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INJURY PATTERNS IN MOTOR-VEHICLE CRASHES IN THE UNITED STATES: 1998-2014

KATHLEEN D. KLINICH, PATRICK BOWMAN,
CAROL A.C. FLANNAGAN, JONATHAN D. RUPP

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UNIVERSITY OF MICHIGAN

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16. Abstract

The NASS-CDS database for years 1998-2014 was analyzed to examine trends in injury patterns. To account for changes in data collection for years 2009 and later, most analyses focused on occupants in vehicles newer than 10 years relative to the given crash year. However, for analysis of trends by crash year, the number of occupants injured in older vehicle was estimated. The number of occupants with AIS2+ or AIS3+ injuries was assessed by main crash type (rollover, frontal, rear, near-side, and far-side) and AIS body region (head, face, neck, thorax, spine, abdomen, upper extremity and lower extremity). Risk of AIS2+ or AIS3+ injury was also calculated. Dependent variables include occupant age, BMI, gender, occupant seating position, and restraint; vehicle type and model year; plus crash year. Additional analyses were performed to determine if injury patterns varied within body region.

Overall trends in injury indicate a substantial drop in the total number of injuries since 1999. Risk has dropped consistently for near- and far-side crashes, but not for rollovers, frontal, or rear impacts. For AIS3+ injured occupants, the 16% of occupants who are unbelted make up between 45-55% of injured occupants in all crash types except for near-side. Rear occupants have a 1.7 times greater risk of AIS2+ injury in far-side impacts and 2.2 times greater risk in rear impacts compared to front seat occupants, but front occupants have 1.5 times greater risk than rear occupants in frontal crashes.

The risk of AIS2+ and AIS3+ injury to all body regions generally increase with age. The proportion of AIS2+ and AIS3+ injured occupants in rollovers decreases with age. In frontal, near-side, and far-side crashes, occupants with AIS2+ injury aged 66 and greater make up a higher proportion of the injured occupants compared to their involvement crashes.

Risk of AIS3+ injury is highest in pickup trucks for frontal crashes, near-side and rear crashes and in passenger cars for far-side and rollovers. Risk of AIS2+ and AIS3+ injury is highest in pickup trucks for all AIS body regions. Risk of AIS3+ injury to the pelvis and femur have dropped substantially since vehicle model years 1999-2004.

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Executive Summary

The NASS-CDS database for years 1998-2014 was analyzed to examine trends in injury patterns. To account for changes in data collection for years 2009 and later, most analyses focused on occupants in vehicles newer than 10 years relative to the given crash year. However, for analysis of trends by crash year, the number of occupants injured in older vehicle was estimated.

Methods

The number of occupants with AIS2+ or AIS3+ injuries was assessed by main crash type (rollover, frontal, rear, near-side, and far-side) and AIS body region (head, face, neck, thorax, spine, abdomen, upper extremity and lower extremity). Risk of AIS2+ or AIS3+ injury was also calculated. Dependent variables include occupant age, BMI, gender, occupant seating position, and restraint; vehicle type and model year; plus crash year. Additional analyses were performed to determine if injury patterns varied within body region, such as comparing trends for cervical, thoracic, and lumbar spine injury to overall patterns of spine injury.

Results: Crash Year and Crash Type

Overall trends in injury indicate a substantial drop in the total number of injuries since 1999. The risk of AIS2+ and AIS3+ injury is highest in 1999-2000 and 2005-2006 crash years and the lowest in the latest 2011-2014 crash year groupings. Risk has dropped consistently for near- and far-side crashes, but not for rollovers, frontal, or rear impacts. The proportion of occupants with AIS2+ and AIS3+ injuries in rollovers and near-side impacts has decreased over time, while the proportion of those injured in frontal impacts has increased. The lower numbers of occupants injured in recent years is likely a combination of reduced exposure because of economic conditions, as well as the prevention of some types of crashes from crash avoidance technologies. The general increase in rollover injury risk over time coupled with the decrease in number of injured occupants in rollovers suggests that reduced crash exposure is contributing to injury reduction. In addition, these trends suggest that the rollovers that still occur are more risky.

The distribution of occupants with AIS2+ injuries by body region has not shifted substantially with crash year. The risk of AIS2+ injury has dropped from 1999 to 2010 fairly consistently for the abdomen, face, upper extremity, and lower extremity. The risk of AIS3+ injury to the lower extremity, head, face, and upper extremity has dropped consistently since 2007-2008. The proportion of occupants with AIS3+ injury to the thorax and spine has increased, while the proportion of occupants with AIS3+ injury to the upper and lower extremities has decreased. The body regions with the largest decrease in the number of AIS3+ injured occupants are the lower extremity, head, and upper extremity.

For occupants with AIS3+ injuries in rollovers, the proportion in 1-2 quarter turn rollovers has decreased with crash year until 2013-2014, which has the highest proportion of 1-2 quarter turn rollovers. The risk of AIS2+ injury in 7+ quarter turn rollovers has increased with crash year, while the risk for the 1-2 or 3-6 quarter turn rollovers is fairly steady. For AIS3+, trends are similar, but with the increase in risk for 7+ quarter turn rollovers occurring since 2003. For frontal subcrash types, occupants in center frontal

impacts have the highest AIS2+ injury risk compared to other categories. Risk of AIS2+ injury in T-type crashes has generally dropped from 1999 to 2014. Among frontal crash subtypes, the proportion of occupants with AIS3+ injuries was highest for left or right SOI crashes in 2005-2008 and 2011-2012.

Frontal crashes have the highest proportion of AIS2+ and AIS3+ lower extremity injuries. Rollovers have the highest proportion of AIS2+ spine injuries, while rear impacts have the highest proportion of AIS3+ spine injuries. Near-side impacts have the highest proportion of AIS2+ and AIS3+ thorax and abdomen injuries. More than half of AIS2+ injuries to occupant body regions in rear impacts are to the head.

Risk of AIS2+ injury is highest in rollovers for all body regions. The same is true for AIS3+ to all body regions, except the highest risk of lower extremity injury is in near-side crashes. Risk of AIS2+ is highest for the head among all crash types, except for lower extremities in frontal crashes. Risk of AIS3+ injury is highest to the thorax among all crash types, except for the head in rear impacts.

Results: Restraint and Seating Position

In the dataset used for occupants with known belt use and injury level, 82% of occupants used the 3-point belt, 2% used a lap belt only, and 16% were unbelted. For most dependent variables, there are too few occupants using lap belts to analyze injury trends. Risk of AIS2+ and AIS3+ injury is highest for unbelted occupants in all crash types. For AIS2+ injured occupants, unbelted occupants make up more than 40% of those in rollovers and in far-side crashes. For AIS3+ injured occupants, unbelted occupants make up between 45-55% of injured occupants in all crash types except for near-side. The risk of AIS2+ injury to any of the AIS body region is 3.2 to 10.1 times higher for unbelted occupants compared to those using a 3-point belt, while the ratio for AIS3+ injury is 3.6 to 6.7 times higher.

For occupants in vehicles less than 10 years old with known seating position and meeting other inclusion criteria, 77% of occupants are drivers, 18% are right-front passengers, and 6% are rear passengers. The distribution of occupants with AIS2+ and AIS3+ injuries by crash type and by body region is similar for each occupant position. Rear occupants have a 1.7 times greater risk of AIS2+ injury in far-side impacts and 2.2 times greater risk in rear impacts compared to front seat occupants, but front occupants have 1.5 times greater risk than rear occupants in frontal crashes.

The distribution of AIS2+ and AIS3+ injured occupants by body region is similar for each occupant position. Risk of AIS2+ injury is highest for the rear passenger for the head, face, upper extremity and spine, highest for the front passenger and abdomen for the thorax, and highest for the driver for lower extremities. Risk of AIS3+ injury is highest for the rear passenger for the head, abdomen and spine, for the front passenger for the upper extremity, and the driver for the lower extremity, although differences are small. Rear occupants have a 1.4 times greater risk of AIS3+ injury in near-side impacts and 3.0 times greater risk in rear impacts compared to front seat occupants, but front occupants have 1.3 times greater risk than rear occupants in frontal crashes.

Results: Age, BMI, Gender

The proportion of AIS2+ and AIS3+ injured occupants in rollovers decreases with age. In frontal, near-side, and far-side crashes, occupants with AIS2+ injury aged 66 and greater make up a higher proportion of the injured occupants compared to their involvement in tow-away crashes. The same is true for AIS3+ injury for all crash types except rollover. Occupants aged 15-30 are more than half of occupants with AIS2+ or AIS3+ injuries from rollover crashes. Risk of AIS2+ injury generally increases with age for frontal, near-side, and rear impacts, while risk of AIS3+ injury consistently increases with age for all crash types. The proportion of occupants with AIS2+ and AIS3+ head and face injuries decreases with age, while the proportion with AIS2+ thorax injuries increases with age. The risk of AIS2+ and AIS3+ injury to all body regions generally increase with age. The head and abdomen have the lowest increases in risk with age, while the thorax and spine show the greatest increases in risk.

For AIS2+ injury, the proportion of occupants in rollovers decreases with BMI but increases for frontal impacts. Risk of AIS2+ and AIS3+ injury changes the most with BMI for frontal impacts, with risk doubling from BMI < 18 to BMI >35+. For other impact types, risk of AIS2+ or AIS3+ injury is fairly consistent with BMI, except for a higher risk of AIS2+ injury in BMI<18 in rollovers and far-side crashes. Also, for AIS3+ injury, the BMI 35+ group has a higher risk of injury in rollovers. Occupants with BMI >35 have the greatest proportion of AIS2+ lower extremity injuries. The risk of AIS2+ injury to the lower extremity injury, upper extremity, and thorax increase with BMI, as does the risk of AIS3+ injury to the head, thorax, upper extremity and lower extremity.

The distribution of men and women with AIS2+ or AIS3+ injury by crash type is nearly identical. Among occupants with AIS2+ injuries, men comprise 56% of injured occupants in rollovers while women comprise slightly more than half of injured occupants in other crash types. For AIS3+ injuries, men comprise 57% of those in far-side crashes and 53% in rollovers, while women comprise 59% of occupants injured in rear impacts. For AIS2+ and AIS3+ injury, risks are similar between men and women in all crash types, but slightly higher for men in near and far-side crashes and slightly higher for women in frontal and rollover crashes. The distribution of occupants with AIS2+ and AIS3+ injury by body region is nearly identical for men and women. The largest difference at the AIS2+ level is a larger proportion of lower extremity injuries for women and a larger proportion of head and face injuries for men. For AIS3+ injuries, men still have a larger proportion of head, face, and spine injuries, but the biggest difference for women is in the proportion of upper extremity injuries. Men have higher risk of AIS3+ injury than women for all body regions except for the abdomen and upper extremity.

Results: Vehicle Type and Model Year

Among AIS2+ and AIS3+ injured occupants, pickups and utilities have the highest proportion of rollovers and the lowest proportion of side and rear impacts. Risk of AIS2+ injury is highest in pickup trucks for rollovers, frontal, and near-side impacts, in passenger cars for near- and far-side impacts, and utility vehicles in rear impacts. Risk of AIS3+ injury is highest in pickup trucks for frontal crashes, near-side and rear crashes and in passenger cars for far-side and rollovers. The distribution of occupants with AIS2+ or

AIS3+ injuries to different body regions does not vary substantially with vehicle type. Risk of AIS2+ and AIS3+ injury is highest in pickup trucks for all AIS body regions.

The proportion of occupants with AIS2+ or AIS3+ injuries fluctuates with model years but does not show clear trends. AIS3+ injury risk in rollovers is fairly constant. The proportion of occupants with AIS2+ lower extremity injuries decreases with vehicle model year. The proportion of occupants with head injury is highest for the most recent two model year groupings. The risk of AIS2+ face, abdomen, and lower extremity injury decreases steadily with vehicle model year group. Spine, thorax, and upper extremity have lower injury risk in the newest two model year groups compared to the two oldest model year groups. All body regions except for the spine show a general decrease in AIS3+ injury risk from the oldest to newest vehicle model year groups.

Results: Specific Injury Types and Components

Specific injuries, specific organs, or specific body components were identified as being clinically significant. Analysis was performed to examine the distribution and risk of AIS2+ or AIS3+ injuries to these components or organs relative to the overall body region as a function of the same dependent variables analyzed previously.

For the head, the distributions and risks of subdural hematomas (SDH), subarachnoid hemorrhages (SAH), and cerebral contusions were compared to the overall injury distributions and risks for the head. Occupants in rear crashes with AIS3+ head injury have lower proportions of cerebral contusions and higher proportions of SDH and SAH than occupants in other crash types. This is associated with cerebral contusions having the highest AIS3+ injury risk of the three injury types for rear impacts and the lowest risk in other crash types. Risk of cerebral contusions is substantially higher for rear passengers compared to front occupants, whereas risk is more similar for SDH and SAH. The proportion of occupants with cerebral contusion decreases with vehicle model year. This is likely associated with a decrease in risk of cerebral contusion. Occupants age 46 and over have a higher risk of SAH than cerebral contusion, while occupants younger than 46 have higher risk of cerebral contusion. The proportions of occupants with cerebral contusion vary in the same way.

Pulmonary contusions (PC) and rib fractures were compared to overall trends in thorax injury. The risk of AIS3+ rib fracture is higher in 2007 and later vehicles compared to PC. The proportion of occupants with AIS3+ rib fractures increases with age, because the risk of AIS3+ rib fracture increases with age while the risk of AIS3+ PC is relatively constant with age. For occupants under age 30, risk of AIS3+ PC is higher than risk of rib fracture, while it is lower for occupants over 30. Men have nearly the same risk of AIS3+ rib fracture and PC, while it is higher for rib fracture among women. Risk of AIS3+ rib fracture and PC decreases with vehicle model year group, but decreases more for PC.

There were a few differences in the distributions and risks of injury to the cervical, thoracic, and lumbar spine compared to overall spine injury patterns. The lumbar spine had the highest proportion of AIS3+ injuries to belted occupants. Risk of AIS3+ cervical spine injury increases with BMI group, while thoracic and lumbar spine injury risk are fairly constant with BMI group.

The distributions and risks of injury to the liver and spleen differed from overall abdomen injury patterns in several ways. Occupants with AIS3+ spleen injuries have higher proportions of near-side impacts and lower proportions of frontal and rollover impacts. The difference between AIS3+ injury risk for liver and spleen is highest in near-side impacts. Occupants with AIS3+ liver injuries have a greater proportion of unbelted occupants than occupants with spleen injury. Risk of AIS3+ liver and spleen injury are similar for 3-point-belted occupants, but higher for liver among unbelted occupants. Occupants with spleen injuries have a higher proportion of occupants with BMI 25-29. This group has the highest risk of AIS3+ spleen injury. Women have a higher proportion of liver injuries. Their risk of AIS3+ liver injury is higher than the risk of AIS3+ spleen injury, while the opposite is true for men.

For the upper extremity, the humerus has several differences in injury patterns compared to overall upper extremity injury and to the radius and ulna. At the AIS3+ level, these include greater proportions of occupants in later crash years, the greatest proportion of occupants in rollovers and far-side impacts, the highest proportion of unbelted occupants, the lowest proportion of drivers and the greatest proportion of rear seat occupants, the greatest proportion of occupants in passenger cars. In addition, Almost 40% of occupants with AIS3+ humerus injuries have BMI above 30, compared to just over 20% for the radius and ulna. Risk of AIS3+ injury increases with age for all three upper extremity bones, but the humerus has a large increase in risk at age 75 and the largest proportion of occupants with humerus injuries among those with AIS3+ upper extremity injuries.

For the lower extremity, the pelvis has the greatest proportion of occupants in near-side impacts. The femur has the highest risk of AIS3+ injury in all crash types except the pelvis in near-side impacts. Women have a greater proportion of AIS3+ injury to the tibia/fibula shaft, knee tissue, and ankle/foot compared to men. Pickup trucks have the highest risk of AIS3+ injury for the pelvis and femur. Risk of AIS3+ injury to the pelvis and femur have dropped substantially since vehicle model years 1999-2004.

Chapter 1. Methods

Exclusions and treatment of missing data

This analysis used the NASS-CDS dataset for calendar years 1998-2014. As discussed in the last section of this chapter, most analyses only considered vehicles that were less than 10 years old at the time of the crash. Thus the 2014 dataset excluded vehicles older than model year 2004, while the 1998 dataset excluded vehicles older than model year 1988. Other criteria for exclusion were:

- VehRatWt > 5000 (to eliminate cases with unusually high and influential weights)
- Age < 15
- Occupant position other than driver, front passenger, rear seat (such as on lap, unenclosed area)
- Vehicle type other than passenger car, pickup, SUV, van
- Shoulder belt only

Eliminating these non-typical adult occupants from the dataset allows better examination of typical injury trends. To ensure consistent calculation of risk for each variable, a uniform strategy for treating missing or unknown data for each variable is as follows:

- Unless meeting the exclusion criteria listed above, keep occupants even if some variable values are missing or unknown.
- Calculate risk based on occupants with known values for the variables of interest.

As an example, an occupant with unknown belt use would be included in the database. The occupant would not be included in analysis of trends by belt restraint, but would be included in other analyses such as age or crash type.

The total number of occupants distributed by the relevant missing data (main crash type vs. another dependent variable) is shown Figure 1. After the exclusions listed above were made, there were roughly 42,602,303 occupants in the weighted dataset. For 10, 957,541 occupants (25.7%), the injury data were either missing or unknown. For 7,026,688 occupants (16.5%), the crash type is either unknown or is not considered a frontal, near-side, far-side, rear, or rollover impact. Crashes would fall into this category if no vehicle inspection is performed. Occupants in these crashes would be excluded from analyses by crash type, but are included in the analyses by body region to increase the size of the occupant database.

For the variables of vehicle type, seating position, gender and age group, the variable value is unknown for less than 2% of subjects. This leaves the total number of occupants with known information to be on average 24,483,829 for these variables, near 57% of the total.

Over 9% of subjects are missing information regarding belt restraint, but most of them are also missing crash type. This puts known N for belt restraint analysis at 24,016,661. Crash year is known for most subjects, but about 3.5% of occupants (from the 1998 crash year) are excluded from the analysis of trends with crash year because 2-year groupings of occupants starting in 1999 were used. (These occupants were not deleted from the dataset, because they included some 1999 vehicles which were

used in the analysis of vehicle model year.) Total known N for crash year is 23,146,268. About 14% of occupants are missing height and/or weight information needed to calculate BMI. Considering the overlap with occupants also missing crash type information, the total N for BMI is 21,257,294.

For vehicle model year, analysis used three-year groupings of vehicles (because of sample size issues for more recent models) of 1999-2001, 2002-2004, 2005-2007, 2008-2010, and 2011-2014. Because of NHTSA's request to focus on vehicles less than 10 years old, vehicle groupings older than those listed were not used. However, occupants in vehicles older than 1999 needed to remain in the dataset, to allow analysis of injury trends with crash year. If all vehicles older than MY1999 were deleted, crash year 1999 would only have MY1999 vehicles, while crash year 2014 would have 2004-2014 MY vehicles. Keeping 10 model years of data for each crash year allows analysis of injury trends with time. As a result, about 26% of occupants were in vehicles with model years older than 1999. Thus the total known, nonexcluded N for vehicle model year analysis is 15,985,696.

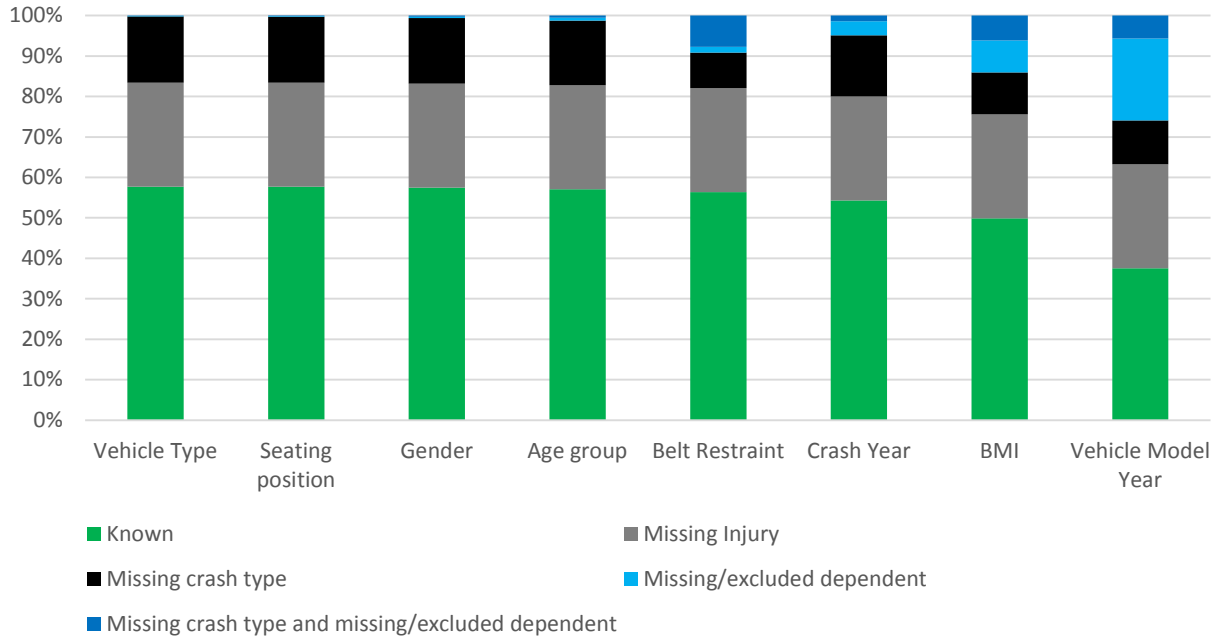


Figure 1. Weighted sample size for each analysis by dependent variable.

Injury Analysis

The database was configured to have one entry per occupant. The AIS98 injury coding scheme was used for all occupants as AIS2005 coding was not available for all crash years. To perform injury analyses, the maximum AIS value for each AIS body region was recorded for each occupant to allow tabulation of occupants with injuries to a particular body region at a particular severity level (AIS2+ or AIS3+). The nine body regions assessed are the head, face, neck, thorax, abdomen, spine, upper extremity, and lower extremity.

The main crash type was categorized as a rollover, frontal, rear, near-side, or far-side crash. First, rollover crashes were identified as any crash with a rollover greater than 0. Frontal and rear crashes were identified using the most severe event of the collision deformation location. Left side and right side values of the collision deformation variable were used to identify near-side and far-side crashes, depending on the seating position of the occupant relative to the side of impact. Occupants in center seating positions were classified as far-side occupants.

Some analyses grouped frontal crashes into subcategories based on specific damage location. NHTSA supplied code that was applied to categorize each crash, which was developed for a prior research project (Hallman et al. 2011). Frontal subcrash types include full frontal, right offset, left offset, center, narrow frontal, left small overlap impact (SOI), and right SOI. In addition, rollover crashes were assigned to sub crash categories based on the number of quarter turns of 1-2, 3-6, and 7+, and side impacts were classified as near-side T-type, near-side L-type, far-side T-type, and far-side L-type.

The main crash type, subcrash type, and body region variables were each crossed with several dependent variables and tabulated by weighted counts of AIS2+ or AIS3+ injuries. Table 1 lists the dependent variables and their categories. For gender, the different categories of pregnant occupant were grouped with other women.

Table 1. Dependent crash and occupant variables and their categories.

Variable	Categories
Occupant age (years)	15-20, 21-30, 31-45, 46-55, 56-65, 66-75, and 75+
BMI group	<18, 18-24, 25-29, 30-34, and > 34
Vehicle model year	1999-2001, 2002-2004, 2005-2007, 2008-2010, and 2011-2014
Crash year	1999-2000, 2001-2002, 2003-2004, 2005-2006, 2007-2008, 2009-2010, 2011-2012, 2013-2014
Seat Position	Driver, front passenger, rear
Gender	Male + female
Belt restraint	3-point, lap, none

All analyses were conducted using SAS 9.4 PROC TABULATE (SAS Institute, 2015) to account for the sample design for NASS-CDS using weighted data. NASS-CDS is geographically divided into 12 strata and 27 probability sampling units (PSUs), which were accounted for in all statistical analyses.

Some analyses examined specific injuries that are either frequent or clinically significant. These injuries are listed in Table 2. In a similar manner, a new variable was created for each occupant to indicate whether or not one of these key injuries was sustained at the AIS2+ or AIS3+ level.

Table 2. Specific injuries and body components injured

Body Region	Injury/specific component injured
Head	Subdural hematoma (SDH), subarachnoid hemorrhage (SAH), cerebral contusion
Thorax	Pulmonary contusion (PC), rib fx
Spine	Cervical, Thoracic, Lumbar
Abdomen	Liver, spleen
Lower Extremity	Pelvis, Femur, Tibia/Fibula, Knee tissue, Ankle/heel
Upper	Radius, ulna, humerus

For most analyses, distribution of number of injured occupants is presented. For risk, the number of injured occupants within a category is divided by the total number of occupants within that category.

For some of the variables examined, particularly when sorting occupants into subcrash categories, the number of injured occupants in the database can be quite small, making analysis of injury trends somewhat unreliable. For each plot, the number of unweighted injured occupants in each category was examined. Categories with less than 25 unweighted injured occupants are indicated with an asterisk (*). In cases when more than half of the categories meet this low unweighted N criteria, the * is included on the axis label rather than on the plot. No additional analyses were performed to determine whether trends presented in this report are statistically significant or not.

Addressing Changes to Injury Documentation

For the 2009 and later NASS-CDS case years, investigators only collected injury data for occupants in vehicles with model years 10 years older relative to the calendar year of the crash. Some preliminary analyses were performed to provide guidance on how to present historical comparisons of injury when the data available are not consistent across case years.

Figure 2 shows for each case year the proportion of occupants in newer (10 years old or less) and older (more than 10 years old) vehicles. The proportion of occupants in older vehicles ranges from 29% to 32% for case years 1999-2008, but ranges from 36% to 45% in case years 2009-2014.

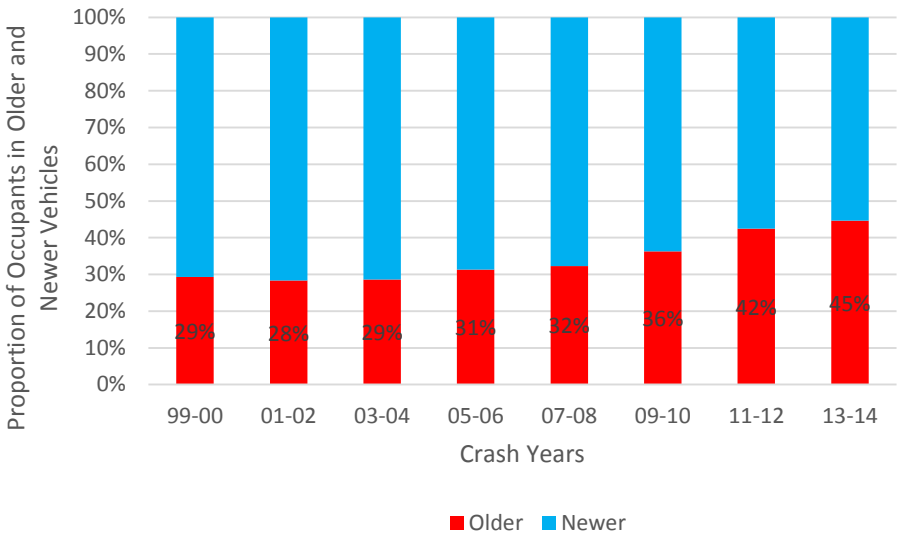


Figure 2. Proportion of occupants for each case year crashing in newer or older vehicles.

Figure 3 shows the proportion of occupants in newer and older cars with AIS2+ and AIS3+ injuries for each case year pair for the years that still collected injury data for all occupants. The rates of injury are fairly consistently higher for the older vehicles compared to the newer vehicles. There is a general decrease in injury rates for both older and newer vehicles but with some fluctuations.

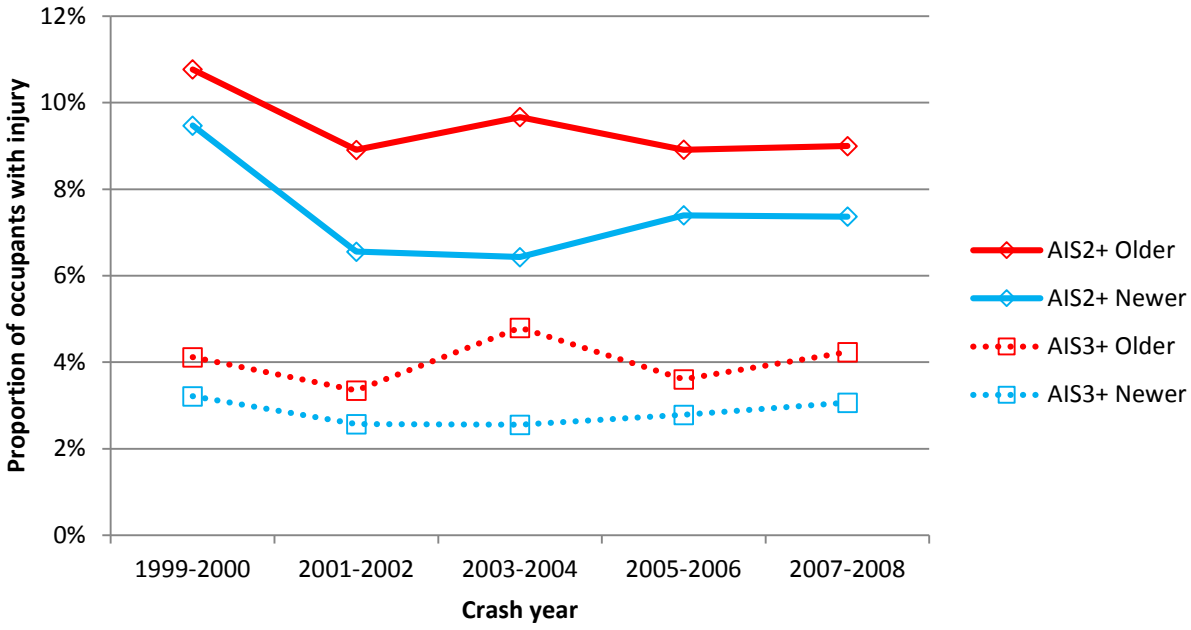


Figure 3. Proportion of occupants with AIS2+ and AIS3+ injuries in older and newer vehicles by crash year.

Data for the injury distributions and injury risk are based on occupants with AIS2+ or AIS3+ injuries who are in vehicles 10 years old or less. However, data for the frequency of injuries in Chapter 2 are adjusted using data from NASS-GES to estimate number of injured occupants in both newer and older vehicles as described below.

To estimate trends in the total number of occupants injured in crashes over time, we begin with the annual number of occupants injured in newer vehicles for each pair of crash years. The number of occupants injured in older vehicles for each time period is estimated by accounting for the proportion of occupants crashing in older and newer vehicles in the NASS-CDS data using the data in Figure 2. However, we know that injury risk is always higher in older vehicles (Figure 3). To estimate a risk ratio between the risk of injury in older and newer vehicles, we use the NASS-GES dataset, which still collects data on all occupants regardless of vehicle model year. The NASS-GES dataset was filtered to select occupants in tow-away crashes that met the other selection criteria used with the NASS-CDS database in this study. The percentage of occupants who received KAB (killed, incapacitating injury, possibly incapacitating injury) injuries in older and newer vehicles was calculated for each crash year. On average from 2005-2014, occupants in older vehicles sustained KAB injuries at a rate 1.21 (STD 0.03) times higher than those in newer vehicles. A multiplier of 1.21 was applied to the estimated number of occupants injured in older vehicles. When checking against years for which NASS-CDS injury data is available for occupants of older vehicles, this method undercounts total number of injured occupants by about 10%. However, the same multiplier was used across all crash years for consistency.

Chapter 2. General Injury Trends by Crash Year.

Injuries by Crash Year and Crash Type

- Injury risks and proportions of injured occupants are based on analysis of newer vehicles only, while counts of injured occupants include estimates for occupants in older vehicles.
- The risk of AIS2+ injury is highest in 1999-2000 and 2005-2006 crash years and the lowest in the latest 2009-2014 crash year groupings. It has dropped consistently for near- and far-side crashes, but not for rollovers, frontal, or rear impacts.
- The risk of AIS3+ injury is highest in 1999-2000 and 2005-2006 crash years and the lowest in the latest 2011-2014 crash year groupings. It has dropped consistently for near- and far-side crashes, but not for rollovers, frontal, or rear impacts.
- The proportion of occupants with AIS2+ and AIS3+ injuries in rollovers and near-side impacts has decreased over time, while the proportion of those injured in frontal impacts has increased.
- The general increase in rollover injury risk over time coupled with the decrease in number of injured occupants in rollovers suggests that reduced crash exposure is contributing to injury reduction. In addition, these trends suggest that the rollovers that still occur are more risky.
- The lower numbers of occupants injured in recent years is likely a combination of reduced exposure because of economic conditions, as well as the prevention of some types of crashes from crash avoidance technologies.
- For AIS2+ injury in narrow frontal, rear, and far-side L-type crashes, there are less than 25 injured occupants (unweighted) in most categories, making analysis of trends for these subcrash types unreliable. The same is true for these categories, plus near-side L-type crashes, in the analysis of AIS3+ injury. These categories are indicated with * on each plot.
- The proportion of AIS2+ injuries by subcrash type varies considerably with crash year.
- For crash years 2003-2006 and 2011-2012, the proportion of occupants with AIS2+ injuries from 1-2 quarter turn rollovers was lower than other crash year groupings, while the proportion from 3-6 quarter turn rollovers was higher than other crash year groupings. For occupants with AIS3+ injuries in rollovers, the proportion in 1-2 quarter turn rollovers has decreased with crash year until 2013-2014, which has the highest proportion of 1-2 quarter turn rollovers.
- The risk of AIS2+ injury in 7+ quarter turn rollovers has increased with crash year, while the risk for the 1-2 or 3-6 quarter turn rollovers is fairly steady. For AIS3+, trends are similar, but with the increase in risk for 7+ quarter turn rollovers occurring since 2003. The drastic increase for 2013-2014 is likely due to low N.
- For frontal subcrash types, occupants in center frontal impacts have the highest AIS2+ injury risk compared to other categories.
- Among side impact subcrashes, the proportion of occupants with AIS2+ and AIS3+ injuries from far-side T-type crashes was highest in the 2003-2004 crash years.
- Risk of AIS2+ injury in T-type crashes has generally dropped from 1999 to 2014.
- Among frontal crash subtypes, the proportion of occupants with AIS3+ injuries was highest for left or right SOI crashes in 2005-2008 and 2011-2012.

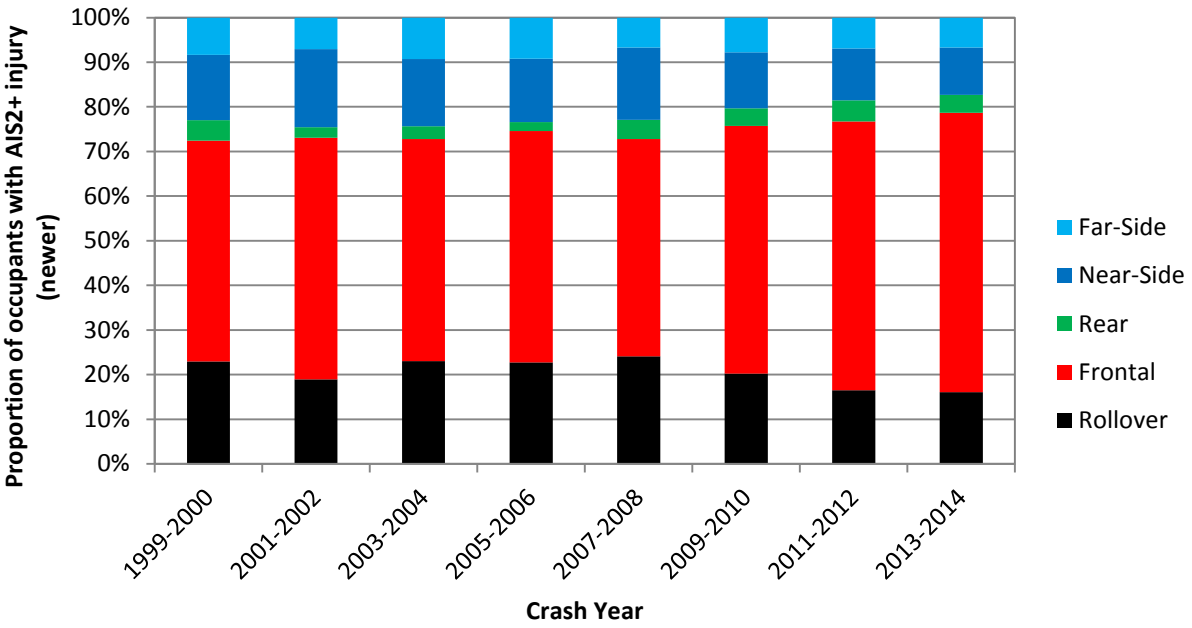


Figure 4. Proportion of occupants with AIS2+ injuries by crash type for each pair of crash years.

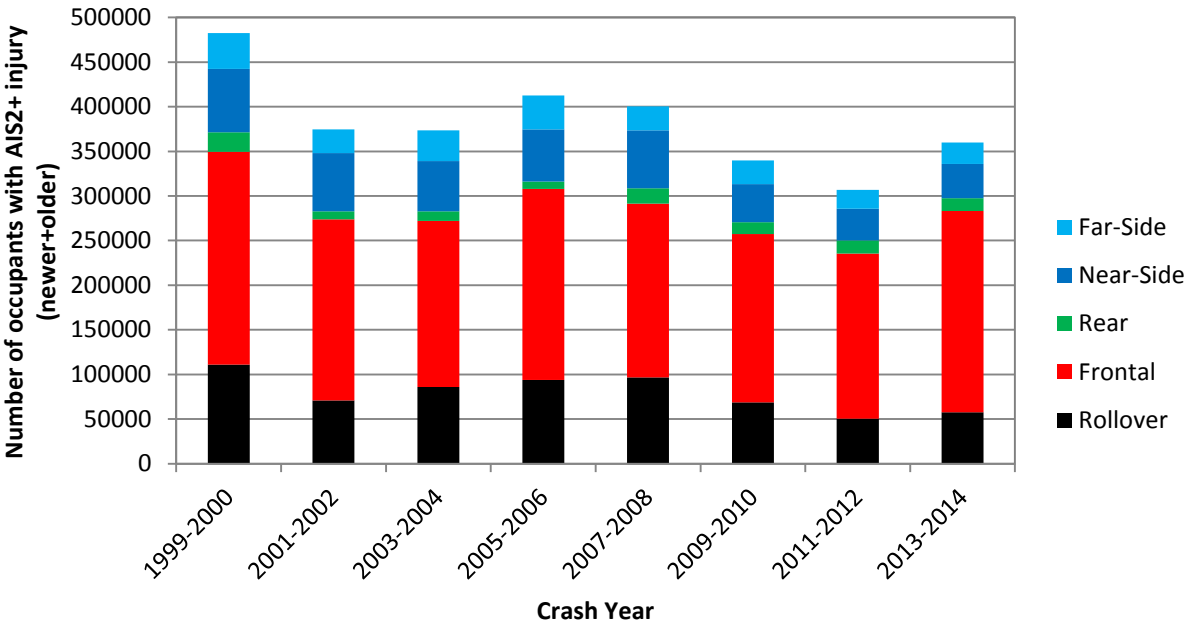


Figure 5. Number of occupants with AIS2+ injuries by crash type for each pair of crash years.

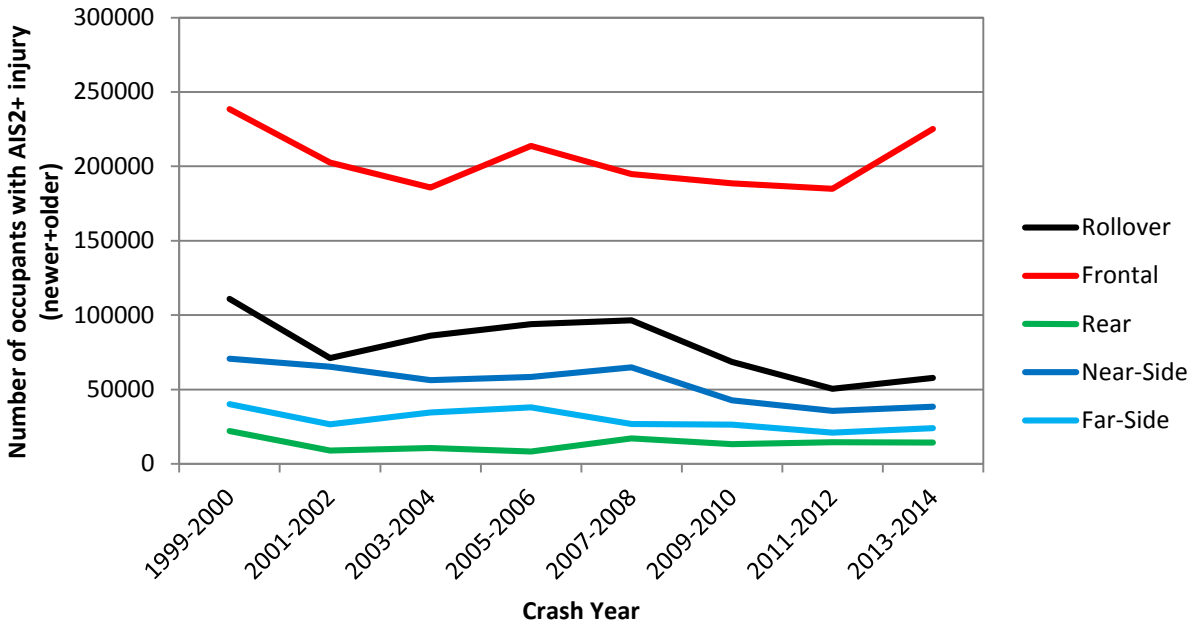


Figure 6. Number of occupants with AIS2+ injuries by crash type for each pair of crash years.

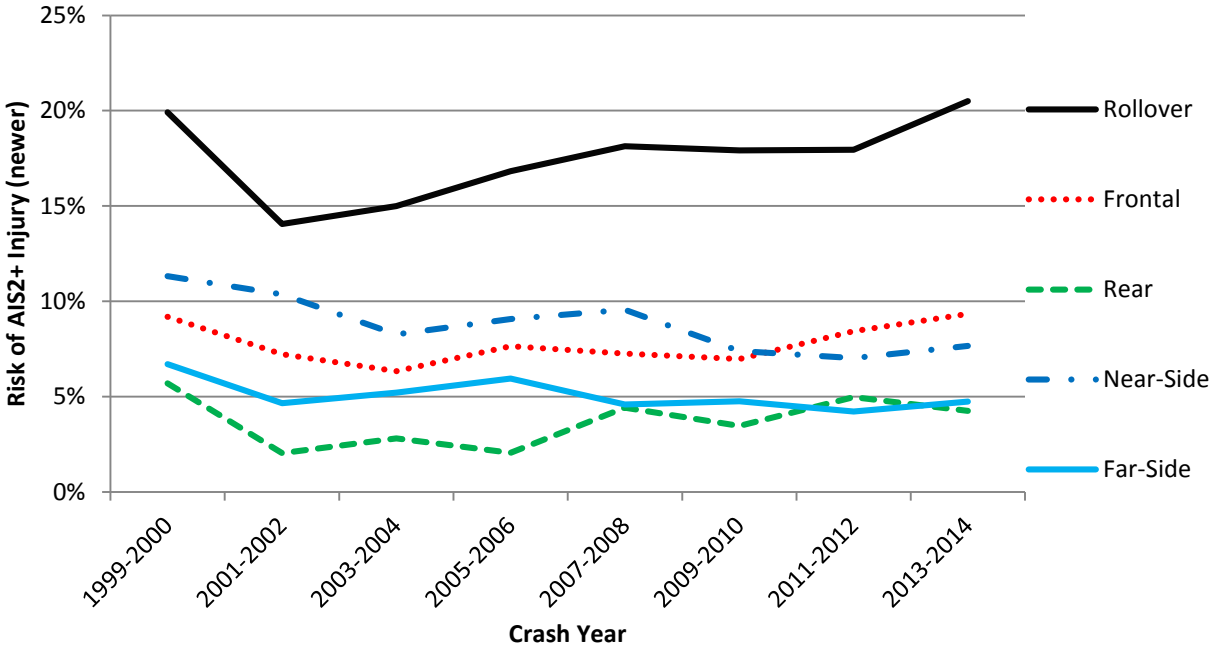
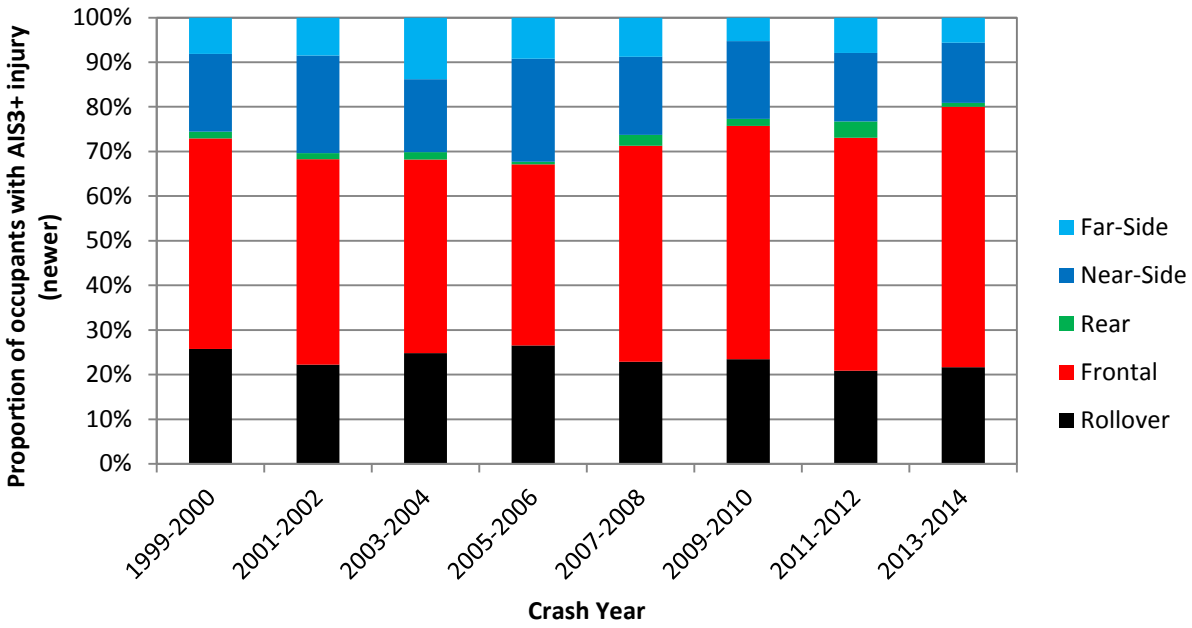


Figure 7. Risk of AIS2+ injury by crash type for each crash year pair.



Proportion of occupants with AIS3+ injuries by crash type for each pair of crash years.

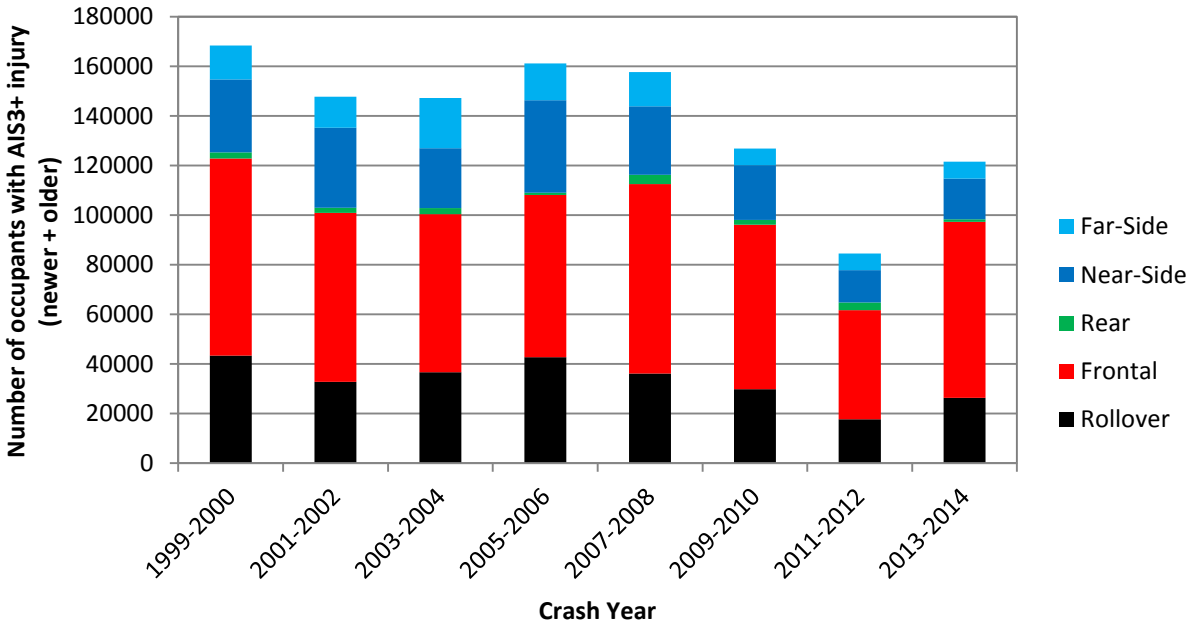


Figure 8. Number of occupants with AIS3+ injury by crash type for each crash year pair.

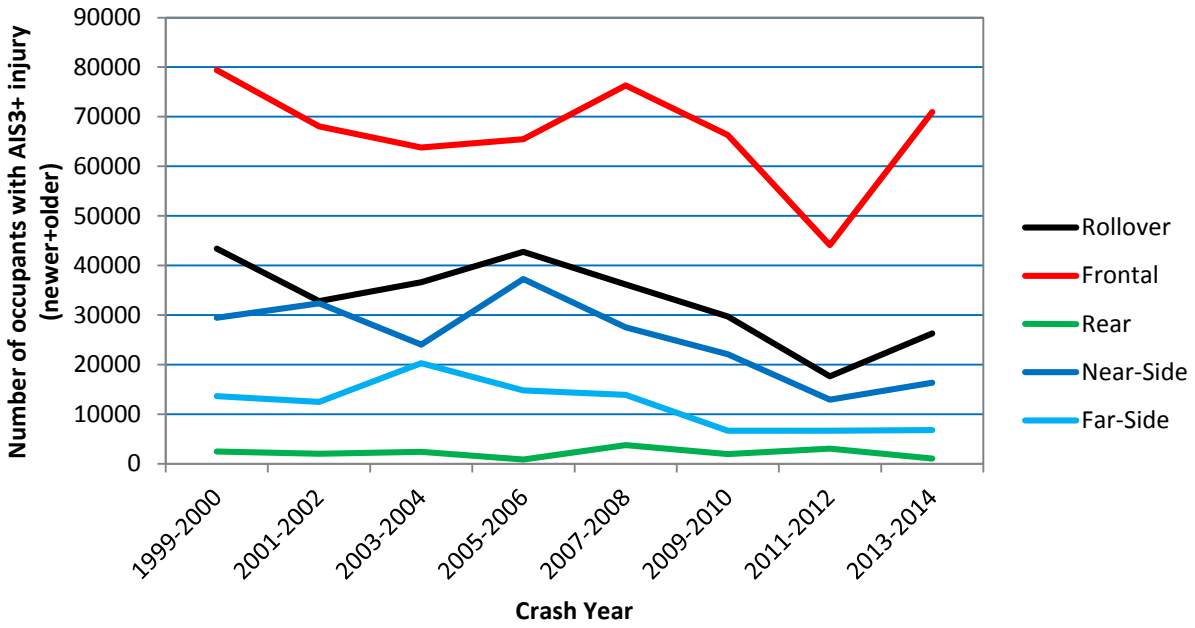


Figure 9. Number of occupants with AIS3+ injury by crash type for each crash year pair.

