medical center of either hospital via ambulance, following a frontal crash in a passenger car, between January 2011 and December 2013. Passenger car denotes the following vehicle types: sedan, coupe, hardtop, hatchback, and station wagon. Exclusion criteria regarding the accident were as follows: vehicles including trucks, sport utility vehicles (SUVs), and vans, which differ from passenger cars in structure and lack a crumple zone; absence of photographs of the damaged vehicle; rear-seat occupants; non-frontal collisions; frontal collisions with rollover or multi-vehicle collisions; and ejection at the time of accident. Exclusion criteria regarding the front-seat passenger were as follows: age < 18; incomplete diagnosis; incomplete preclinical history; history of cardiac operation and coagulopathy; and history of recent car-related major injuries.

2. Methods

2.1. Data Collection on Passenger Injuries

Information on patients was gathered from their medical reports and during an interview. The study subjects were occupants injured by frontal collision of a passenger car. The severity of a patient's injury was expressed as the injury

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severity score (ISS), which was coded through a review of medical charts and radiographs at the time of discharge from the hospital, transfer to another hospital, or death. Study subjects were classified into groups with a major (ISS $\geq$ 16) or minor injury (ISS $\leq$ 14).

2.2. Data Collection on Accident Information

Accident data including cause, occupant position, safety devices, and demographics were recorded. First, we interviewed the occupant. Second, we collected photographs of the damaged vehicle by taking pictures of the crashed car at the repair shop or accident scene. The images included external aspects to determine the collision deformation classification (CDC) code and interior views to confirm whether the airbag had been deployed. Accident investigators measured the maximum depth and width of the crushed vehicle. Seat belt restraint was confirmed by scratch marks, loosening the belt, or checking for a "bull's eye-like" broken front windshield. For a severely injured or deceased occupant, the investigators contacted police and emergency medical services to obtain the police report and rescue information.

2.3. Collision Deformation Classification

The extent of vehicle deformation was expressed in terms of the CDC code, a 7-column code provided by the Society of Automotive Engineers (14). Seven parameters including the PDOF, location, and extent of the crash were recorded with this code, with the 7th column representing the amount of DE. Here, the CDC code was finalized when emergency physicians and engineers achieved a consensus by reconstructing and analyzing the photographs.

Considering the impact energy from the viewpoint of the occupant's position,

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horizontal locations were divided into four levels: minimal, for right offset crash at the driver position and left offset crash at the passenger position; low, for central crash (C in CDC code); moderate, for full-width crash (D in CDC code, D is the distributed zone, which is divided into 3 zones. C is center, L is left, R is right, Y is L + C, and Z is R + C.); and high, for offset crash in the same direction as the occupant position (Fig. 1). Here, an offset crash was defined as that which caused asymmetric horizontal damage (L, R, Y, and Z in CDC code). Vertical locations were also divided into four levels of impact: minimal, at the level of the bumper; low, at the level of the engine room or windshield; moderate, at the level of waist height to ground level or all heights except the bumper; and high, at all heights. A wide damage pattern was regarded as damage extending over 41 cm in the horizontal direction. The distance from the center of the front bumper to the base of the windshield was equally divided into five zones. The 6^{th} zone was any direct damage that penetrated as far as the windshield. The 7th and 8th zones were determined by dividing the distance between the top of the windshield and the B-pillar, and 9th zone contained all crashes extending rearward of the B-pillar (14).

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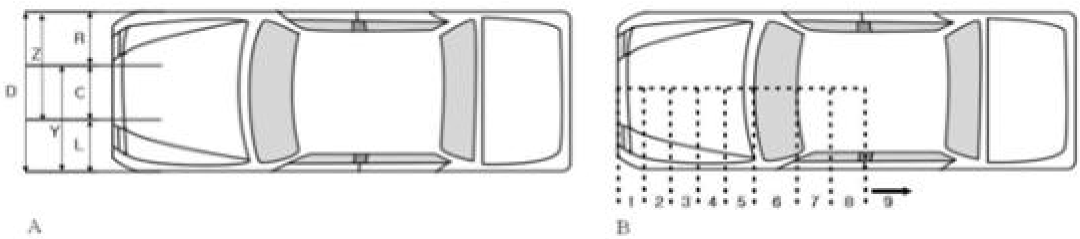

Fig. 1. Classification of horizontal location (A) and deformation extent (B) in the frontal collision of a sedan.

