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Potential Occupant Injury Risks of Mixed Traffic Crashes in Automated Vehicles

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Key Words : Injury risk(상해위험), Automated vehicles(자율주행차), Mixed traffic crashes(혼재주행 사고), Finite element analysis(유한요소해석), Korean-in-depth accident Study(KIDAS)

ABSTRACT

The ADS and ADAS features of Automated Vehicles (AV) reduce crash and injury severity by reducing crash speed. The penetration of the AV will gradually increase and is expected to lead to an increase in mixed traffic crashes between autonomous and non-autonomous vehicles, but data on such crashes is limited. This study aimed to simulate a mixed traffic crash of AV and analyze the expected injury reduction effect based on real-world data. The study used the Korean In-Depth Accident Study (KIDAS) as a data source. We chose 446 occupants who suffered MAIS2+ injuries in car-to-car single frontal collisions out of 5,179 occupants. The included data were partitioned using k-medoids clustering based on the difference of car-to-car crash angle. The crash speeds of the two vehicles were analyzed within the 0-90th percentile range for each cluster, and 90th percentile results were integrated into the mixed traffic crash simulation. AEB engagement was implemented for both vehicles through prescan-based simulations to evaluate pre-crash speed reduction in mixed traffic crashes. FE analysis was performed using the FE sled model with Hybrid III ATD for occupant injury evaluation.

Four clusters were partitioned according to crash angle, which comprises two head-on and two longitudinal crashes. Among eight AEB simulation scenarios two avoided a crash and one showed no AEB activation. The other five produced three cases of reduced crash speed at 18.0 ± 8.9 km/h and two cases of increased speed at 36.0 ± 12.7 km/h. The Hybrid III dummy's probability of injury tends to decrease in FE analysis of the most frequent head-on crash configuration.

In conclusion, the injury reduction effect was confirmed in mixed traffic crashes in a real-world data-based computational simulation. Continuous research is needed to track injury reduction because AV features have not yet fully secured crash prevention

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정면충돌 교통사고에서 벨트 착용 탑승자의 늑골골절 해부학적 특성

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Anatomical Characteristics of Rib Fractures on Belted Occupant in Frontal Crashes

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Key Words : Rib fracture(늑골골절), Musculoskeletal anatomy(근골격 해부학), Frontal crashes(정면충돌), Seatbelt(안전 벨트), Motor vehicle occupant(승객), Korean in-depth accident study(KIDAS)

ABSTRACT

Thorax is a major injury region of serious injury in motor vehicle crashes and rib fractures are a common thoracic injury types with a high incidence. This study aimed to examine the detailed rib fracture patterns based on musculoskeletal anatomy data of occupants in real-world crashes.

The study used the Korean In-Depth Accident Study (KIDAS) database. Among 5,179 occupants, we excluded cases with missing sex, age, or injury information and included 81 first row seated belted passenger-car occupants involved in frontal crashes with rib fracture image and diagnosis. The specific locations of rib fracture were examined by categorizing them into left and right, vertical (ribs 1-12), and horizontal (anterior, antero-lateral, lateral, postero-lateral, and posterior). The rib fracture patterns was analyzed by occupants.

Among occupants involved in frontal crashes 107 occupants (16.8%) sustained rib fractures. Detailed rib fracture analysis based on radiology imaging was possible in 81 cases (75.7%). Female occupants had a higher rib fracture incidence than males. The left rib suffered higher fractures than the right. The most frequently fractured ribs in the vertical direction were the fourth and fifth ribs. In the horizontal direction, the most common rib fracture occurred in the antero-lateral region. The outer rib suffered higher fractures than the inner rib after adjusting for occupant position.

In analyses of occupant rib fractures based on real-world crash data sex-specific musculoskeletal differences were identified. Future work will conduct demographic analyses to identify crash types associated with increased rib fracture risk.

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NHTSA SGO 데이터 기반 자율주행레벨2 차량사고의 상해중증도에 따른 사고특성

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Investigating Level 2 Autonomous Driving Vehicle Crashes According to Injury Severity Based on NHTSA SGO Data

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Key Words : Standing general order(SGO), Autonomous vehicle(자율주행차), Advanced driver assistance system(첨단 운전지원시스템), Injury surveillance(손상감시)