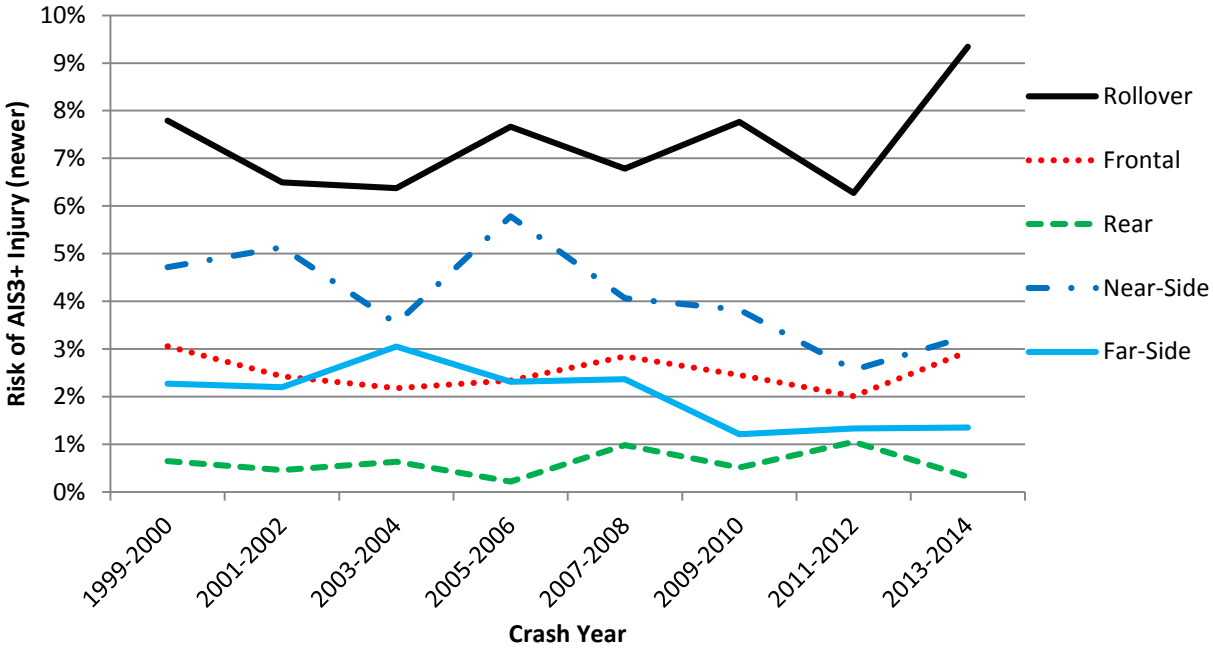


Figure 10. Risk of AIS3+ injury by crash type for each crash year.

Crash Year by Subcrash Type

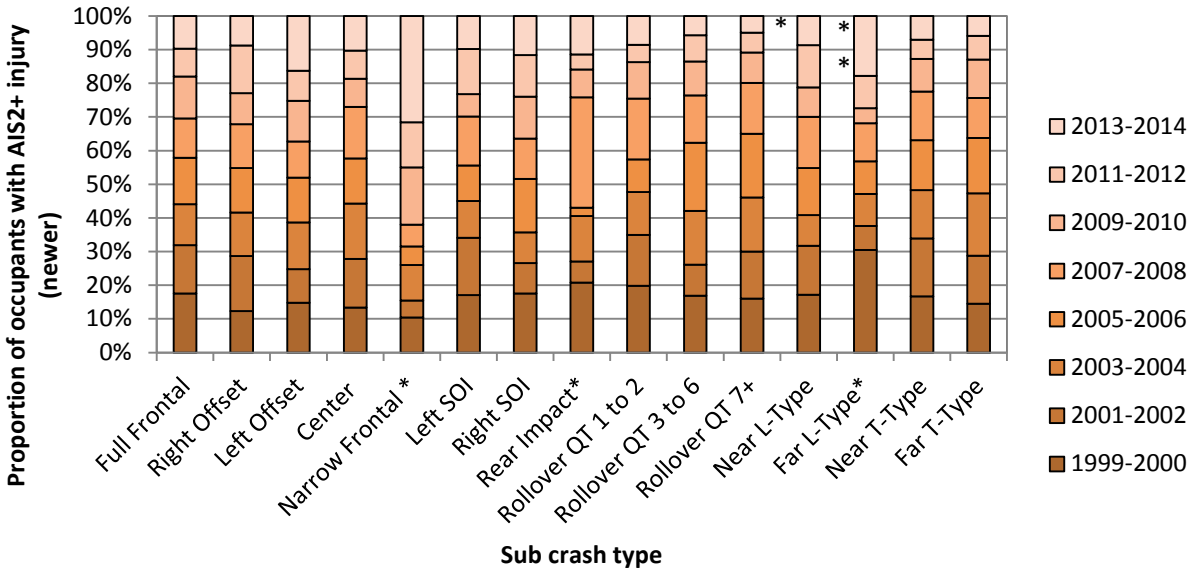


Figure 11. Proportion of occupants with AIS2+ injury by crash year for each sub crash type.

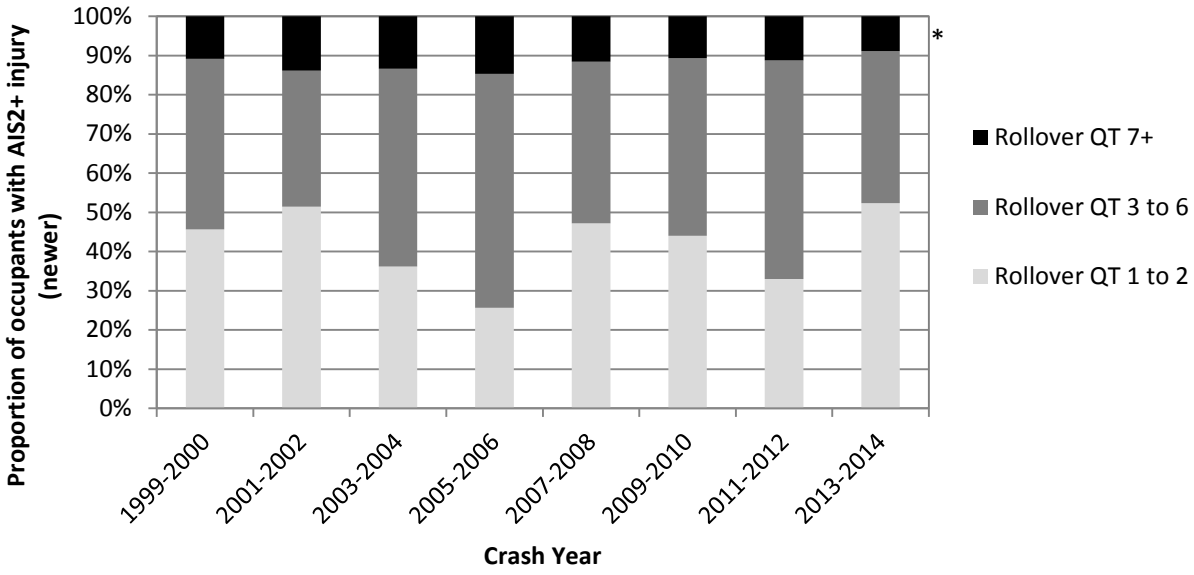


Figure 12. Proportion of occupants with AIS2+ injury by rollover type for each crash year.

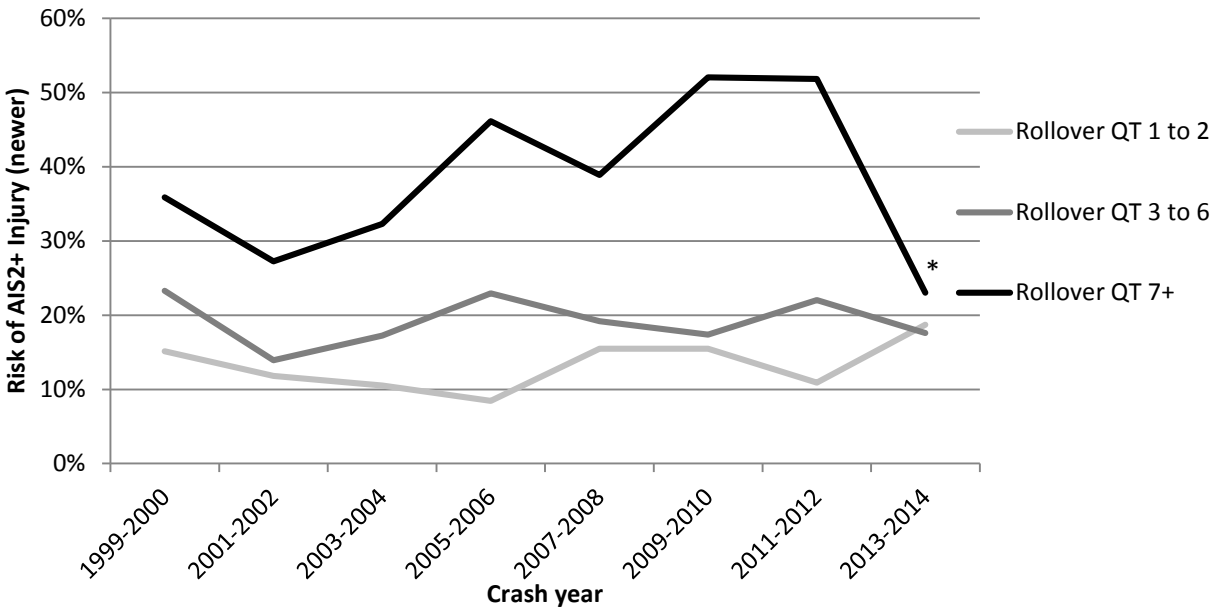


Figure 13. Risk of AIS2+ injury for each rollover type by crash year.

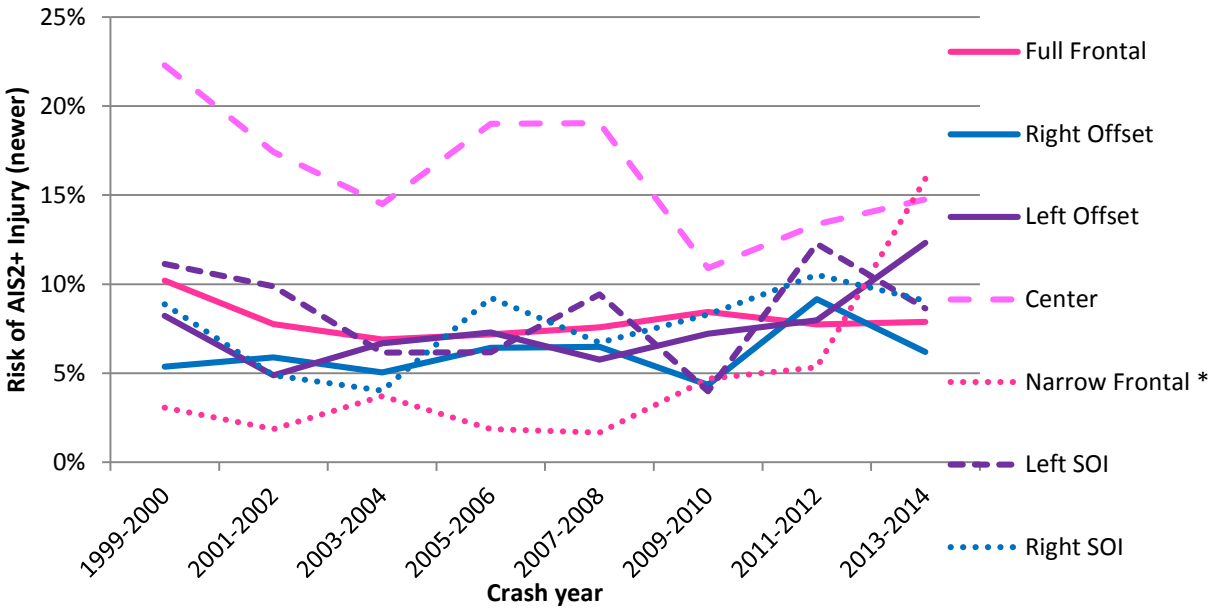


Figure 14. Risk of AIS2+ injury for each frontal sub crash type by crash year.

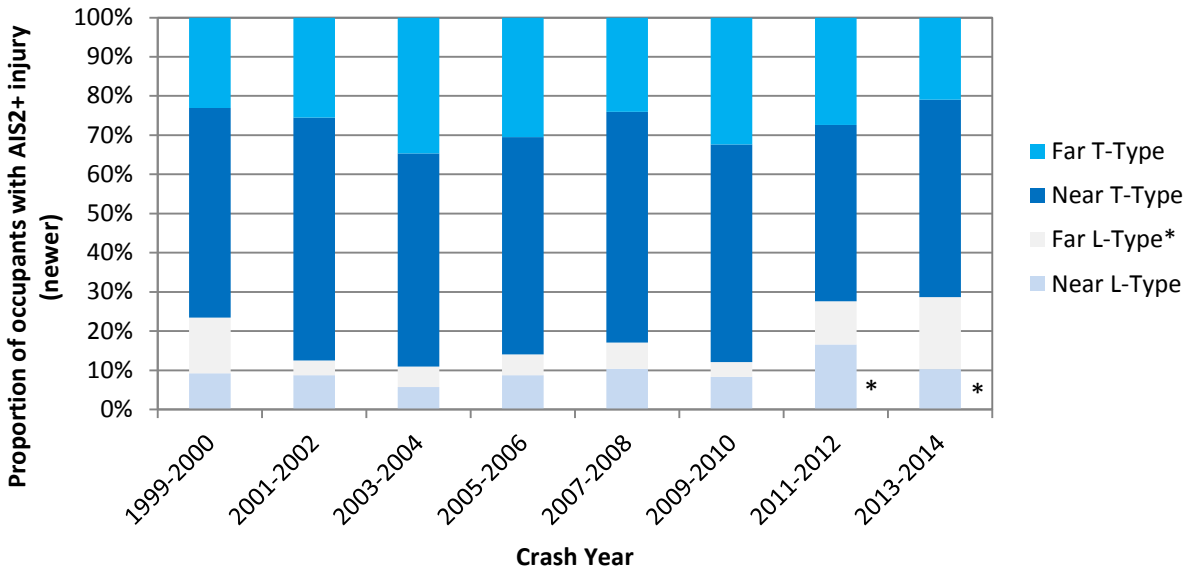


Figure 15. Proportion of occupants with AIS2+ injury by each side subcrash type for each crash year.

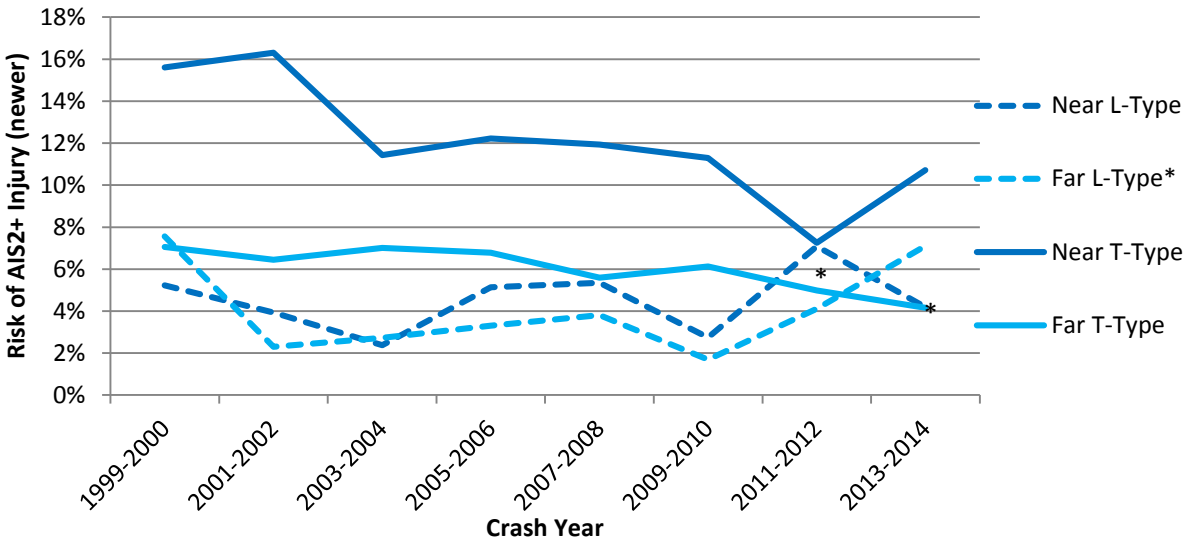


Figure 16. Risk of AIS2+ injury for side subcrash types for each crash year.

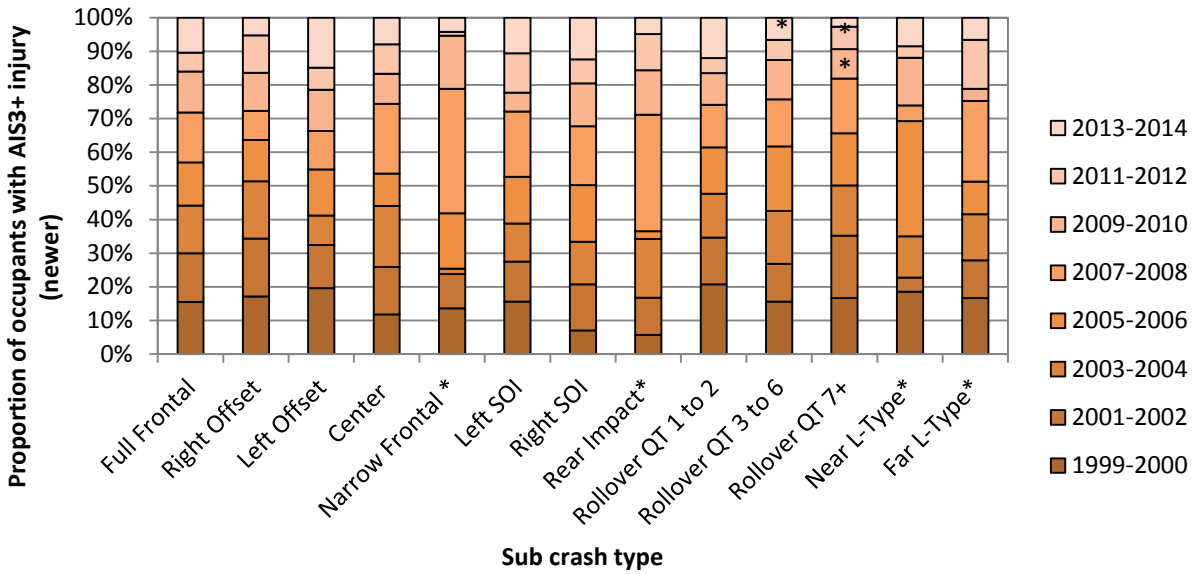


Figure 17. Proportion of occupants with AIS3+ injury by crash year for each sub crash type.

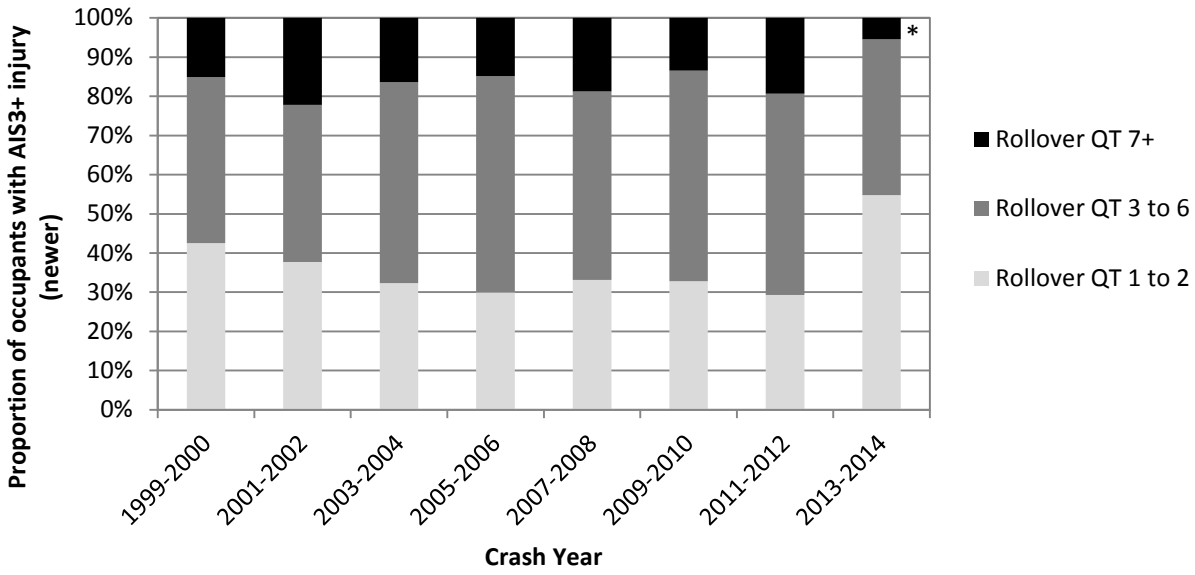


Figure 18. Proportion of occupants with AIS3+ injury by rollover type for each crash year.

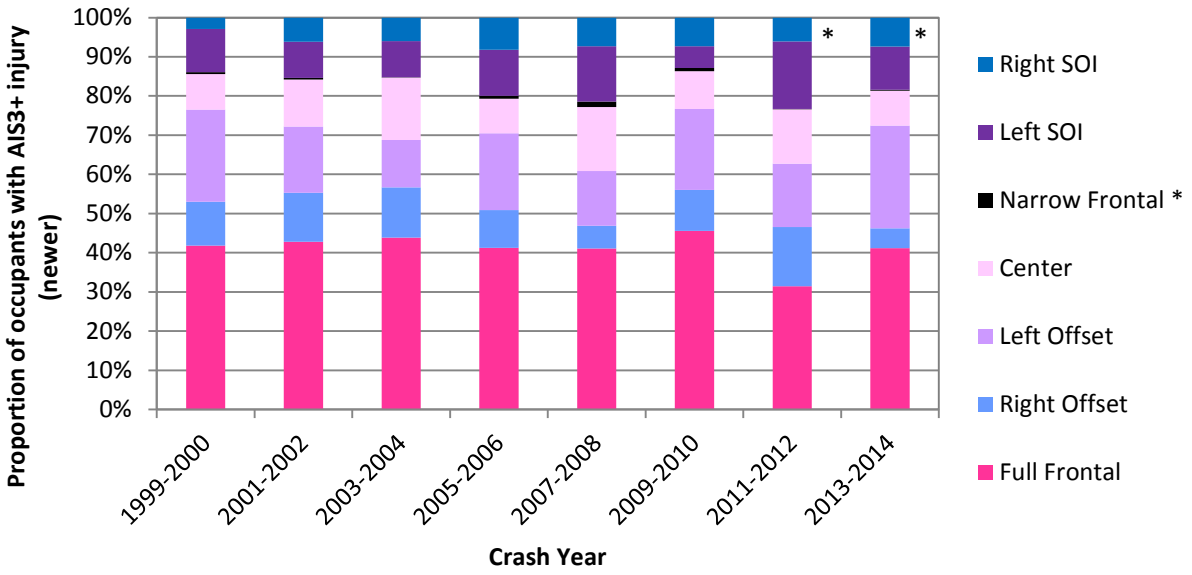


Figure 19. Proportion of occupants with AIS3+ injury by frontal subcrash type for each crash year.

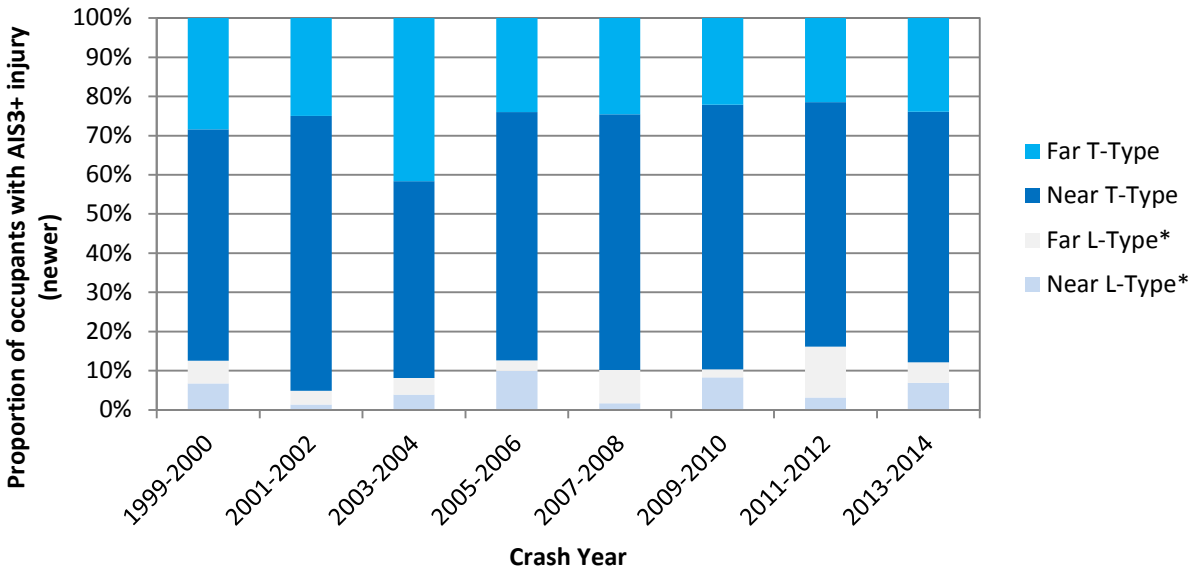


Figure 20. Proportion of occupants with AIS3+ injury by side subcrash type for each crash year.

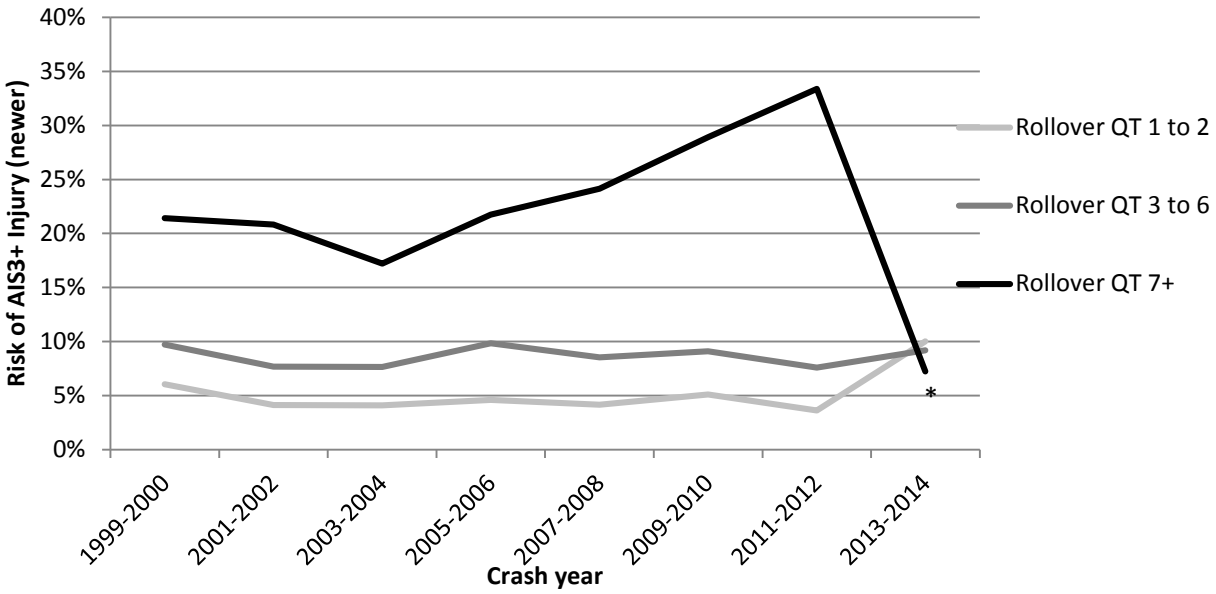


Figure 21. Risk of AIS3+ injury by rollover type for each crash year.

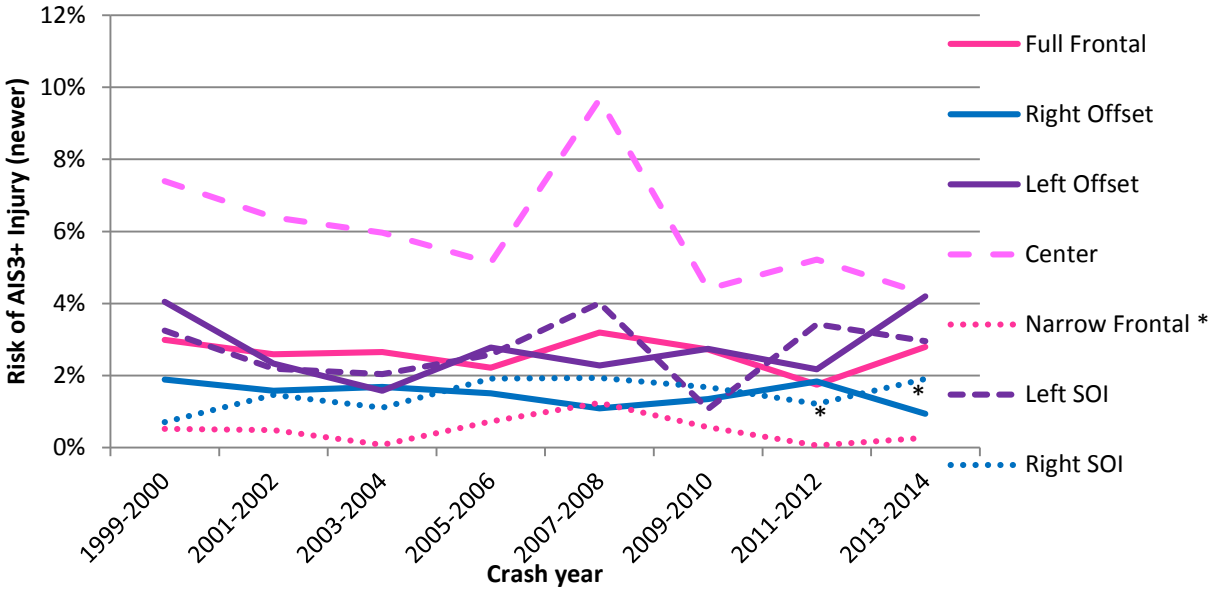


Figure 22. Risk of AIS3+ injury by frontal subcrash type for each crash year.

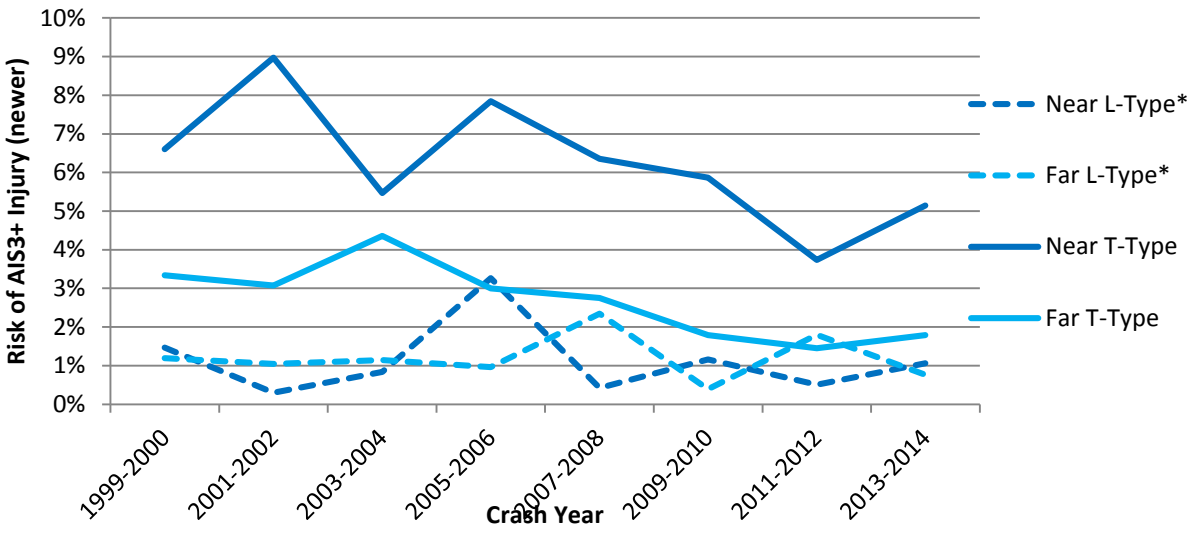


Figure 23. Risk of AIS3+ injury by side subcrash type for each crash year.

Injuries by Crash Year and Body Region

- For most crash years, the number of occupants with neck injuries (at AIS2+ or AIS3+ level) is less than 25 (unweighted). This makes analysis of neck injury patterns unreliable. The labels for neck injuries include an * to indicate their low frequency.
- The distribution of occupants with AIS2+ injuries by body region has not shifted substantially with crash year.
- The risk of AIS2+ injury has dropped from 1999 to 2010 fairly consistently for the abdomen, face, upper extremity, and lower extremity.
- The proportion of occupants with AIS3+ injury to the thorax and spine has increased, while the proportion of occupants with AIS3+ injury to the upper and lower extremities has decreased.
- The body regions with the largest decrease in the number of AIS3+ injured occupants are the lower extremity, head, and upper extremity.
- The risk of AIS3+ injury to the lower extremity, head, face, and upper extremity has dropped consistently since 2007-2008.

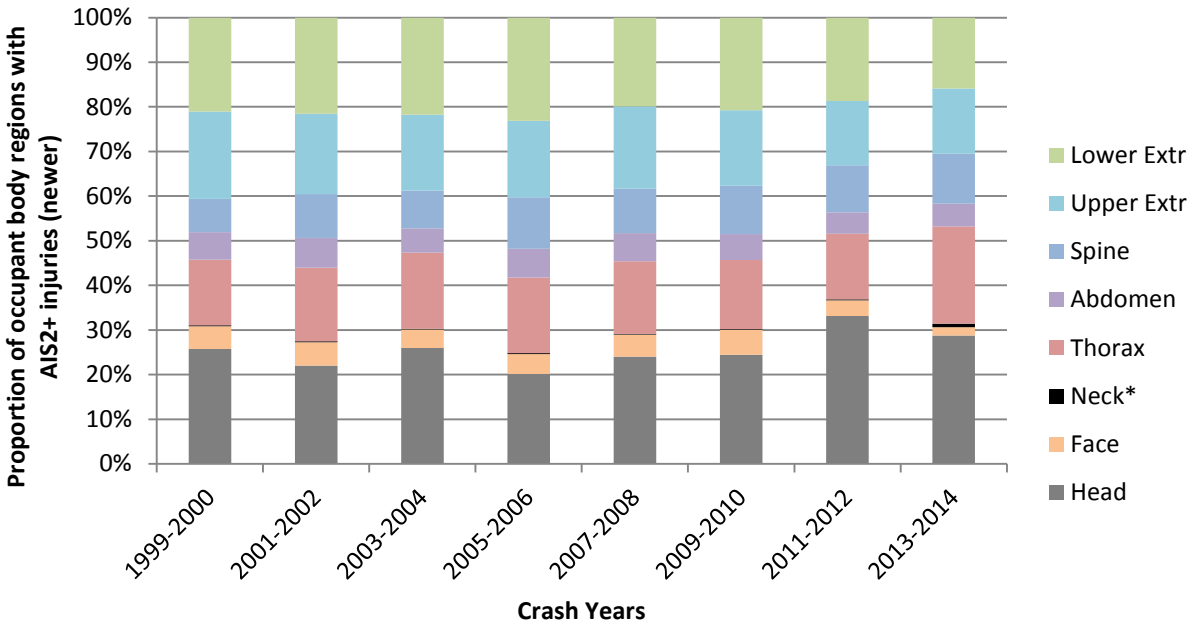


Figure 24. Proportion of occupant body regions with AIS2+ injuries by body region for each crash year (newer vehicles.)

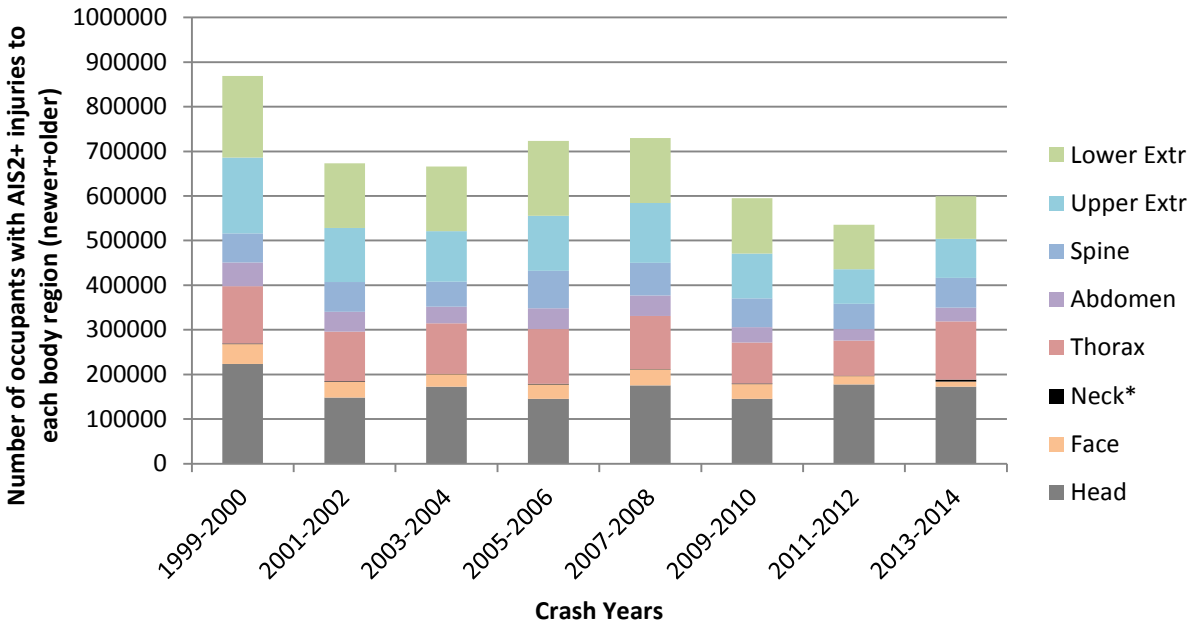


Figure 25. Number of occupant body regions with AIS2+ injuries to each AIS body region for each crash year (newer + older vehicles.)

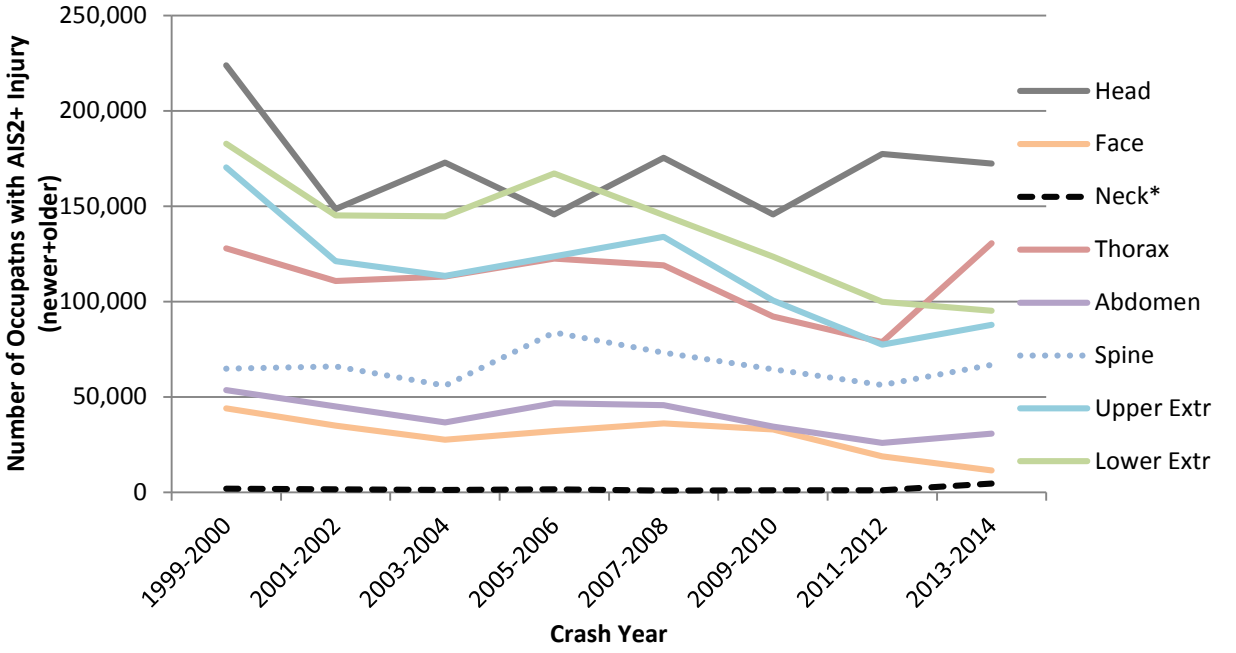


Figure 26. Number of occupant body regions with AIS2+ injuries to each AIS body region for each crash year (newer + older vehicles.)

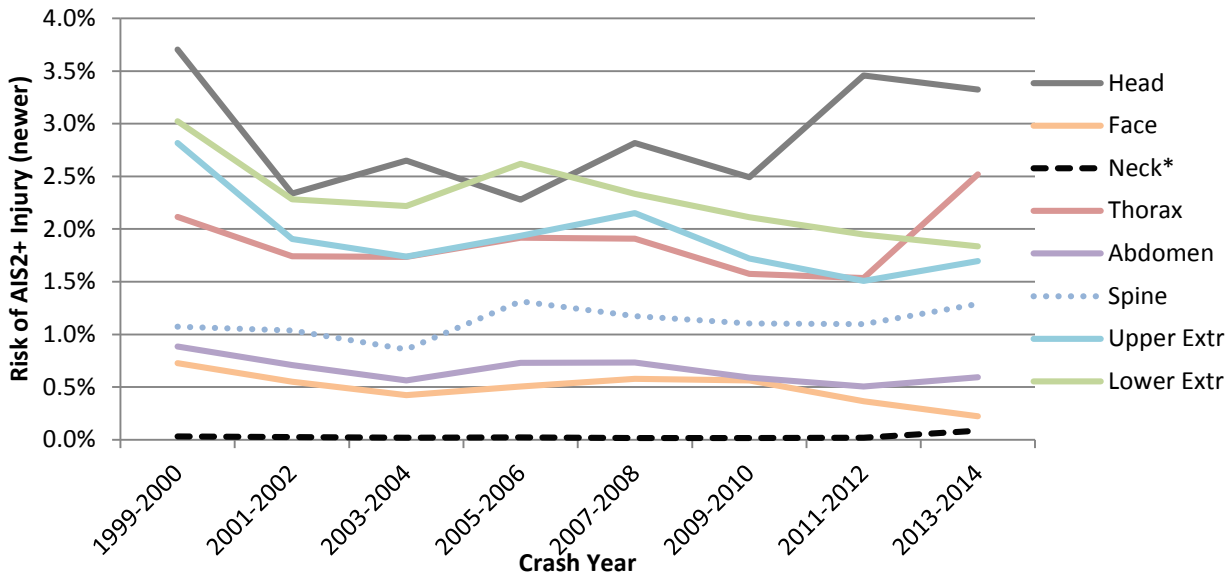


Figure 27. Risk of AIS2+ injury to each AIS body region for each crash year (newer vehicles.)

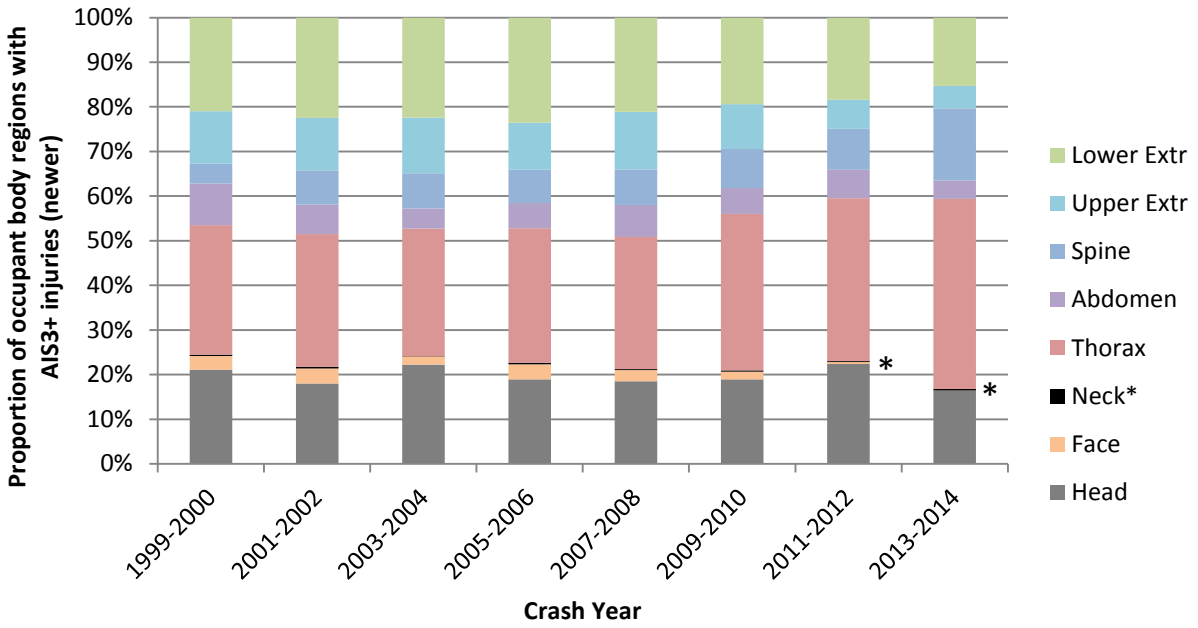


Figure 28. Proportion of occupant body regions with AIS3+ injury by body region for each crash year (newer vehicles.)

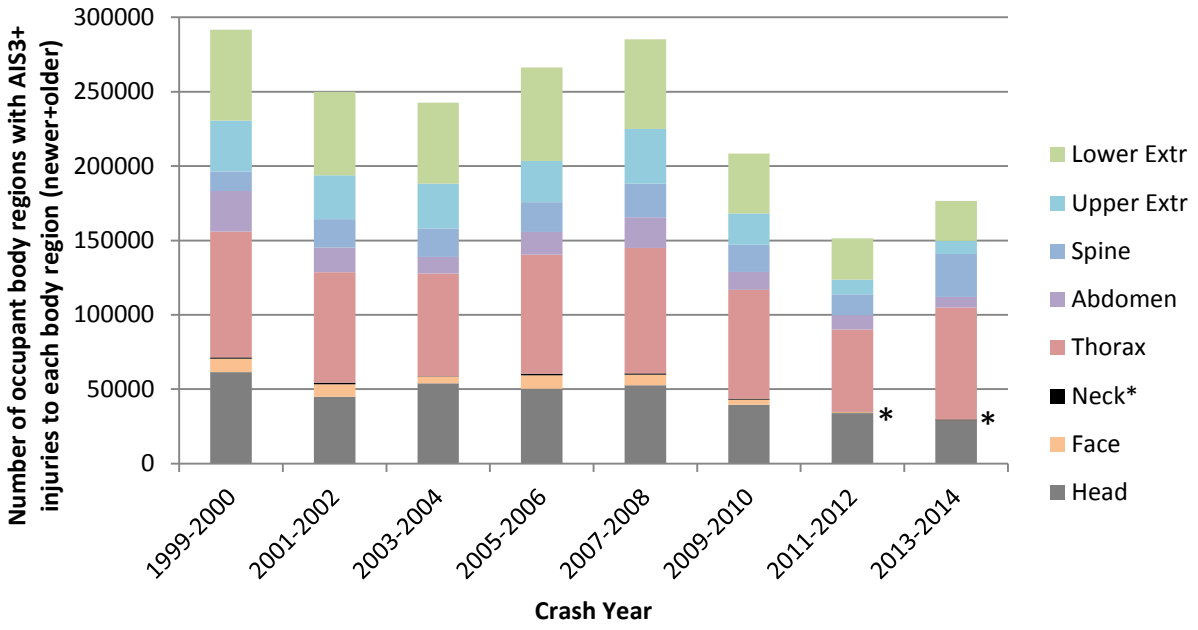


Figure 29. Number of occupant body regions with AIS3+ injury to each AIS body region for each crash year (newer + older vehicles.)

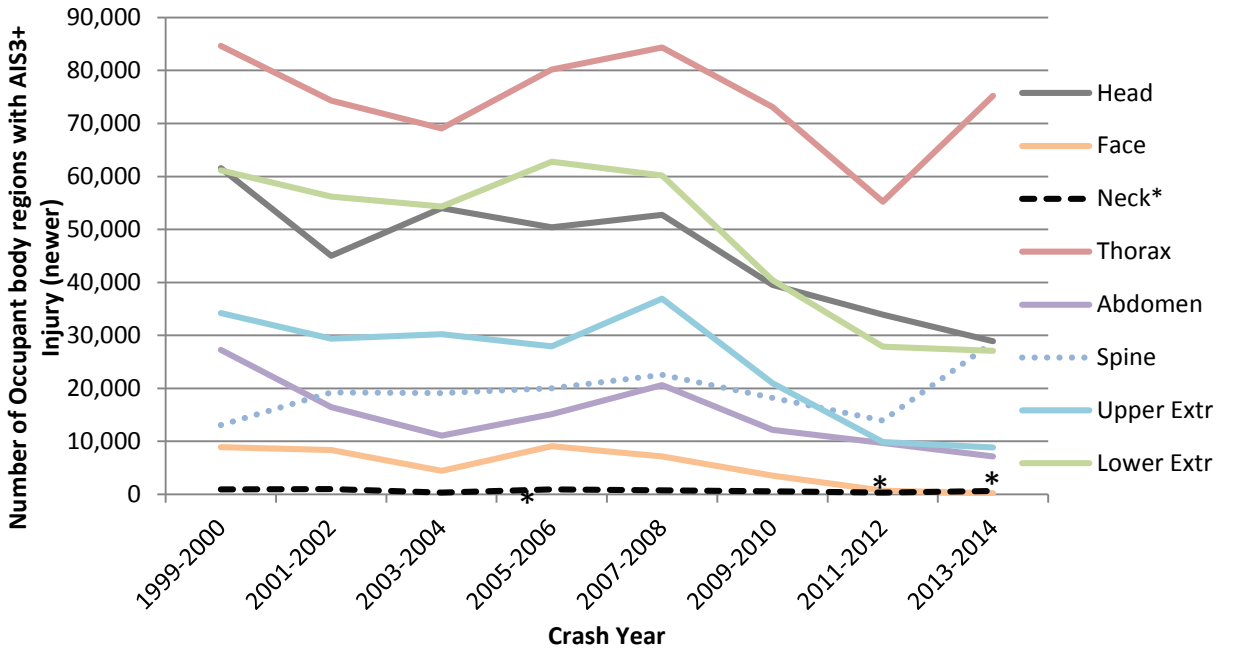


Figure 30. Number of occupant body regions with AIS3+ injuries to each AIS body region for each crash year (newer + older vehicles.)

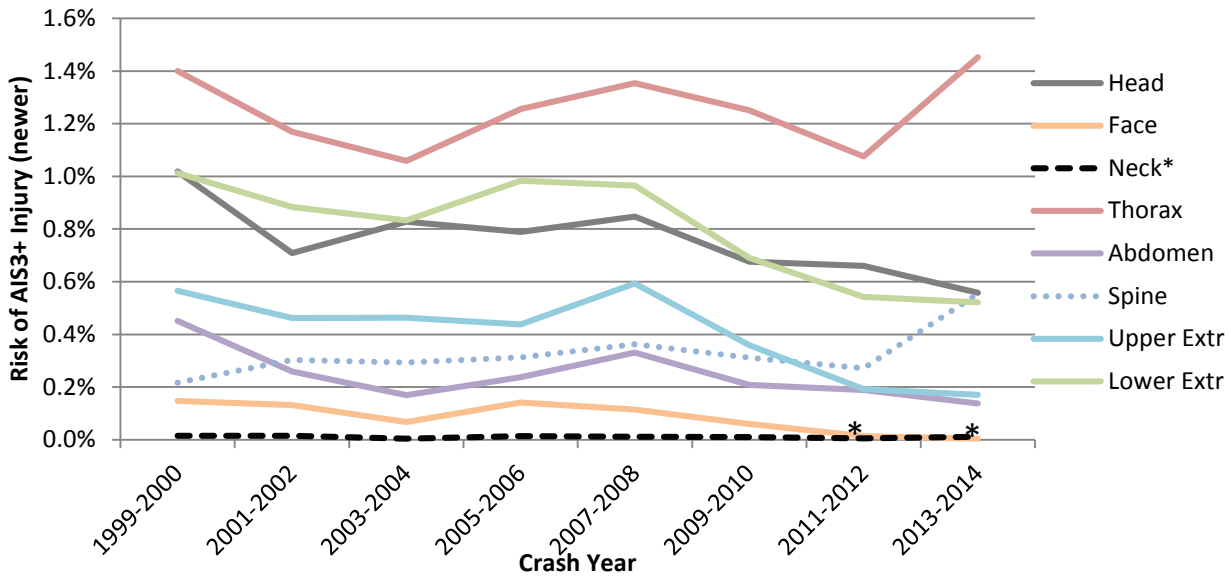


Figure 31. Risk of AIS3+ injury to each AIS body region for each crash year (newer vehicles.)