A) D is the distributed zone, which is divided into 3 zones. C is center, L is left, R is right, Y is L + C, and Z is R + C.

B) The crumple zone is equally divided into five zones from the center of the vehicle's front bumper to the base of the windshield. The 6th zone is any direct damage that penetrated as far as the windshield. The 7th and 8th zones are determined by dividing the distance between the top of the windshield and the B-pillar, and the 9th zone contains all crush extending rearward of the B-pillar

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3. Statistical Analysis

Statistical tests were carried out with SPSS (ver. 18, Chicago, Illinois, USA) and ROC analysis was performed with Medcalc (ver. 13, Ostend, Belgium). Continuous variables were expressed as mean ± standard deviation, and differences between means were compared with Student's t-test. Categorical variables were expressed as frequency (percentage) and analyzed with Pearson's chi-square test. We selected variables with p-values below 0.15 in the univariate analysis, and performed bivariate logistic regression analysis to compare these binary variables with other binary factors.

The DE that predicted major injury for front-seat passengers and the severity of the injury according to seat belt status (fastened or unfastened) in frontal collisions was measured by the area under the generated ROC curve (AUC). The sensitivity, specificity, false positives false negatives, and positive predictive value between the two groups were calculated on the basis of the Youden index. The criterion for statistical significance was defined as $p < 0.05$.

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III. Results

Of the 6325 patients that were involved in motor vehicle collisions and admitted to one of the two hospitals between 2011 and 2013, 3223 were enrolled in our study. Of these, 1613 (50.0%) declined to participate in the study, and 690 (21.4%) were excluded because we could not investigate their crushed vehicle. An additional 401 (12.4%) passengers in non-frontal collisions, 255 (7.9%) in non-passenger car vehicles, and 72 (2.1%) rear-seat passengers were excluded. The final number of eligible participants was 192 (6.0% of those enrolled), 113 (58.9% of those eligible) of whom were male (Fig. 2).

The accident reports of minor and major injuries were compared in terms of patient and car crash characteristics (Table 1). Fifty two (27.1%) had a major injury. The minor- and major-injury groups did not differ in terms of age, body mass index, or seating position. However, major injuries were more often reported in men than in women ($p = 0.035$), and seat belt use was more often associated with minor injuries ($p = 0.014$). ISS was 4-fold lower for minor injuries than for major injuries ($p < 0.001$). With respect to the vehicles, frontal air bag deployment was confirmed in 47.9% of accidents. Surprisingly, deployment did not affect the severity of injuries. A minimal or low vertical crash was more often associated with minor injuries ($p = 0.047$), whereas curb weight, horizontal crash, and damage pattern did not affect injury severity. For minor injuries, 47.9% were associated with accidents when DE < 3, whereas for major injuries, 80.8% were associated with accidents when DE ≥ 3 ($p < 0.01$). These data identified the determinants of major injuries for front-seat passengers in frontal collisions.

The DE that predicted major injury for front-seat passengers was determined as 3, which had the maximum AUC (0.643, 95% CI 0.571 – 0.711, 80.8% sensitivity,

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47.9% specificity, and 36.5% positive predictive value) among the generated ROC curves (Table 2).

Table 3 contains the results of bivariate logistic regression analysis. Not fastening the seat belt and a DE over 3 were associated with major injury of the front-seat passenger in the frontal collision of a passenger car. When front-seat occupants did not fasten their seat belt, the odds (OR = 2.2, 95% CI 1.061 - 4.390) of having a major injury nearly doubled, and occupants with a DE over 3 were 3 times (OR = 3.2, 95% CI 1.382 - 7.343) more likely to have a major injury than those with a DE below 3.