ABSTRACT

Manufacturers annually introduce new vehicles with partial automation and advanced driver-assistance systems (ADAS) intended to mitigate human-error-related crashes. However, these technologies are not yet mature enough to prevent all crashes. This study investigates the differences in crash characteristics between minor and moderate-or-fatal injury groups in level 2 autonomous vehicles. We analyzed 492 crash reports from the National Highway Traffic Safety Administration's Standing General Order (SGO) database (January 2021-August 2025). Variables of interest included model year, driver and operator type, crash object, airbag deployment, passenger belted, and injury severity. A statistical analysis was performed to observe significant differences between injury severity groups. Vehicle's model year 2024-2026 had the lowest risk of moderate injury (AOR, 0.316; 95% CI, 0.115-0.868). According to crash object, the highest risk was in crashes with commercial vehicles (AOR, 1.985; 95% CI, 1.047-3.765) and non-motorists (AOR, 4.159; 95% CI, 1.113-15.541). Compared with airbag deployment, the non-deployment had increased risk of moderate injury (AOR, 3.617; 95% CI, 2.442-5.358). Particularly, the risk of moderate injury increased at higher pre-crash speeds of 41-50 mph (AOR, 2.827; 95% CI, 1.281-6.240) and ≥ 60 mph (AOR, 2.718; 95% CI, 1.474-5.012). In this study, the crash characteristics of level 2 automated vehicles were analyzed by injury severity. Latest model years showed a reduced likelihood of moderate injury, whereas crash object commercial vehicles or non-motorists, airbag non-deployment and higher pre-crash speeds were associated with increased injury severity. The results suggest the need for improvements of advanced vehicle systems to ensure avoiding crashes associated with vulnerable road users (VRUs) under high-speed conditions.

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경트럭 탑승자 교통사고에서 중증도에 따른 하지 손상 부위별 위험요인

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Risk Factors for Lower Extremity Injuries Across Injury Severity among Cab-Over Truck Occupants in Road Traffic

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Key Words : Cab-Over Truck(캡오버 트럭), Lower Extremity(하지), Injury(손상), Risk Factor(위험요인), Korea In-Depth Accident Study(KIDAS)

ABSTRACT

This study aimed to analyze LE injury patterns and severity among cab-over truck occupants and to identify independent risk factors associated with these injuries.

A retrospective study was conducted using data from the Korean In-Depth Accident Study (KIDAS) collected between 2011 and 2024. Among cab-over truck occupants, those aged <15 years or with unclear injury sites or collision directions were excluded, leaving 547 cases for analysis. Injury severity was assessed using the Abbreviated Injury Scale (AIS) across six body regions, and lower extremity injuries were categorized as pelvis, femur, knee, lower leg, and foot. Logistic regression identified predictors of injury by subregion.

An extent ≥ 6 had a significantly higher risk of lower leg injury than those with extent 1-2 (OR: 7.21, 95% CI: 1.45-35.92). Rear impacts were associated with increased risk of knee injury compared with frontal impacts (OR: 11.62, 95% CI: 1.18-114.42). Frontal airbag deployment was signassociated with pelvis, femur, and foot injuries. Among occupants with Injury Severity Score (ISS) <16, airbag deployment remained persisted as a significant factor for pelvis and foot injuries, whereas knee and lower leg injuries were mainly associated with vehicle intrusion. In the high-severity group (ISS ≥ 16), Severely injured group sustained in only foot injuries which had a statistically significant related to airbag deployment.

Severe vehicle deformation (intrusion ≥ 6 cm) was identified as a major risk factor for lower leg and foot injuries. The association between airbag deployment and foot injury likely reflects higher crash severity rather than a direct effect. These findings highlight the vulnerability of the lower extremities in cab-over truck occupants and the need for improved structural reinforcement vehicle design and geometry to reduce lower limb traumainjuries in frontal crashes. In this study, vehicle deformation (intrusion ≥ 6 cm) was identified as a major risk factor for lower leg and foot injuries. Among the severely injured occupants, frontal airbag deployment was significantly associated with foot injuries, likely serving as a surrogate marker of higher crash severity rather than a direct airbag effect. These findings highlight the structural vulnerability of light trucks, indicating that occupants' lower limbs are highly exposed to impact forces, emphasizing the need for reinforced structures and enhanced energy-absorbing designs to prevent lower extremity trauma.

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차대차 사고에서 탑승열과 안전벨트 착용 여부에 따른 탑승자 상해 양상 및 중증도

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Occupant Injury Patterns and Severity According to Seating Row and Seatbelt Use in Vehicle-to-Vehicle Crashes

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Key Words : Vehicle-to-vehicle crashes(차대차사고), Seating row(탑승 열), Seatbelt(안전벨트), Injury patterns(상해양상),
Injury severity(상해중증도), Korea In-Depth Accident Study(KIDAS)