Chapter 3. Injuries by Crash Type

Body Region by Crash Type

- In this dataset, the distribution of occupants with known crash type is shown in Figure 32.

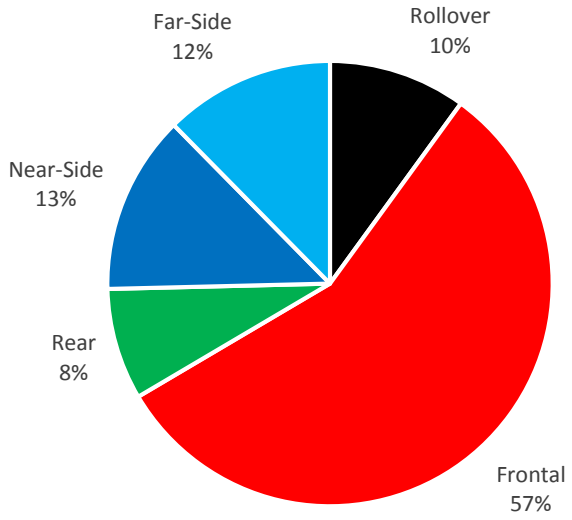


Figure 32. Distribution of occupants by crash type.

- For AIS2+ injury to the neck in rear, near-side, or far-side crashes, as well as to the face in rear crashes, there are less than 25 injured occupants (unweighted) in each category, making analysis of trends for these crash types and body regions unreliable. These categories are indicated with * on each plot.
- For AIS3+ injury to the neck in any type of crash, as well as to the face, abdomen, and upper extremity in rear crashes, there are less than 25 injured occupants (unweighted) in each category, making analysis of trends for these crash types and body regions unreliable. These categories are indicated with * on each plot.
- Frontal crashes have the highest proportion of AIS2+ and AIS3+ lower extremity injuries.
- Rollovers have the highest proportion of AIS2+ spine injuries, while rear impacts have the highest proportion of AIS3+ spine injuries.
- Near-side impacts have the highest proportion of AIS2+ and AIS3+ thorax and abdomen injuries.
- More than half of AIS2+ injuries to occupant body regions in rear impacts are to the head.
- Risk of AIS2+ injury is highest in rollovers for all body regions. The same is true for AIS3+ to all body regions, except the highest risk of lower extremity injury is in near-side crashes.
- Risk of AIS2+ is highest for the head among all crash types, except for lower extremities in frontal crashes. Risk of AIS3+ injury is highest to the thorax among all crash types, except for the head in rear impacts.
- For several body regions in different subcrash groups, there are less than 25 injured occupants (unweighted) in each category, making analysis of trends for these crash types and body regions unreliable. These categories are indicated with * on each plot.

- For AIS2+ injuries in frontal subcrashes, the lower extremities have the highest proportion of injuries occurring in full frontal and center crashes; the spine has the highest proportion of injuries occurring in left SOI, while the face has the highest proportion in right SOI.
- For all body regions but the abdomen, the highest proportion of AIS3+ injuries among rollover types occurs in 3-6 QT rollovers, followed by 1-2 QT rollovers.
- Among frontal subcrash types, AIS3+ injury risk is highest in center impacts for all body regions.

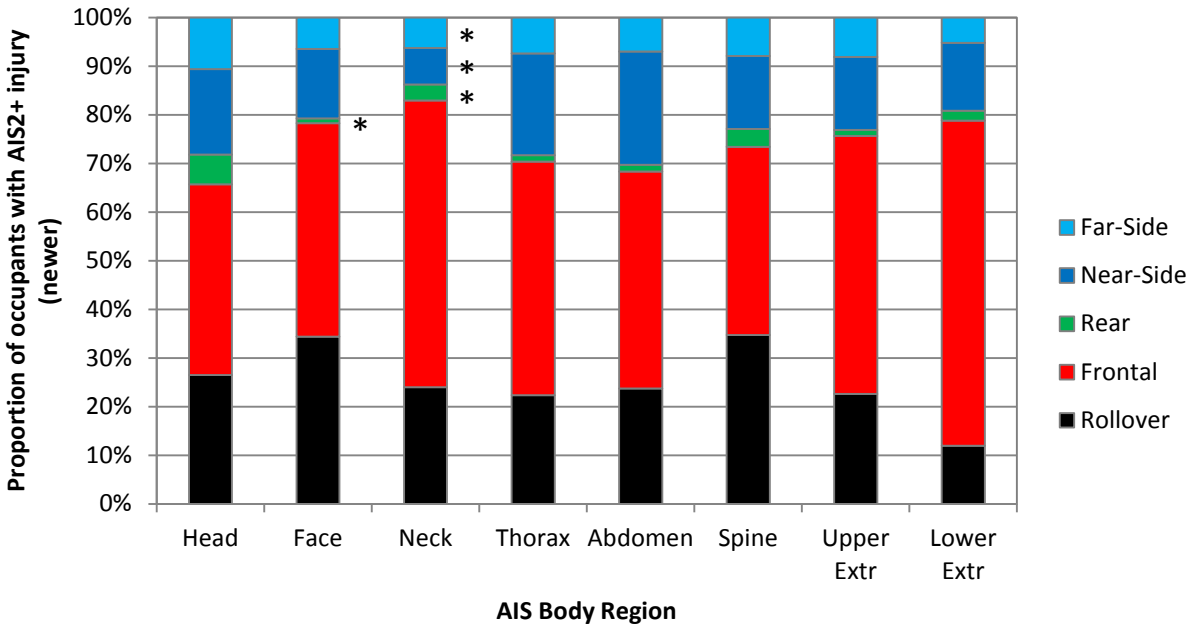


Figure 33. Proportion of occupants with AIS2+ injury by crash mode for each AIS body region.

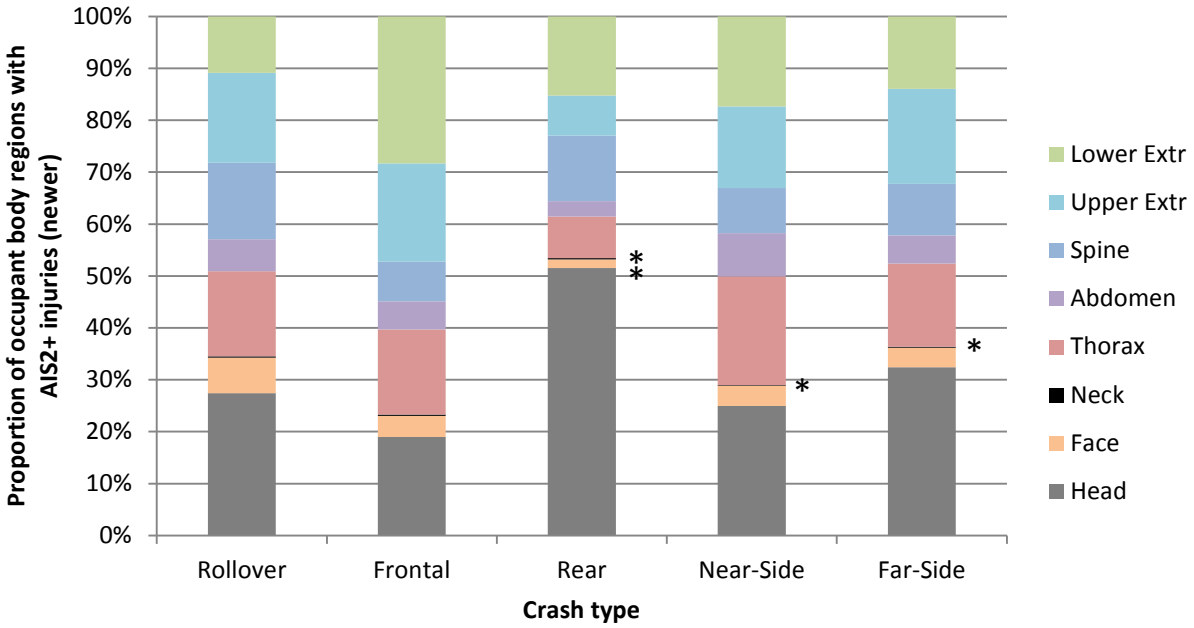


Figure 34. Proportion of occupant body regions with AIS2+ injury by AIS body region for each crash mode.

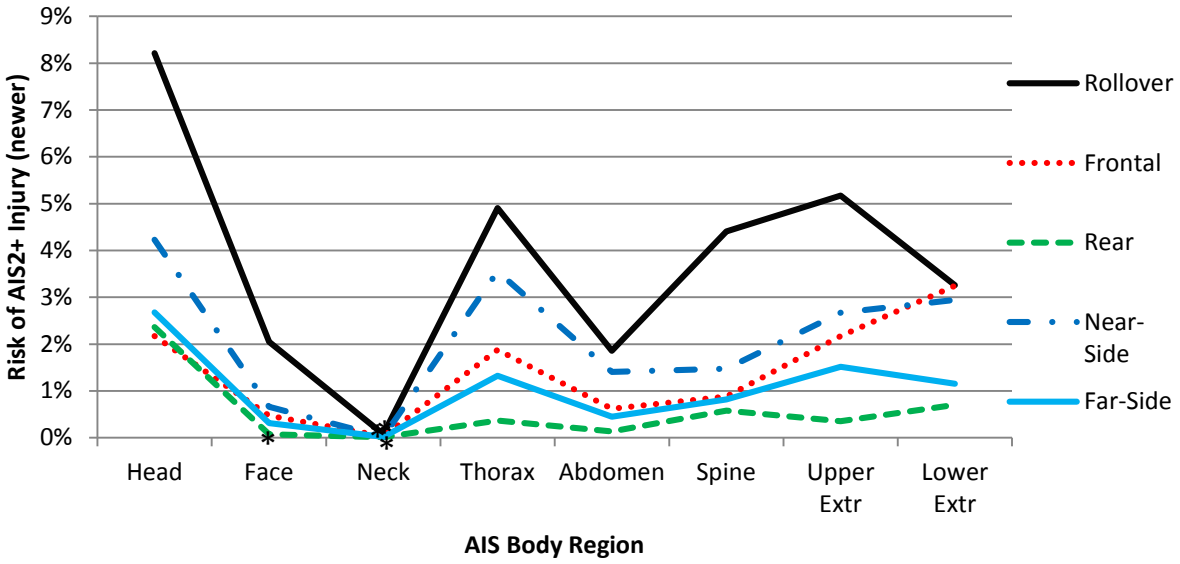


Figure 35. Risk of AIS2+ injuries by crash mode for each AIS body region.

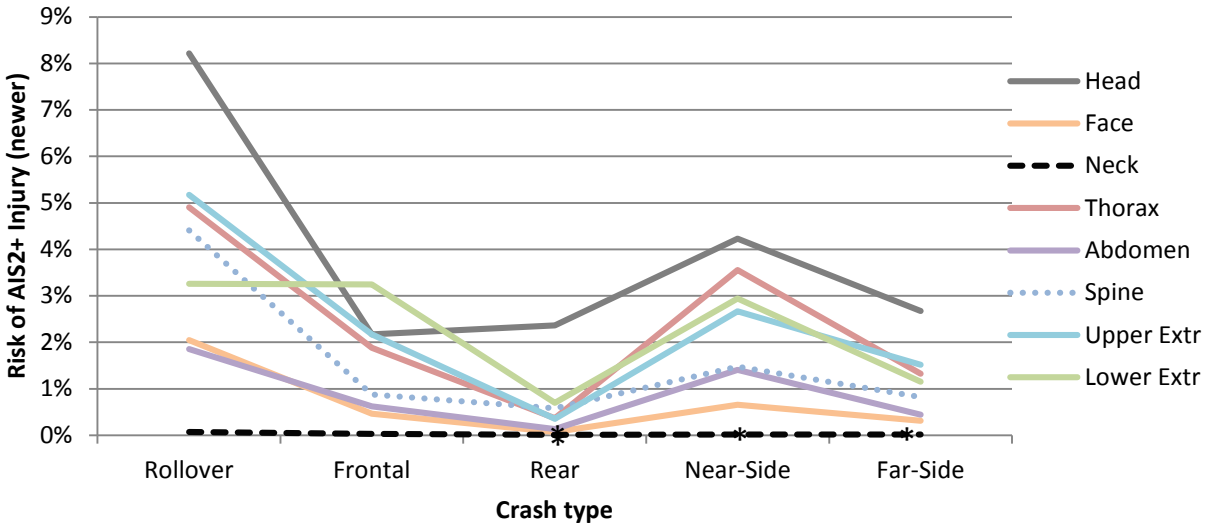


Figure 36. Risk of AIS2+ injury by AIS body region for each crash mode.

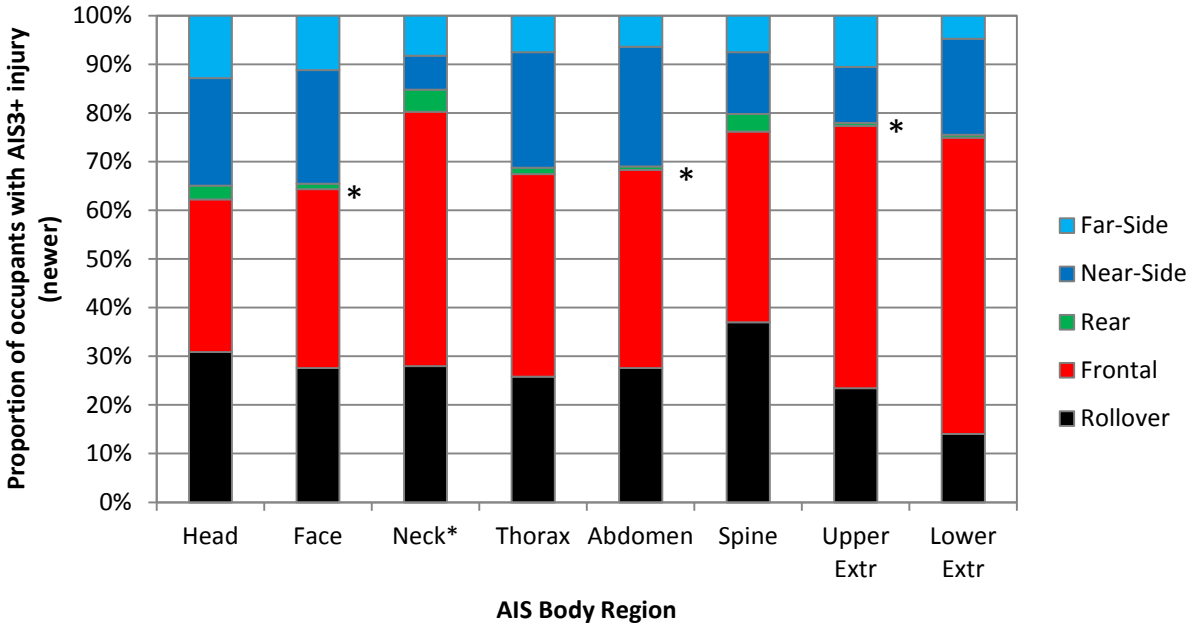


Figure 37. Proportion of occupant body regions with AIS3+ injury by crash mode for each AIS body region.

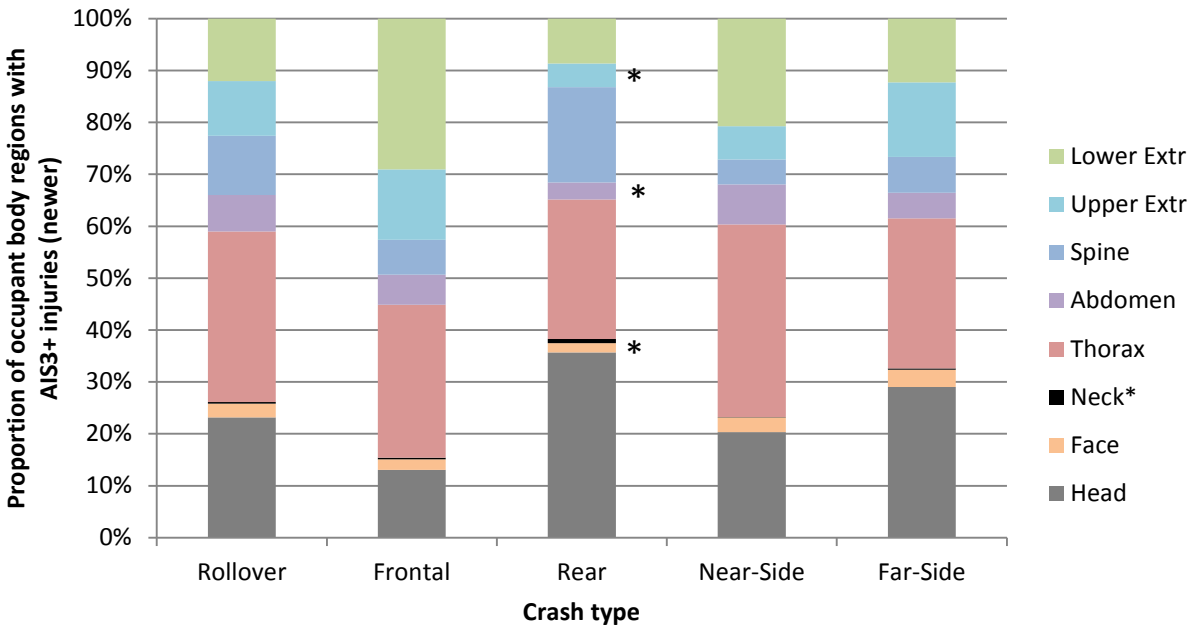


Figure 38. Proportion of occupant body regions with AIS3+ injury by AIS body region for each crash mode.

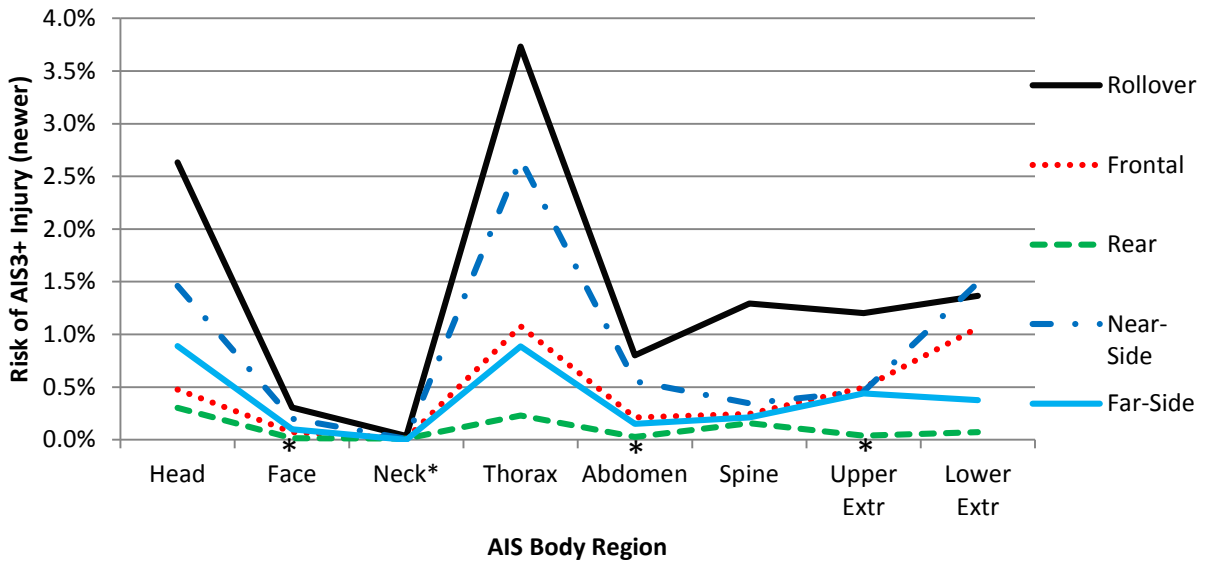


Figure 39. Risk of AIS3+ injury by crash mode for each AIS body region.

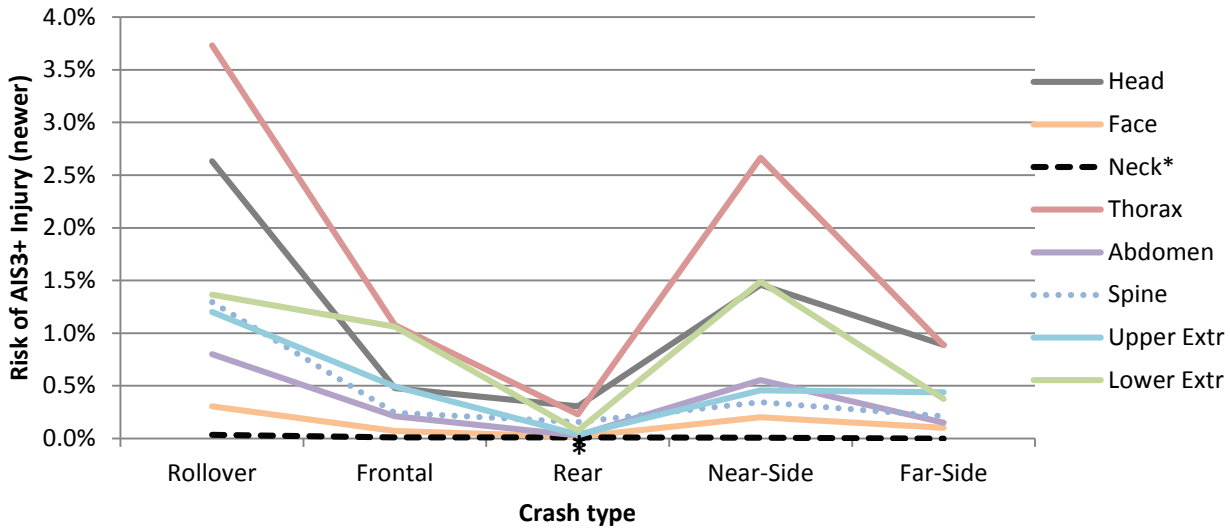


Figure 40. Risk of AIS3+ injury by AIS body region for each crash mode.

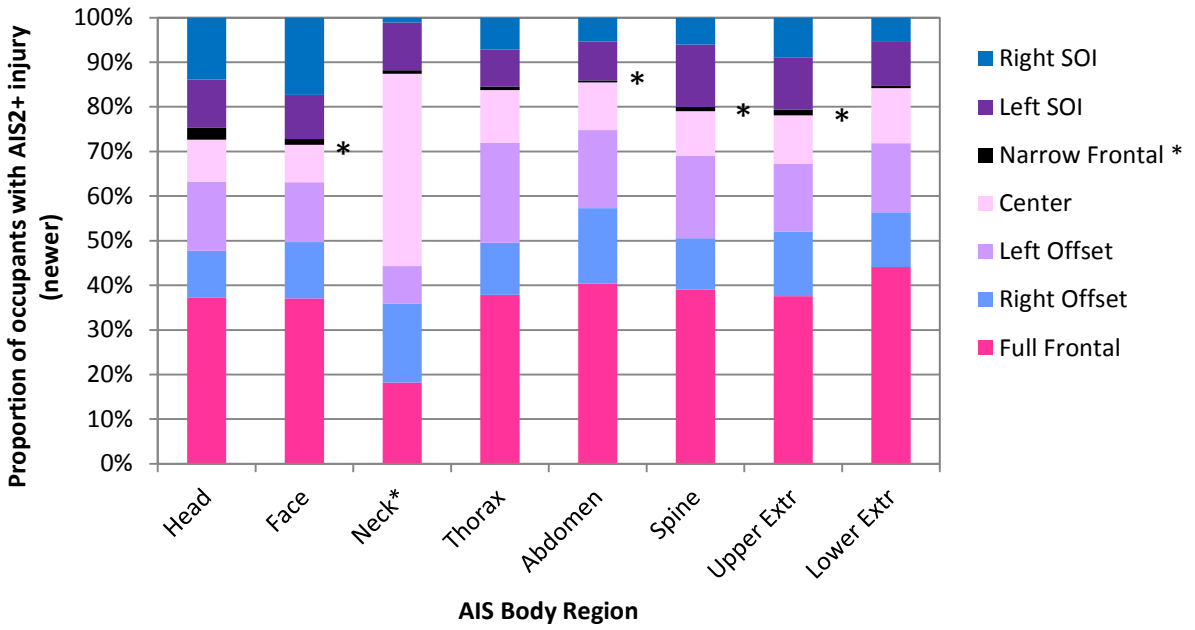


Figure 41. Proportion of occupant body regions with AIS2+ injury by frontal subcrash type for each body region.

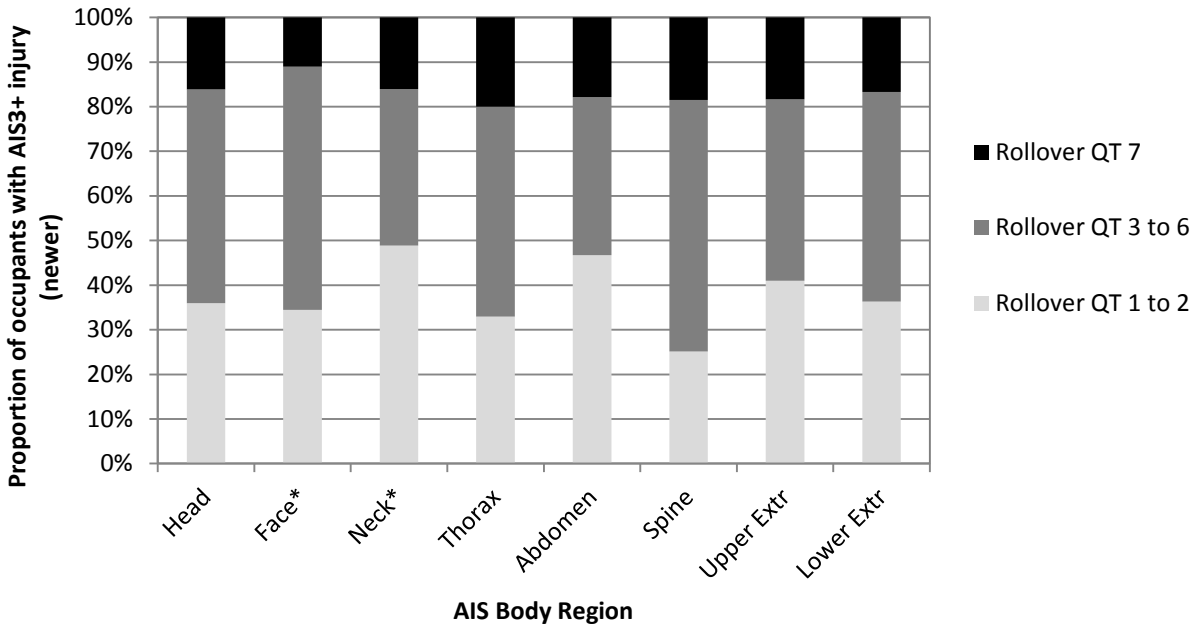


Figure 42. Proportion of occupant body regions with AIS3+ injury by rollover type for each body region.

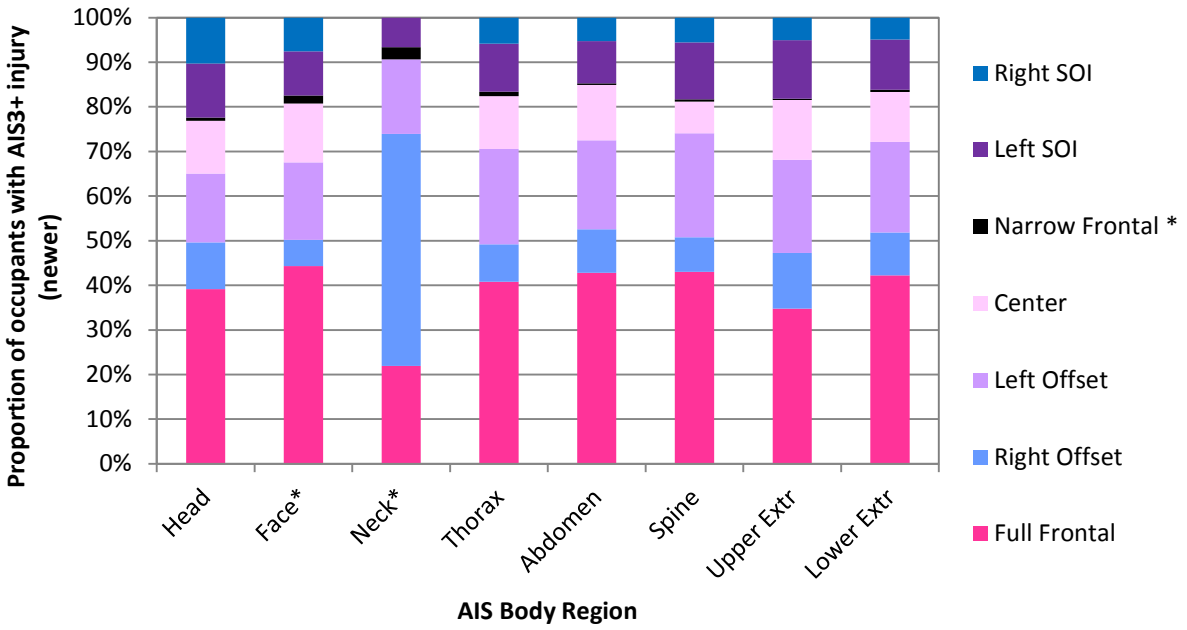


Figure 43. Distribution of AIS3+ injuries by frontal subcrash type for each body region.

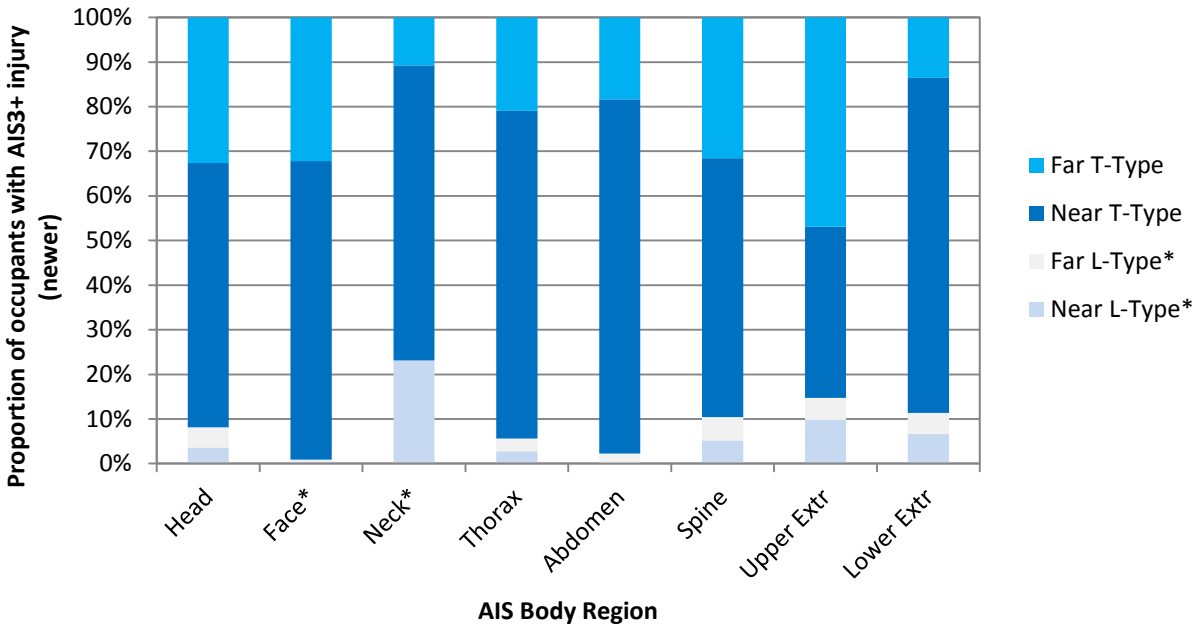


Figure 44. Distribution of AIS3+ injuries by side subcrash type for each body region.

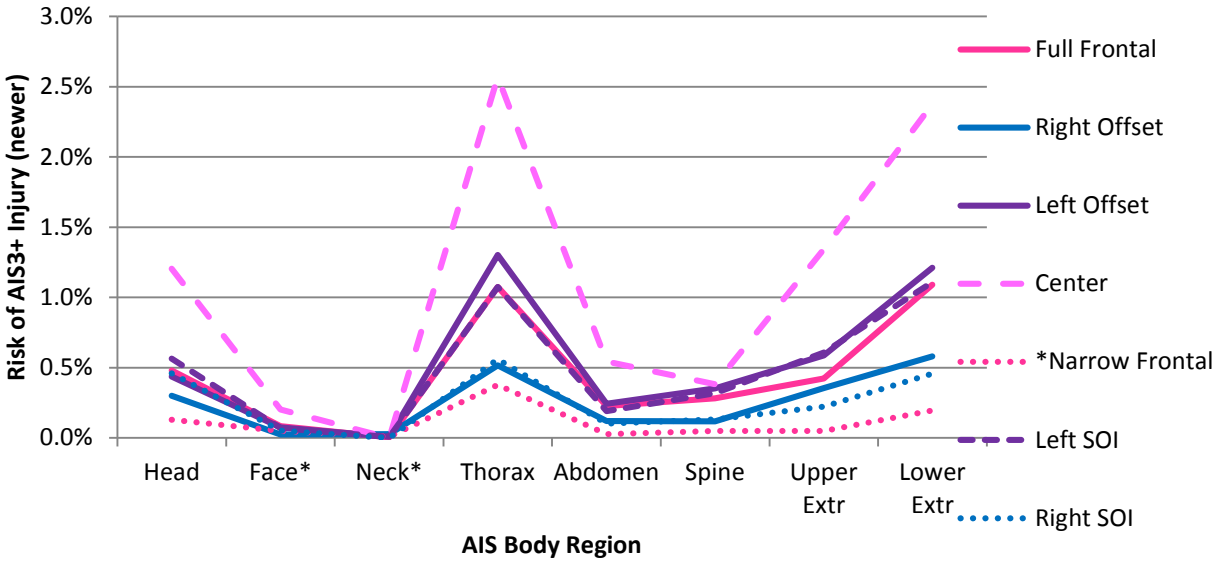


Figure 45. Risk of AIS3+ injury by frontal subcrash type for each body region.

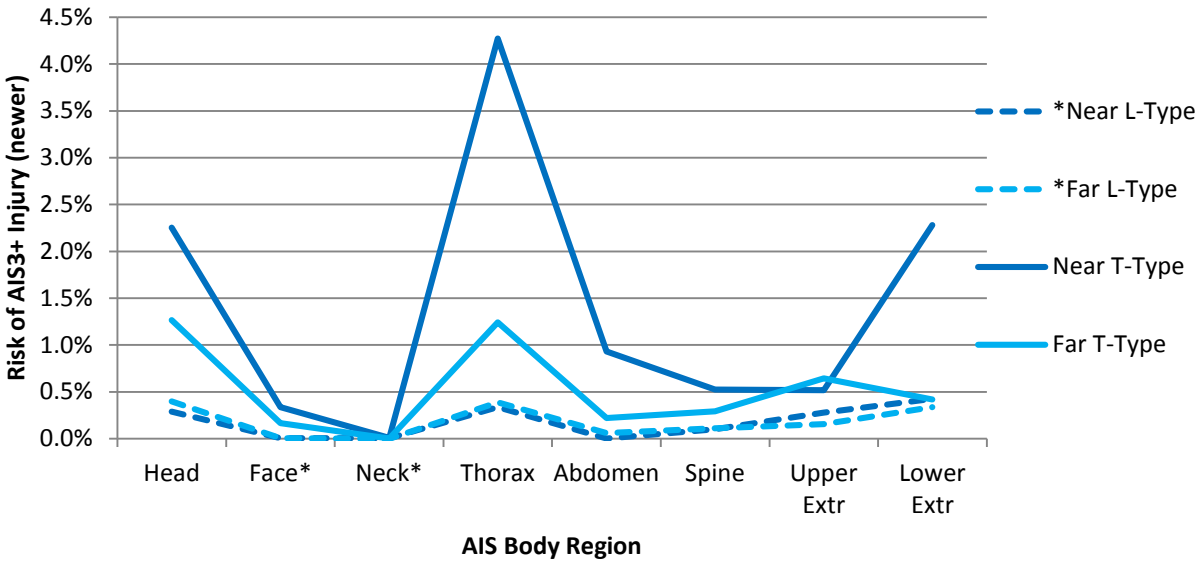


Figure 46. Risk of AIS3+ injury by side subcrash type for each body region.

Chapter 4. Injuries by Occupant Belt Restraint

Crash Mode by Belt Restraint

- In the dataset used for occupants with known belt use and injury level, 82% of occupants used the 3-point belt, 2% used a lap belt only, and 16% were unbelted.
- Among AIS2+ injured occupants, there were less than 25 unweighted occupants using lap belts in rear impacts and in most subcrash categories. As a result, analysis of injury trends with lap belts for these cases is unreliable. They are indicated with an * on the plots.
- Among AIS3+ injured occupants, there were less than 25 unweighted occupants using lap belts in most subcrash categories and in rear, rollover, and far-side impacts. In addition, there were low numbers of unweighted occupants in narrow frontal crashes. As a result, analysis of injury trends for these cases is unreliable. They are indicated with an * on the plots.
- For AIS2+ injured occupants, unbelted occupants make up over more than 40% of those in rollovers and in far-side crashes. For AIS3+ injured occupants, unbelted occupants make up between 45-55% of injured occupants in all crash types except for near-side.
- Risk of AIS2+ and AIS3+ injury is highest for unbelted occupants in all crash types.
- For each rollover type, unbelted occupants have an AIS2+ injury risk 2 to 3 times higher than occupants using three-point belts, while the ratio averages to 3.5 for AIS3+ injuries.

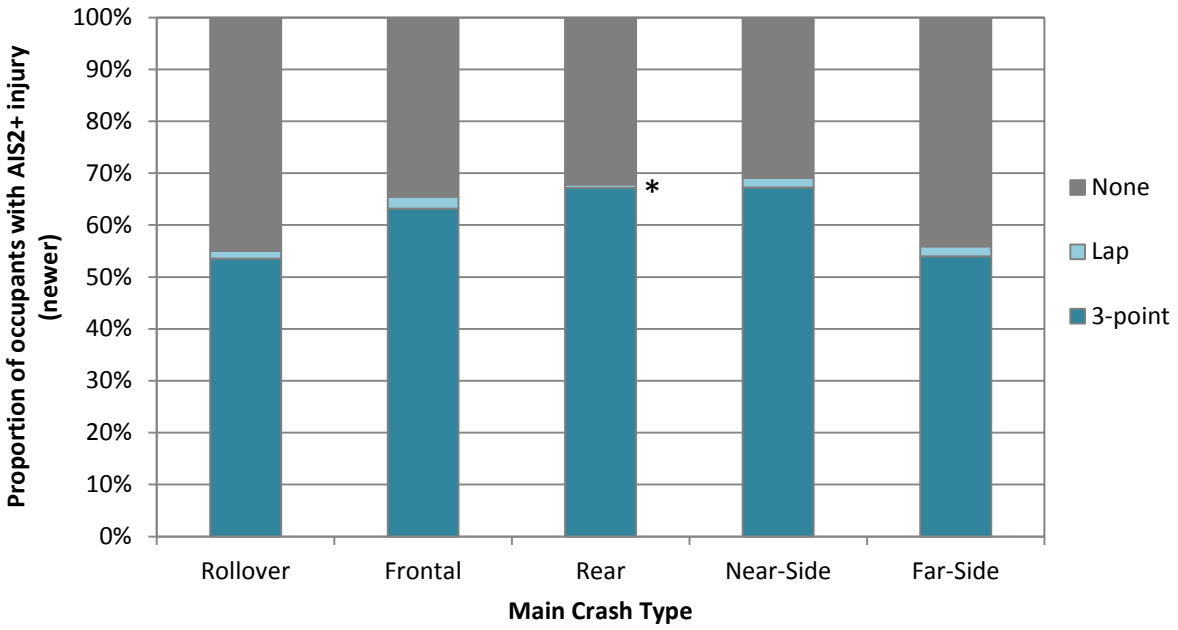


Figure 47. Proportion of occupants with AIS2+ injury by belt restraint for each crash type.

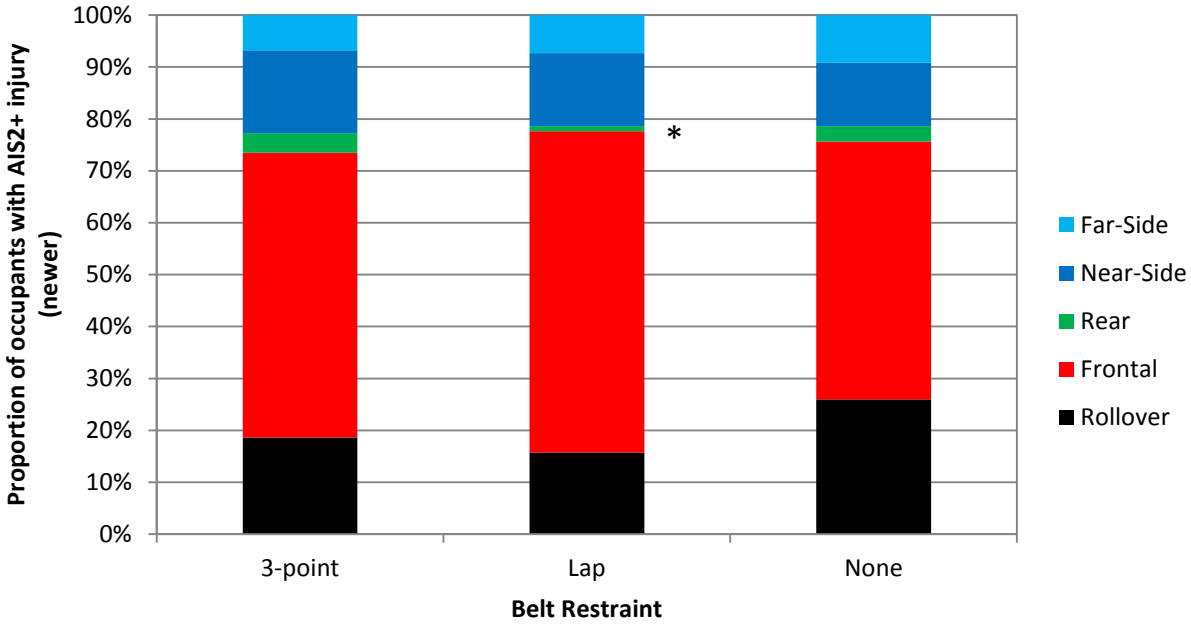


Figure 48. Proportion of occupants with AIS2+ injury by crash type for each belt restraint.

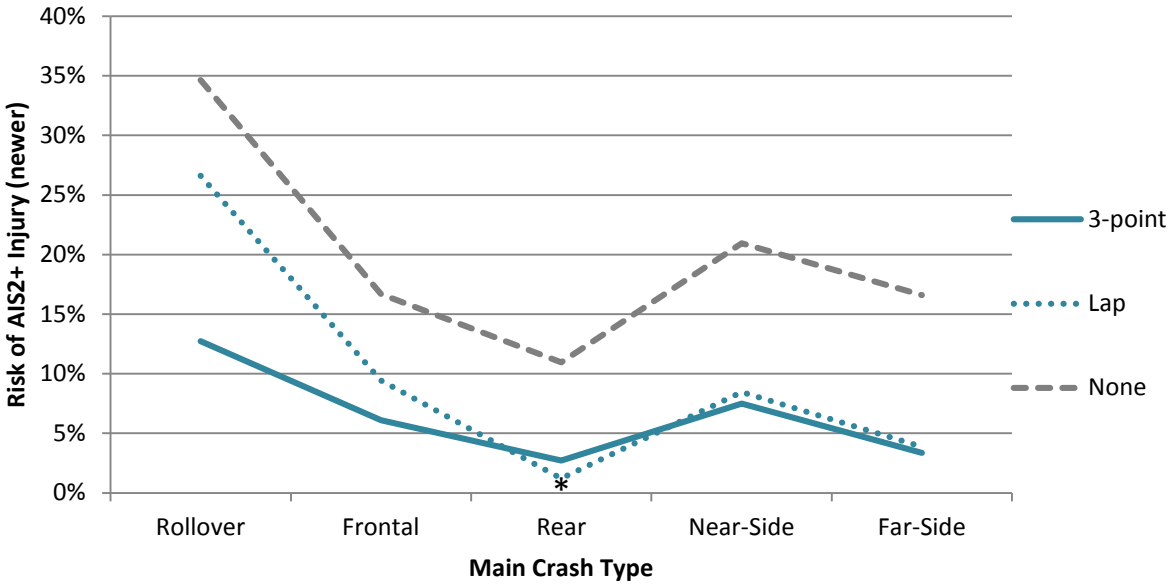


Figure 49. Risk of AIS2+ injury by belt restraint for each crash mode.

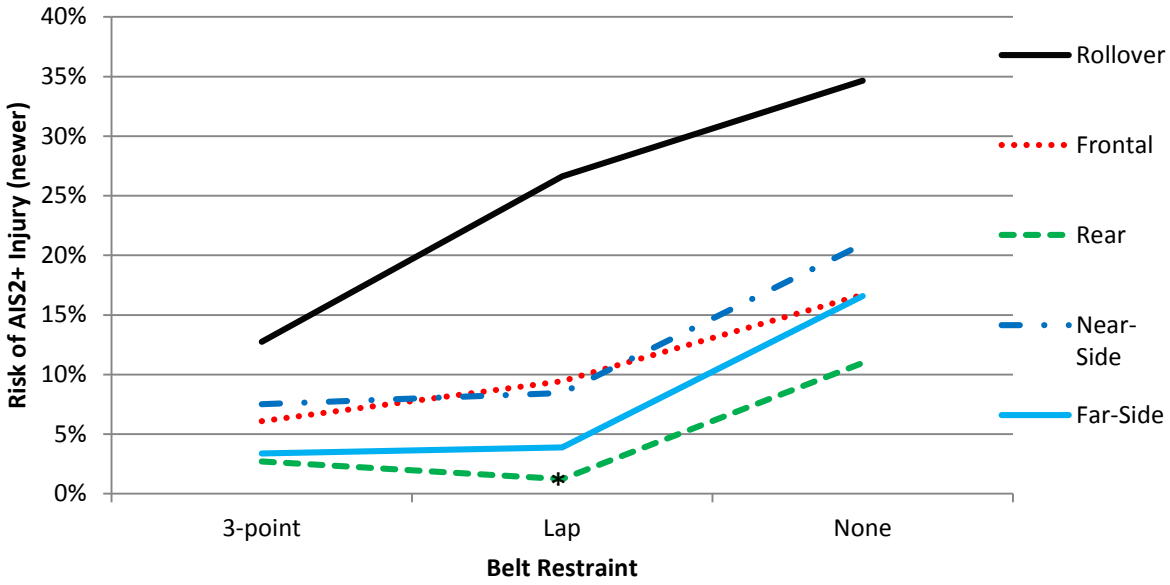


Figure 50. Risk of AIS2+ injury by crash mode for each belt restraint.

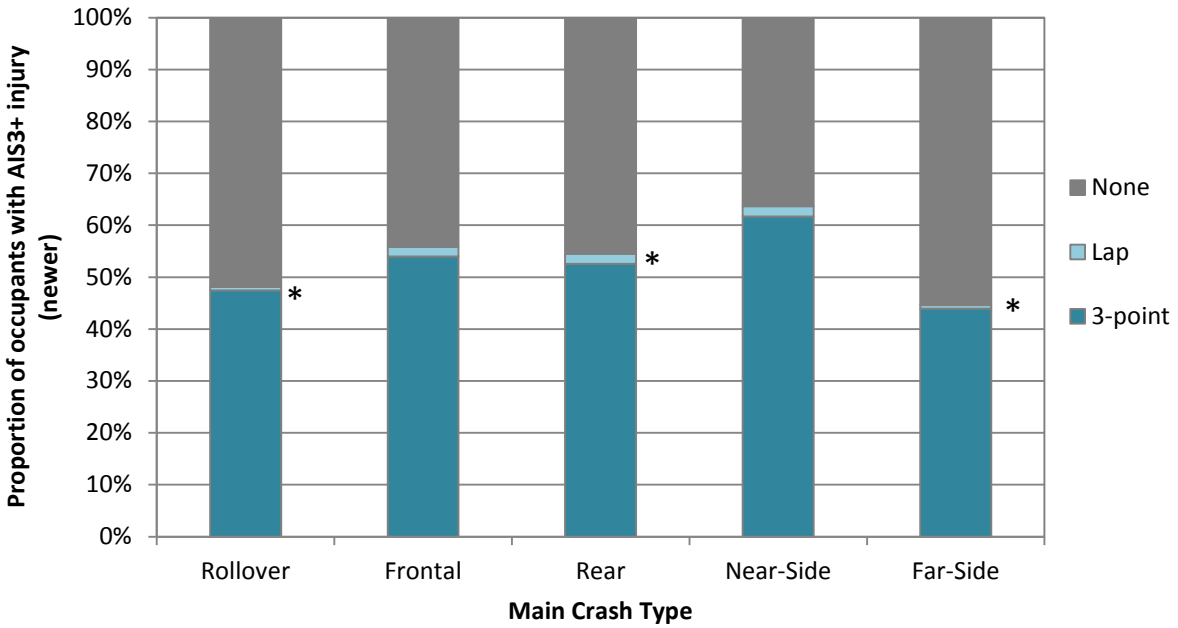


Figure 51. Proportion of occupants with AIS3+ injury by belt restraint for each crash mode.

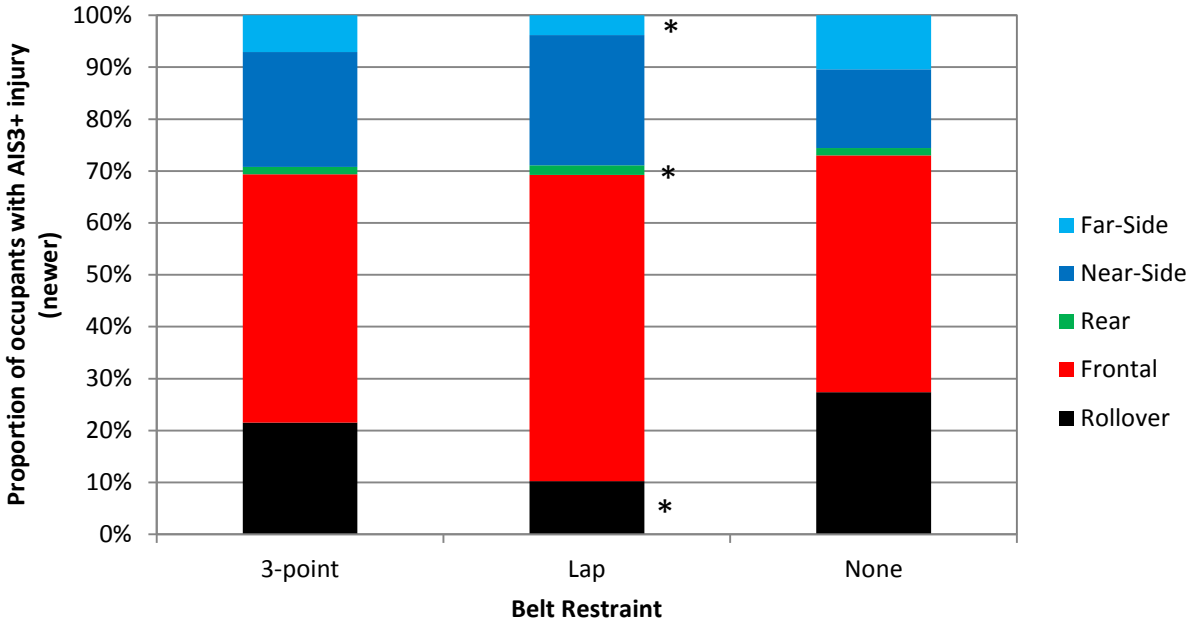


Figure 52. Proportion of occupants with AIS3+ injury by crash mode for each belt restraint.