In ROC analysis, DE 3 predicted major injury (≥ ISS 16) (AUC: 0.709 [95% CI, 0.639 - 0.772], sensitivity 80.8%, specificity 47.9%, Fig. 3). When the seat belt was fastened, DE 5 predicted major injury (AUC: 0.696 [95% CI, 0.604 - 0.778], sensitivity 41.7%, specificity 94.6%, Fig. 4A). However, when the seat belt was not fastened, DE 3 predicted major injury (AUC: 0.740 [95% CI, 0.627 - 0.834], sensitivity 89.3%, specificity 52.1%, Fig. 4B).

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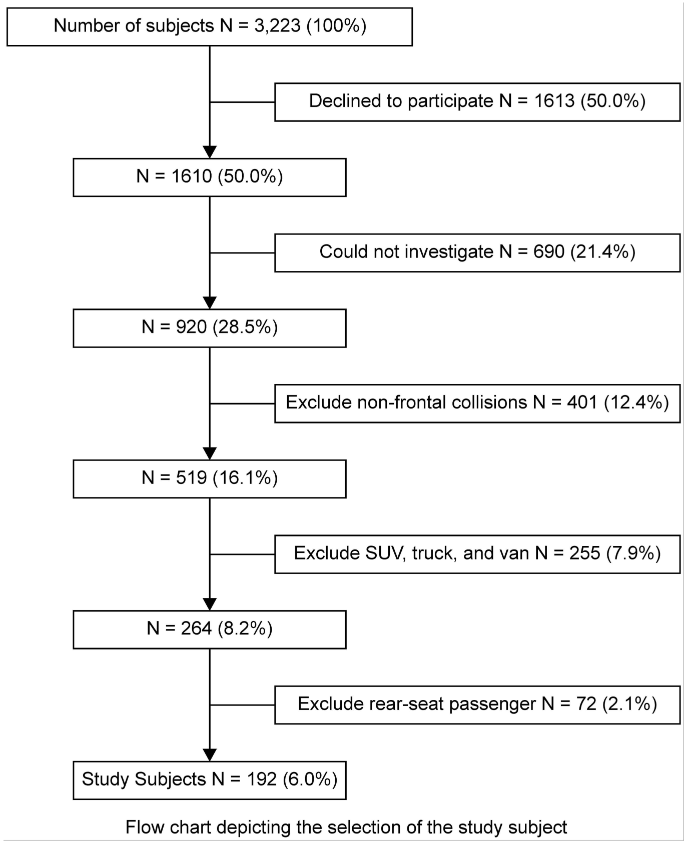

Fig. 2. Flowchart depicting the selection of study subjects.

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Table 1. Comparison of occupant and crash vehicle between major and minor injuries in frontal collision of passenger car

Number of subjects (%)		Minor Injury 140 (72.9)	Major Injury 52 (27.1)	Total 192 (100)	p value
Age in years, mean ± SD		45.2 ± 15.8	44.7 ± 14.8	45.1 ± 15.5	0.837
≤29		26 (18.6)	10(19.2)	36 (18.8)	0.985
30 - 39		31 (22.1)	12(23.1)	43 (22.4)	
40 - 49		26 (18.6)	8(15.4)	34 (17.7)	
50 - 59		35 (25.0)	12(23.1)	47 (24.5)	
60 - 69		12 (8.6)	8 (15.4)	20 (10.4)	
70≤		10 (7.1)	2 (3.8)	12 (6.3)	
BMI		23.4 ± 3.1	23.5 ± 3.3	23.4 ± 3.1	0.813
Gender					
	Male	76 (54.3)	37 (71.2)	113 (58.9)	0.035*
	Female	64 (45.7)	15 (28.8)	79 (41.1)	
Severity, mean ± SD					

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ISS	6.3 ± 7.1	25.8 ± 14.1	11.6 ± 12.9	<0.001*
Seating position				
Driver	108 (77.1)	43 (82.7)	151 (78.6)	0.404
Passenger	32 (22.9)	9 (17.3)	41 (21.4)	
Seat belt use				
Fastened	92 (65.7)	24 (46.2)	116 (60.4)	0.014*
Unfastened	48 (34.3)	28 (53.8)	78 (39.6)	
Frontal airbag deployment				
Deployed	68 (48.6)	24 (46.2)	92 (47.9)	0.766
Undeployed	72 (51.4)	28 (53.8)	100 (52.1)	
Side airbag deployment				
Deployed	4 (2.9)	2 (3.8)	6 (3.1)	0.663
Undeployed	136 (97.1)	50 (96.2)	186 (96.9)	
Curb weight (Kg)				
≤999	21 (15.0%)	10 (19.2%)	31 (16.1%)	0.479
≥1000	119 (85.0%)	42 (80.8%)	161 (83.9%)	
Collision				