ABSTRACT

This study aimed to analyze serious injury patterns by seating row and seatbelt use among occupants involved in vehicle-to-vehicle (V2V) crashes. A retrospective observational study was conducted using data from the Korean In-Depth Accident Study (KIDAS) collected between 2011 and 2024. We analyzed 595 adults (≥ 18 years) patients sustained in V2V crashes. Serious injury was defined as ISS ≥ 15 and body-region-specific serious injury as AIS ≥ 3 . Independent variables included sex, age, BMI, seating position, seatbelt status, airbag deployment, vehicle type, road category, road type, crash object, crash type, and crash extent. Statistical analyses were performed using the IBM SPSS Statistics 25.0 (t-test, chi-square, Fisher's exact, logistic regression). In the serious-injury group (ISS ≥ 15), 40.0% were unbelted, higher than in the non-serious group ($p=0.010$). Rear-seated occupants had higher serious injury rates in head, face, and neck injuries compared to front-seated occupants ($p<0.05$). Among front-seat occupants, the proportion with serious thoracic injury was 21.3% in the unbelted group, higher than in the belted group ($p=0.028$). The mean ISS was also higher in the unbelted (9.79 ± 8.59) than in the belted (6.56 ± 6.71) group ($p<0.001$). Among rear-seat occupants, the proportion with serious abdominal injury was higher in the belted group than in the unbelted group ($p=0.030$). In logistic regression, increasing age (OR 1.02, 95% CI 1.01-1.04), unbelted (OR 1.69, 95% CI 1.01-2.85), and intrusion (OR 3.80, 95% CI 1.92-7.53) were associated with serious injury. When MAIS ≥ 3 was defined as the dependent variable, rear-seat occupants had twice the odds of serious injury compared with front-seat occupants (OR, 1.975; 95% CI, 1.005-3.878). These findings indicate that seating row and seatbelt use are key determinants of injury patterns and outcomes in V2V crashes, underscoring the need for seat-specific protection enhancements and policies to improve seatbelt use.

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Comparison of Relative Risk for Severe Injuries Among Types of Vulnerable Road Users

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Key Words : Vulnerable road users(도로교통약자), Relative risk(상대위험도), Severe injury(중증손상), Poisson regression model(포아송 회귀 모델), Emergency Department-based In-depth Injury Surveillance(응급실 손상환자심층조사)

ABSTRACT

Purpose: This study aimed to identify the relative risk and key factors associated with severe injuries among vulnerable road users (VRUs)—including pedestrians, cyclists, motorcyclists, and electric scooter users—who differ from general motor vehicle occupants in terms of exposure and protection.

Methods: Data were derived from the Emergency Department-based In-depth Injury Surveillance (EDIIS) system operated by the Korea Disease Control and Prevention Agency, covering 23 hospitals from 2011 to 2024. Injury severity was classified using the Excess Mortality Ratio-adjusted Injury Severity Score (EMR-ISS): scores <25 were defined as non-severe and ≥ 25 as severe. Independent variables included month, time of day, sex, age group, alcohol use, work-relatedness, road type, collision object, and helmet use. A Poisson regression model with a log link function was used to estimate the adjusted Relative Risk (RR) and 95% Confidence Intervals (CI) for severe injury, using SAS 9.4 (SAS Institute, Cary, NC, USA).

Results: The risk of severe injury significantly increased with age ($p < 0.05$). Among those aged ≥ 65 years, the adjusted RRs were 2.56 (95% CI 2.43–2.70) for pedestrians, 3.84 (3.58–4.13) for cyclists, and 2.58 (1.75–3.79) for motorcyclists compared with those aged <25 years. Female users had a statistically lower risk than males (pedestrians: RR=0.88, 95% CI 0.83–0.93; bicycles: RR=0.75, 0.69–0.82; motorcycles: RR=0.89, 0.81–0.97; all $p < 0.01$). Alcohol involvement significantly increased the risk across all user types ($p < 0.001$), with RRs ranging from 1.33 in pedestrians to 1.68 in cyclists. Nighttime crashes (18:00–24:00) were also associated with increased risk, particularly among electric scooter users (RR=2.63, 95% CI 2.10–3.29).

Helmet use was associated with a significantly lower risk of severe injury among motorcyclists (RR=0.67, 95% CI 0.61–0.73) and electric scooter users (RR=0.62, 0.48–0.81), whereas no protective effect was observed for cyclists (RR=0.98, 0.93–1.04; $p = 0.41$). Collisions involving large vehicles (RR=2.71, 95% CI 2.33–3.15) or railway vehicles (RR=4.88, 3.42–6.96) markedly increased the risk of severe pedestrian injury.

Conclusion: Older age, alcohol use, nighttime crashes, and lack of helmet use were significant risk factors for severe injuries among all VRU types. These findings underscore the need for targeted prevention strategies and policy interventions to enhance safety for vulnerable road users.

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