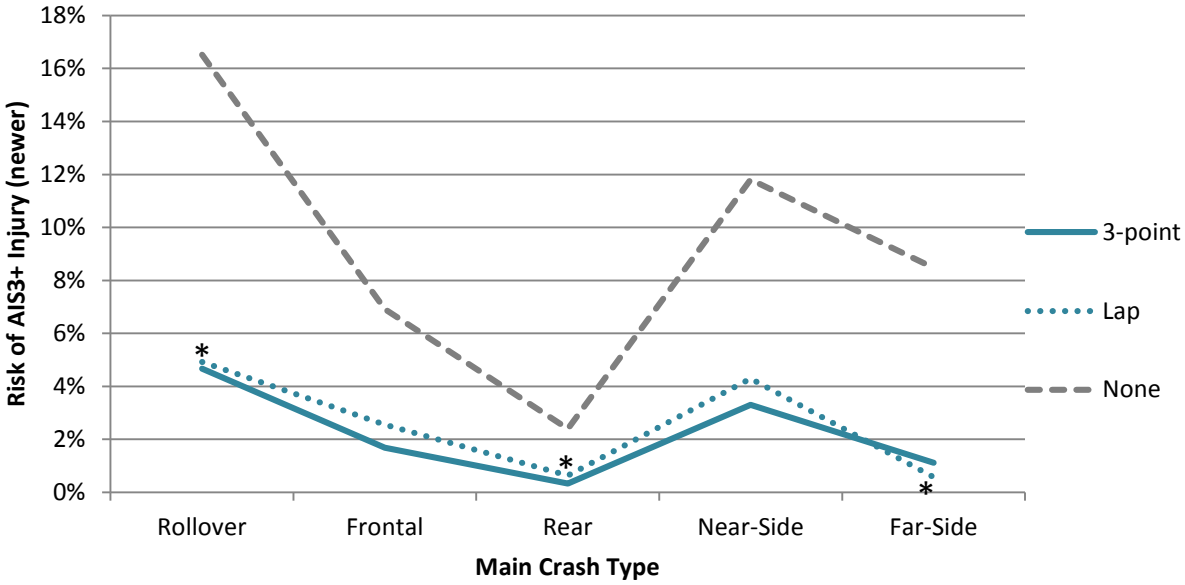


Figure 53. Risk of AIS3+ injury by belt restraint for each crash type.

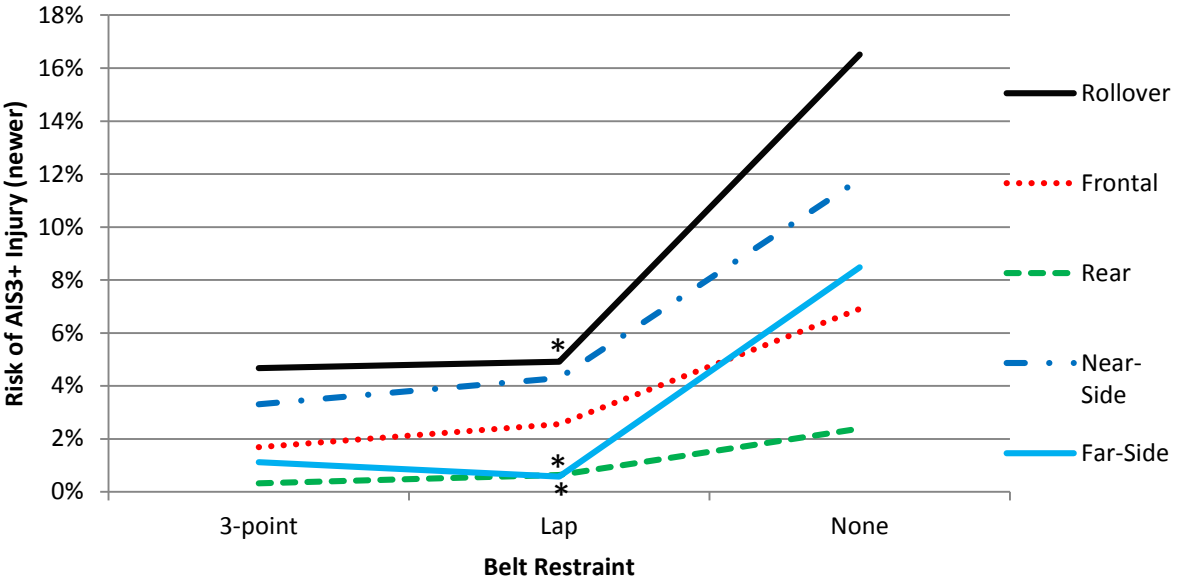


Figure 54. Risk of AIS3+ injury by crash type for each belt restraint.

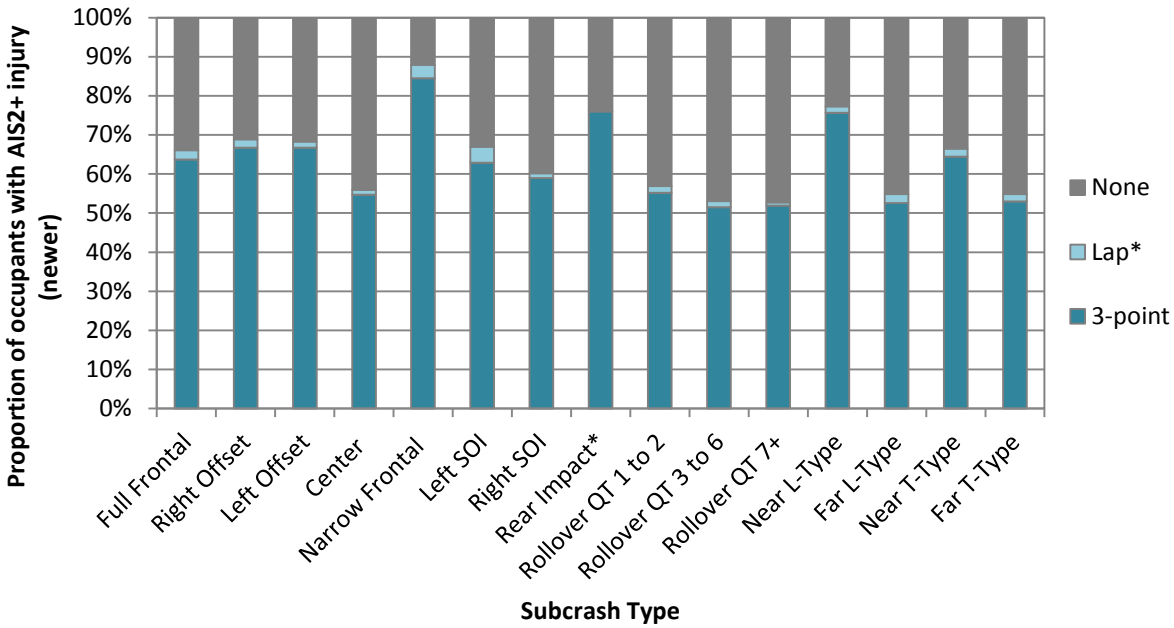


Figure 55. Proportion of occupants with AIS2+ injury by belt restraint for each subcrash type.

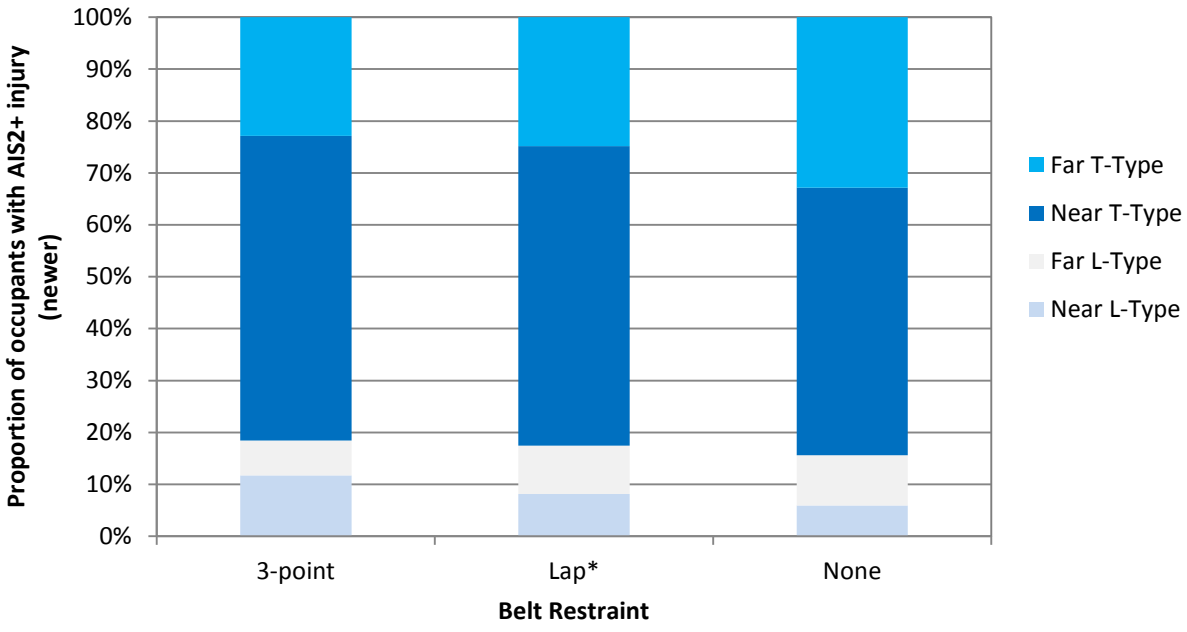


Figure 56. Proportion of occupants with AIS2+ injury by side subcrash type for each belt restraint.

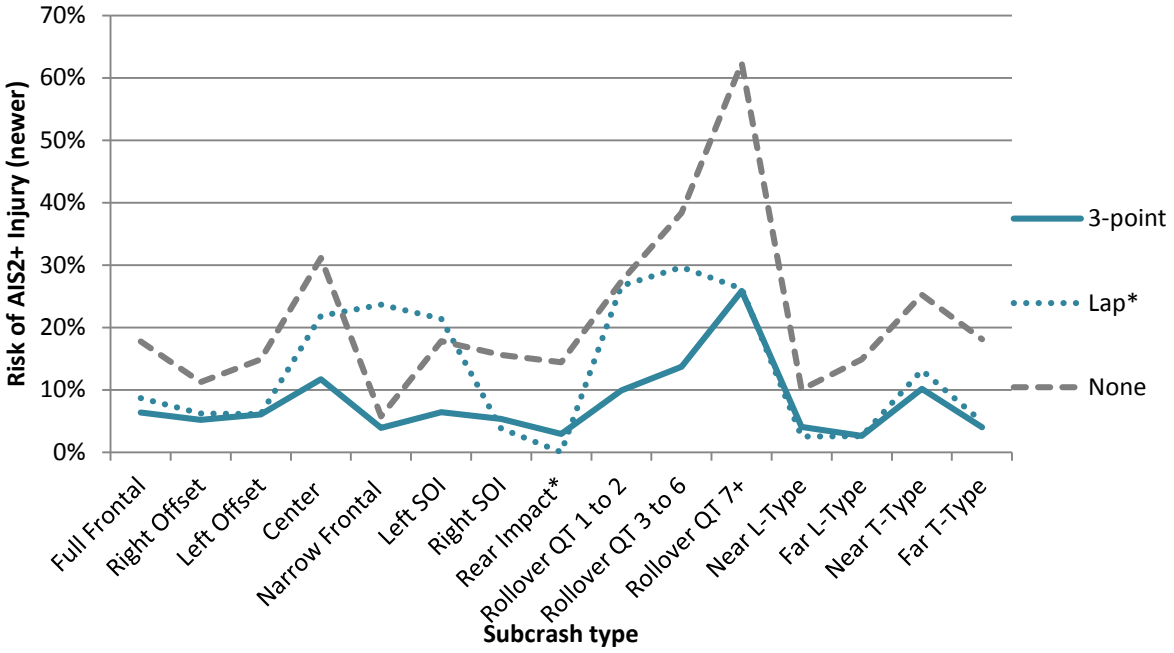


Figure 57. Risk of AIS2+ injury by restraint type for each subcrash type.

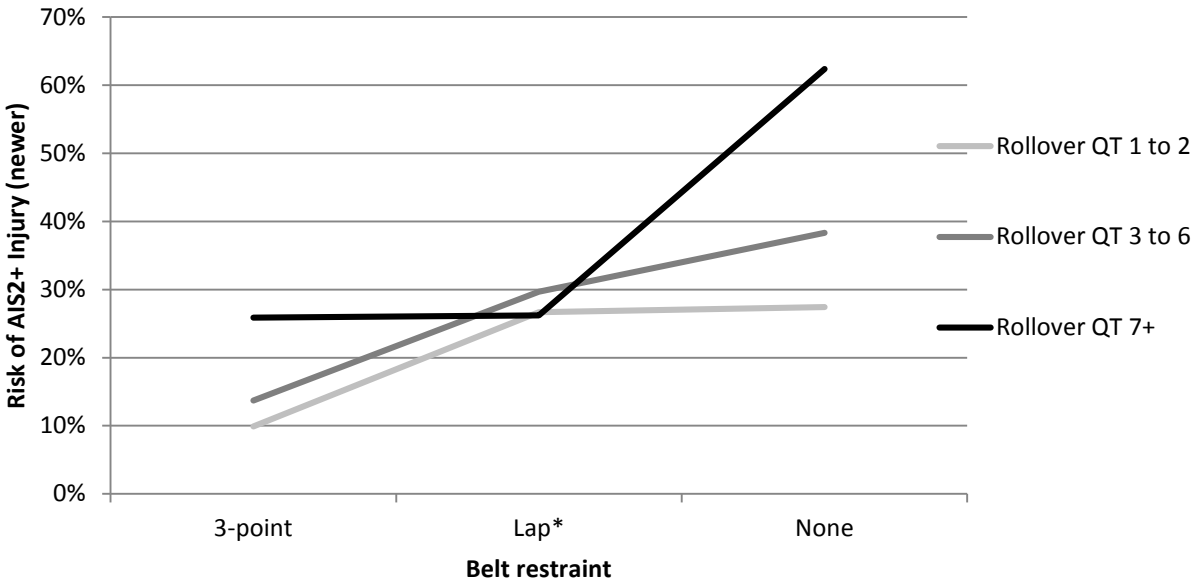


Figure 58. Risk of AIS2+ injury by rollover type for each belt restraint.

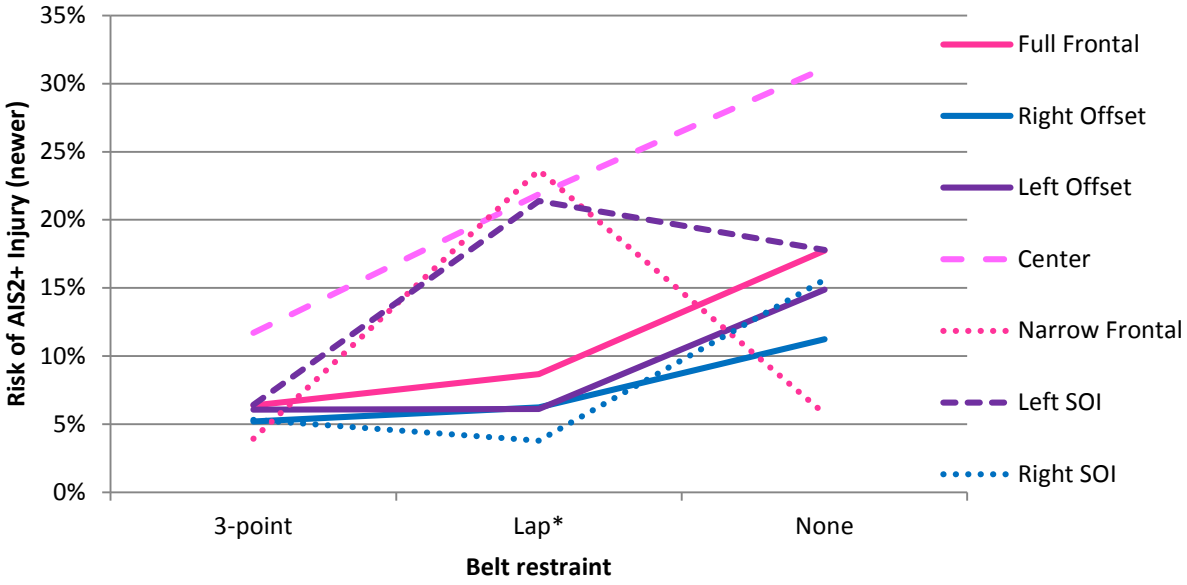


Figure 59. Risk of AIS2+ injury by frontal subcrash type for each belt restraint.

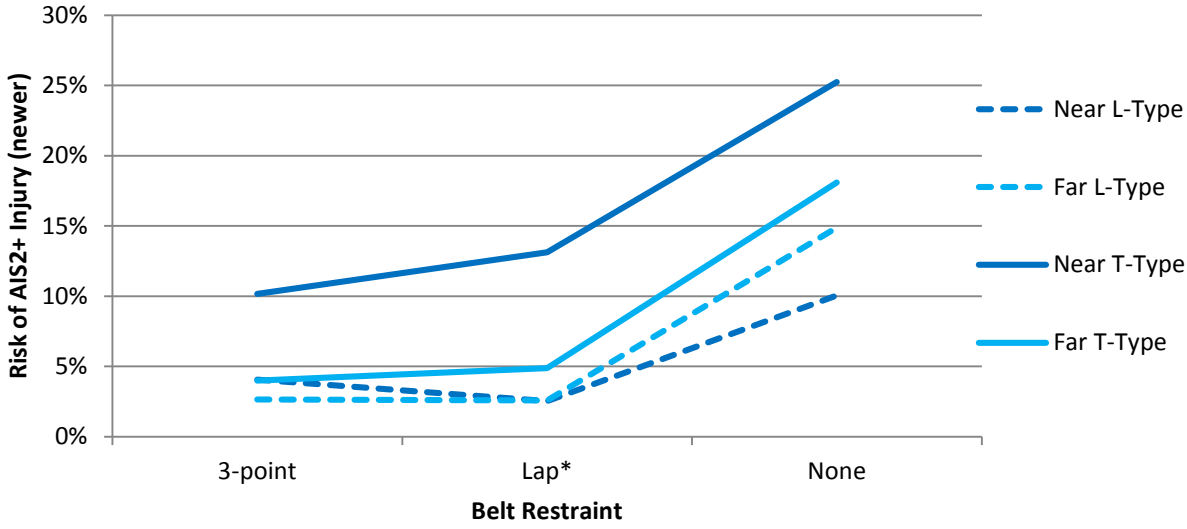


Figure 60. Risk of AIS2+ injury by side subcrash type for each belt restraint.

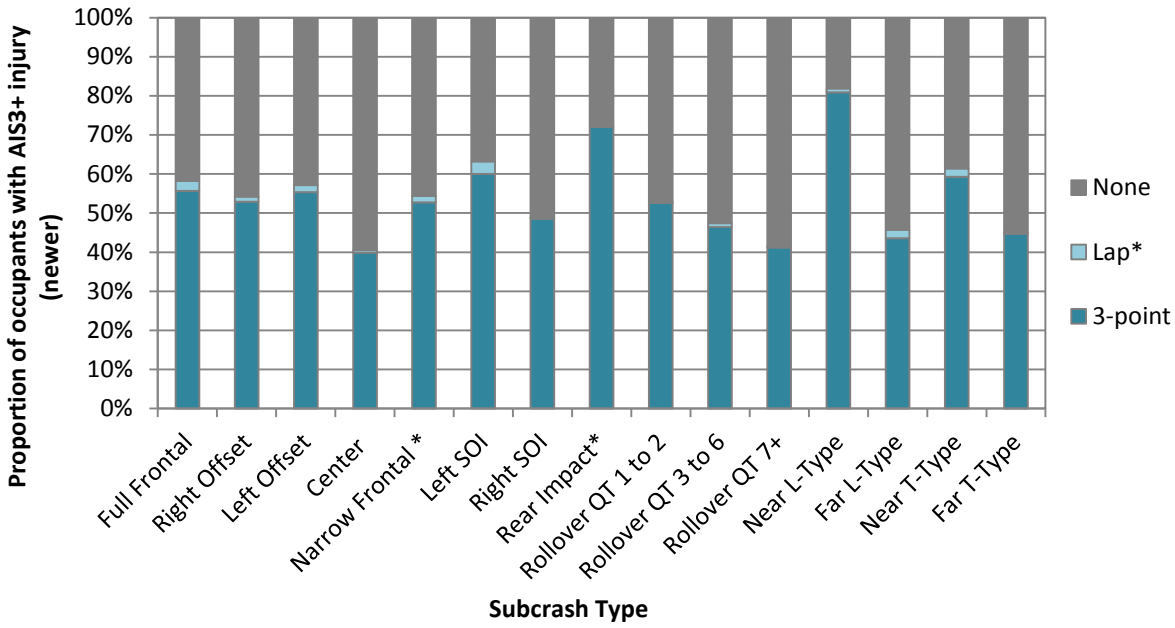


Figure 61. Proportion of occupants with AIS3+ injury by belt restraint for each crash type.

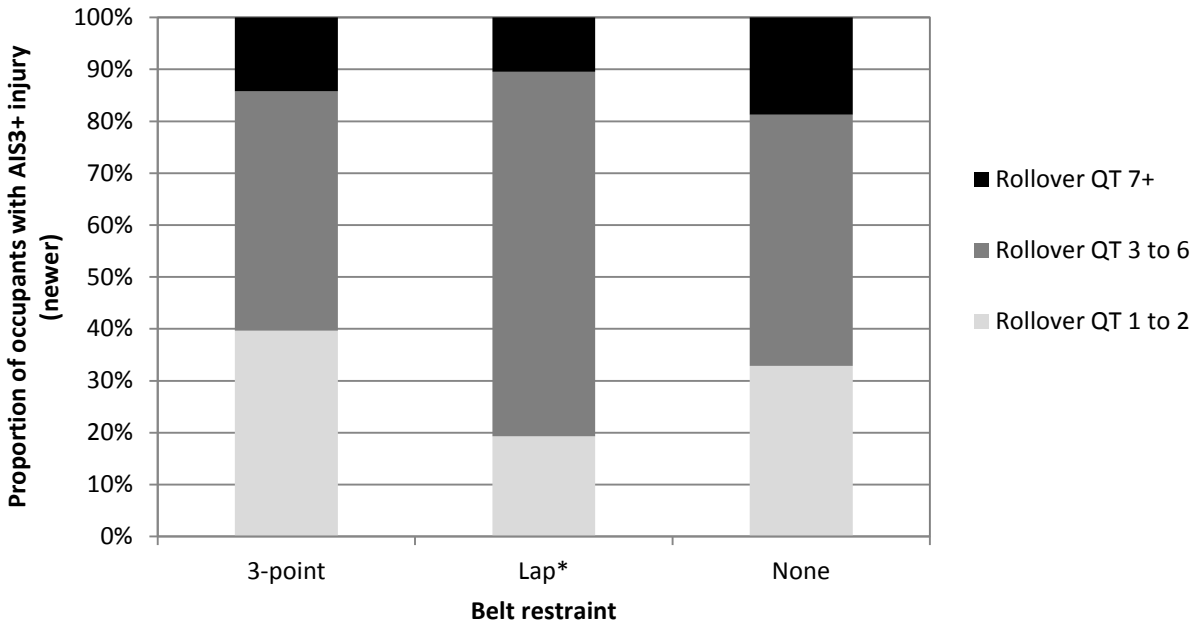


Figure 62. Proportion of occupants with AIS3+ injury by rollover type for each belt restraint.

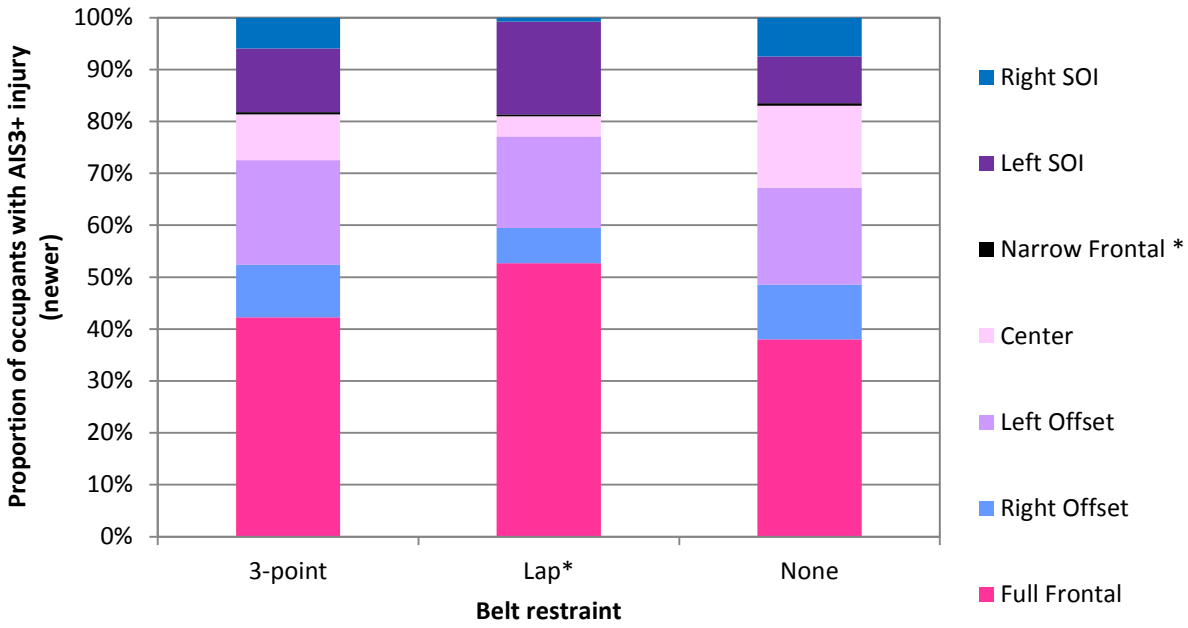


Figure 63. Proportion of occupants with AIS3+ injury by frontal subcrash type for each belt restraint.

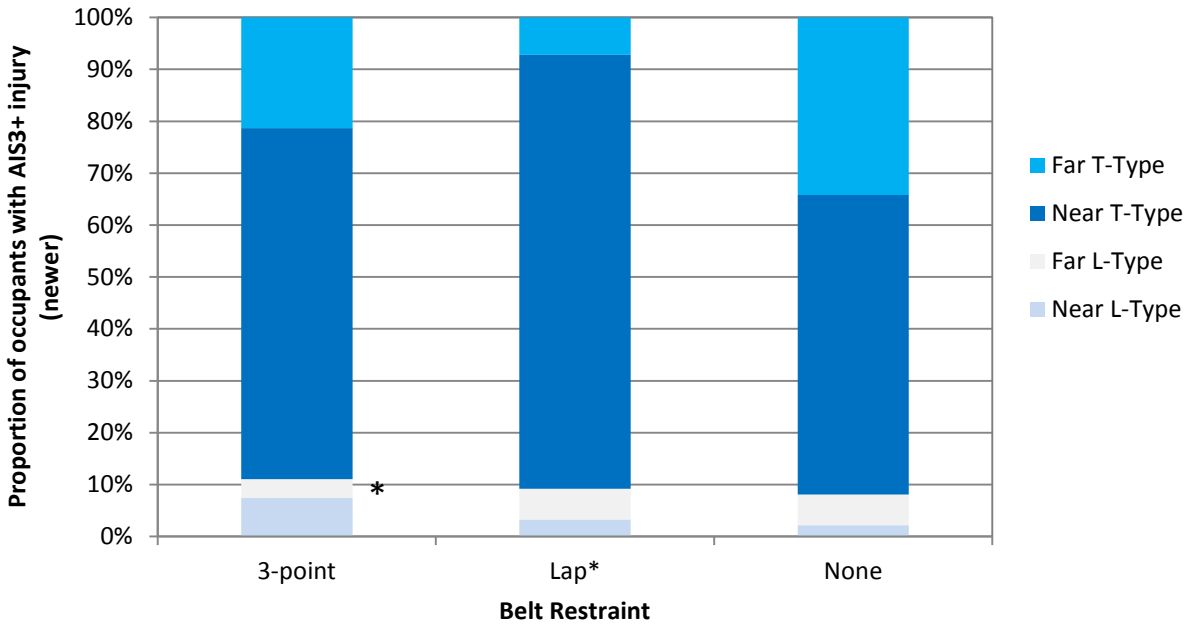


Figure 64. Proportion of occupants with AIS3+ injury by side subcrash type for each belt restraint.

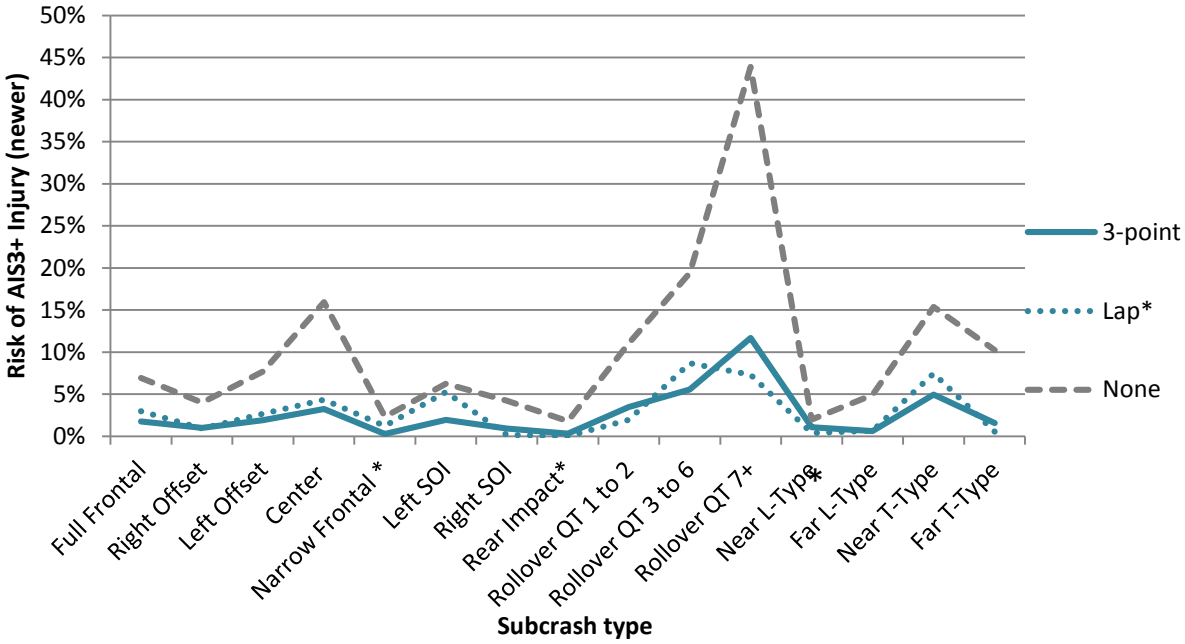


Figure 65. Risk of AIS3+ injury by belt restraint for each subcrash type.

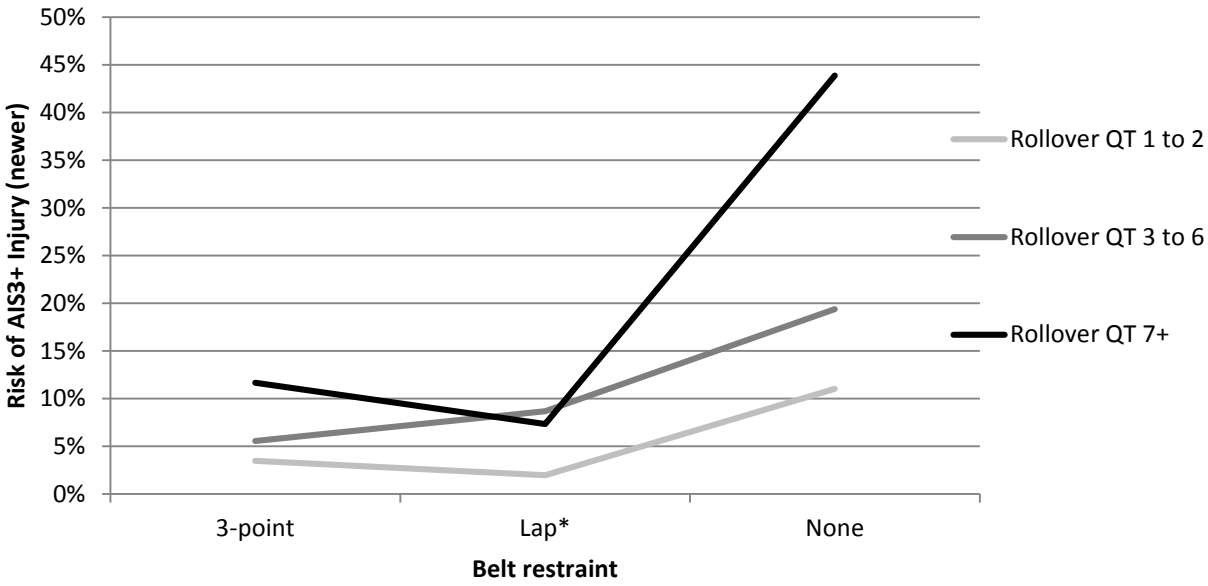


Figure 66. Risk of AIS3+ injury by rollover type for each belt restraint condition.

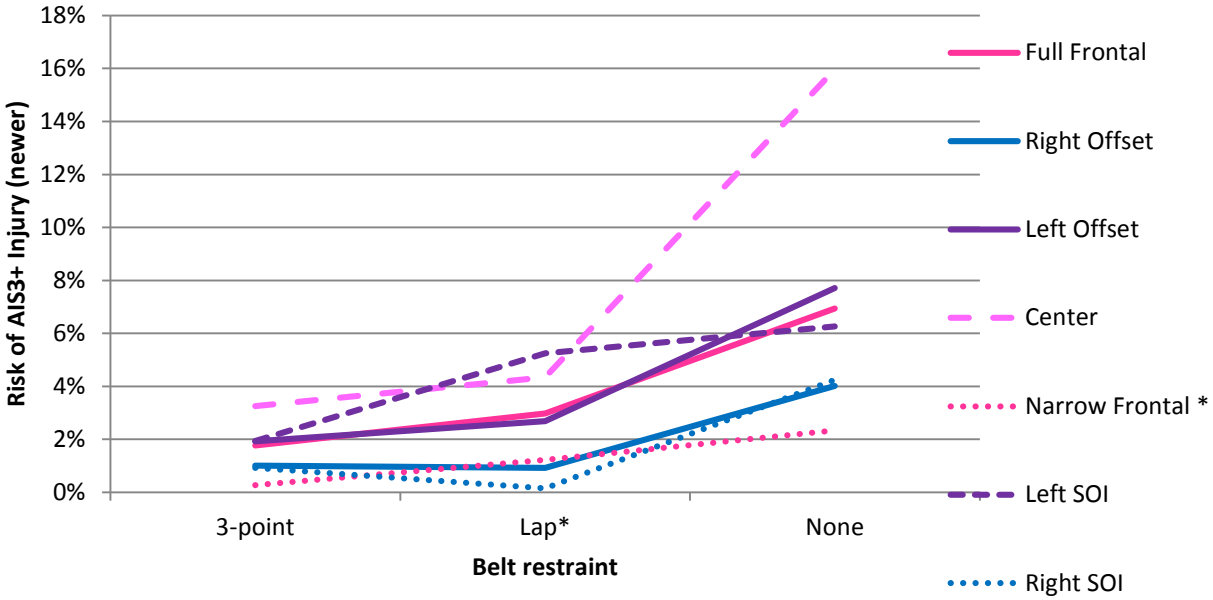


Figure 67. Risk of AIS3+ injury by frontal subcrash type for each belt restraint condition.

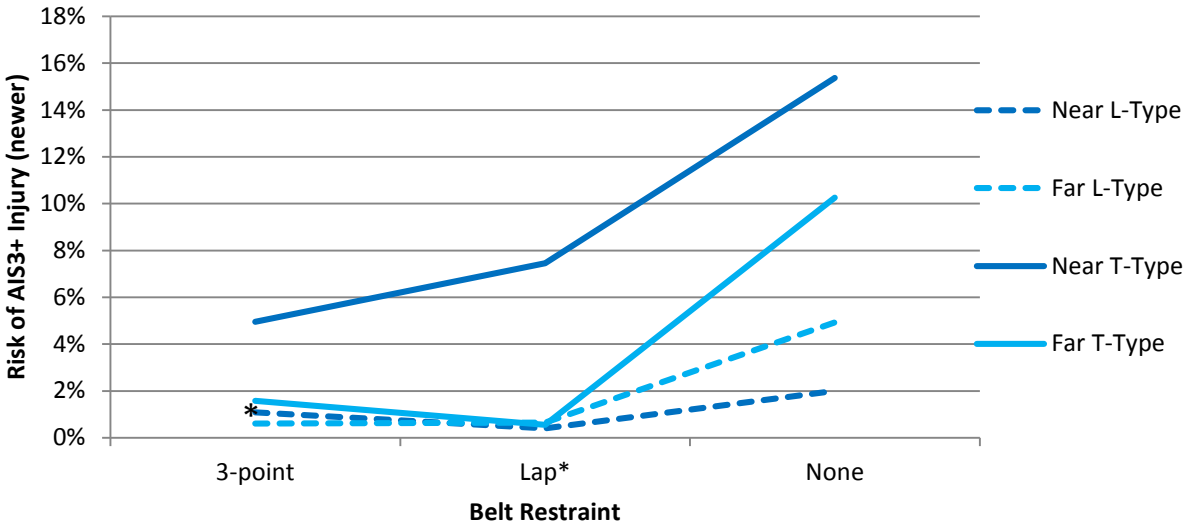


Figure 68. Risk of AIS3+ injury by side subcrash type for each belt restraint condition.

Body Region by Belt Restraint

- Among occupants with AIS2+ injuries, there are less than 25 unweighted occupants using lap belts with injuries to the neck or face. For AIS3+ injuries, the same is true for these body regions as well as the spine and upper extremity. This makes analysis of injury trends for these cases unreliable. They are indicated with an * on the plots.
- Unbelted occupants have greater proportions of AIS2+ head and face injuries among injured body regions compared to occupants using a 3-point belt.
- The risk of AIS2+ injury to any of the AIS body region is 3.2 to 10.1 times higher for unbelted occupants compared to those using a 3-point belt.
- The risk of AIS3+ injury to any of the AIS body region is 3.6 to 6.7 times higher for unbelted occupants compared to those using a 3-point belt.

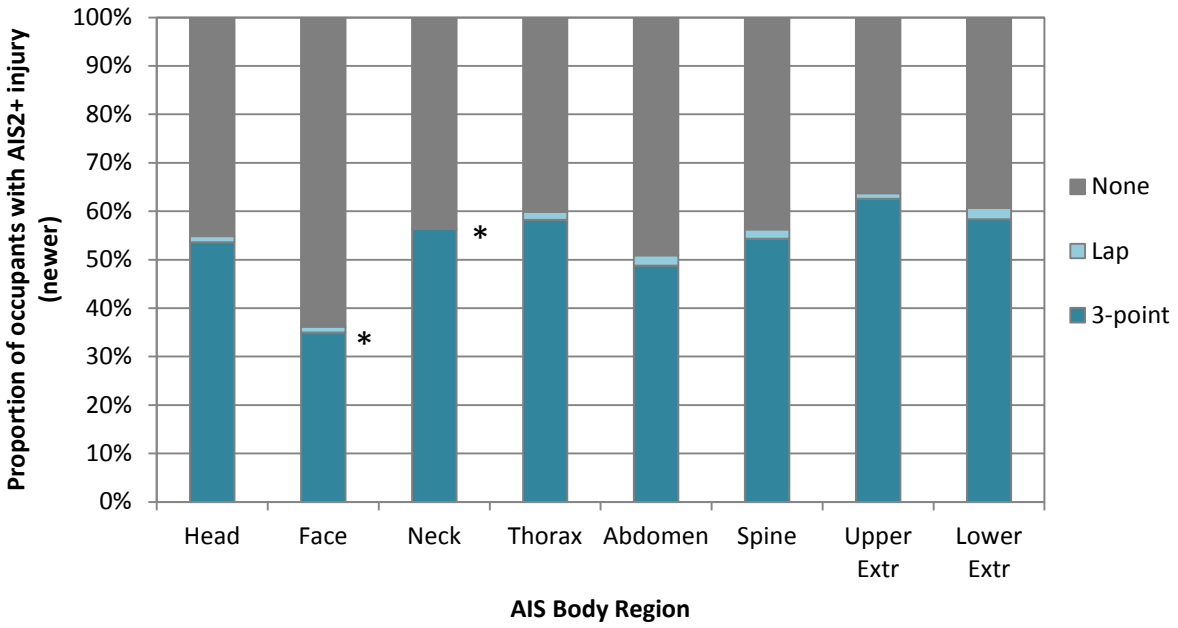


Figure 69. Proportion of occupants with AIS2+ injury by belt restraint for each AIS body region.

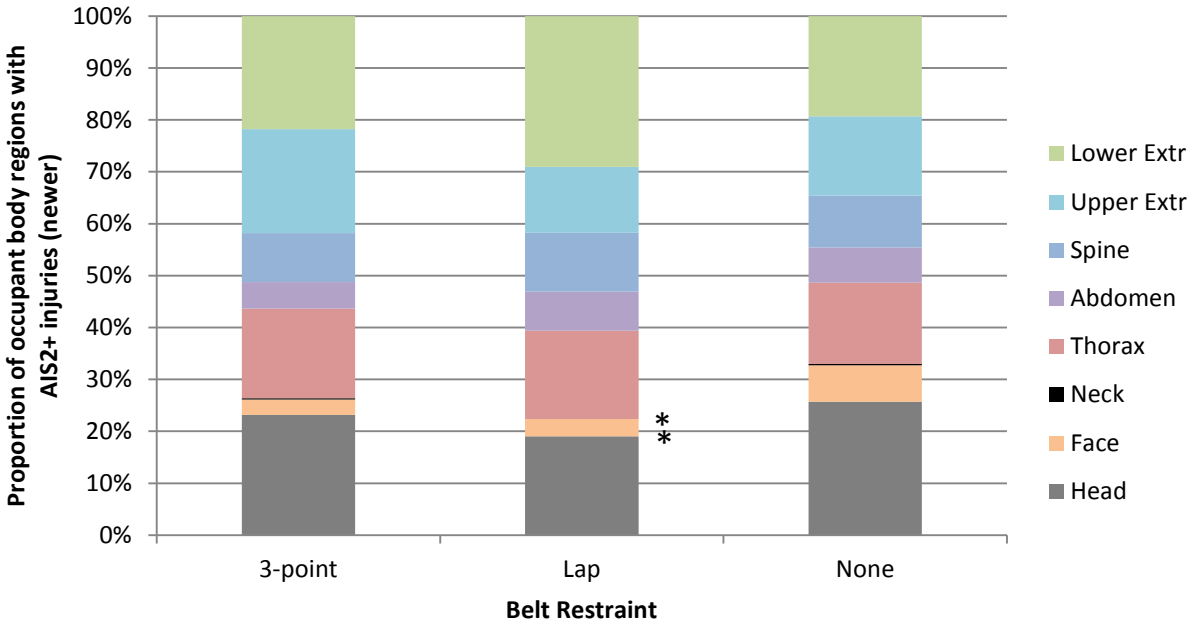


Figure 70. Proportion of occupants with AIS2+ injury by AIS body region for each belt restraint condition.

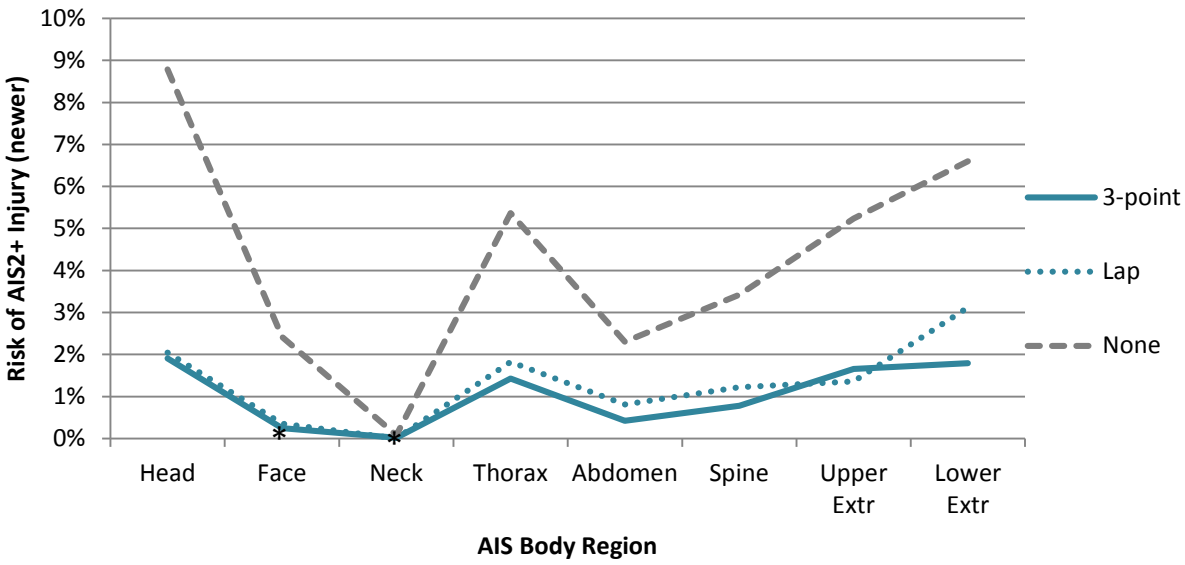


Figure 71. Risk of AIS2+ injury by belt restraint condition for each AIS body region.

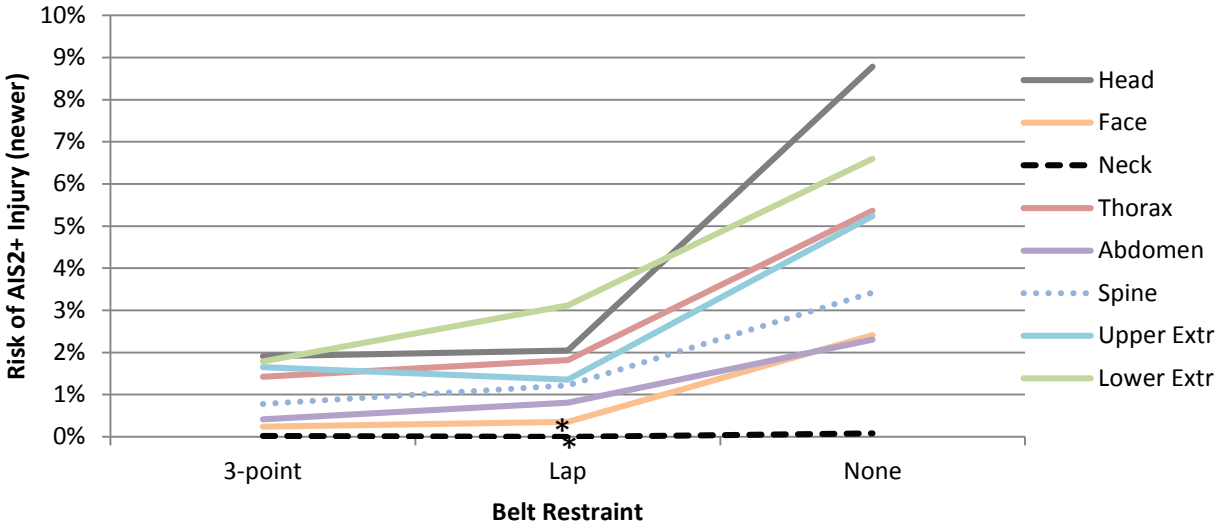


Figure 72. Risk of AIS2+ injury by AIS body region for each belt restraint condition.

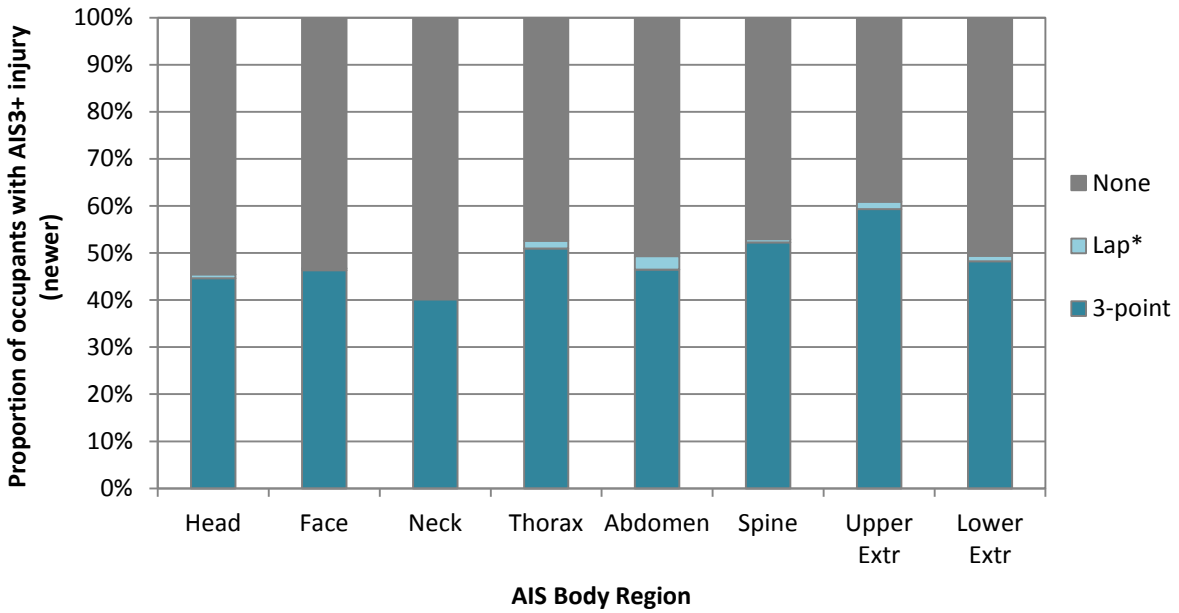


Figure 73. Proportion of occupants with AIS3+ injury by belt restraint for each AIS body region.

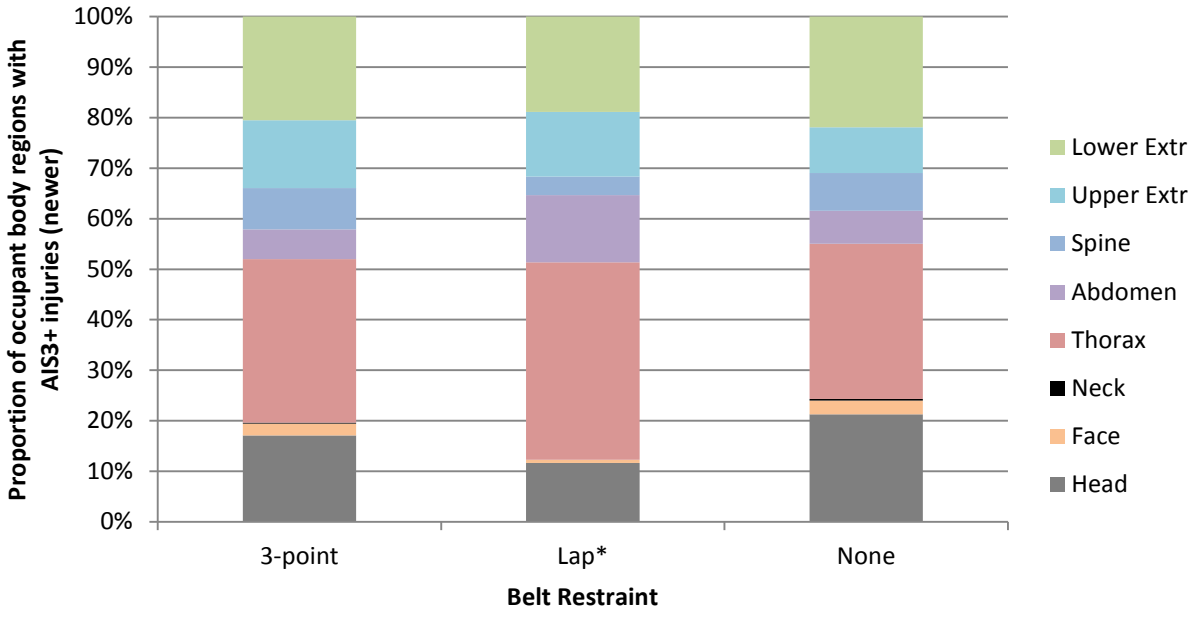


Figure 74. Proportion of occupants with AIS3+ injury by AIS body region for each belt restraint condition.