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Extent of horizontal crash				
Minimal	36 (25.7)	12 (23.1)	48 (25.0)	0.690
Mild	18 (12.9)	6 (11.5)	24 (12.5)	
Moderate	39 (27.9)	16 (30.8)	55 (28.6)	
High	47 (33.6)	18 (34.6)	65 (33.9)	
Extent of vertical crash				
Minimal	15 (10.7)	2 (3.8)	17 (8.9)	0.047*
Low	11 (7.9)	2 (3.8)	13 (6.8)	
Moderate	114 (81.4)	47 (90.4)	161 (83.9)	
High	0 (0.0)	1 (1.9)	1 (0.5)	
Damage pattern				
Narrow	9 (6.4)	1 (1.9)	10 (5.2)	0.292
Wide	131 (93.6)	51 (98.1)	182 (94.8)	
Deformation extent, mean ± SD	2.7 ± 1.2	3.9 ± 1.7	3.0± 1.4	<0.001*
DE <3	67 (47.9)	10 (19.2)	77 (40.1)	<0.001*
DE ≥3	73 (52.1)	42 (80.8)	115 (59.9)	

Minor injury: ISS ≤ 14, Major injury: ISS ≥ 16

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Categorical variables were compared by chi-square test

Continuous variables (age and severity) were compared by Student's t-test

* $p < 0.05$

SD: Standard deviation

BMI: Body mass index

ISS: Injury severity score

Damage pattern: Narrow <41 cm, wide ≥ 41 cm

DE: Deformation extent

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Table 2. Sensitivity and specificity of deformation extent cut offs to predict major injury of front-seat occupant

Cut off point (DE)	Sensitivity	Specificity	False positive	False negative	PPV	AUC (95% CI)	LR	p value
2	98.1	11.4	88.6	1.9	29.1	0.548 (0.474 - 0.619)	5.484	0.045
3	80.8	47.9	52.1	19.2	36.5	0.643 (0.571 - 0.711)	13.860	<0.001
4	46.2	80.7	19.3	53.8	47.1	0.634 (0.561 - 0.703)	13.207	<0.001
5	32.7	95.0	5.0	67.3	70.8	0.638 (0.566 - 0.706)	23.370	<0.001
6	15.4	95.0	5.0	84.6	53.3	0.552 (0.479 - 0.624)	5.046	0.030

DE: Deformation extent, PPV: Positive predictive value, LR: Likelihood ratio

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Table 3. Results of bivariate logistic regression for analysis of factors affecting severity of frontal collision of passenger car

Characteristic	p value	OR (95%CI)
Age in years	0.850	
≤29	.	1
30-39	0.884	1.084 (0.370 - 3.175)
40-49	0.840	1.129 (0.348 - 3.665)
50-59	0.728	1.211 (0.412 - 3.564)
60-69	0.237	2.146 (0.605 - 7.605)
70≤	0.764	0.761 (0.128 - 4.529)
Gender		
Male		1
Female	0.101	0.542 (0.260 - 1.126)
Seat belt use		
Fastened		
Unfastened	0.034*	2.158 (1.061 - 4.390)

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Extent of vertical crash	0.905	
Minimal		1
Mild	0.836	1.265 (0.136 - 11.748)
Moderate	0.503	1.769 (0.333 - 9.393)
High	1.000	
Deformation extent		
DE <3		
DE ≥ 3	0.007*	3.186 (1.382-7.343)