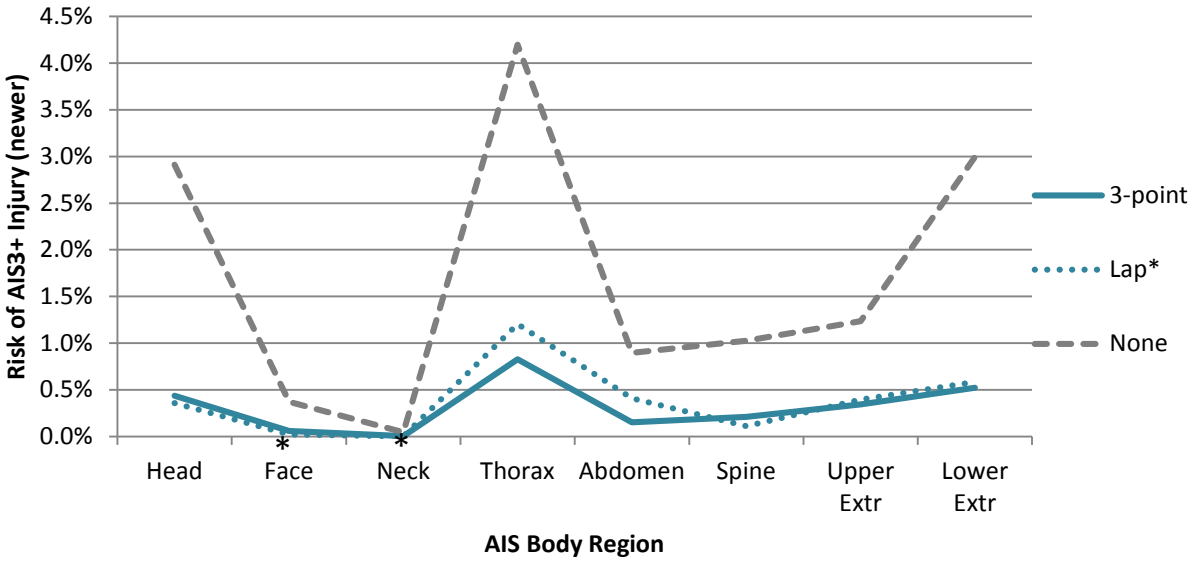


Figure 75. Risk of AIS3+ injury by belt restraint condition for each AIS body region.

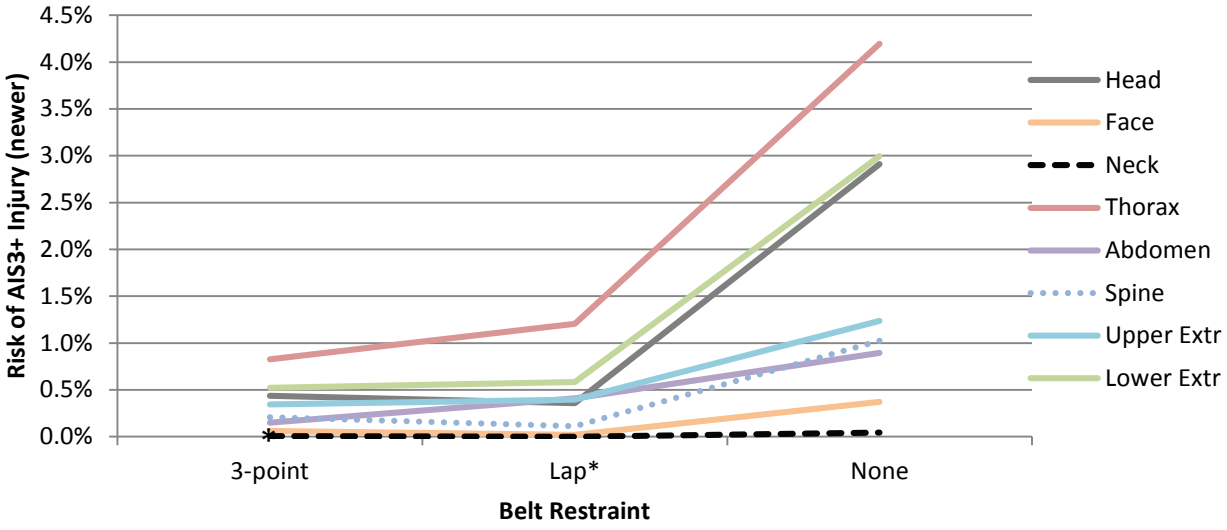


Figure 76. Risk of AIS3+ injury by AIS body region for each belt restraint condition.

Chapter 5. Injuries by Occupant Position

Crash Mode by Occupant Position

- For occupants in vehicles less than 10 years old with known seating position and meeting other inclusion criteria, 77% of occupants are drivers, 18% are right-front passengers, and 6% are rear passengers.
- Among AIS2+ injured occupants, those in the rear seat have a greater proportion of injuries from rollovers, far-side, and rear impacts compared to front seat occupants.
- Rear occupants have a 1.4 times greater risk of AIS2+ injury in far-side impacts and 2.2 times greater risk in rear impacts compared to front seat occupants, but front occupants have 1.5 times greater risk than rear occupants in frontal crashes.
- Among AIS3+ injured occupants, those in the rear seat have a greater proportion of injuries from in all types of crashes except for frontal impacts compared to front seat occupants.
- Rear occupants have a 1.4 times greater risk of AIS3+ injury in near-side impacts and 3.0 times greater risk in rear impacts compared to front seat occupants, but front occupants have 1.3 times greater risk than rear occupants in frontal crashes.
- Among occupants with AIS2+ injury involved in different types of frontal crashes, front passengers have the largest proportion of occupants in right SOI impacts, while drivers have the largest proportion of occupants in left SOI impacts. Rear occupants have a greater proportion of occupants in right offset crashes compared to either type of front occupant.
- Drivers have the highest risk of AIS2+ injury in 1-2 and 3-6 quarter turn rollovers, while rear passengers have the highest risk in 7+ quarter turn rollovers.
- Risk of AIS2+ injury in near T-type crashes is similar for all occupant seating positions, but higher for rear occupants in far-side T-type impacts.
- For AIS3+ injury risk, risks are similar for 1-2 quarter turn rollovers, highest for drivers in 3-6 quarter turn rollovers, and highest for rear passengers in 7+ quarter turn rollovers.
- Risk of AIS3+ injury in T-type crashes is similar for drivers and front passengers but higher for rear passengers.

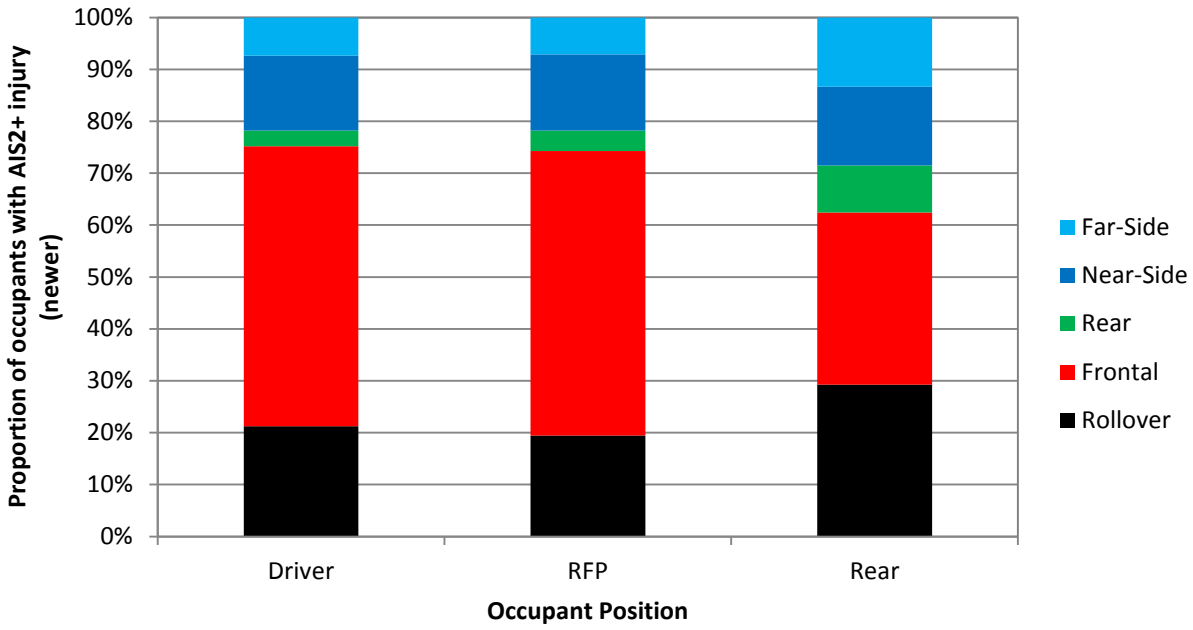


Figure 77. Proportion of occupants with AIS2+ injury by crash mode for each occupant position.

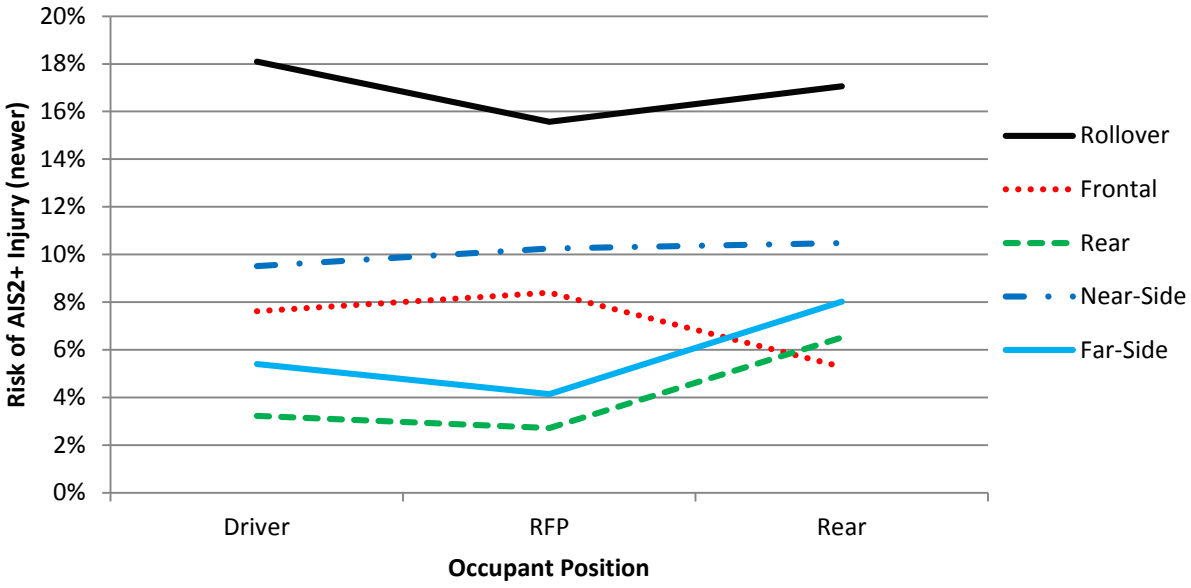


Figure 78. Risk of AIS2+ injury by crash mode for each occupant position.

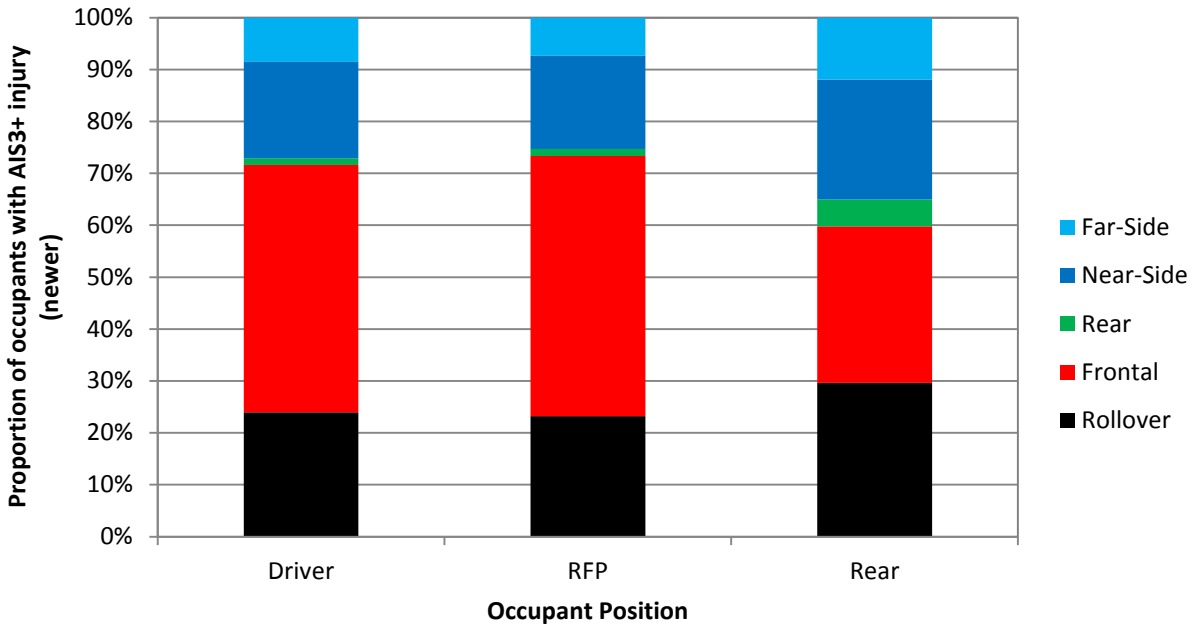


Figure 79. Proportion of occupants with AIS3+ injury by crash mode for each occupant position.

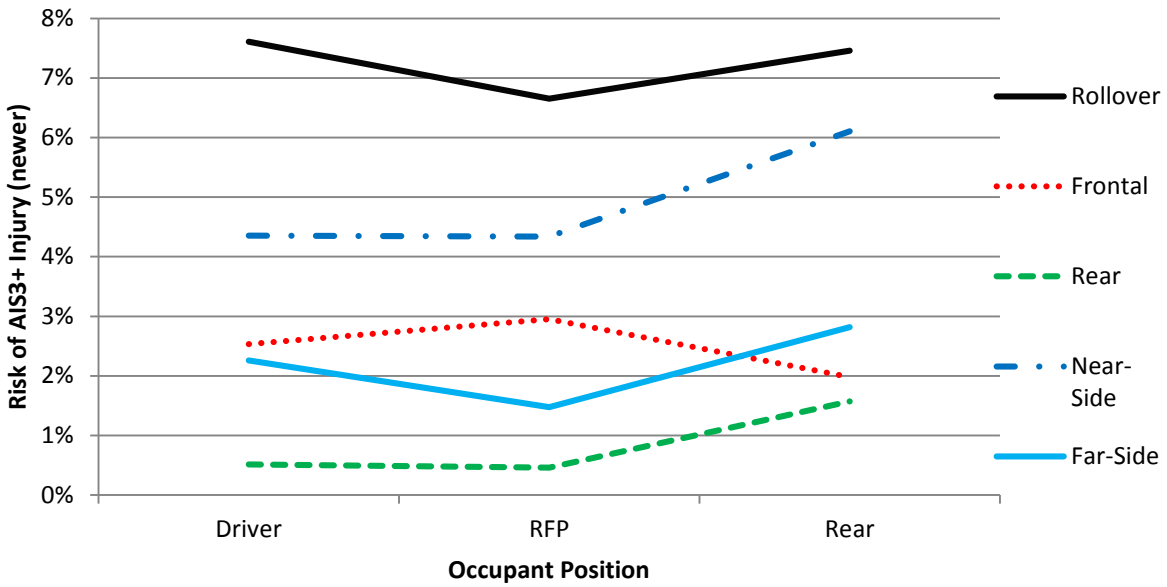


Figure 80. Risk of AIS3+ injury by crash mode for each occupant position.

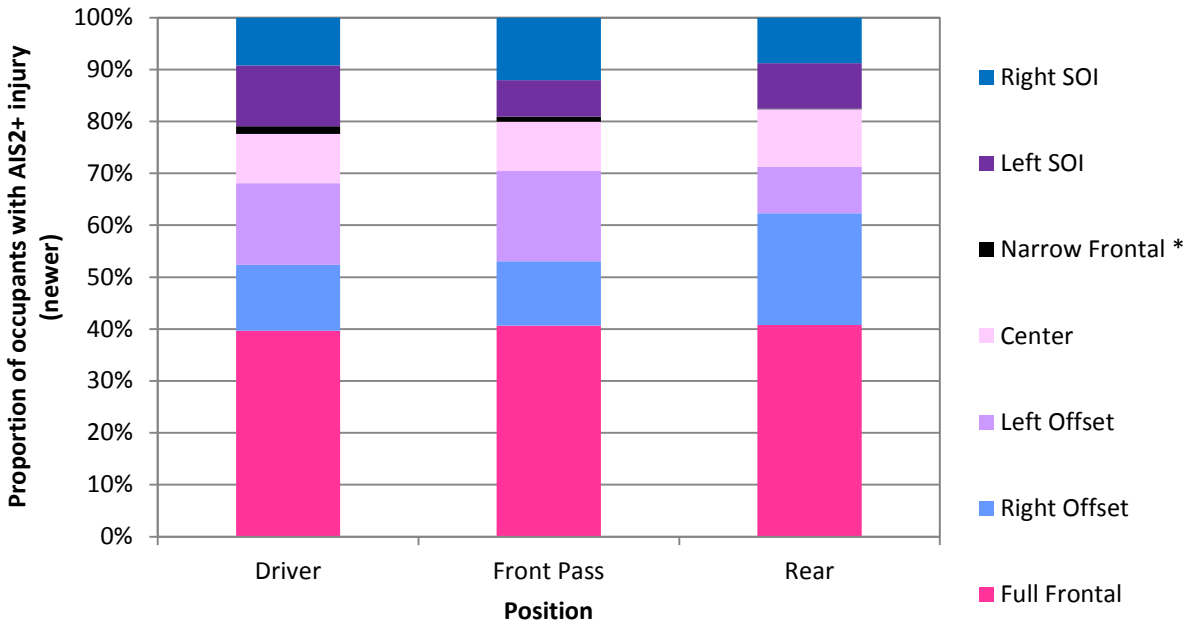


Figure 81. Distribution of occupants with AIS2+ injury by frontal subcrash type for each occupant position.

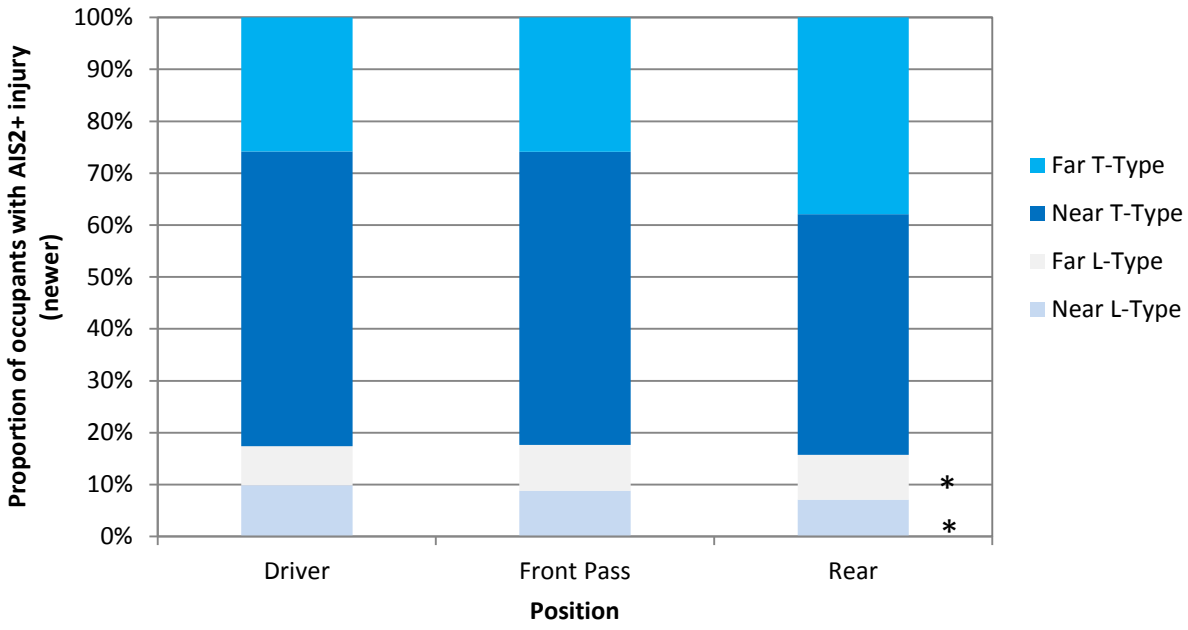


Figure 82. Distribution of occupants with AIS2+ injury by side subcrash type for each occupant position.

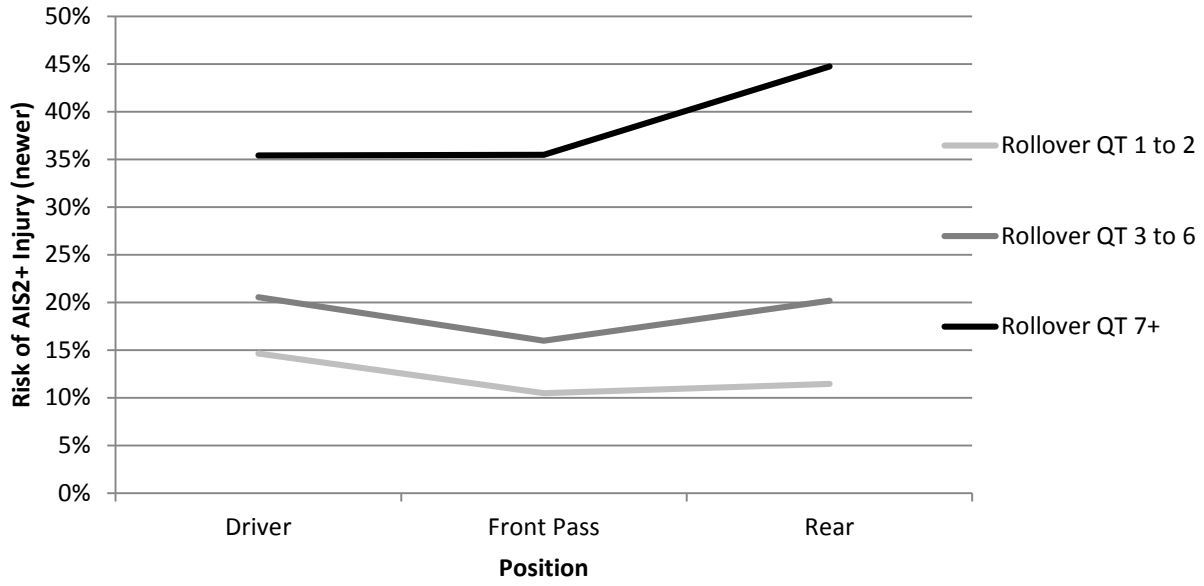


Figure 83. Risk of AIS2+ injury by rollover type for each occupant position.

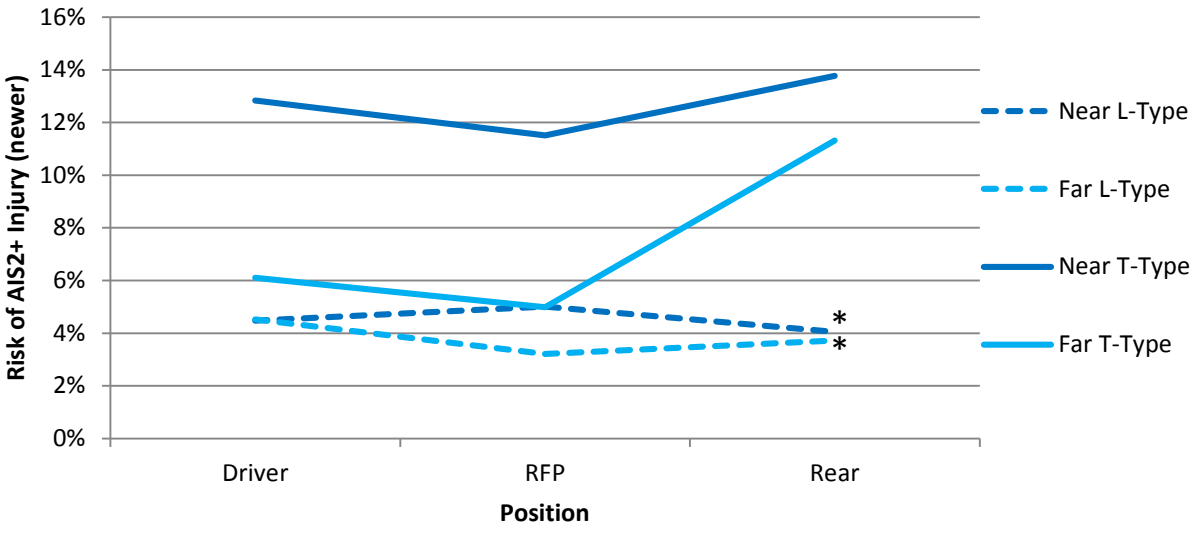


Figure 84. Risk of AIS2+ injury by side subcrash type for each occupant position.

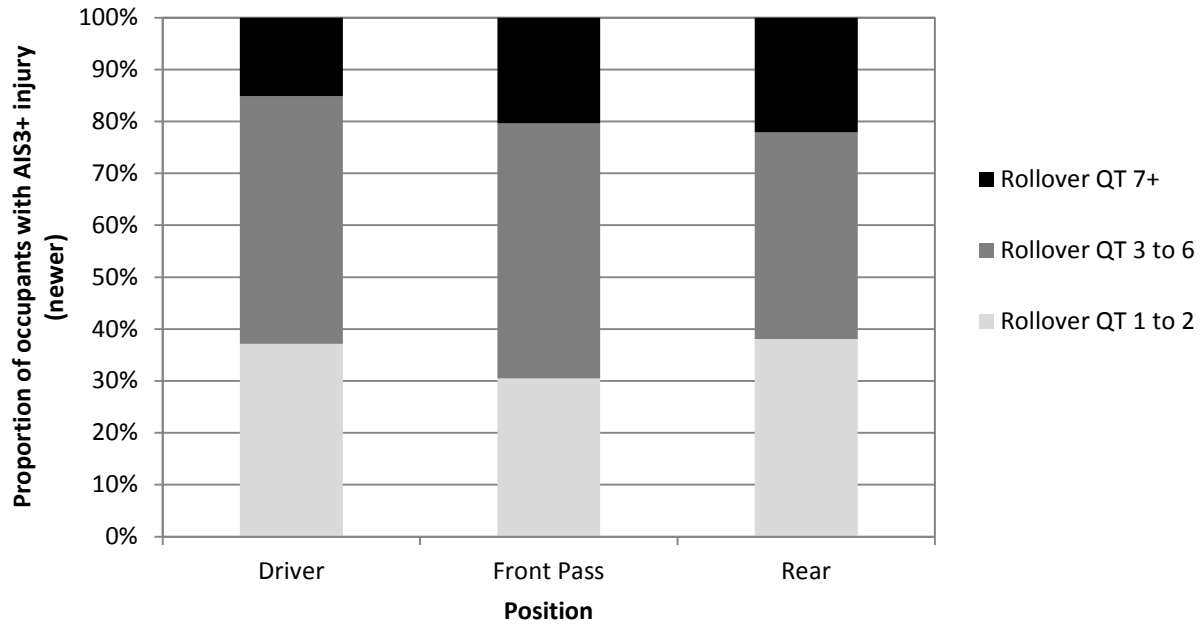


Figure 85. Proportion of occupants with AIS3+ injury by rollover type for each occupant position.

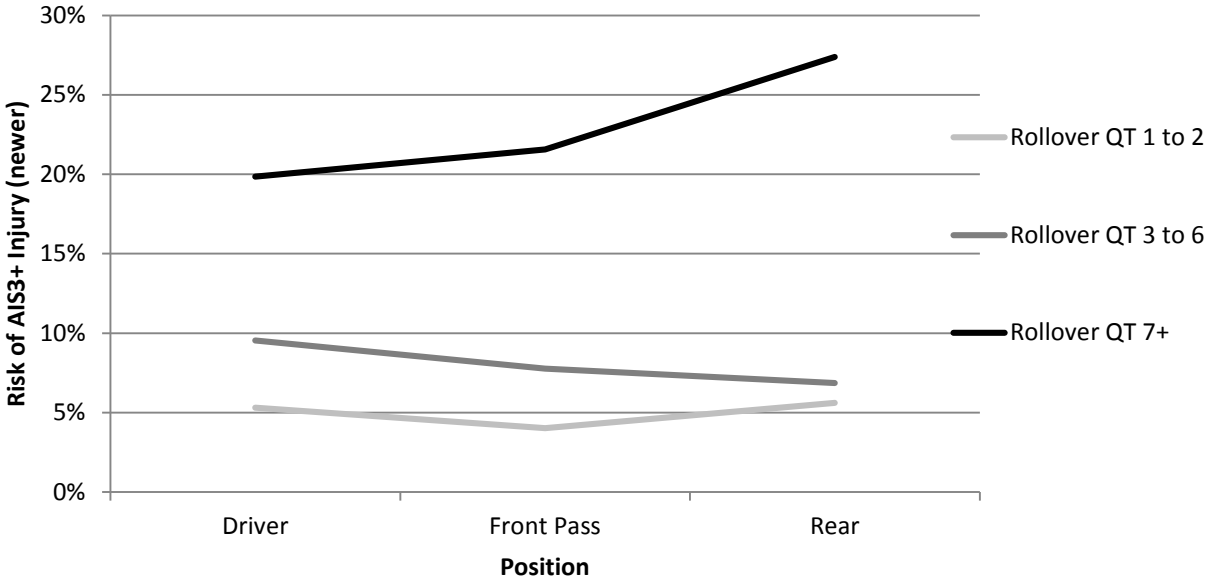


Figure 86. Risk of AIS3+ injury by rollover type for each occupant position.

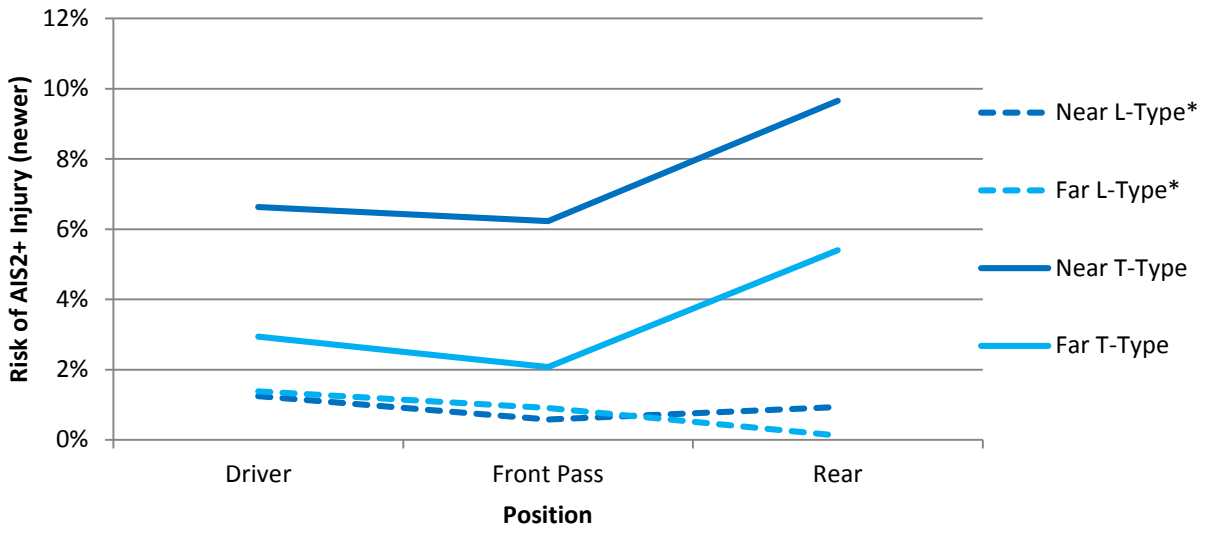


Figure 87. Risk of AIS3+ injury by side subcrash type for each occupant position.

Body Region by Occupant Position

- In this dataset, 77% of occupants are drivers, 18% are right-front passengers, and 6% are rear passengers.
- Among AIS2+ and AIS3+ injured occupants, there are less than 25 unweighted injured occupants with neck injuries for each restraint category. As a result, analysis of neck injury trends are unreliable and indicated with an * on each plot.
- The distribution of AIS2+ and AIS3+ injured occupants by body region is similar for each occupant position.
- Risk of AIS2+ injury is highest for the rear passenger for the head, face, upper extremity and spine, highest for the front passenger and abdomen for the thorax, and highest for the driver for lower extremities.
- Risk of AIS3+ injury is highest for the rear passenger for the head, abdomen and spine, for the front passenger for the upper extremity, and the driver for the lower extremity, although differences are small.

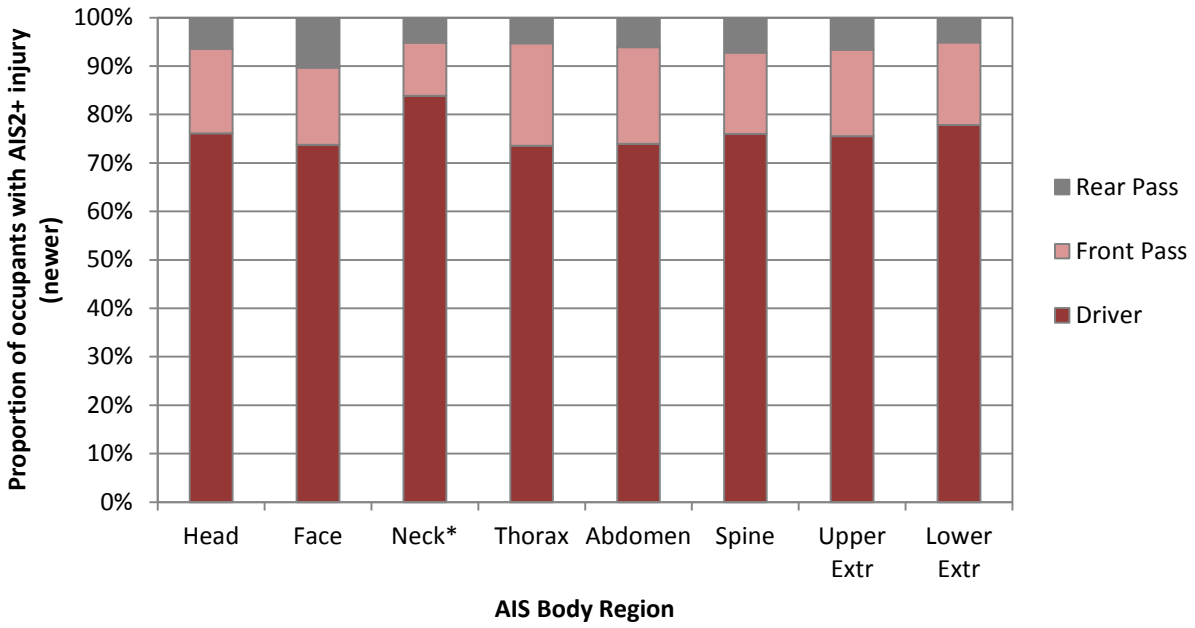


Figure 88. Proportion of occupants with AIS2+ injury by occupant position for each body region.

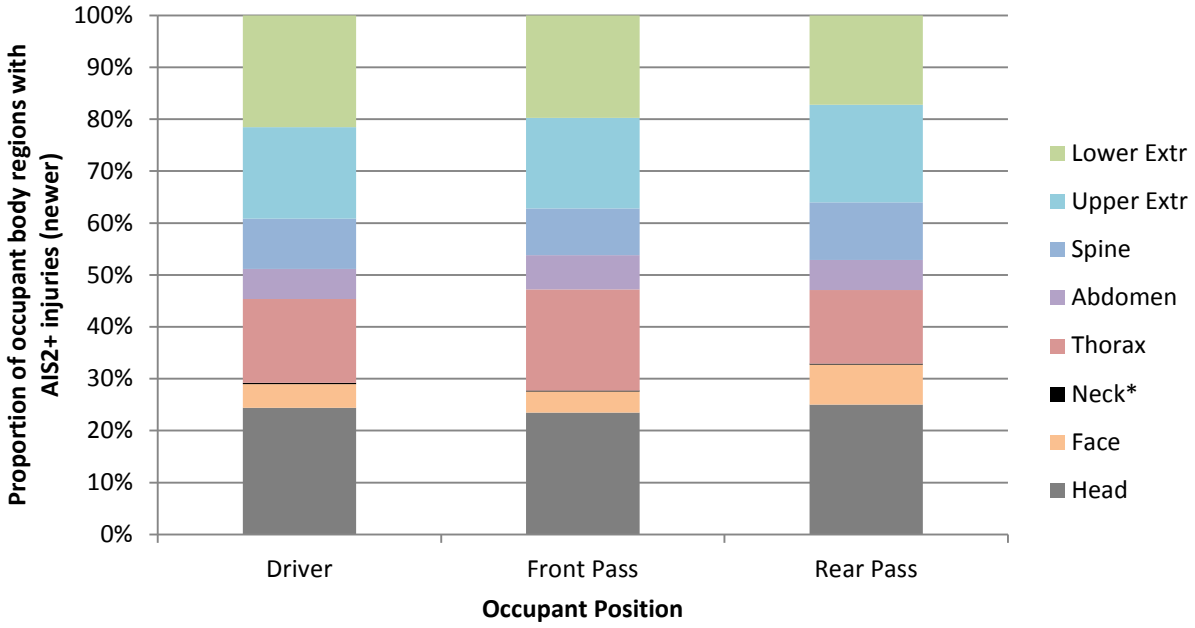


Figure 89. Proportion of occupant body regions with AIS2+ injury by AIS body region for each occupant position.

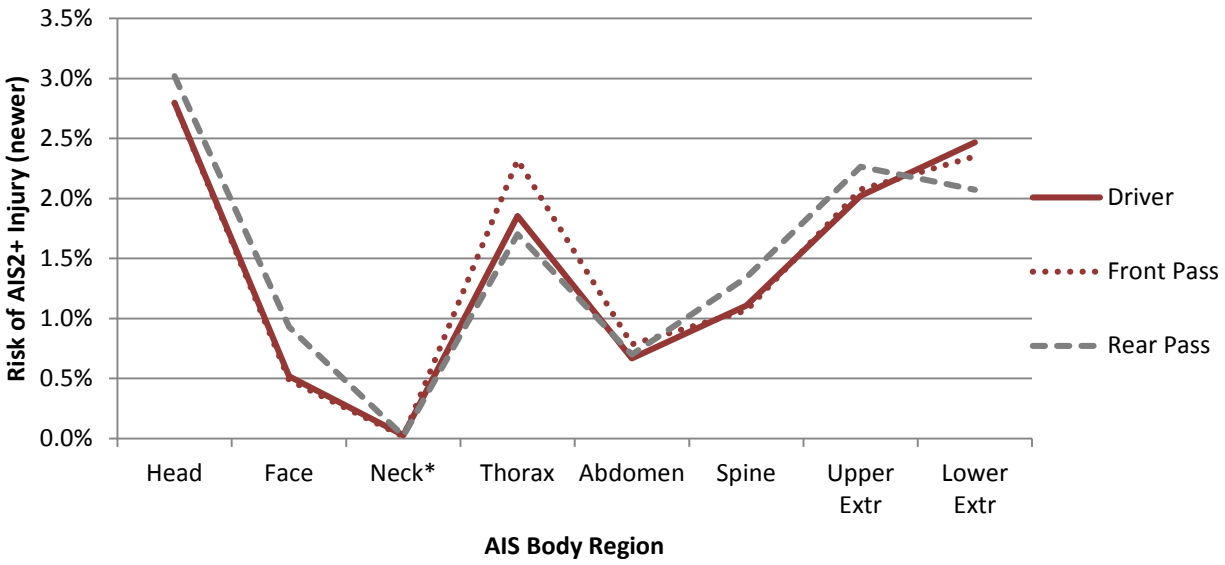


Figure 90. Risk of AIS2+ injury by occupant position for each AIS body region.

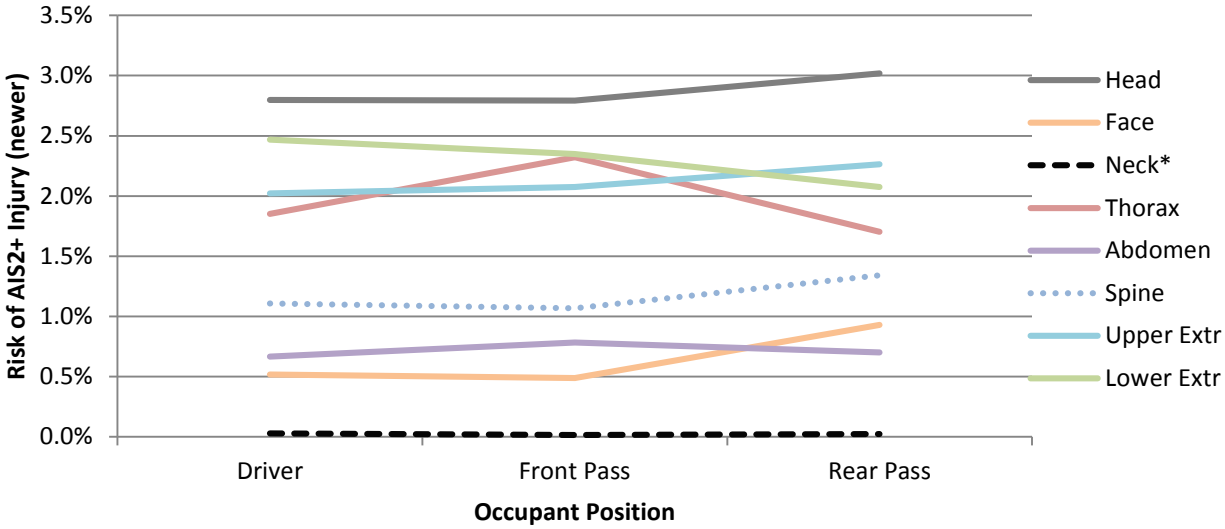


Figure 91. Risk of AIS2+ injury by AIS body region for each occupant position.

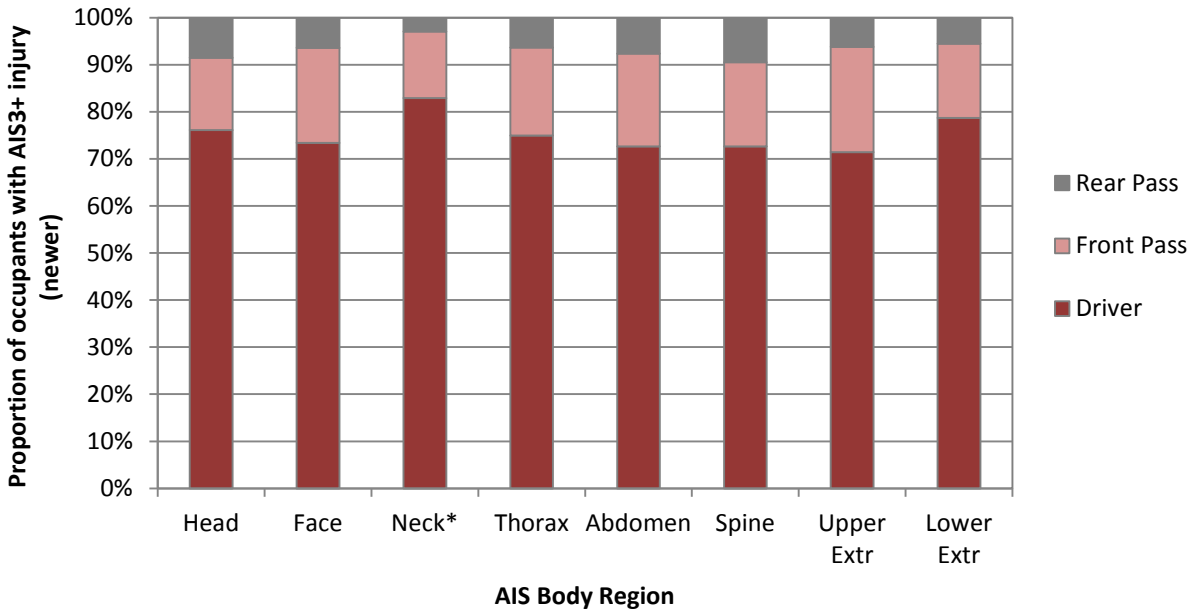


Figure 92. Proportion of occupants with AIS3+ injury by occupant position for each body region.

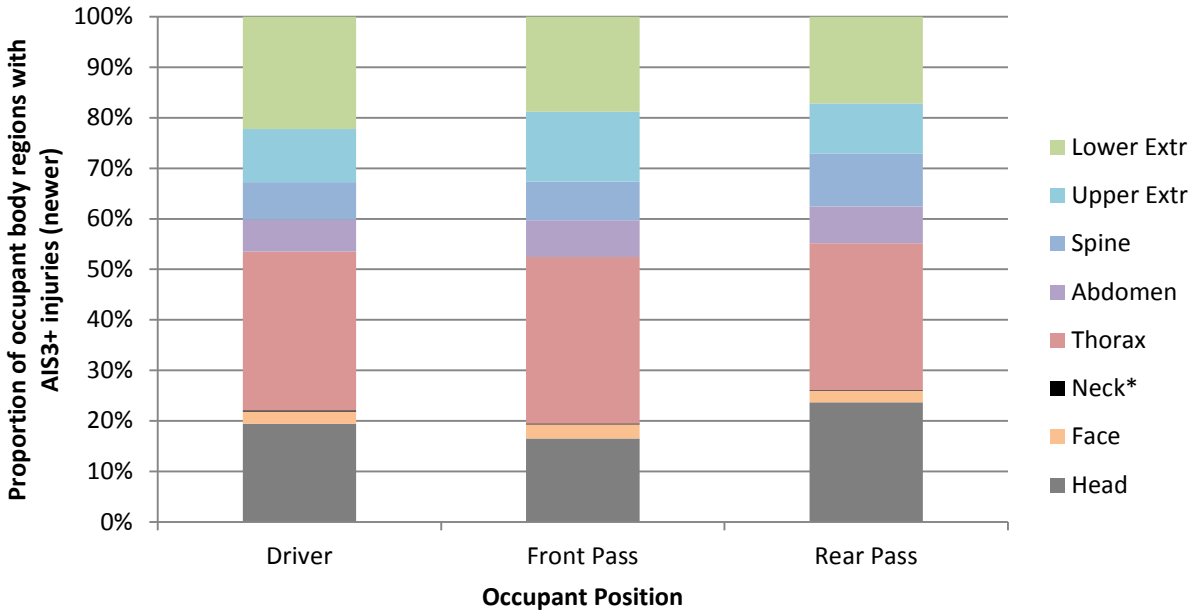


Figure 93. Proportion of occupant body regions with AIS3+ injury by AIS body region for each occupant position.

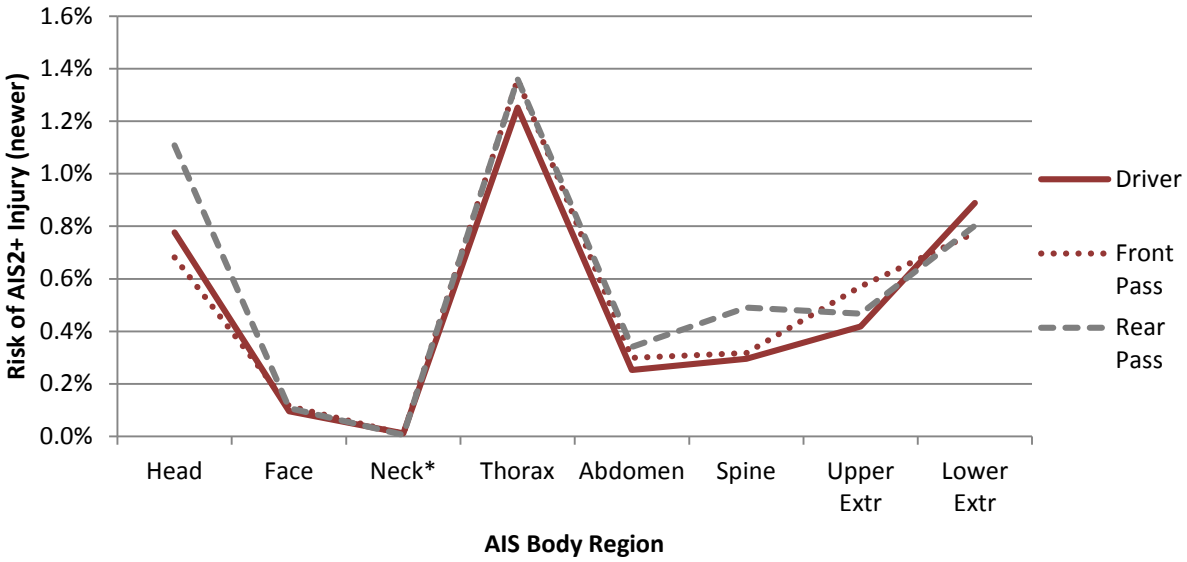


Figure 94. Risk of AIS3+ injury by occupant position for each body region.

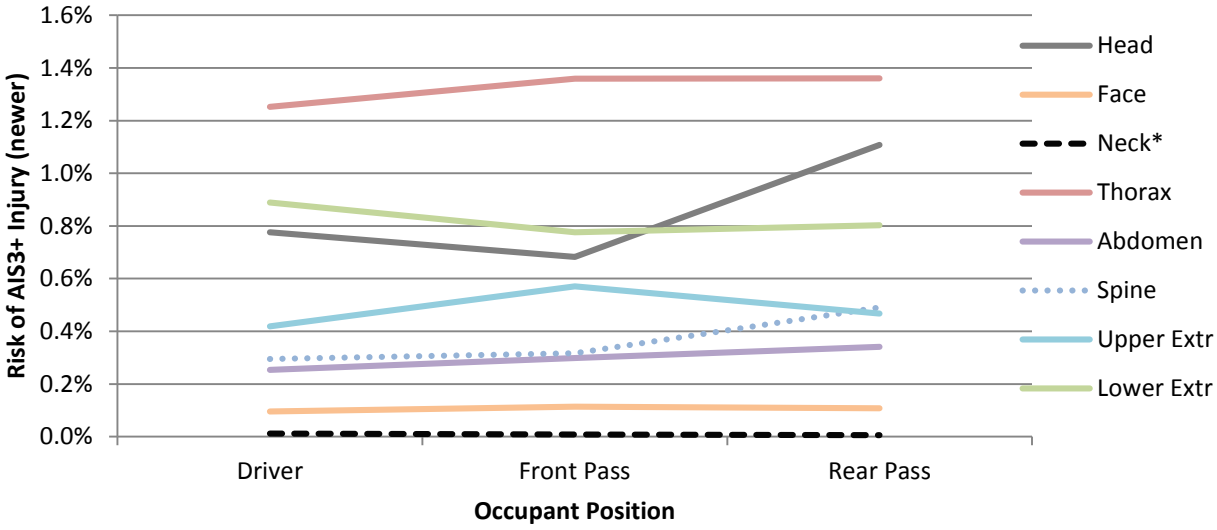
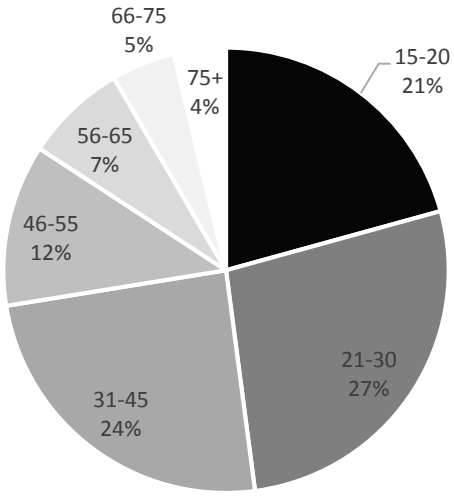


Figure 95. Risk of AIS3+ injury by body region for each occupant position.

Chapter 6. Injuries by Occupant Age

Crash mode by Occupant Age

- The distribution of occupants with known age and injury level in this dataset is shown below:



- Among AIS2+ injured occupants, there are less than 25 unweighted injured 75+ year-olds in rear impacts. This makes analysis of injury trends for these categories unreliable. They are indicated with an * on each plot.
- For AIS3+ injury, there are less than 25 unweighted injured occupants in the following categories: 66-75 and 75+ in rollovers with more than 7 quarter turns; all occupant ages in narrow frontals and rear impacts; 66-75 and 75+ occupants in near L-type crashes; and 66-75 year-old occupants in far L-type crashes.
- The proportion of AIS2+ and AIS3+ injured occupants in rollovers decreases with age.
- In frontal, near-side, and far-side crashes, occupants with AIS2+ injury aged 66 and greater make up a higher proportion of the injured occupants compared to their involvement in tow-away crashes. The same is true for AIS3+ injury for all crash types except rollover.
- Occupants aged 15-30 are more than half of occupants with AIS2+ or AIS3+ injuries from rollover crashes.
- Risk of AIS2+ injury generally increases with age for frontal, near-side, and rear impacts. Occupants aged 31-65 have the lowest AIS2+ injury risk in far-side impacts compared to those older and younger than these age groups. AIS2+ injury risk in rollovers generally increases with age, except for the 46-55 and 75+ age groups, which have similar risk to the 21-30 age groups.
- Risk of AIS3+ injury consistently increases with age for all crash types.
- The proportion of occupants with AIS2+ or AIS3+ injury from 1-2 QT rollovers increases with age.

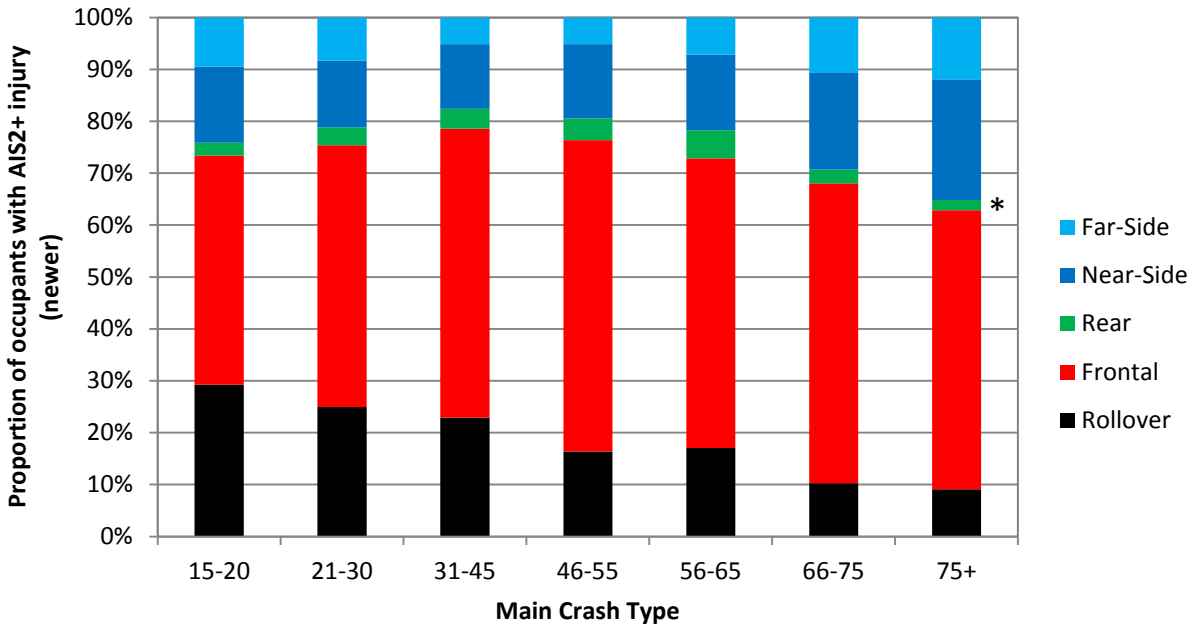


Figure 96. Proportion of occupants with AIS2+ injury by crash mode for each age group.

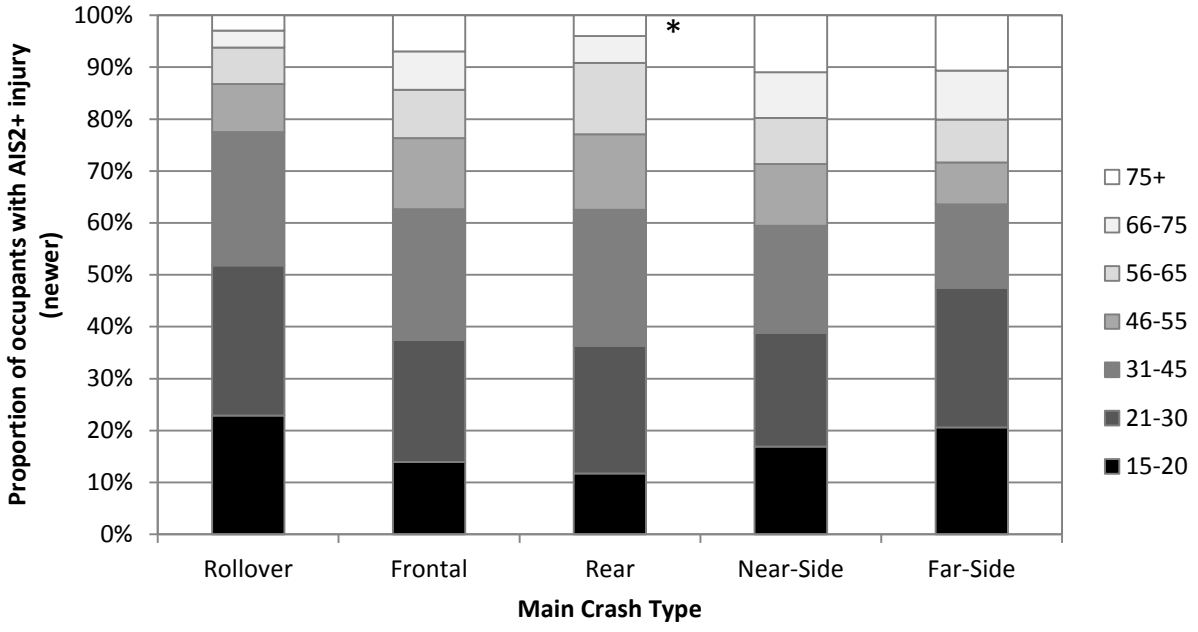


Figure 97. Proportion of occupants with AIS2+ injury by age group for each crash mode.

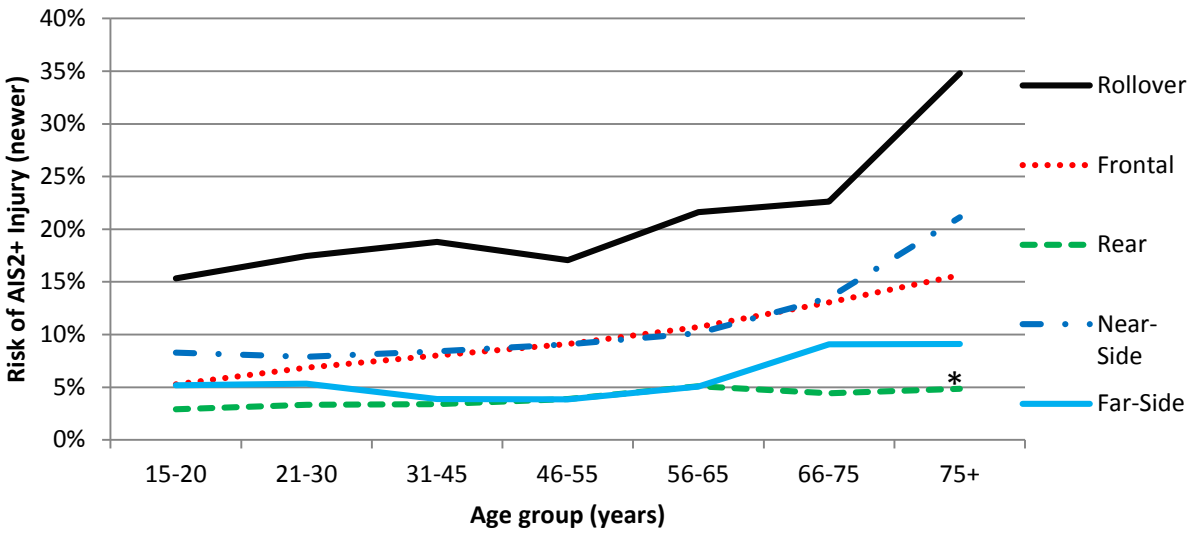


Figure 98. Risk of AIS2+ injury by crash mode for each age group.

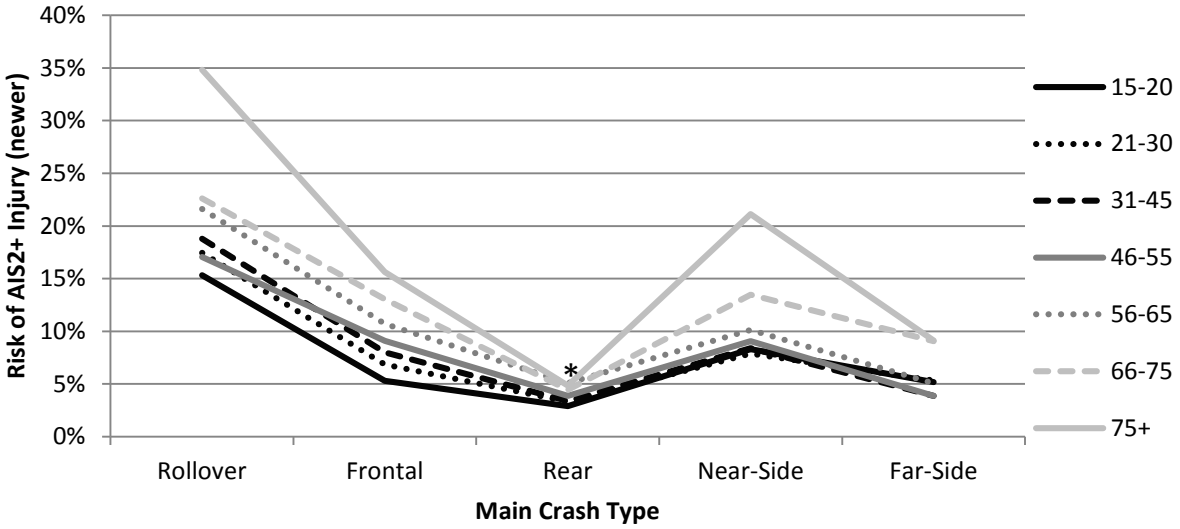


Figure 99. Risk of AIS2+ injury by age group for each crash mode.

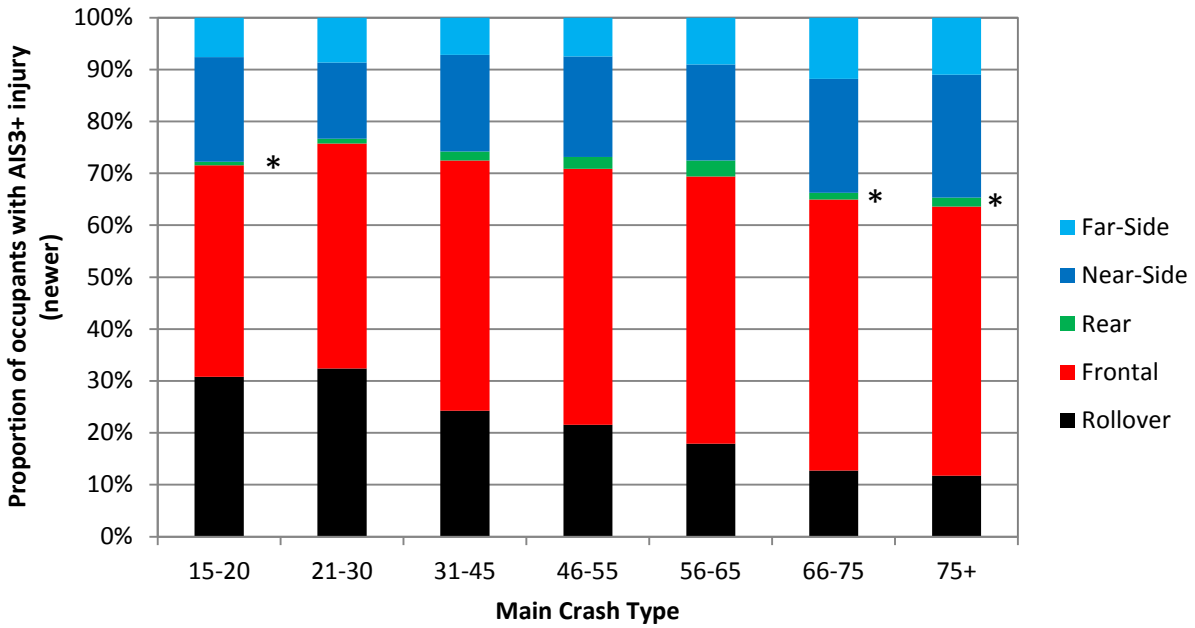


Figure 100. Distribution of occupants with AIS3+ injury by crash type for each age group.

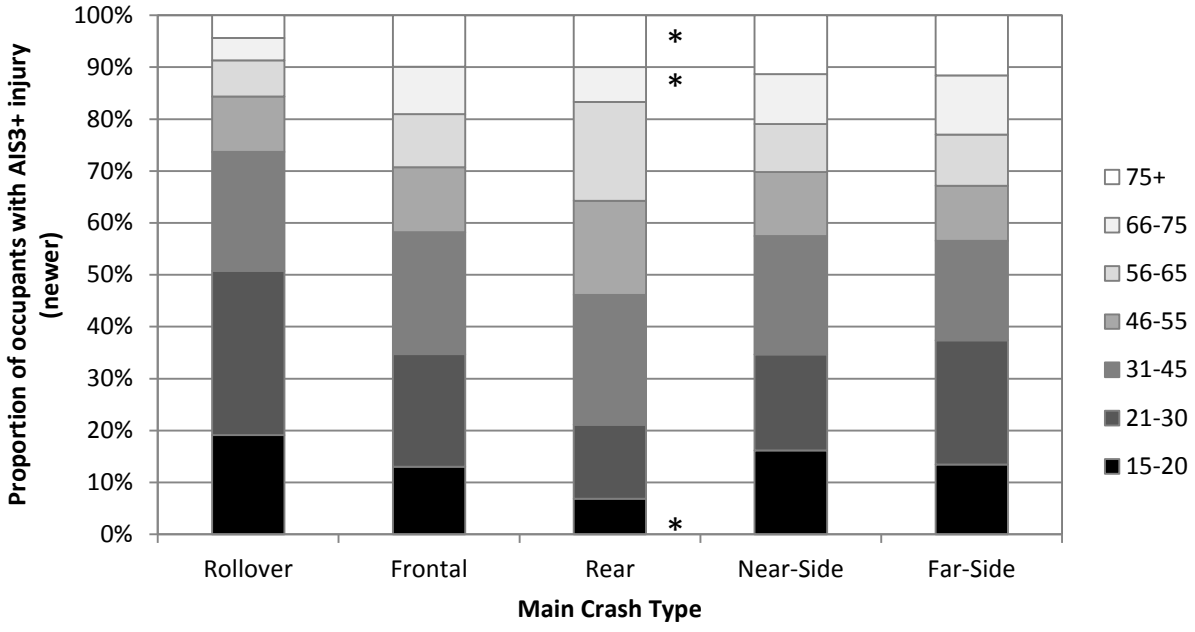


Figure 101. Distribution of occupants with AIS3+ injury by age group for each crash type.

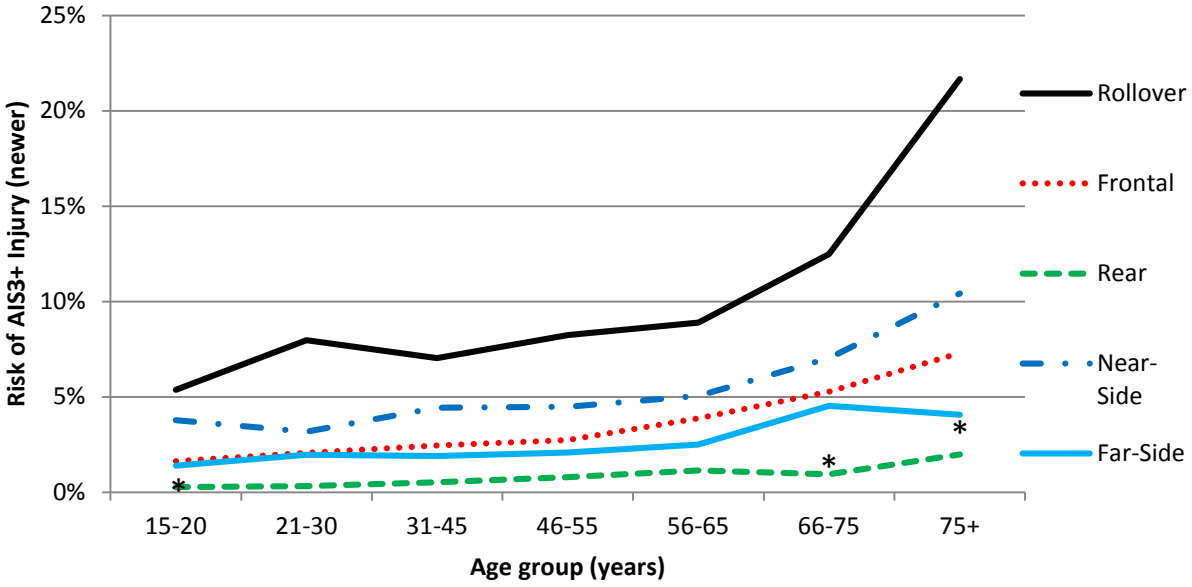


Figure 102. Risk of AIS3+ injury by crash type for each age group.

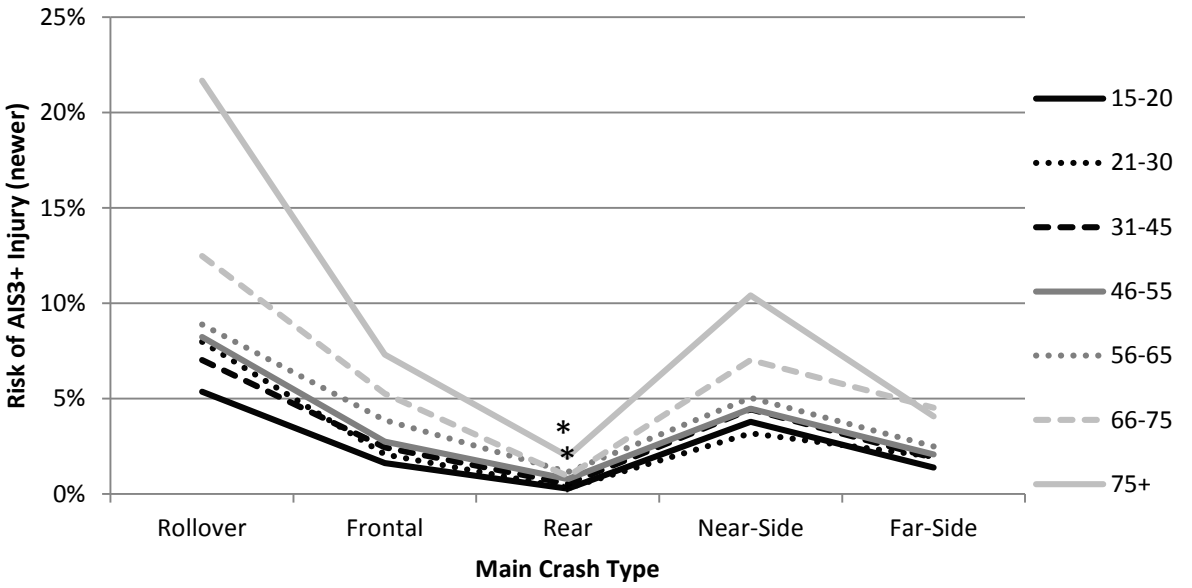


Figure 103. Risk of AIS3+ by age group for each crash type.

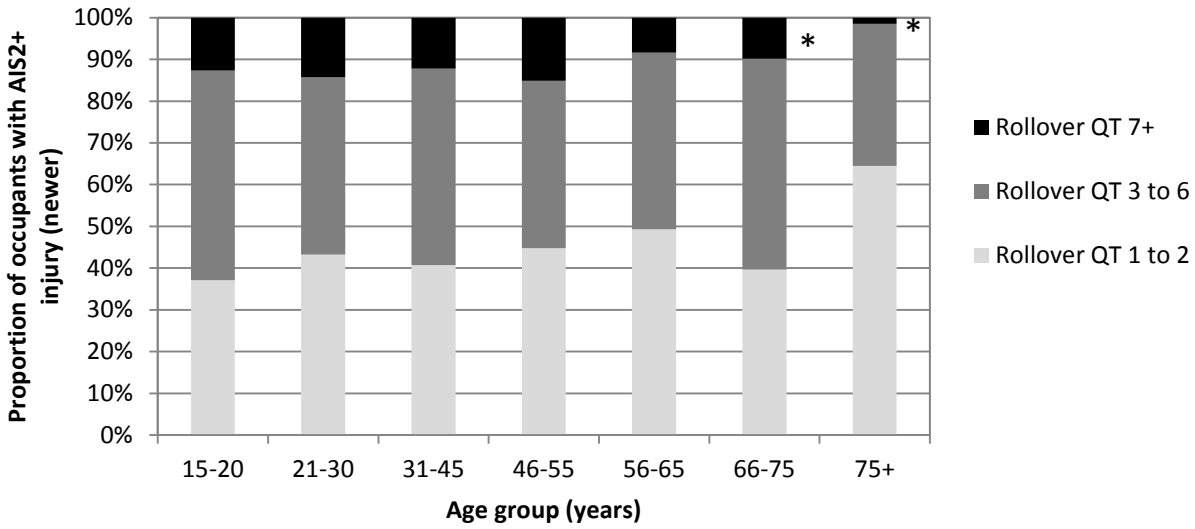


Figure 104. Proportion of occupants with AIS2+ injury by rollover crash type for each age group.

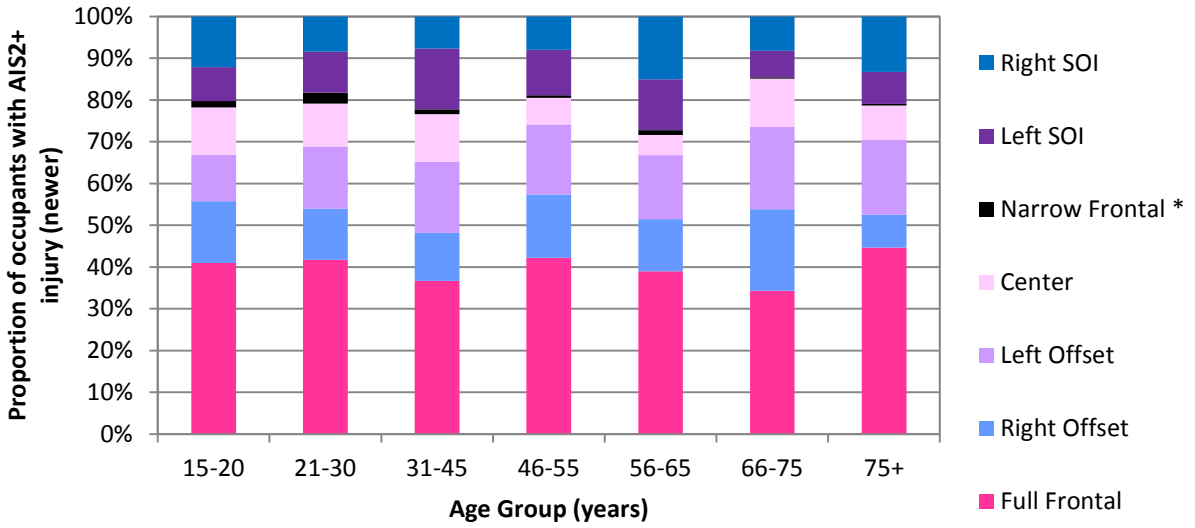


Figure 105. Proportion of occupants with AIS2+ injury by frontal subcrash type for each age group.

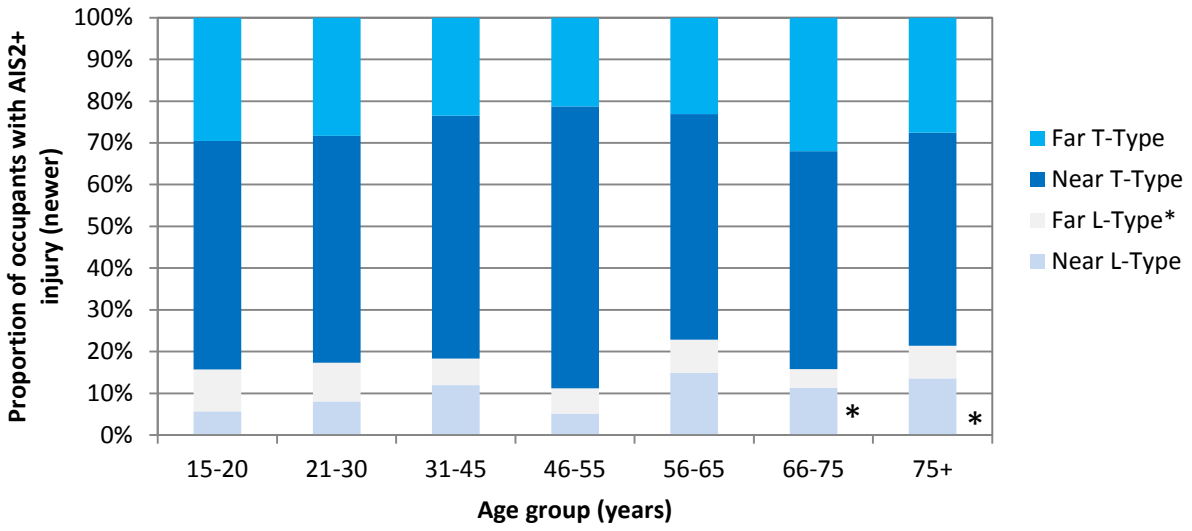


Figure 106. Proportion of occupants with AIS2+ injury by side subcrash type for each age group.

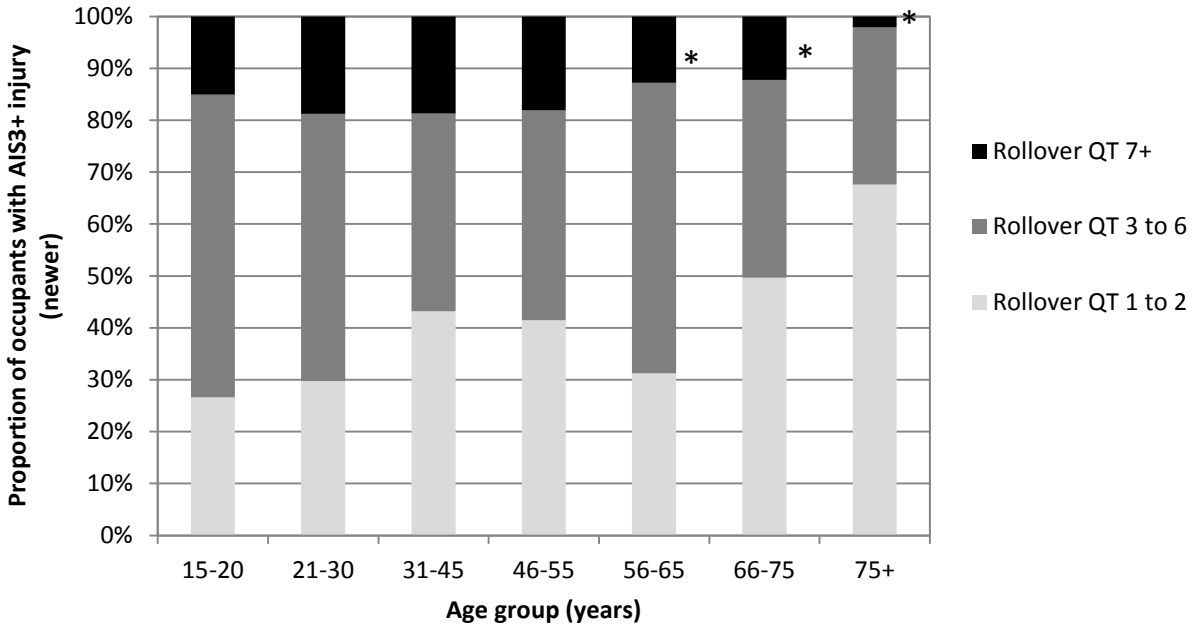


Figure 107. Proportion of occupants with AIS3+ injury by rollover type for each age group.

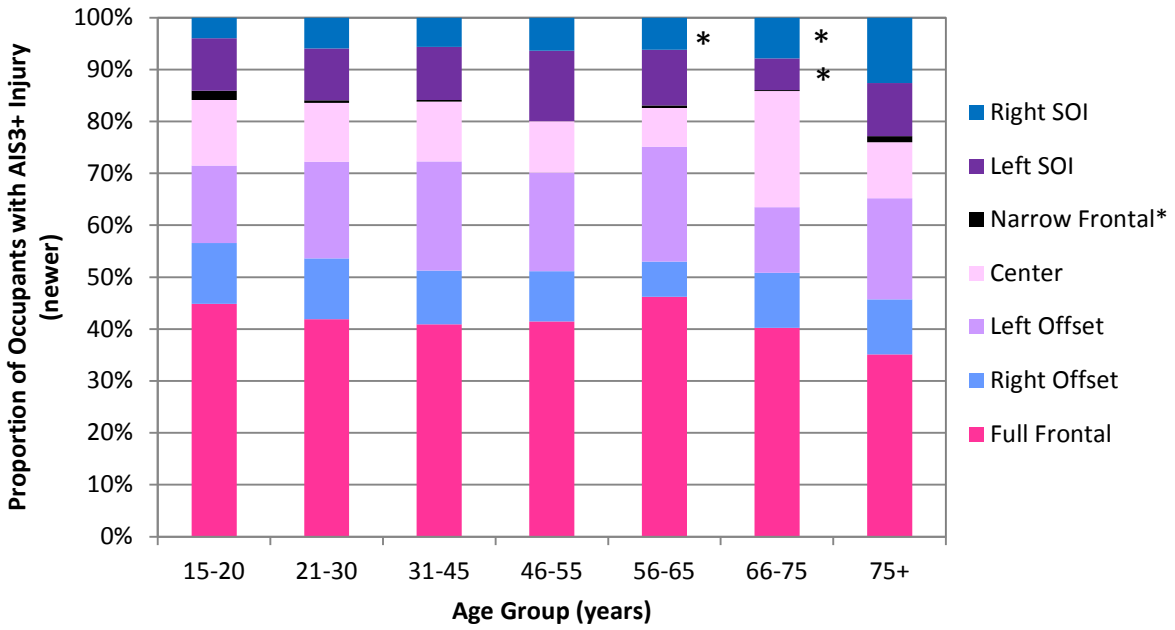


Figure 108. Proportion of occupants with AIS3+ injury by frontal subcrash type for each age group.

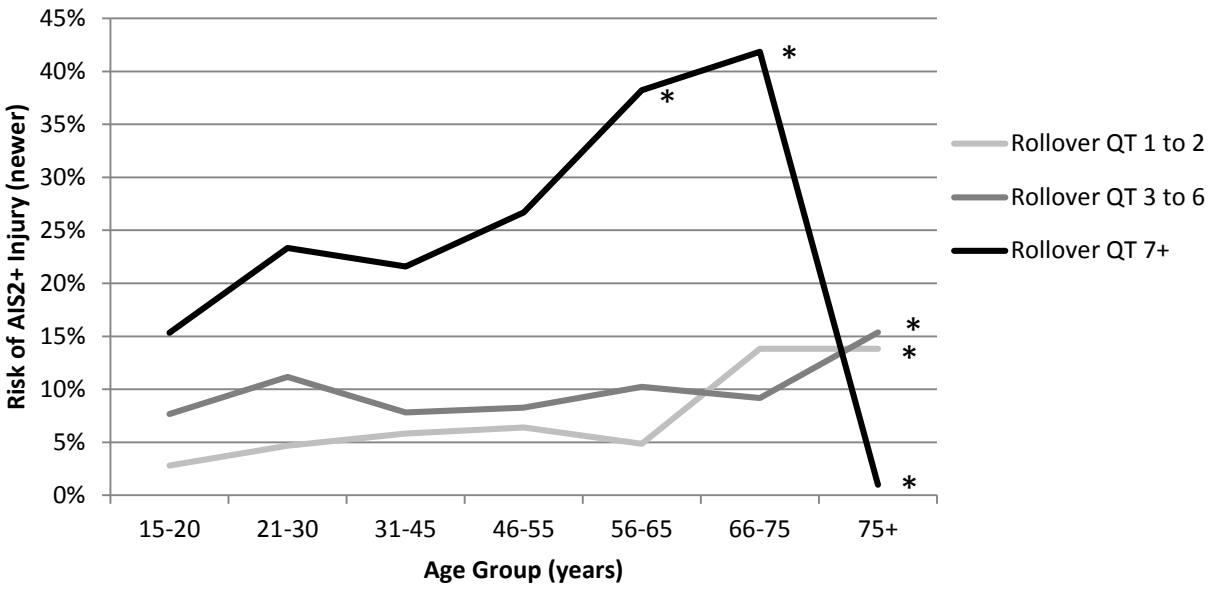


Figure 109. Risk of AIS2+ injury by rollover type for each age group.

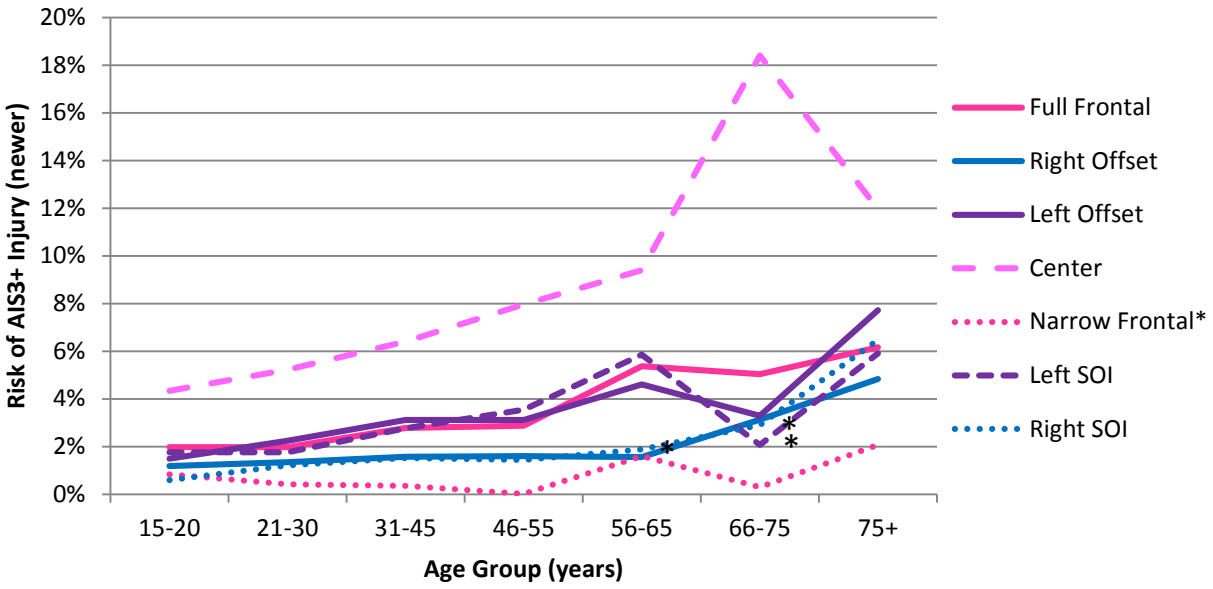


Figure 110. Risk of AIS3+ injury by frontal subcrash type for each age group.

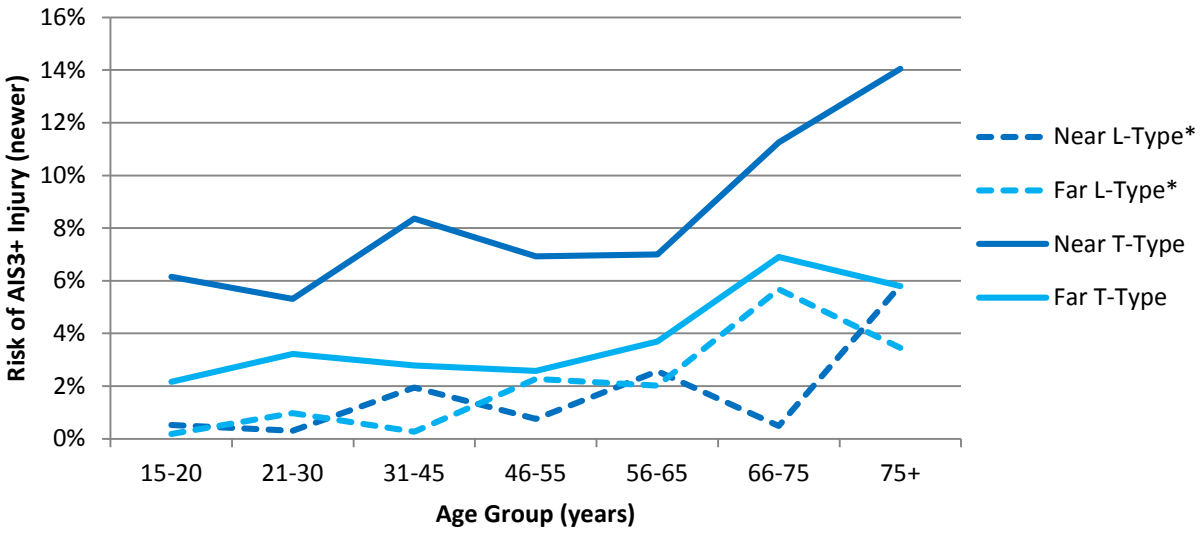


Figure 111. Risk of AIS3+ injury by side subcrash type for each age group.

Injuries by Body Region and Occupant Age

- The proportion of occupants with AIS2+ and AIS3+ head and face injuries decreases with age, while the proportion with AIS2+ thorax injuries increases with age. For other body regions, the proportions of body regions injured in each age group are fairly constant.
- Occupants aged 15-30 have higher than average proportions of AIS2+ and AIS3+ injured occupants with head, face, and abdomen injuries.
- The risk of AIS2+ and AIS3+ to most body regions generally increase with age. The head and abdomen have the lowest increases in risk with age, while the thorax and spine show the greatest increases in risk.

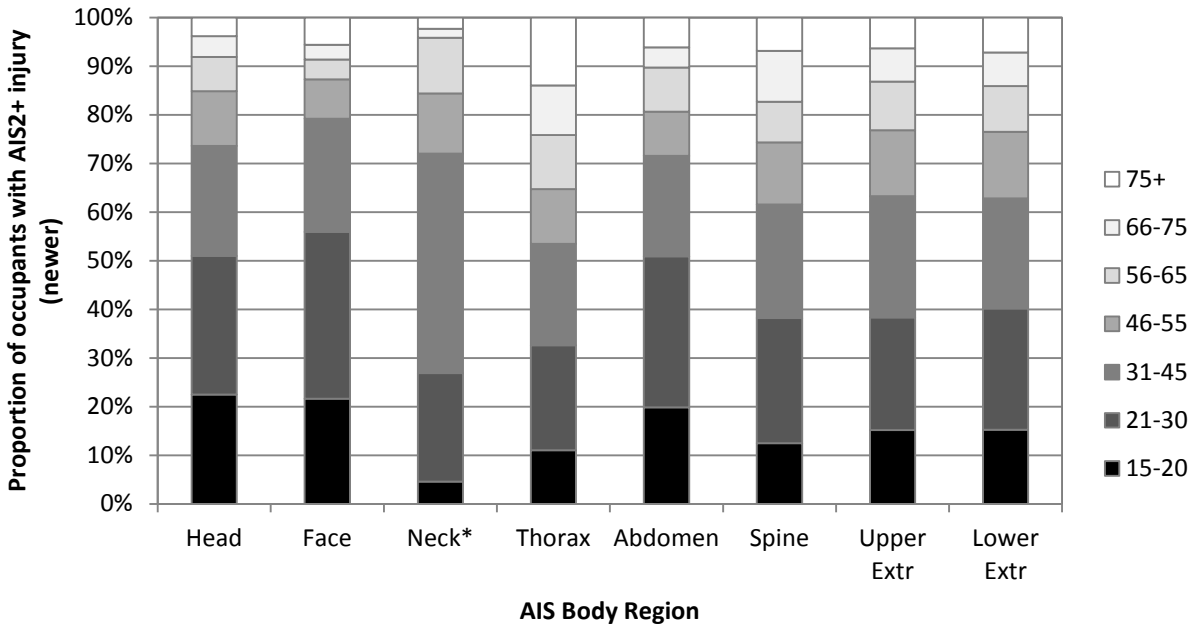


Figure 112. Proportion of occupants with AIS2+ injury by age group for each body region.

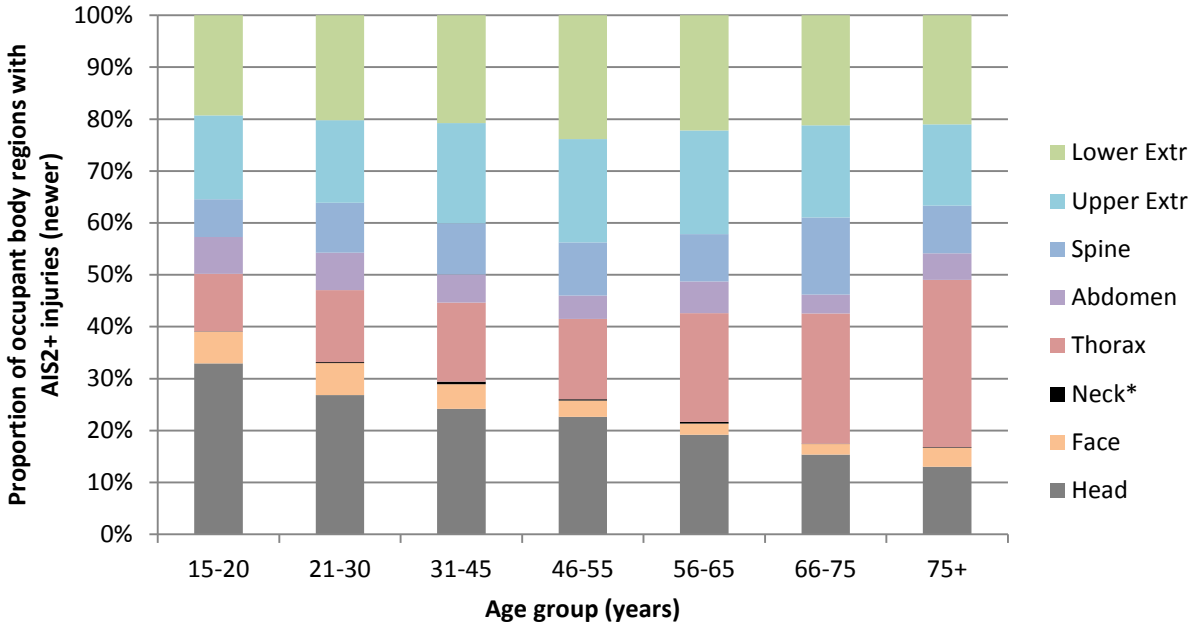


Figure 113. Proportion of occupant body regions with AIS2+ injury by body region for each age group.

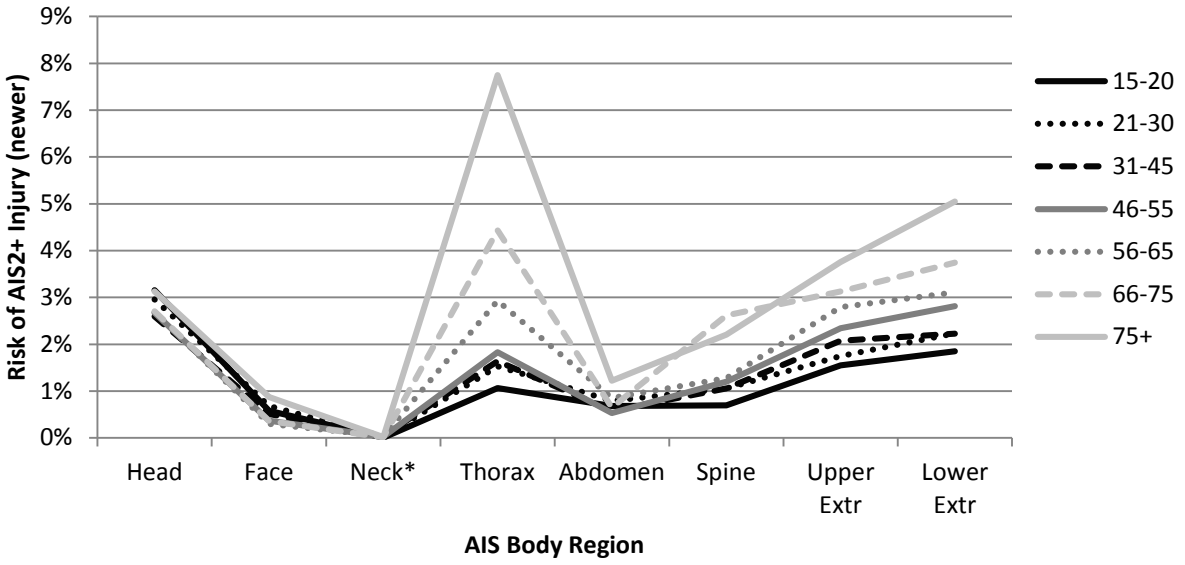


Figure 114. Risk of AIS2+ injury by age group for each body region.

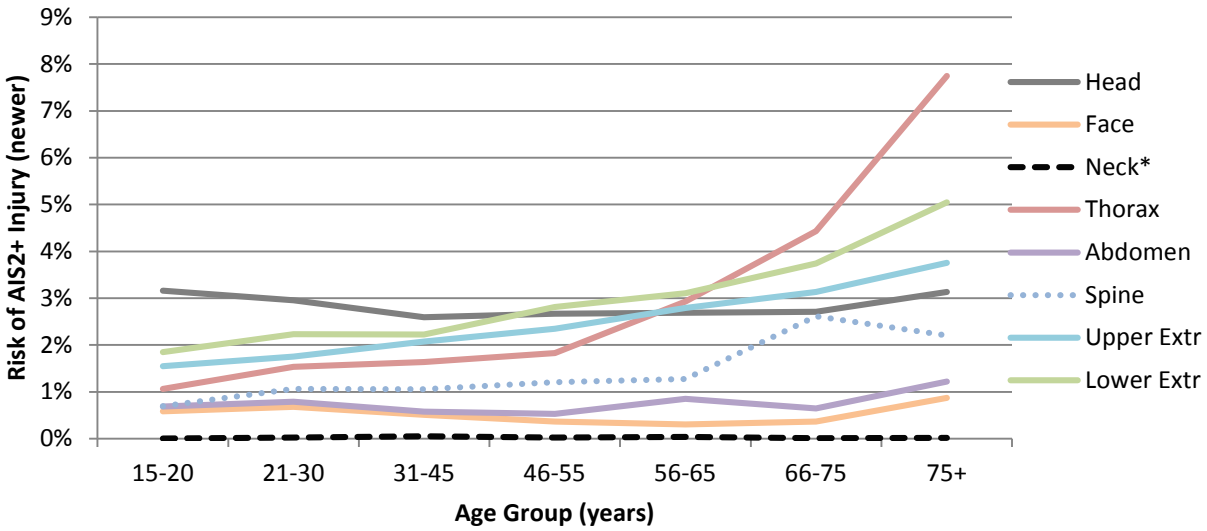


Figure 115. Risk of AIS2+ injury by body region for each age group.

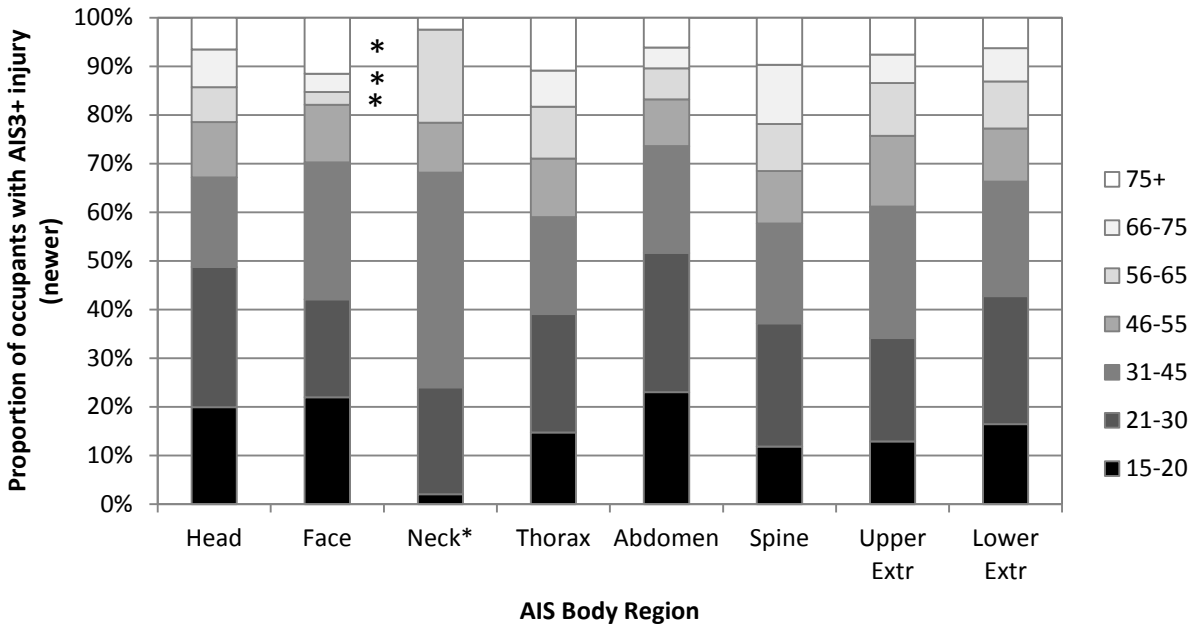


Figure 116. Distribution of occupants with AIS3+ injury by age group for each body region.

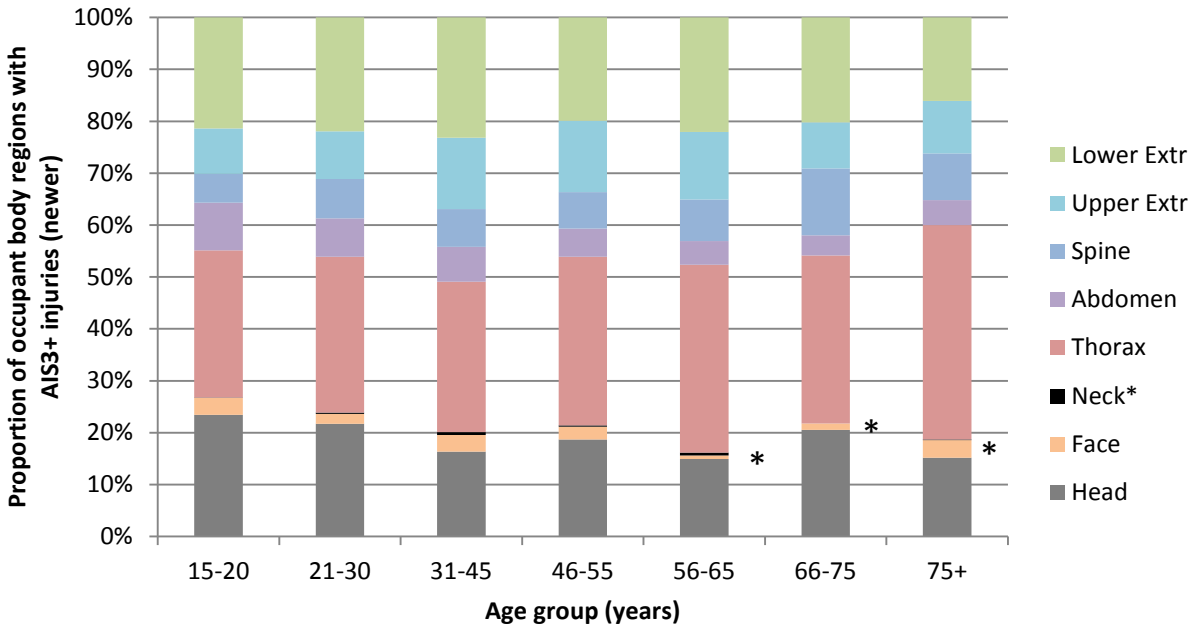


Figure 117. Distribution of occupant body regions with AIS3+ injury by body region for each age group.