Minor injury: ISS $\leq$ 14, Major injury: ISS $\geq$ 16

Categorical variables were compared by chi-square test

Continuous variables (age and severity) were compared by Student's t-test

* $p < 0.05$

DE: Deformation extent

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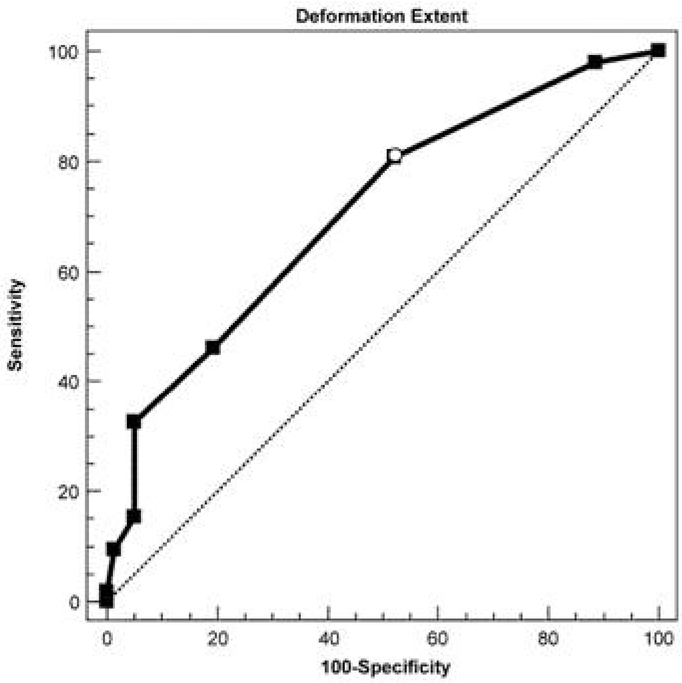

ROC curve of deformation extent for the prediction of major injury of the front-seat occupant in Frontal Motor Vehicle Collision. The area under the curve is 0.709 (95% CI 0.639-0.772) with a cutoff value of 3 (80.8% sensitivity and 47.9% specificity)

Fig. 3. ROC curve of deformation extent to predict major injury of the front-seat occupant in a frontal motor vehicle collision. The area under the curve is 0.643 (95% CI 0.571 - 0.711) with a cutoff value of 3 (80.8% sensitivity and 47.9% specificity).

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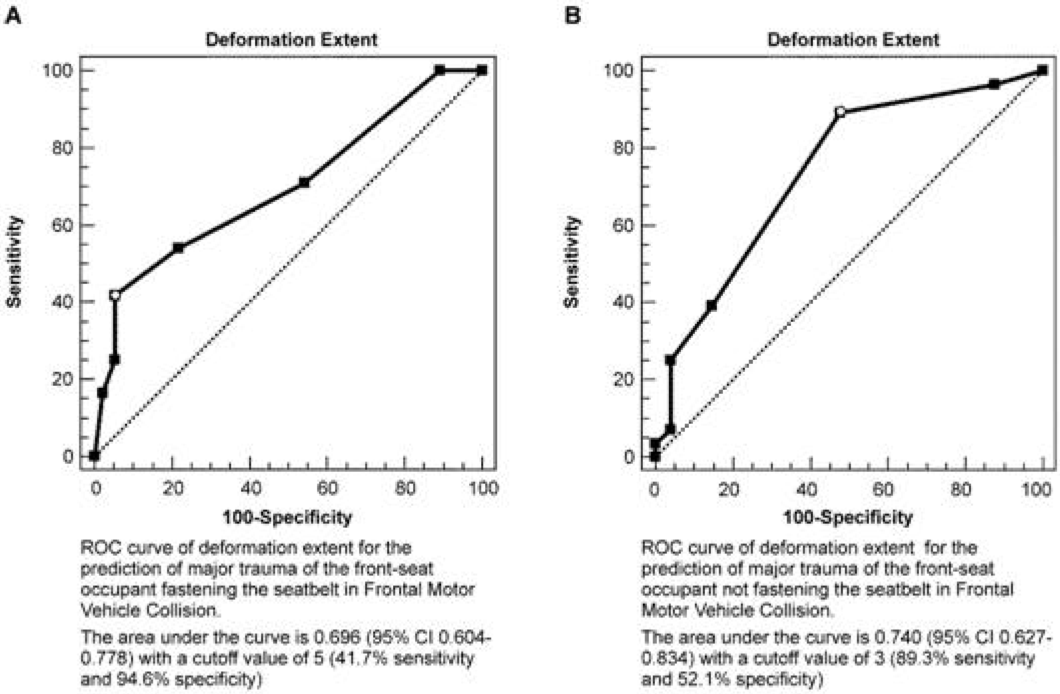

Fig. 4 A. ROC curve of deformation extent to predict major trauma of the front-seat occupant with seat belt fastened in a frontal collision.
The area under the curve is 0.696 (95% CI 0.604 - 0.778) with a cutoff value of 5 (41.7% sensitivity and 94.6% specificity).