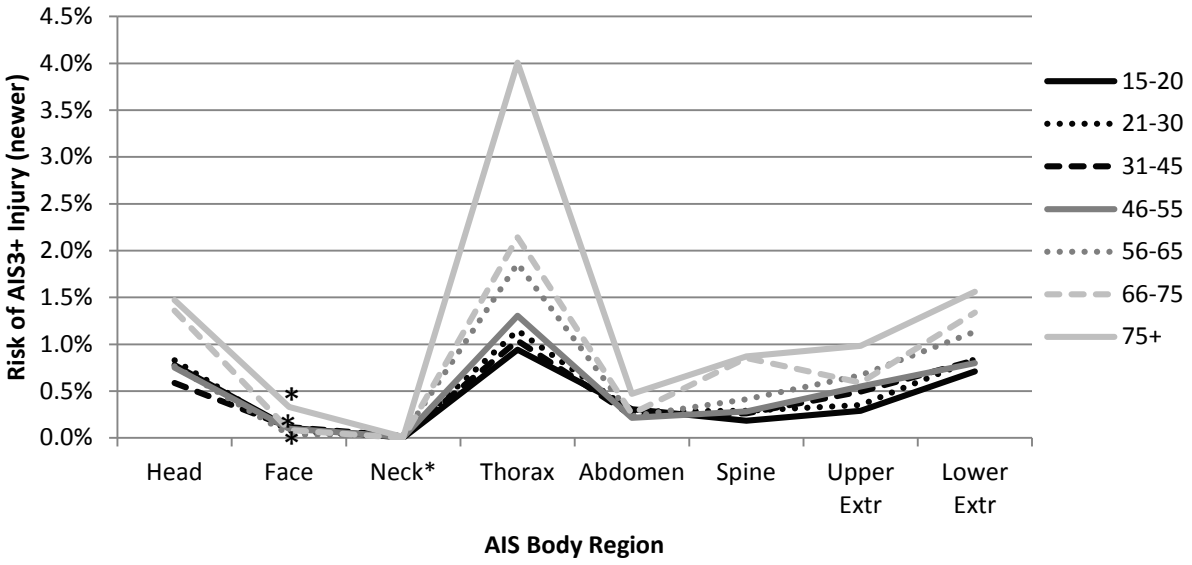


Figure 118. Risk of AIS3+ injury by age group for each body region.

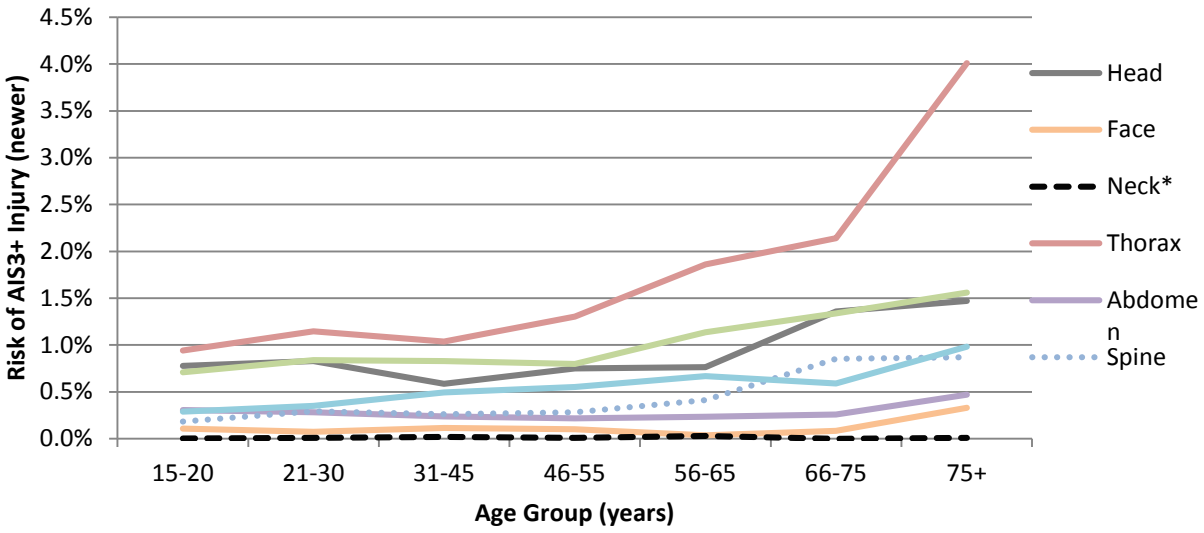
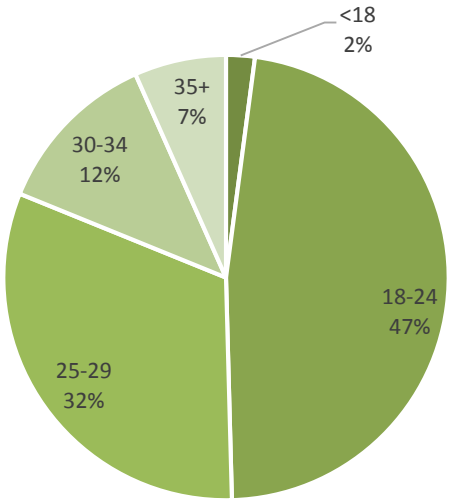


Figure 119. Risk of AIS3+ injury by body region for each age group.

Chapter 7. Injuries by Occupant BMI

Crash mode by Occupant BMI

- The distribution of occupants with known BMI in this dataset is shown in the figure below.



- For AIS2+ injury, there are less than 25 unweighted injured occupants with BMI <18 in rear impacts, for the neck in three BMI classes, and in most categories of subcrashes. As a result, analysis of injury trends for these groups is unreliable. They are indicated with an * on plots.
- For AIS3+ injury, numbers are low for BMI < 18 in rear and far-side impacts, four BMI categories with neck injury, the highest and lowest BMI categories with face injury, and abdomen and upper extremity for <18 BMI. For subcrash analysis, most categories of BMI <18, narrow frontals, rear, near- and far L-type crashes, and for BMI 35+ in rear impacts also had low unweighted counts. As a result, analysis of injury trends for these groups is unreliable. They are indicated with an * on plots.
- For AIS2+ injury, the proportion of occupants in rollovers decreases with BMI but increases with increasing BMI for frontal impacts.
- Risk of AIS2+ injury and AIS3+ changes the most with BMI for frontal impacts, with risk doubling from BMI < 18 to BMI >35+.
- Occupants with BMI of 35+ have the highest proportion of rollover injury from QT1-2 rollovers.
- For other impact types, risk of AIS2+ or AIS3+ injury is fairly consistent with BMI, except for a higher risk of AIS2+ injury in BMI<18 in rollovers and far-side crashes. (Numbers are too low to analyze this BMI group at the AIS3+ level.) Also, for AIS3+ injury, the BMI 35+ group has a higher risk of injury in rollovers.

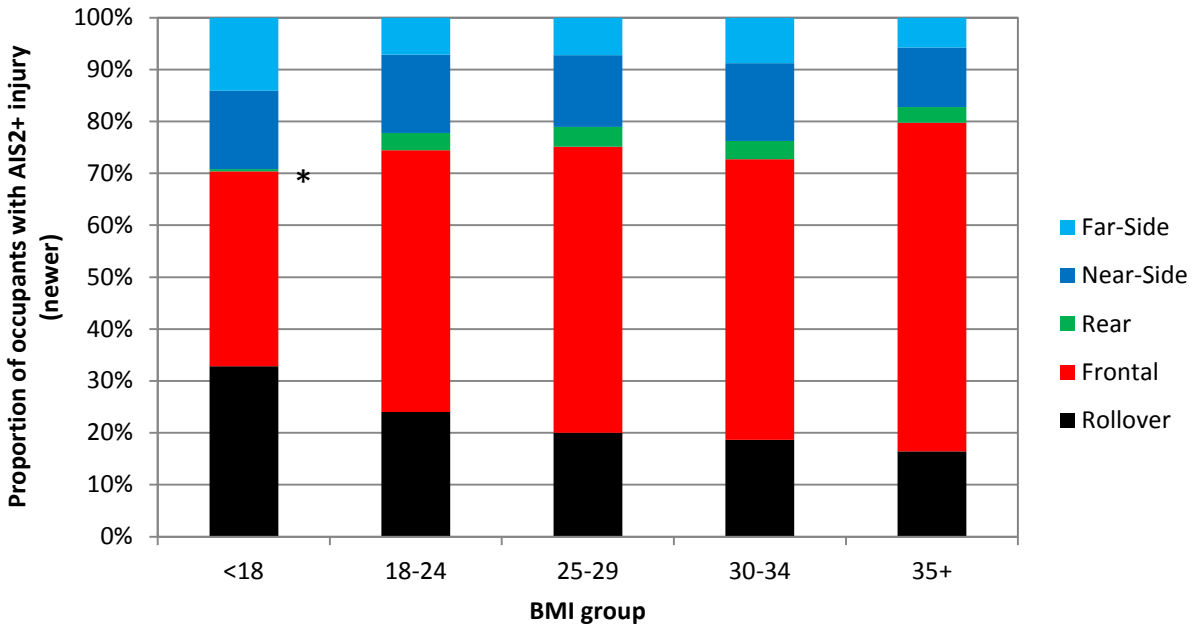


Figure 120. Distribution of occupants with AIS2+ injury by crash type for each BMI group.

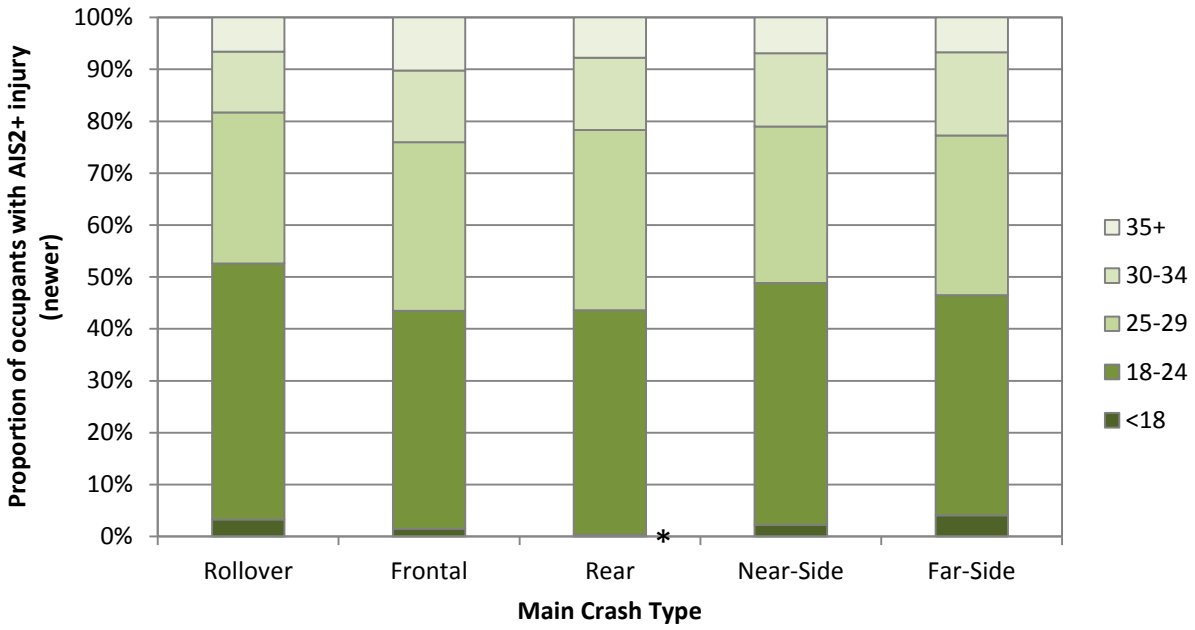


Figure 121. Distribution of occupants with AIS2+ injury by BMI group for each crash type.

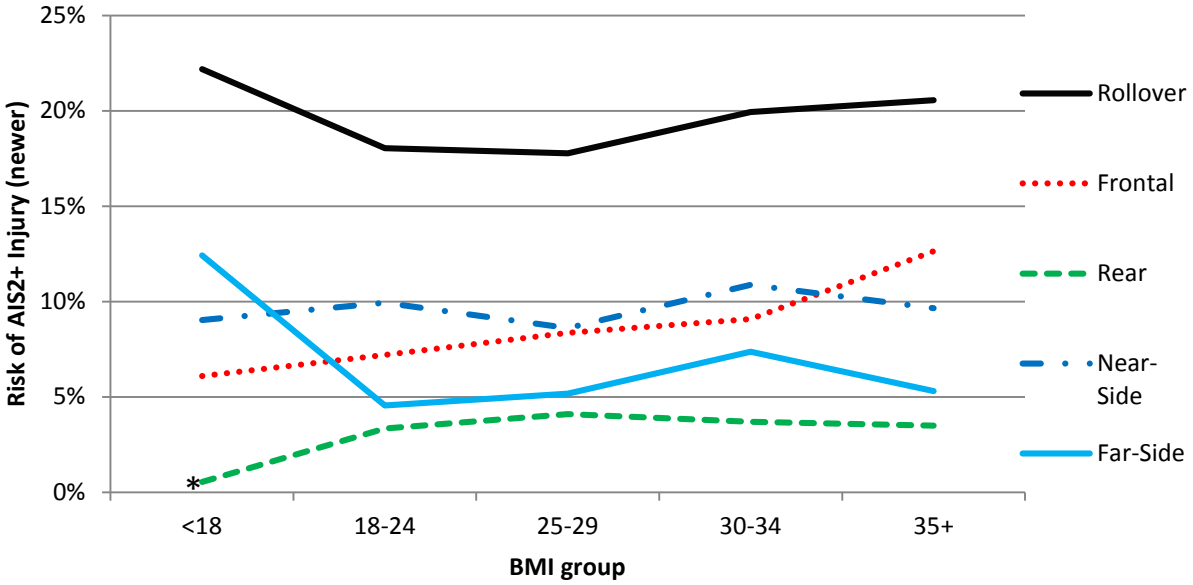


Figure 122. Risk of AIS2+ injury by crash type for each BMI group.

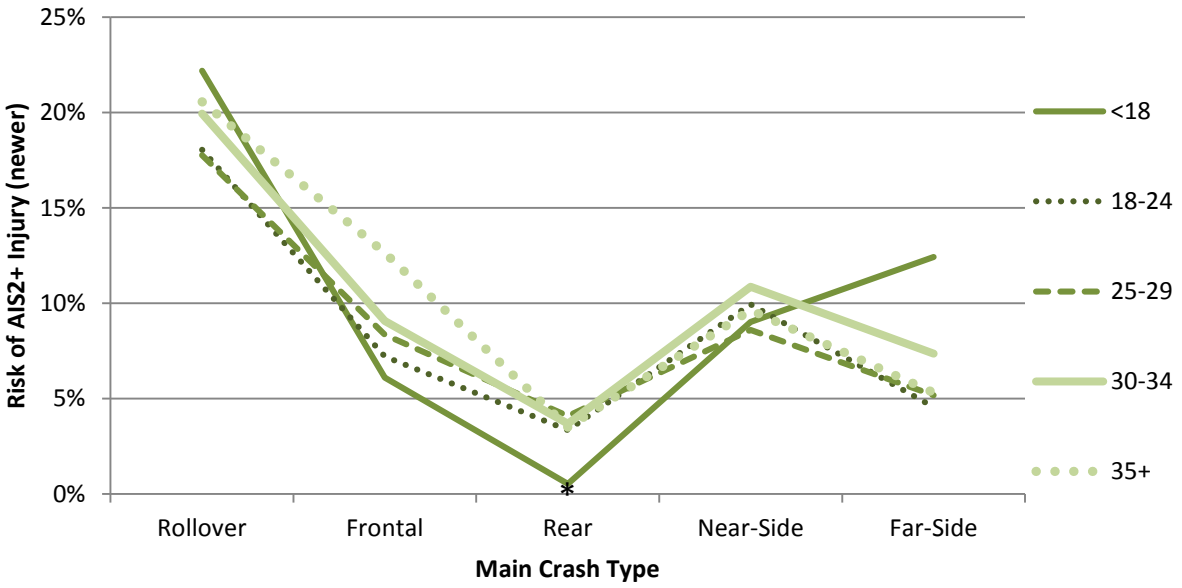


Figure 123. Risk of AIS2+ injury by BMI group for each crash type.

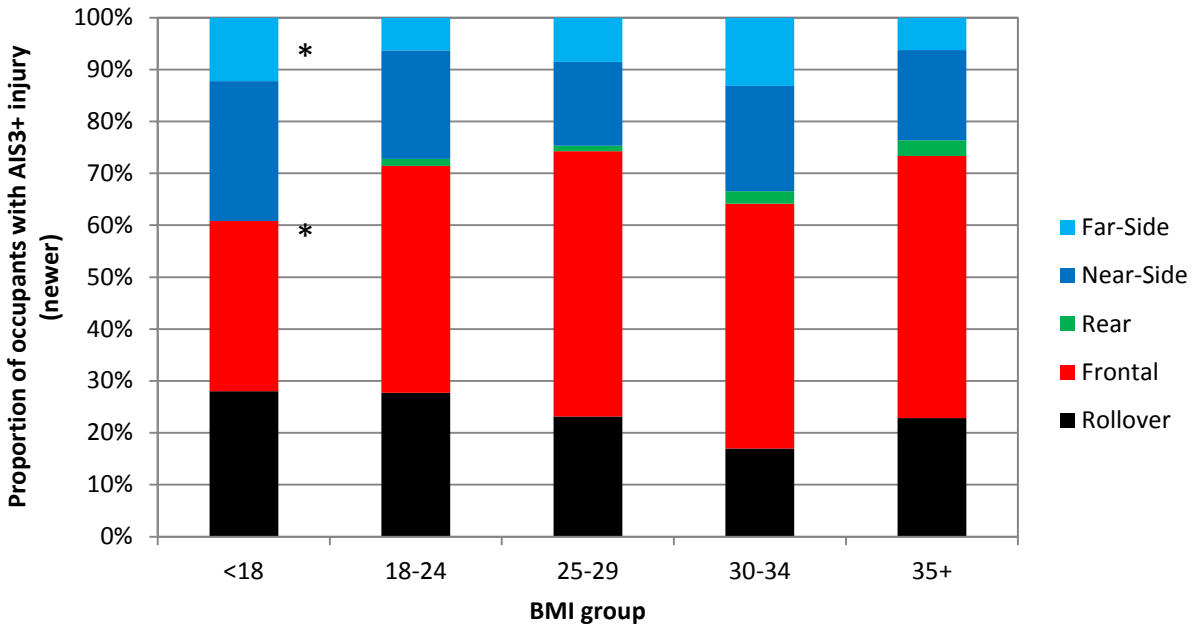


Figure 124. Distribution of occupants with AIS3+ injury by crash type for each BMI group.

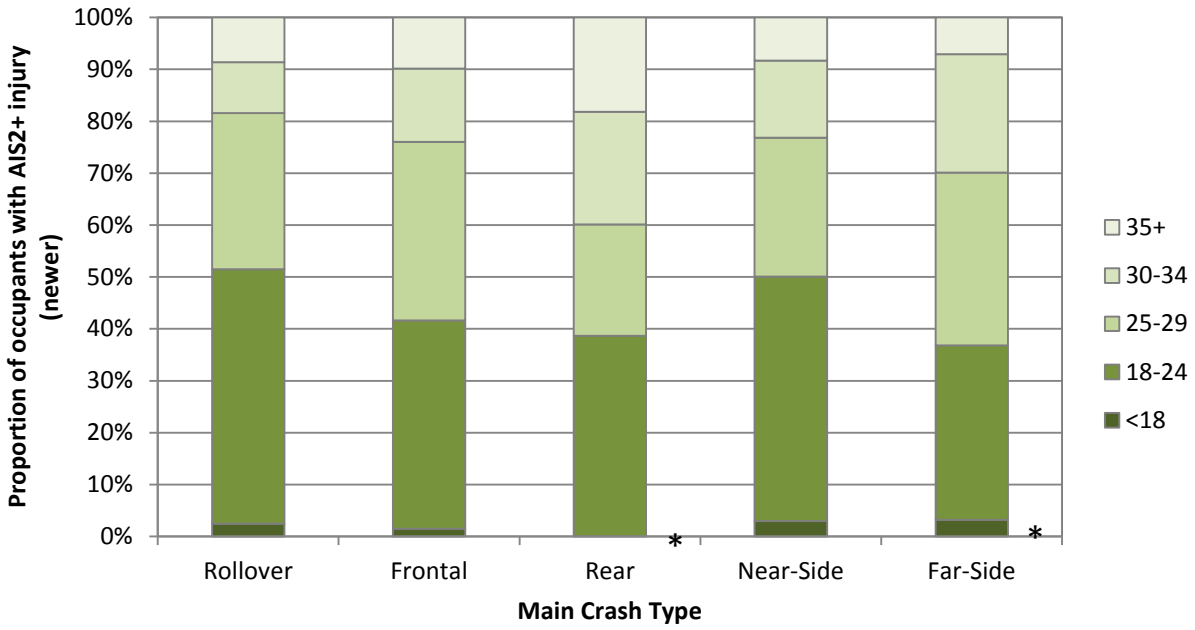


Figure 125. Distribution of occupants with AIS3+ injury by BMI group for each crash type.

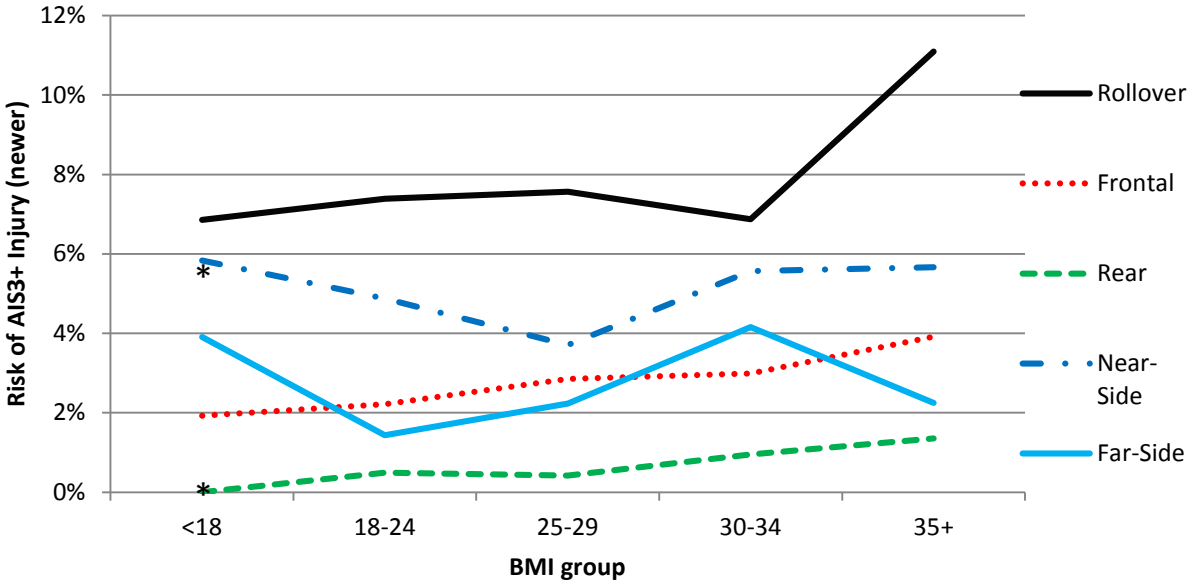


Figure 126. Risk of AIS3+ injury by crash type for each BMI group.

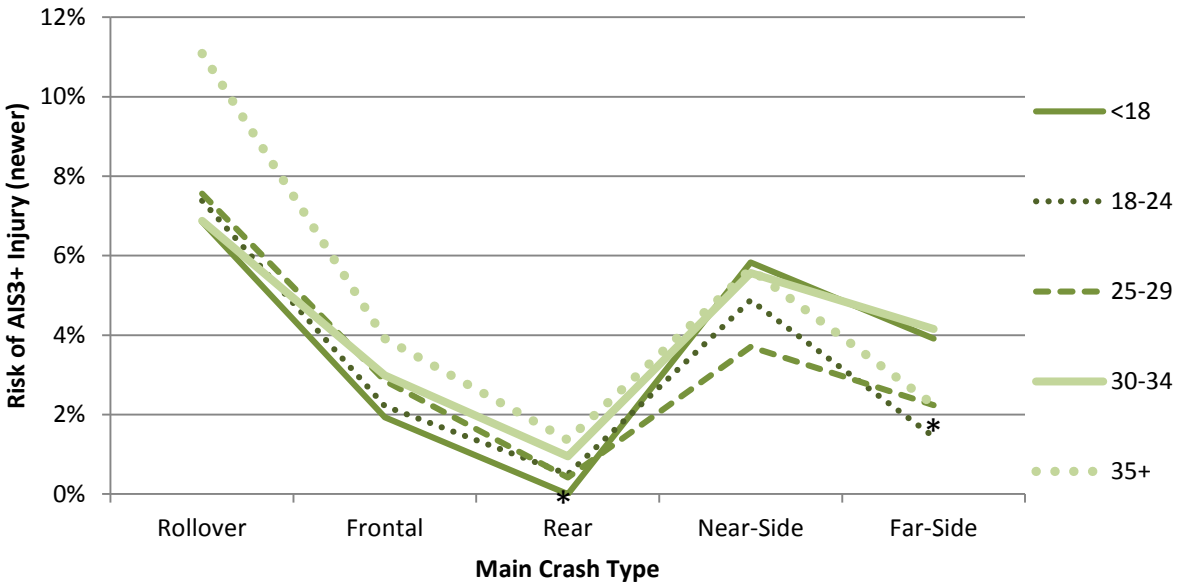


Figure 127. Risk of AIS3+ injury by BMI group for each crash type.

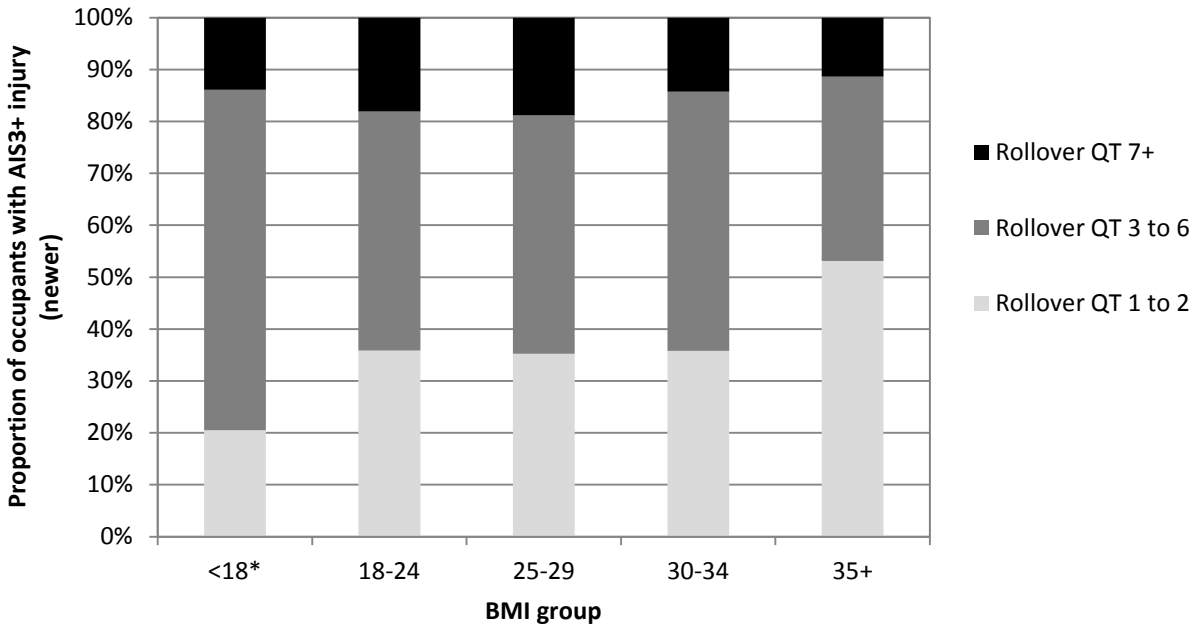


Figure 128. Proportion of occupants with AIS3+ injury by rollover type for each BMI group.

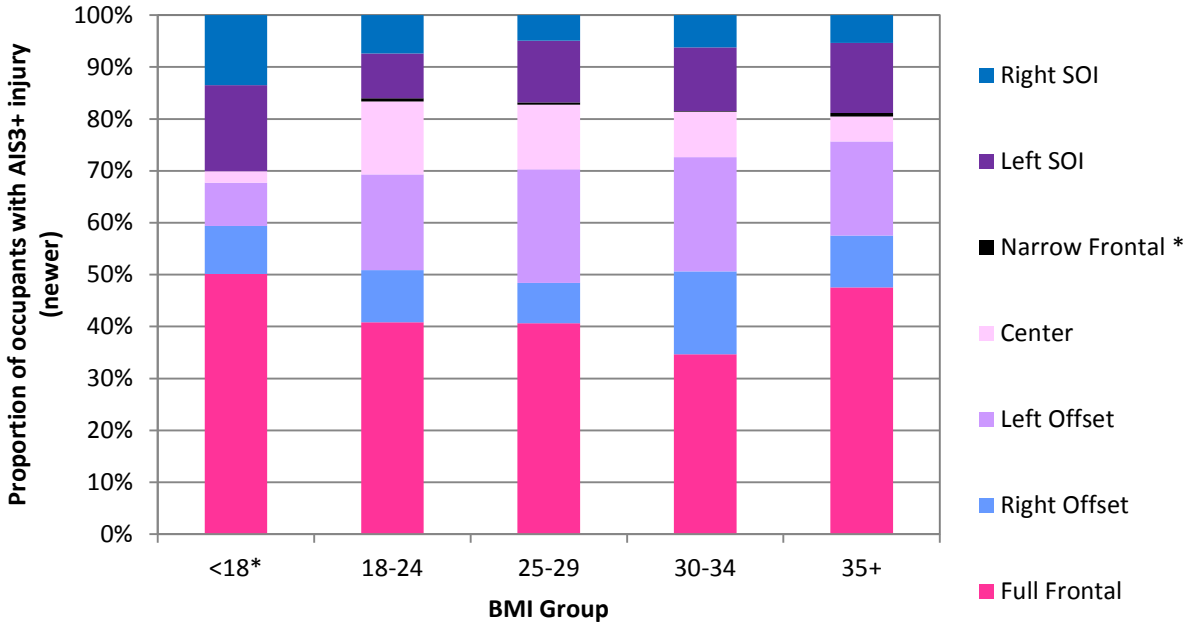


Figure 129. Proportion of occupants with AIS3+ injury by frontal subcrash group for each BMI group.

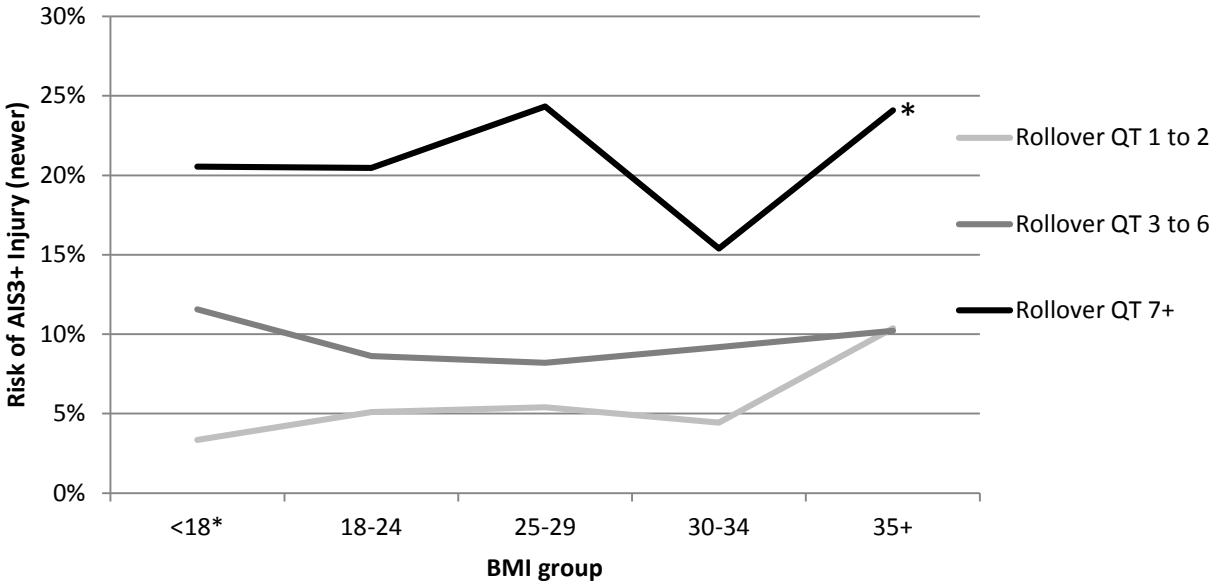


Figure 130. Risk of AIS3+ injury by rollover type for each BMI group.

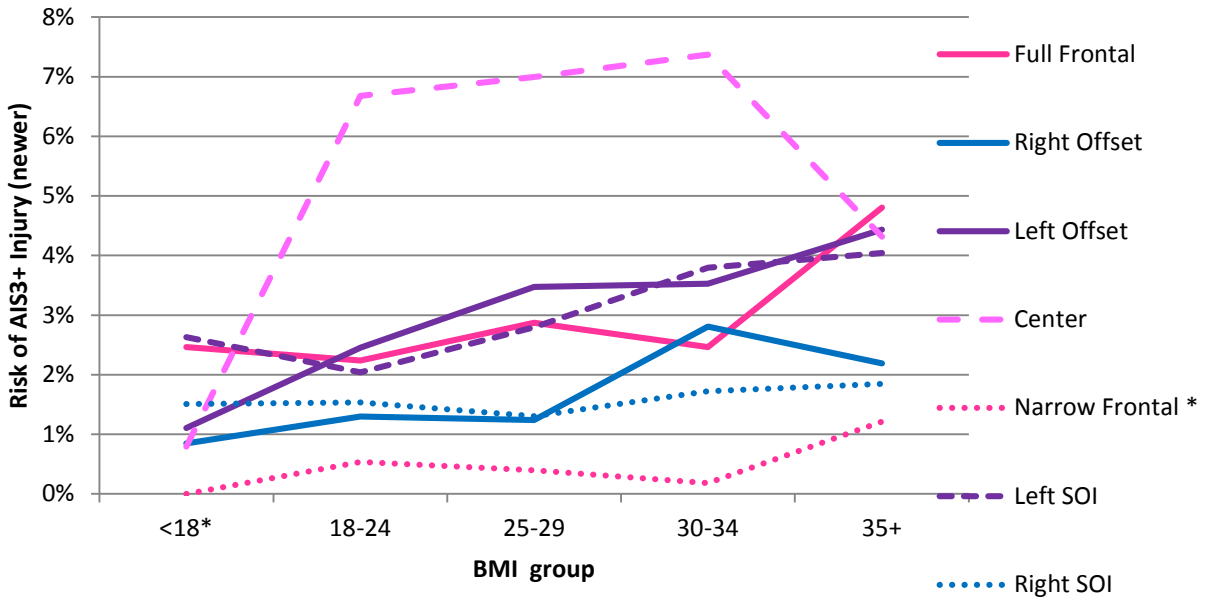


Figure 131. Risk of AIS3+ injury by frontal subcrash group for each BMI group.

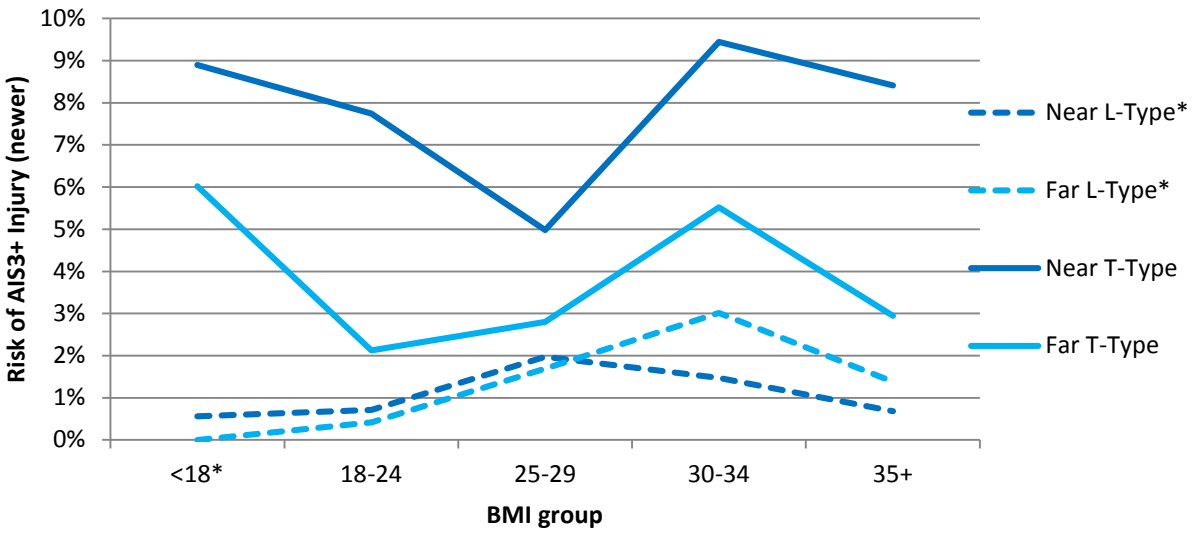


Figure 132. Risk of AIS3+ injury by side subcrash group for each BMI group.

Injuries by Body Region and Occupant BMI

- Occupants with BMI >35 have the greatest proportion of AIS2+ lower extremity injuries.
- The risk of AIS2+ injury to the lower extremity, upper extremity, and thorax generally increase with BMI.
- The risk of AIS3+ injury to the head, thorax, upper extremity and lower extremity increase with BMI.

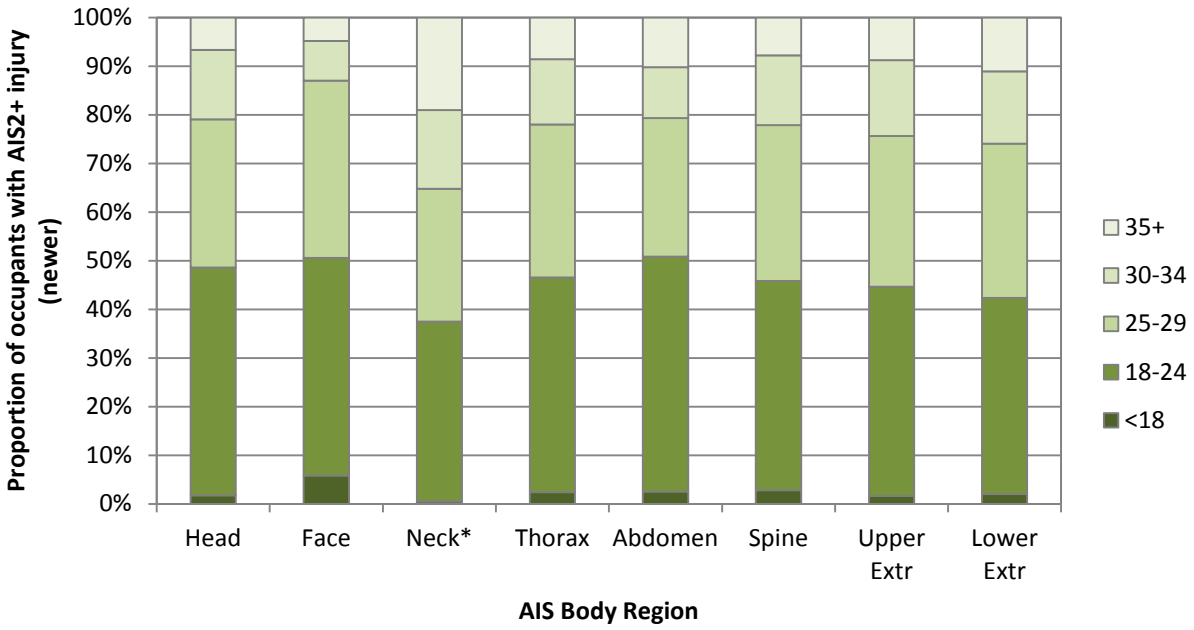


Figure 133. Distribution of occupants with AIS2+ injury by BMI group for each AIS body region.

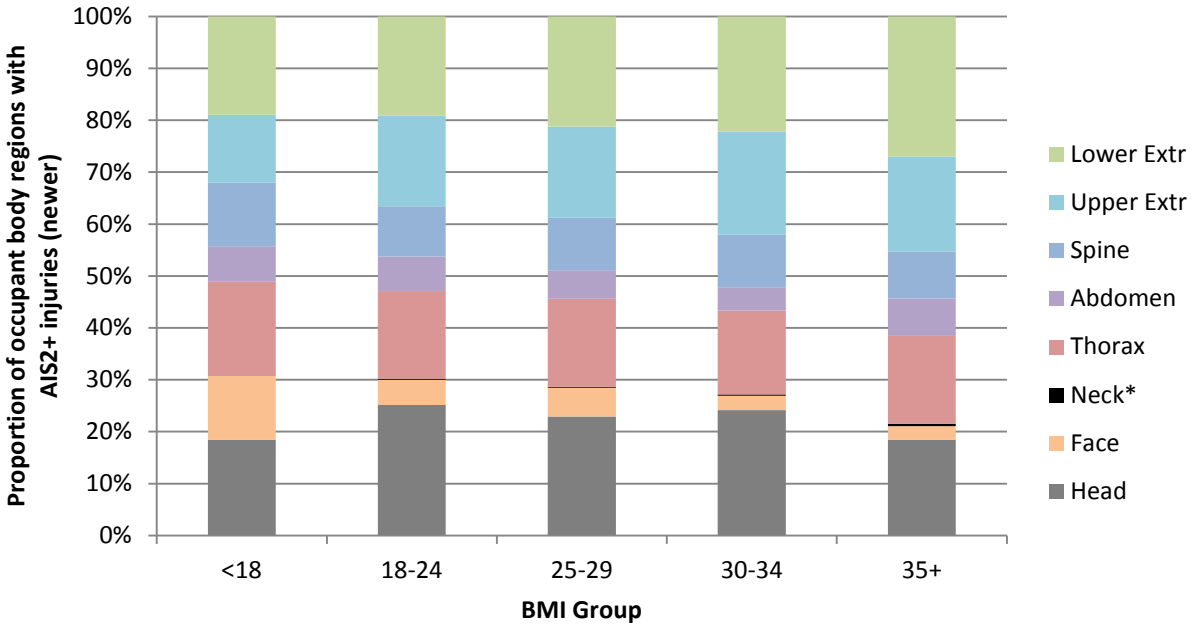


Figure 134. Distribution of occupant body regions with AIS2+ injury by AIS body region for each BMI group.

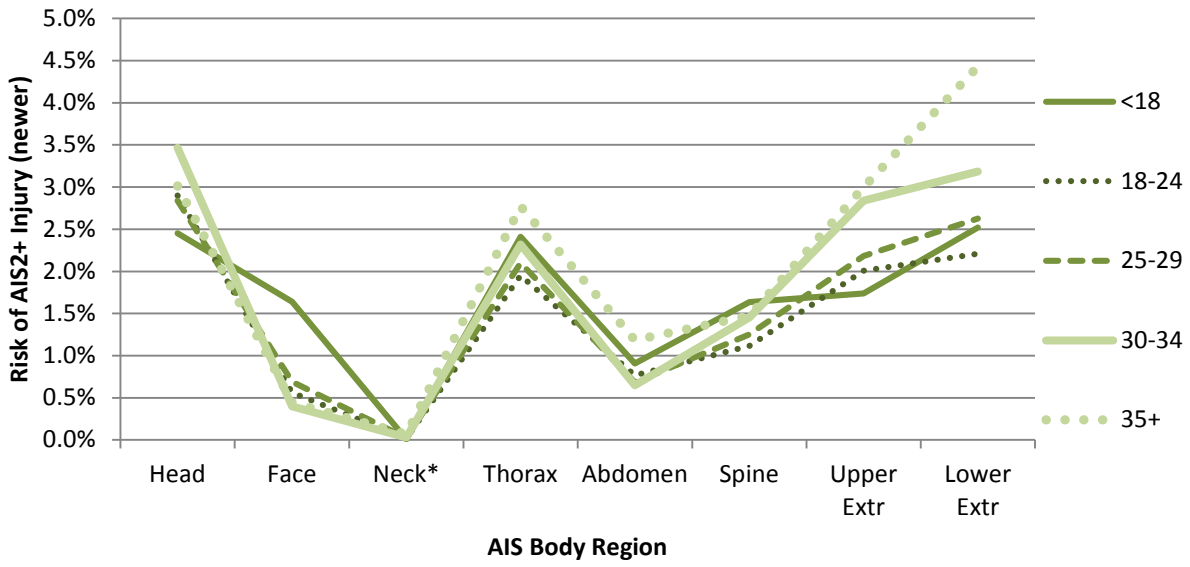


Figure 135. Risk of AIS2+ injury by BMI group for each AIS body region.

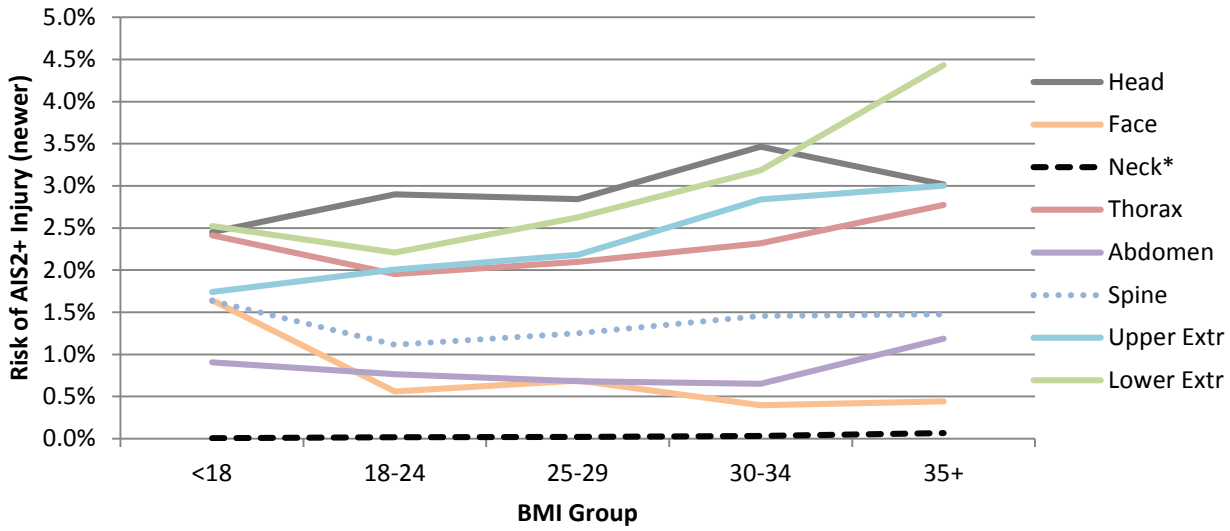


Figure 136. Risk of AIS2+ injury by AIS body region for each BMI group.

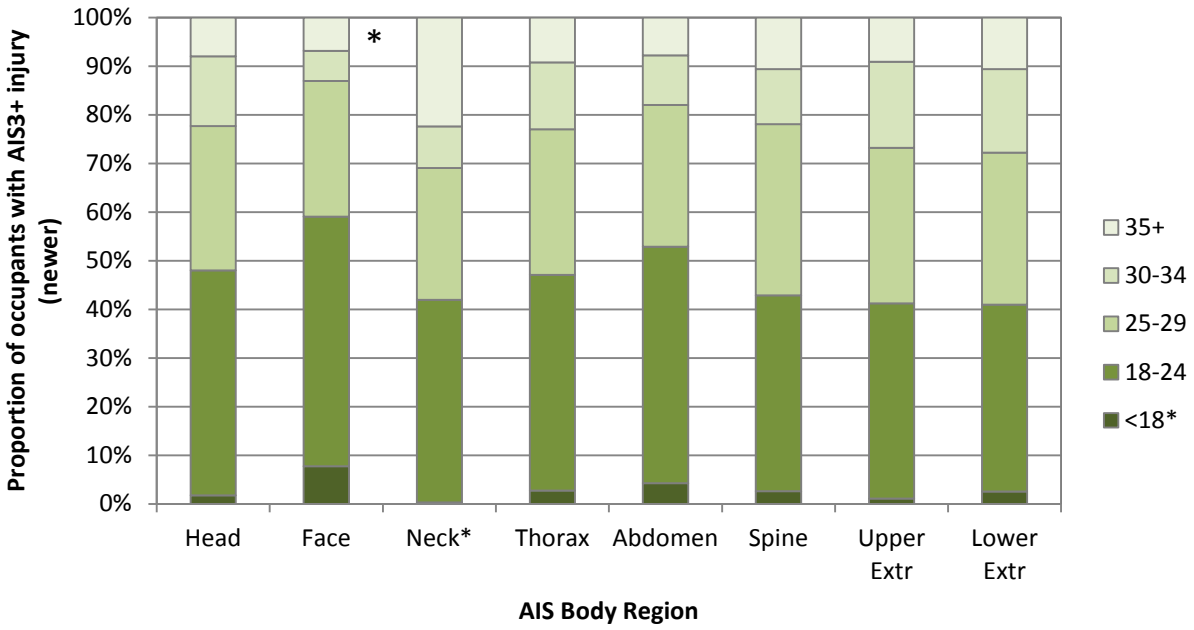


Figure 137. Distribution of occupants with AIS3+ injury by BMI group for each body region.

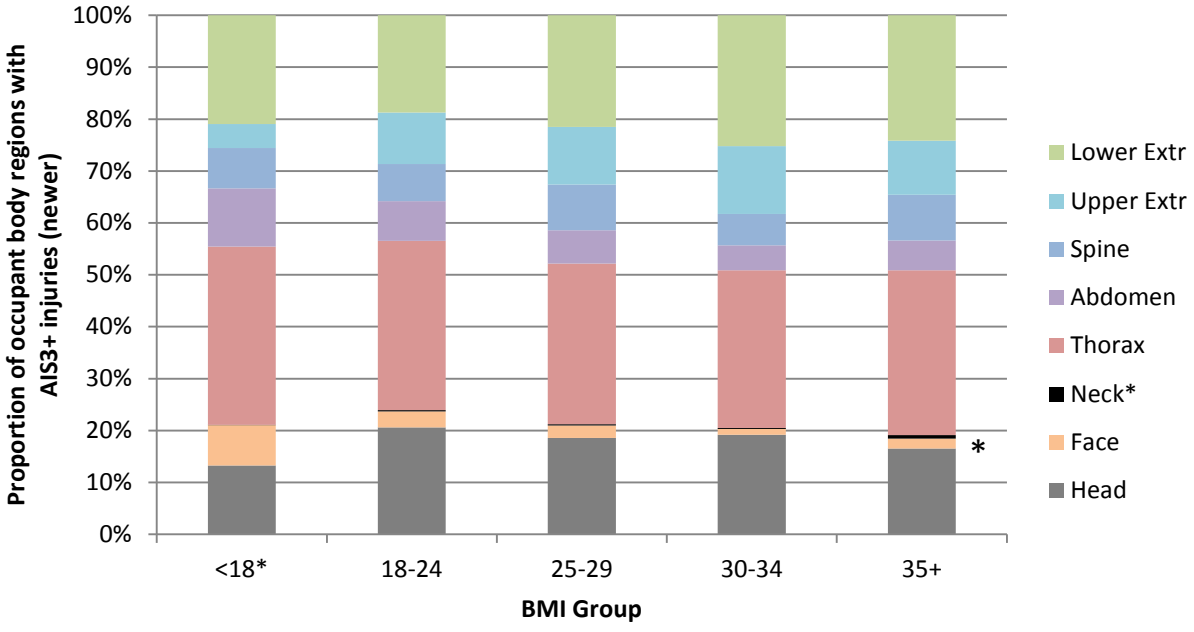


Figure 138. Distribution of occupant body regions with AIS3+ injury by body region for each BMI group.