Fig. 4 B. ROC curve of deformation extent to predict major trauma of the front-seat occupant with seat belt unfastened in a frontal collision.
The area under the curve is 0.740 (95% CI 0.627 - 0.834) with a cutoff value of 3 (89.3% sensitivity and 52.1% specificity).

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IV. Discussion

Frontal crashes are one of the most common types of vehicle accident. Seat belts and airbags are designed to protect occupants in frontal collisions by reducing their forward movement and preventing injuries caused by being thrown against the steering wheel, windshield, or dashboard. However, high values of delta V that exceed the specifications of safety devices are associated with increased mortality, injury rate, and injury severity of the occupant (10, 11). Although Delta V has been used to predict significant injury in motor vehicle collisions (15, 16), it is nearly impossible to measure promptly in the field. Therefore, we considered DE, which is used in the CDC code, as a predictor of the occupant's injury severity. In our study, front-seat occupants who did not fasten their seat belt were more than twice as likely as those who did fasten their seat belt to have a major injury in the frontal collision of a passenger car, and more than 3 times as likely to have a major injury when DE was over 3.

We enrolled all cases of minor and major injuries due to a collision accident. Therefore, we could overcome selection bias due to a limitation in the Crash Injury Research and Engineering Network dataset, which is based on criteria for occupants who are required to visit a trauma center because their injuries are so severe.

Jones and Champion found that 90% of patients with ISS $\geq$ 16 were associated with 20 inches (508 mm) of crush in frontal collisions and 28 inches of crush in offset frontal collisions (12). For the i30 (HYUNDAI®, full length 4300 mm) and GRANDEUR (HYUNDAI®, full length 4910 mm), 20 inches of crush corresponds to DE = 3 and DE = 2, respectively. In our study, when the values of DE were 2 and 3 in a frontal collision, the sensitivities for major injury of the occupant were

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98.1% and 80.8%, respectively. Thus, the results of Jones and Champion showed higher sensitivity than our results for DE = 3 (Table 2).

Conroy et al. demonstrated that the distribution of exterior vehicle damage across the front vehicle plane affected the injury characteristics of the occupant (17). Compared with a narrow impact, a wide impact that causes damage across more than 66% of the vehicle's frontal plane was 50% less likely to cause severe injury to the occupant in frontal collisions with a PDOF of 12 o'clock, because it allowed the vehicle to absorb the crash energy. In our results of horizontal crashes classified according to energy, there was no significant difference. The combined effects of a PDOF between 11 o'clock and 1 o'clock and the distribution of impact widths in our study may account for the discrepant findings.

In our study, the risk of having a major injury was more than doubled for front-seat occupants without seat belts. However, airbag deployment did not affect the probability of major injury. Without a safety system including a seat belt and airbag, occupants in frontal collisions are likely to have injuries in the face, brain, chest, and lower extremities (18). Seat belt use has been identified as an important contributor to the reduction of morbidity and mortality related to motor vehicle collisions (19). It reduces fatality by 42% in frontal collisions, with airbags additionally reducing fatality by about 5% to 9% for drivers fastening their seat belt (3, 4). The fatality reduction associated with the airbag alone was estimated to be 31% for frontal collisions and 21% for all crashes (4).

DE has value as a predictor of major injury for a front-seat passenger in the frontal collision of a passenger car. When DE was over 3, the risk of a major injury more than tripled for a front-seat passenger (80.8% sensitivity and 47.9% specificity). The rate of false positives (over-triage) was 52.1%, which exceeds the range of over-triage (25% - 50%) permitted by the American College of Surgeons (ACS) committee on trauma (20), and the rate of false negatives (under-triage)

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was 19.2%, which also exceeds the range of 5% under-triage permitted by the ACS. A DE over 2 can be used to reduce under-triage to within this permitted range (Table 2).

The limitations of this study are as follows. First, we did not measure delta V, a factor that determines the quantity of energy. Because intensity and structure are different for each vehicle, DE is not correlated with delta V. However, delta V is unavailable at the scene of an accident. In the field, seat belt status and deformation are useful factors for predicting an occupant's injury severity in a frontal collision accident. Second, we did not classify the passenger cars by curb weight. A lighter vehicle is weaker in an accident. Impacts that cause the same DE may have different effects on the occupant in light and heavy vehicles. Third, the number of study subjects was small because it was confined to front-seat occupants of passenger cars, who were admitted to one of two institutions. It will be necessary to construct a national data bank to apply our findings to other types of vehicle.

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V. Conclusion

In frontal collisions of a passenger car, the risk of a major injury doubled for front-seat occupants who did not fasten their seat belt and more than tripled when DE was over 3. When front-seat occupants did not fasten their seat belts, DE 3, and when they fastened seat belts, DE 5, predicted major injury at sensitivities of 89.3% and 41.7%, respectively. Emergency personnel can use our results as simple criteria to triage front-seat occupants at the scene of a frontal collision of a passenger car. This method should be helpful in drawing conclusions for other types of vehicles such as trucks and SUVs.

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Abstract in Korean

승용차 정면충돌 사고에서 전방탑승자의 중증손상을 예측하는 요인분석

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배경과 목적: 차량 정면 충돌사고는 탑승자 사망을 초래하는 흔한 형태의 충돌 유형이다. 이 연구에는 승용차의 정면충돌사고에서 전방 탑승자의 중증손상을 예측하는 간단한 기준을 제안하고자 한다.

대상 및 방법: 2011 년 1 월부터 2013 년 12 월 사이에 차량 정면충돌사고로 119 구급차를 타고 두 개 기관 응급센터에 내원한 환자가운데 전방 탑승자에 관한 자료를 수집하였다. 사고원인, 차량 파손 정도, 탑승자 정보, 손상정보를 조사하였다. 사고로 파손된 차량사진을 촬영하여 collision deformation classification code를 이용하여 차량 파손을 평가 하였고, 환자의 손상 정도는 injury severity score (ISS)를 이용하여 평가하였다. 이변량 로지스틱 회귀분석을 이용하여 중증손상을 예측하는 요소를 알아보았고, 차량변형(deformation extent)의 절단 값은 수신기 작동 특성(receiver operating characteristic) 곡선 분석을 이용하여 구하였다.

결과: 192명의 대상자 가운데 113명은 남성이었고, ISS가 15점 이상의 중증손상인 환

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자는 52명이었다. 성별, 안전벨트 착용상태, 수직 충돌의 정도와 차량변형 이 중증손상과 경증손상에서 차이를 보이는 요소였다. (P <0.05) 혼란변수를 조정한 분석에서는 안전벨트를 착용하지 않은 것은 중증손상을 입을 위험이 2배이었고(OR = 2.2, 95% CI 1.061 - 4.390), 차량변형의 절단 값이 3일 경우 중증손상을 입을 위험이 3배이었다. (OR = 3.2, 95% CI 1.382 - 7.343) 수신기 작동 특성 곡선 분석에서 안전벨트를 착용하지 않은 그룹에서는 차량변형 값이 3인 경우 곡선아래면적(area under the curve)이 0.740 [95% CI, 0.627 - 0.834], 민감도 89.3%, 특이도52.1%, 안전벨트를 착용한 그룹에서는 차량변형 값이 5인 경우 곡선아래면적이 0.696 [95% CI, 0.604 - 0.778], 민감도 41.7%, 특이도94.6%로 각각 중증손상을 예측하는 절단 값이었다.

결론: 승용차량 정면충돌 현장에서 응급 구조사는 전방탑승자가 안전벨트 미착용 및 차량변형 3 이상인 경우를 외상 센터로 이송해야 하는 기준으로 이용할 수 있다.

핵심되는 말: 교통사고(Traffic accident), 자동차(Motor vehicles), 외상(Trauma), 환자 분류(Triage), 안전벨트(Seat belts)

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