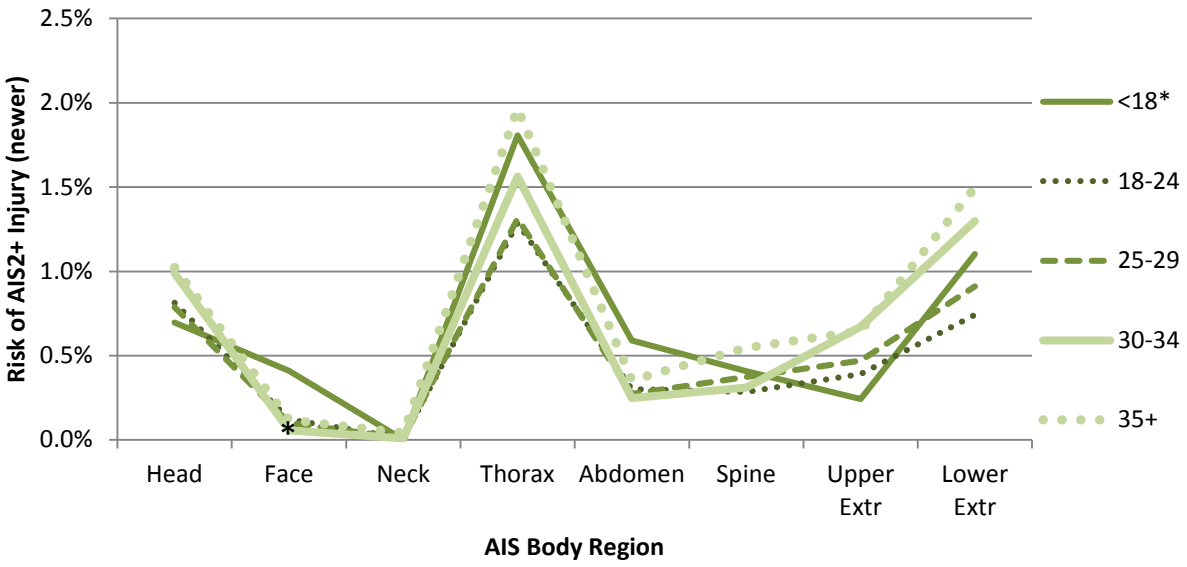


Figure 139. Risk of AIS3+ injury by BMI group for each AIS body region.

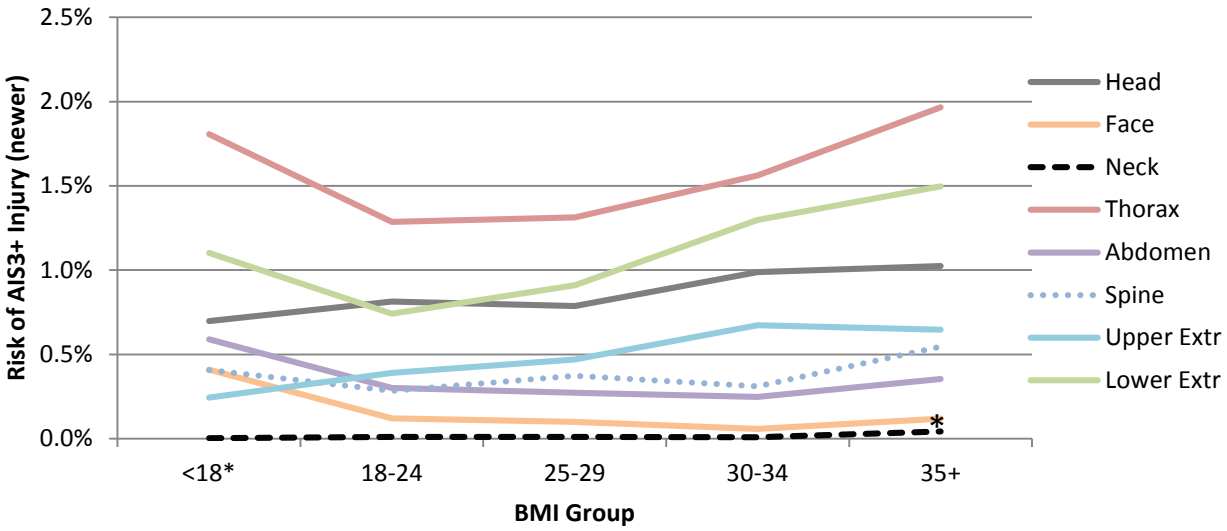


Figure 140. Risk of AIS3+ injury by AIS body region for each BMI group.

Chapter 8. Injuries by Occupant Gender

Crash Mode by Gender

- There are less than 25 unweighted injured occupants with AIS3+ injuries in narrow frontal impacts, making analysis of injury trends for this group unreliable. These categories are marked with an *.
- Among occupants with AIS2+ injuries, men comprise 56% of injured occupants in rollovers while women comprise slightly more than half of injured occupants in other crash types.
- Among occupants with AIS3+ injuries, men comprise 55% of occupants injured in far-side crashes and 53% in rollovers. Women comprise 59% of occupants injured in rear impacts.
- For AIS2+ injury, risks are similar between men and women in all crash types, but slightly higher for men in rear and far-side crashes and slightly higher for women in frontal and rollover crashes.
- For AIS3+ injury, risks are similar between men and women in all crash types, but slightly higher for men in near- and far-side crashes and slightly higher for women in rollover crashes.
- Women have a higher risk of AIS3+ injury in QT1-2 and QT3-6 rollover crashes, while men have a higher risk in QT7+ rollovers.

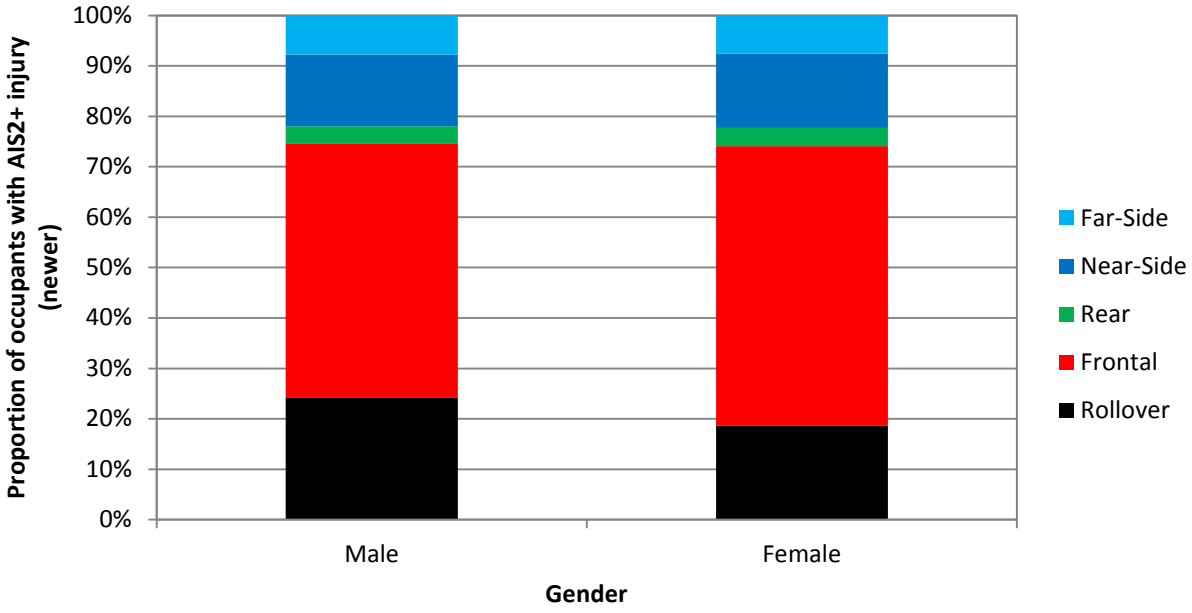


Figure 141. Distribution of occupants with AIS2+ injury by crash type for each gender.

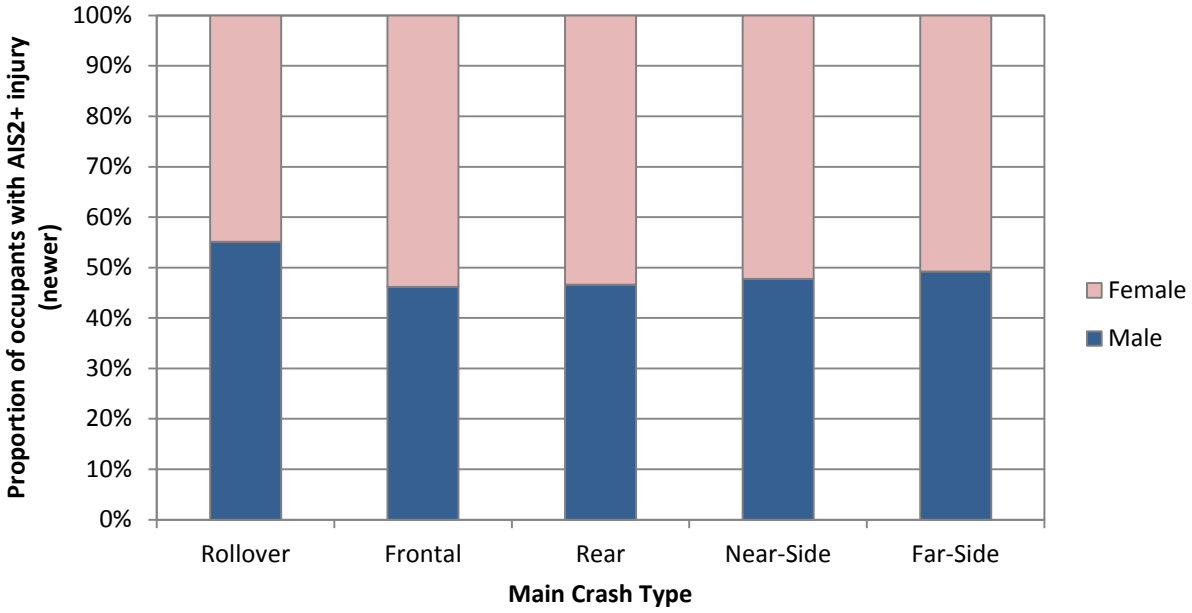


Figure 142. Distribution of occupants with AIS2+ injury by gender for each crash type.

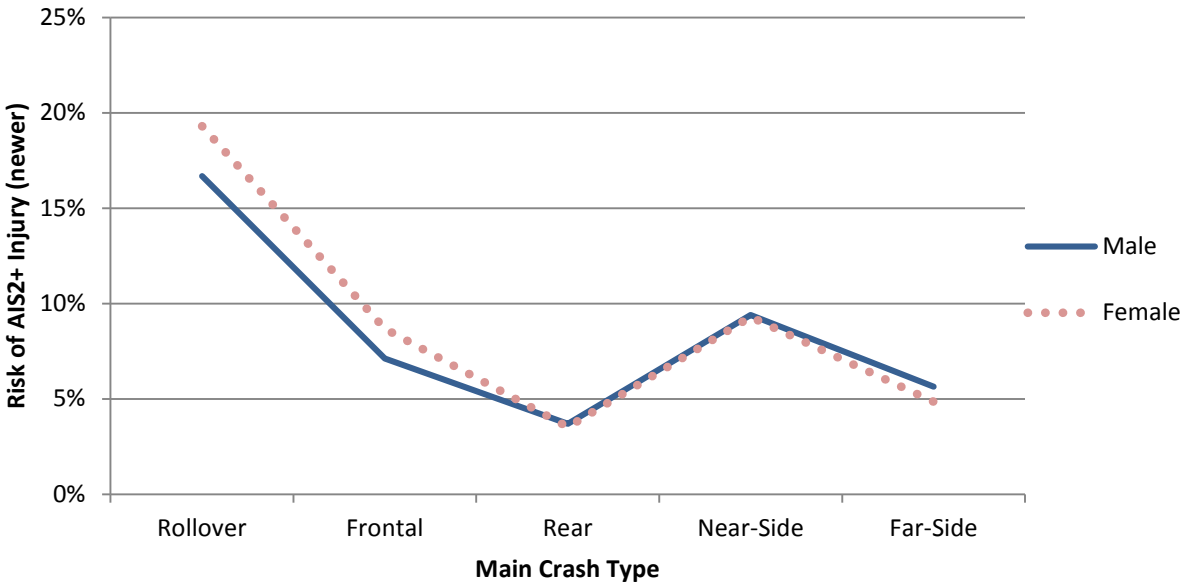


Figure 143. Risk of AIS2+ injury by gender for each crash type.

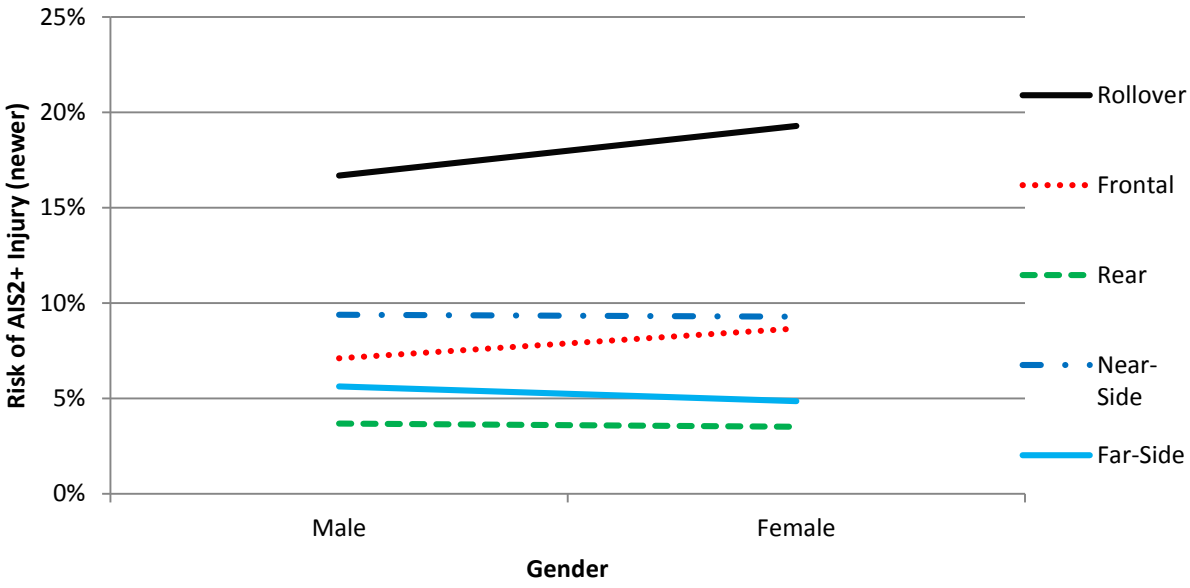


Figure 144. Risk of AIS2+ injury by crash type for each gender.

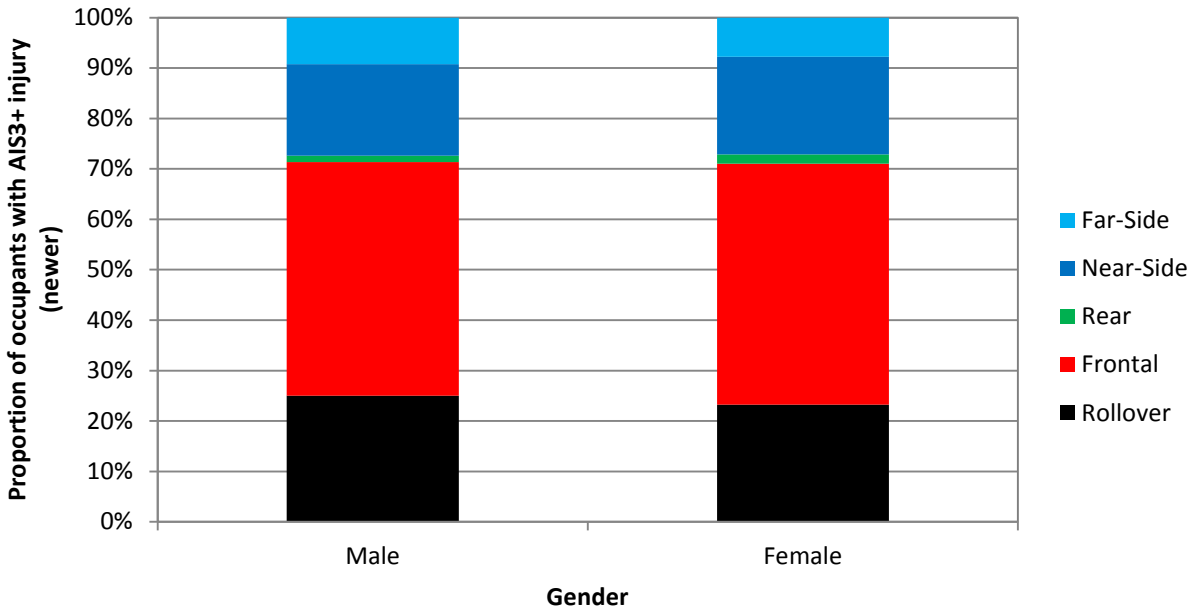


Figure 145. Distribution of occupants with AIS3+ injury by crash type for each gender.

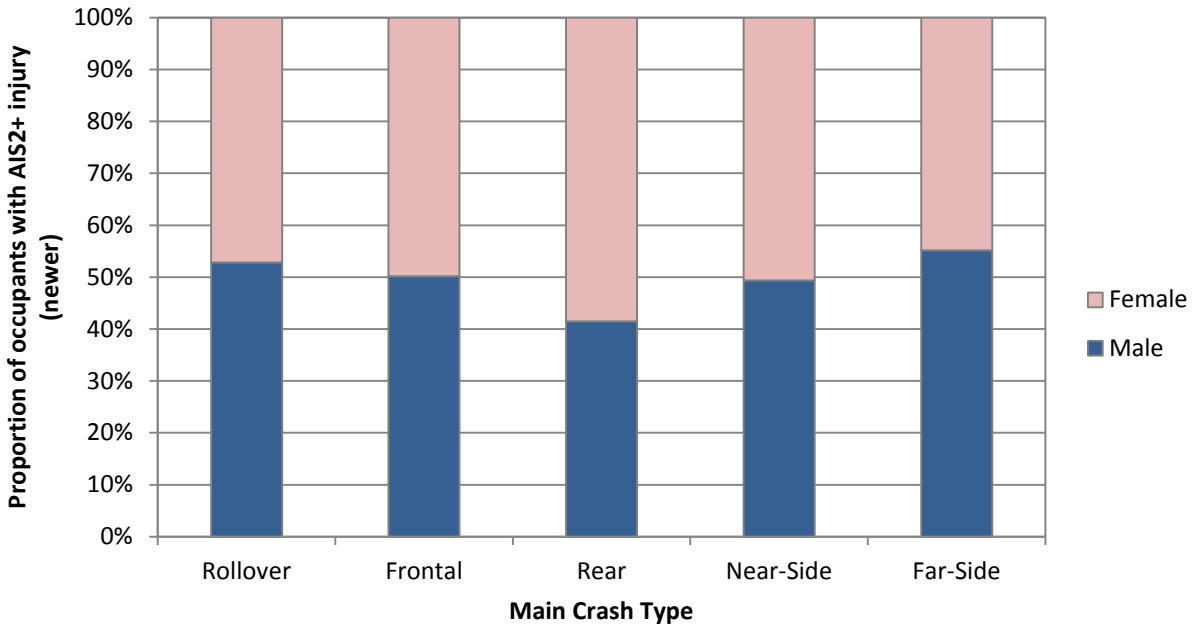


Figure 146. Distribution of occupants with AIS3+ injury by gender for each crash type.

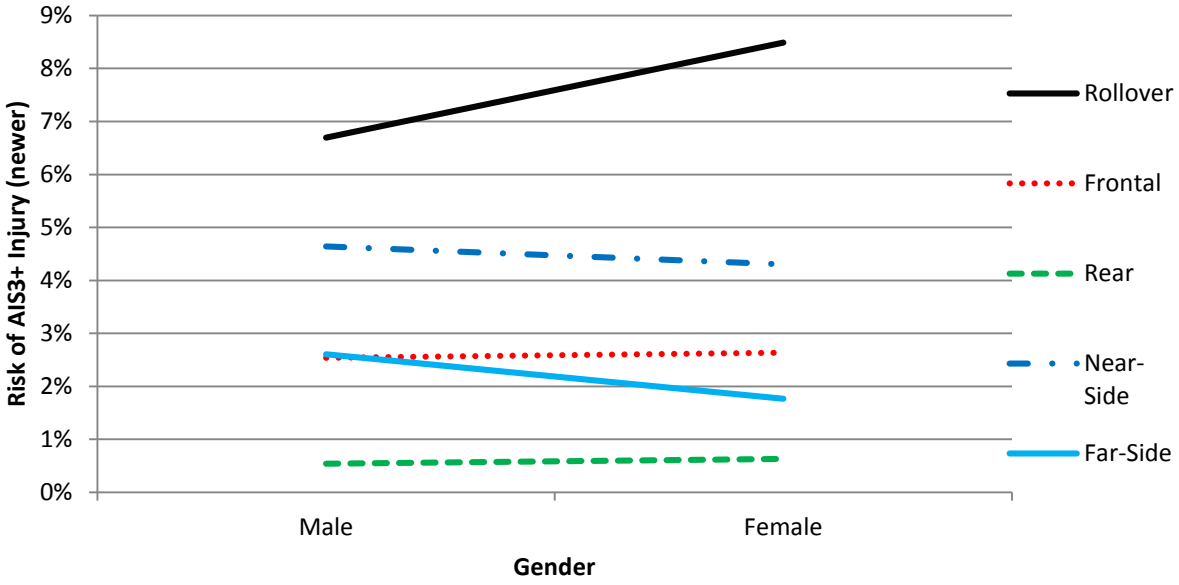


Figure 147. Risk of AIS3+ injury by crash type for each gender.

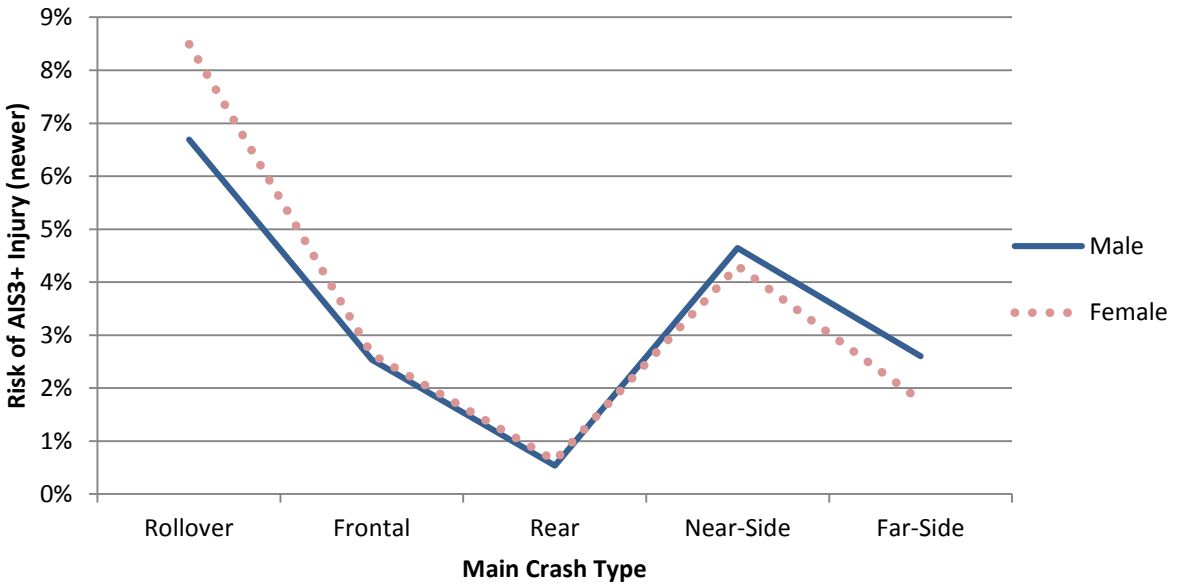


Figure 148. Risk of AIS3+ injury by gender for each crash type.

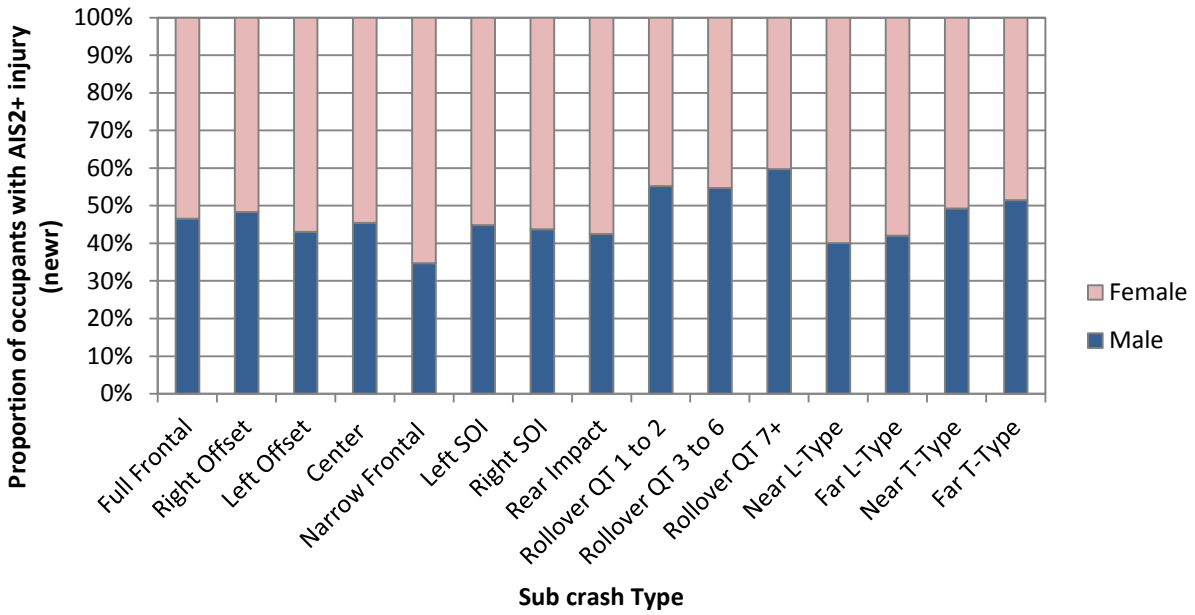


Figure 149. Distribution of AIS2+ injured occupants by gender for each subcrash type.

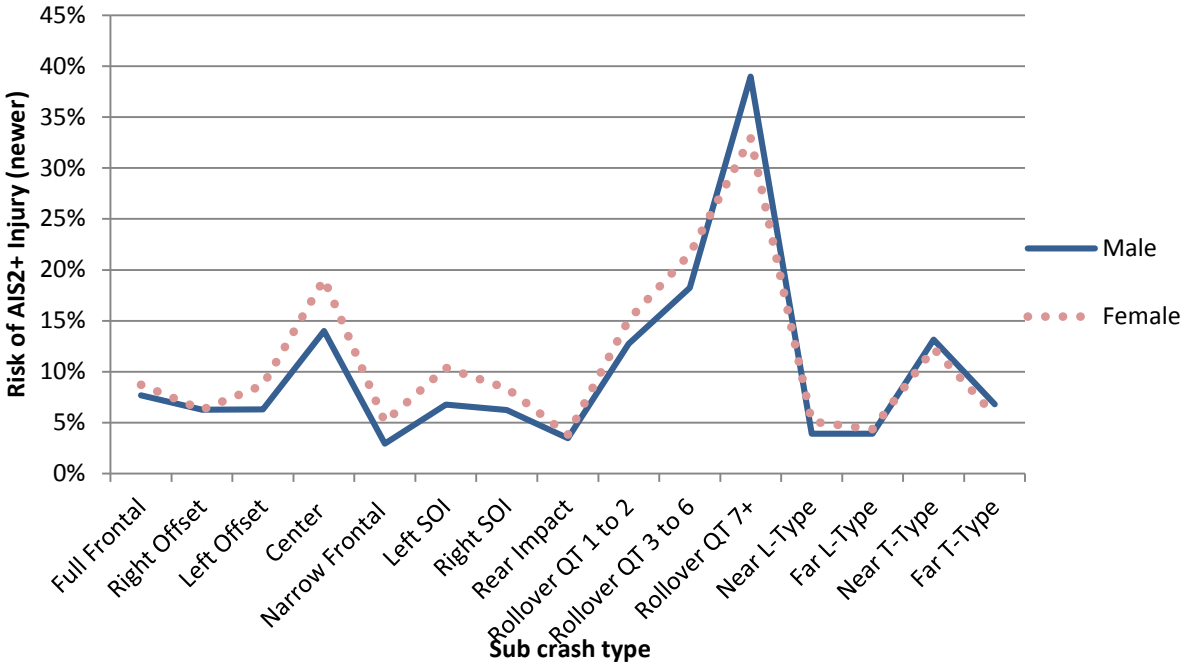


Figure 150. Risk of AIS2+ injury by gender for each subcrash type.

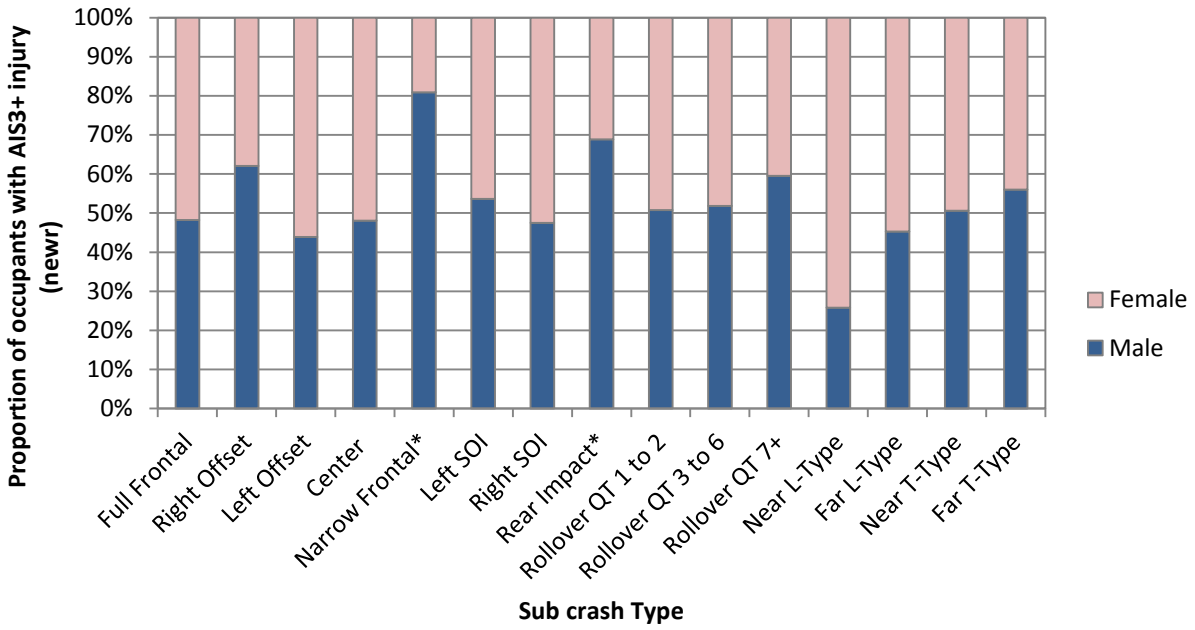


Figure 151. Proportion of occupants with AIS3+ injury by gender for each subcrash type.

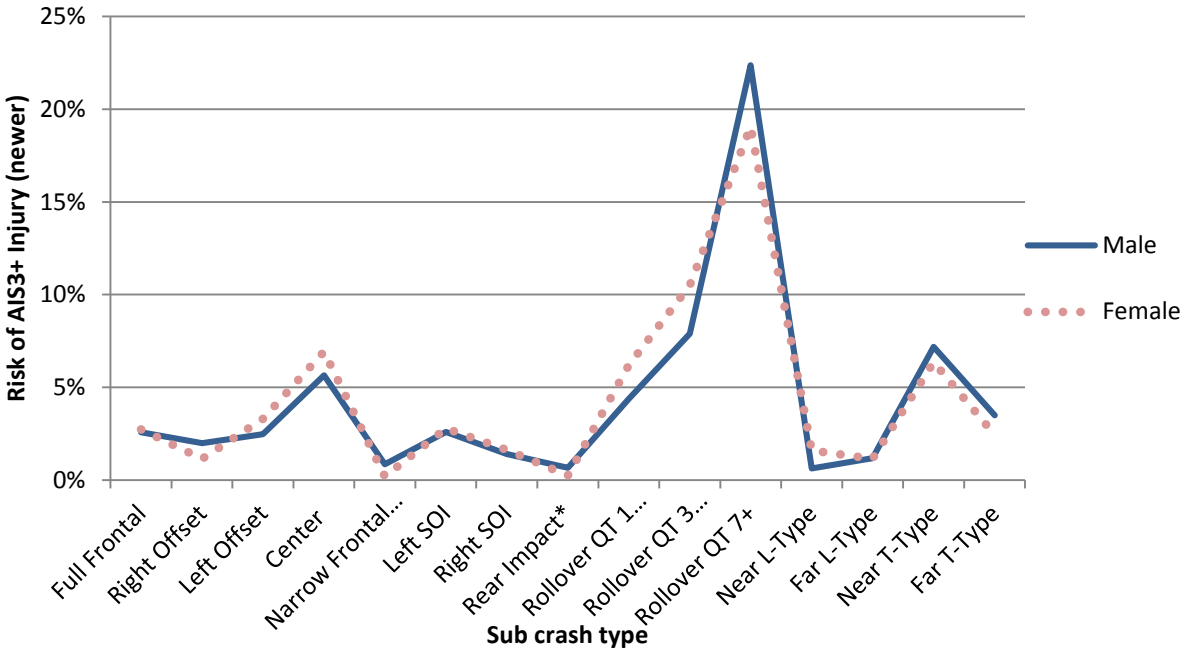


Figure 152. Risk of AIS3+ injury by gender for each subcrash type.

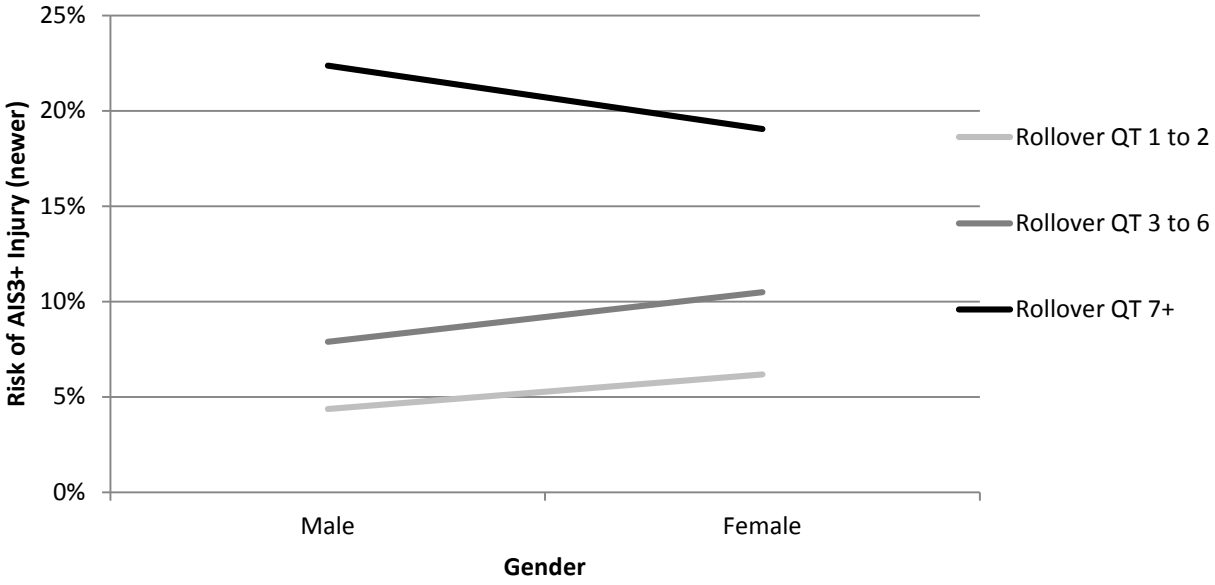


Figure 153. Risk of AIS3+ injury for each rollover type by gender.

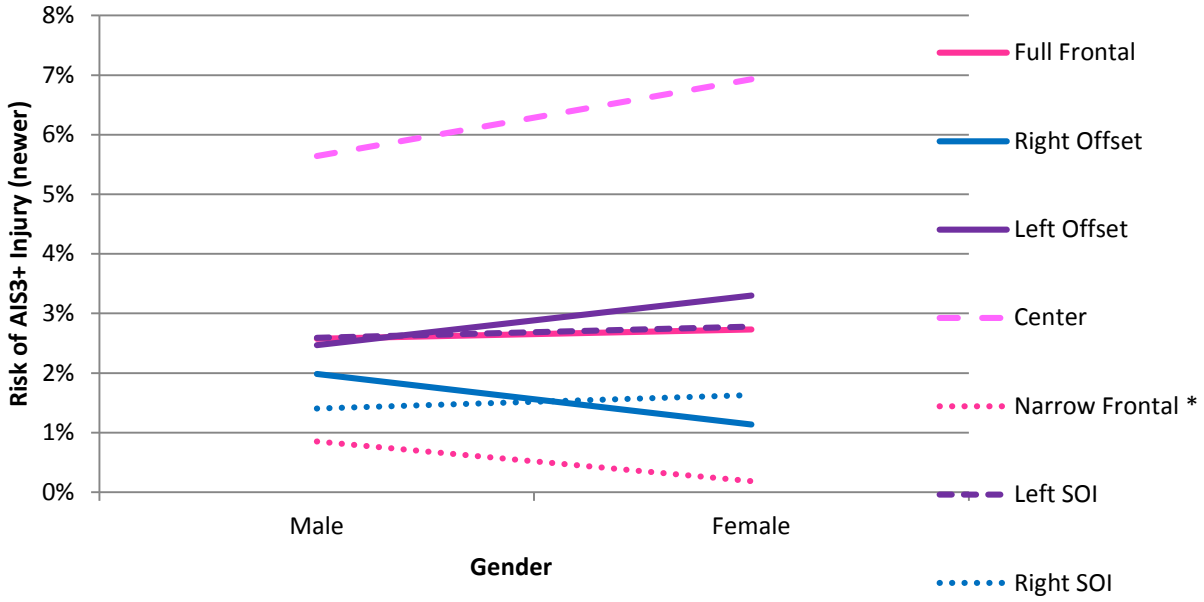


Figure 154. Risk of AIS3+ injury by frontal subcrash type for each gender.

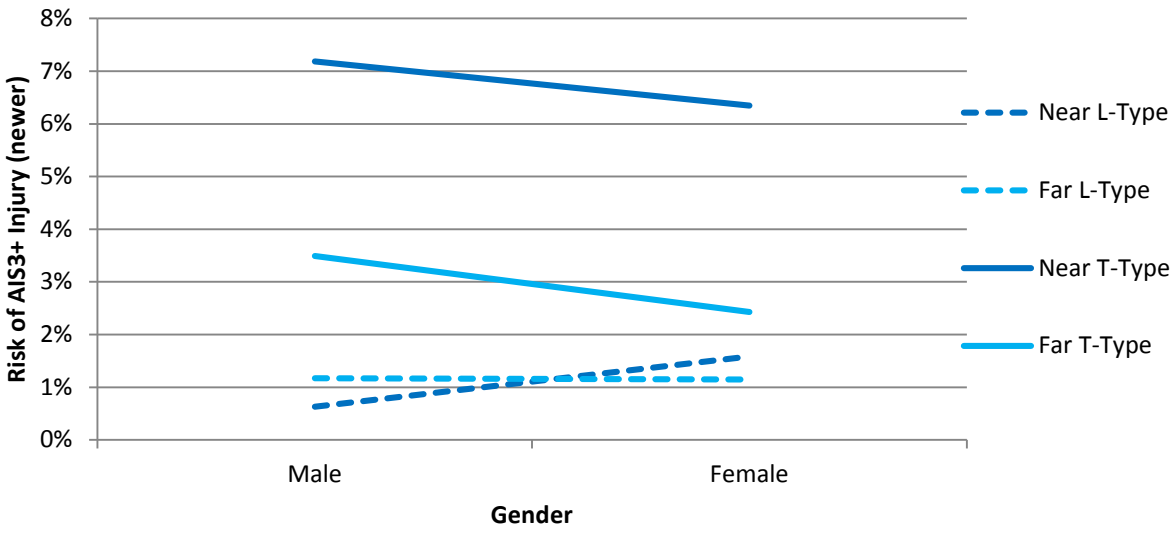


Figure 155. Risk of AIS3+ injury by side sub crash type for each gender.

Injuries by Body Region and Occupant Gender

- The distribution of occupants with AIS2+ and AIS3+ injury by body region is nearly identical for men and women. The largest difference at the AIS2+ level is a larger proportion of lower extremity injuries for women and a larger proportion of head and face injuries for men. For AIS3+ injuries, men have a larger proportion of head, face, and spine injuries, but the biggest difference for women is in the proportion of upper extremity injuries.
- Men comprise just over half of the occupants with AIS2+ injuries to each body region except for the abdomen and upper and lower extremities.
- For AIS3+ injuries, men comprise between more than half of occupants with AIS3+ injuries to all body regions, with the exceptions of the abdomen and upper extremity.
- Men have higher risk of AIS3+ injury than women for all body regions except for the abdomen and upper extremity.

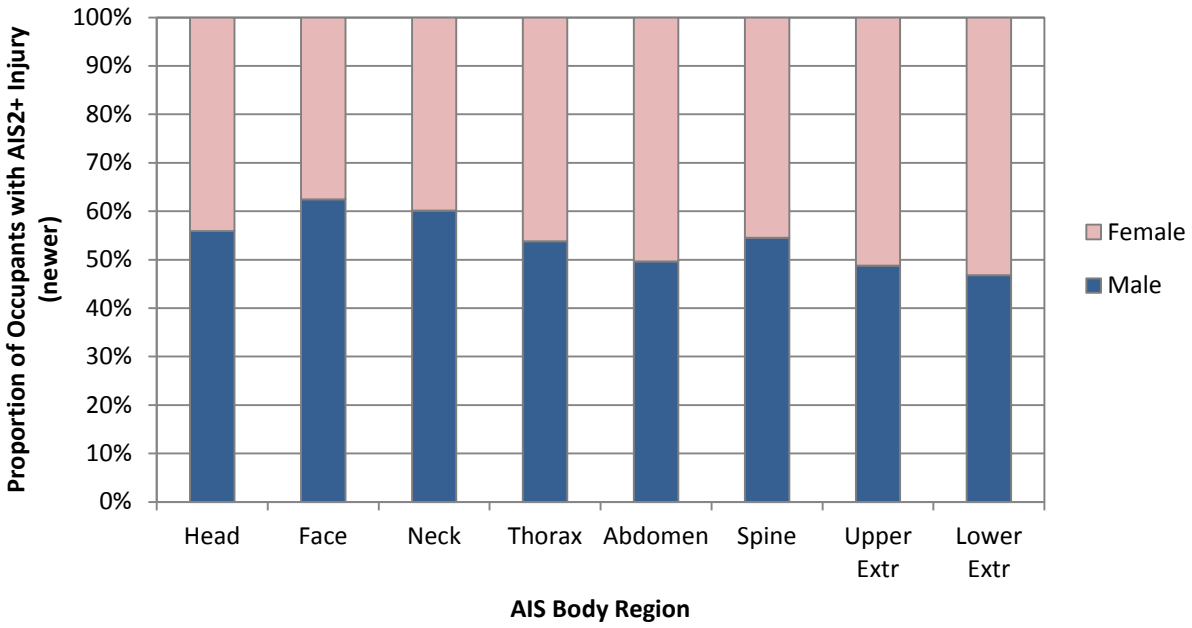


Figure 156. Distribution of occupants with ASI2+ injury by gender for each AIS body region.

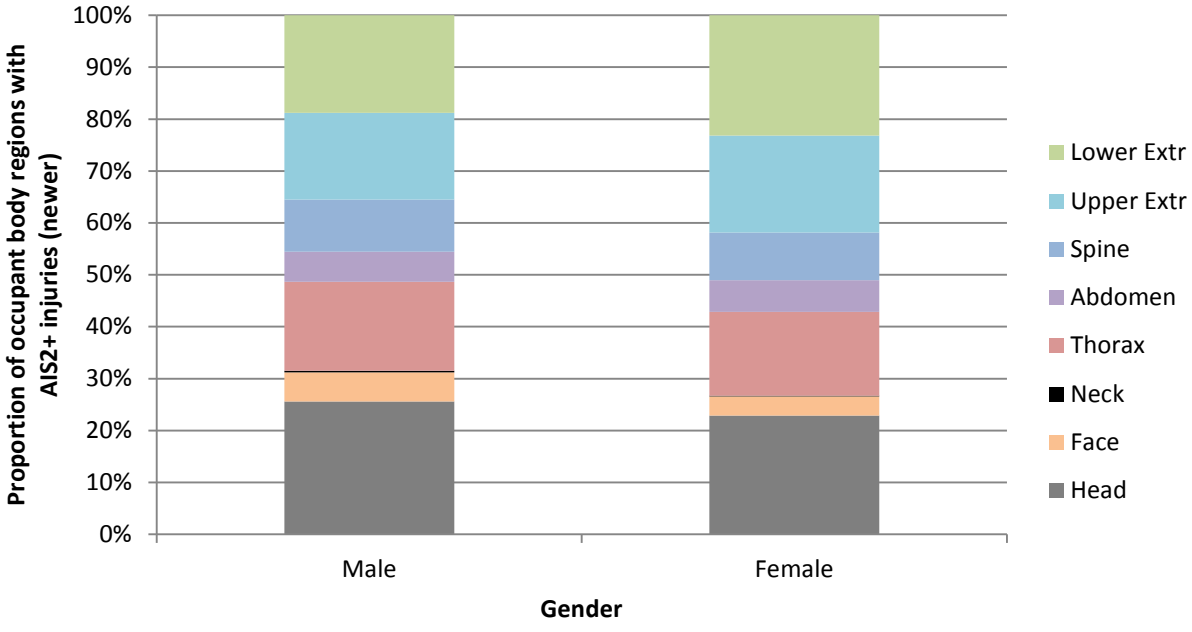


Figure 157. Distribution of occupant body regions with AIS2+ injury by AIS body region for each gender.

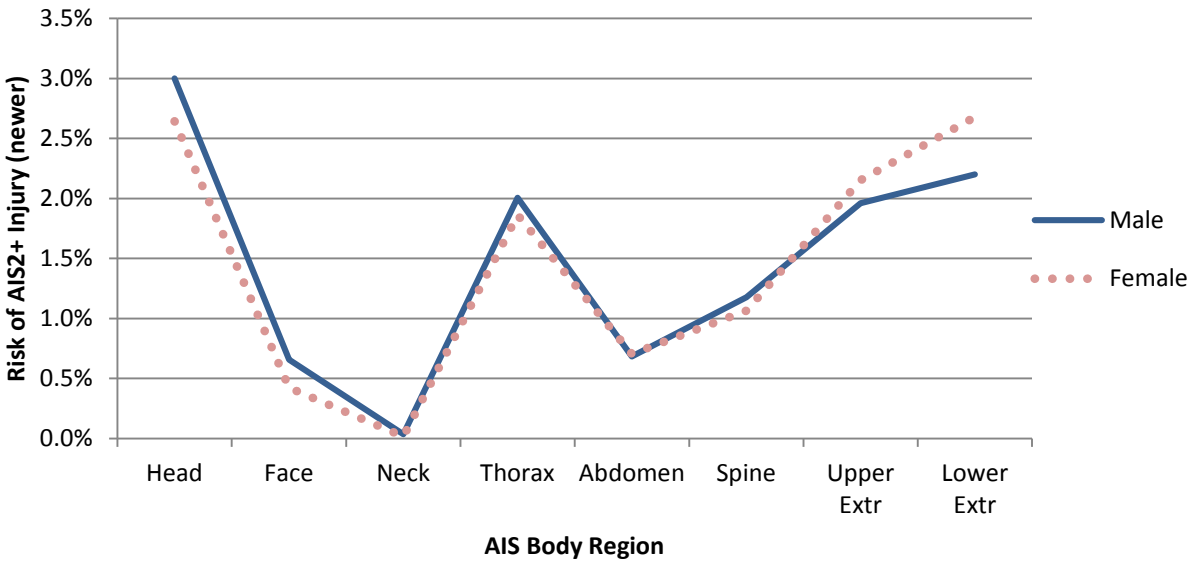


Figure 158. Risk of AIS2+ injury by gender for each AIS body region.

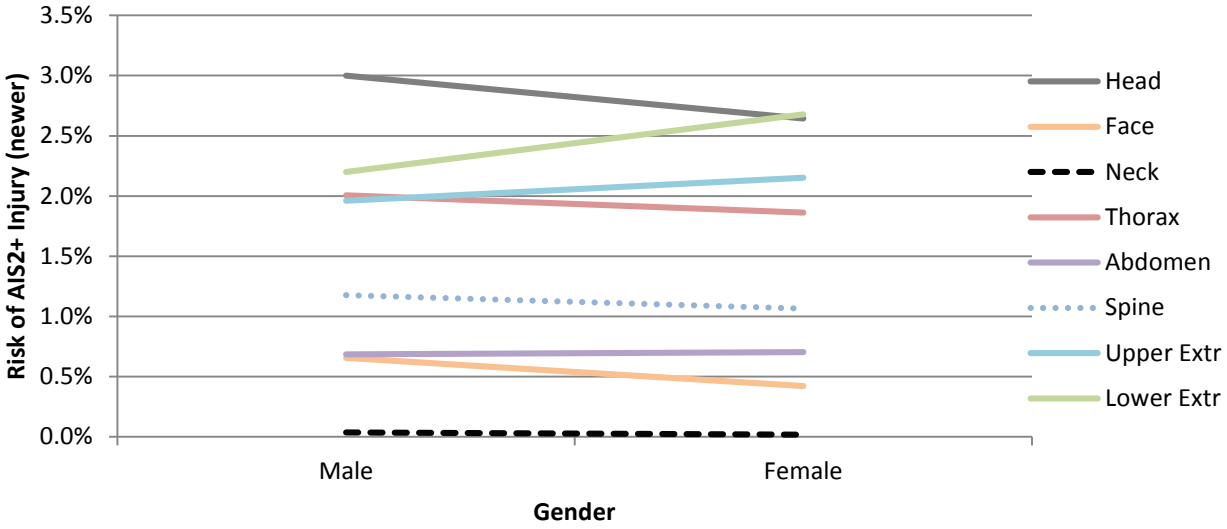


Figure 159. Risk of AIS2+ injury by AIS body region for each gender.

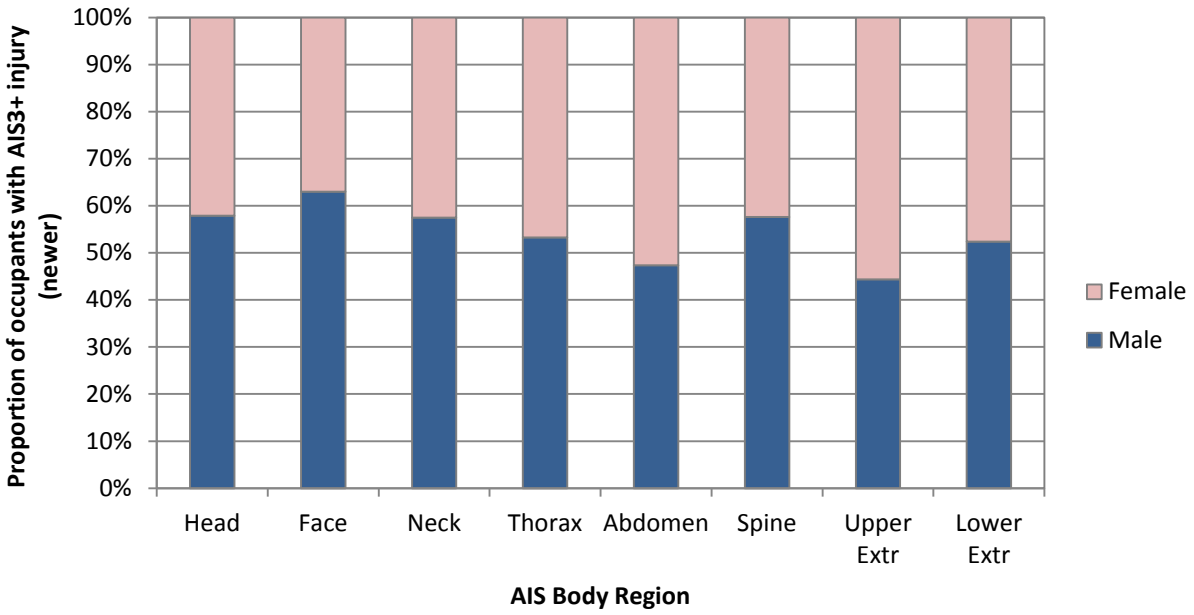


Figure 160. Distribution of occupants with AIS3+ injury by gender for each body region.

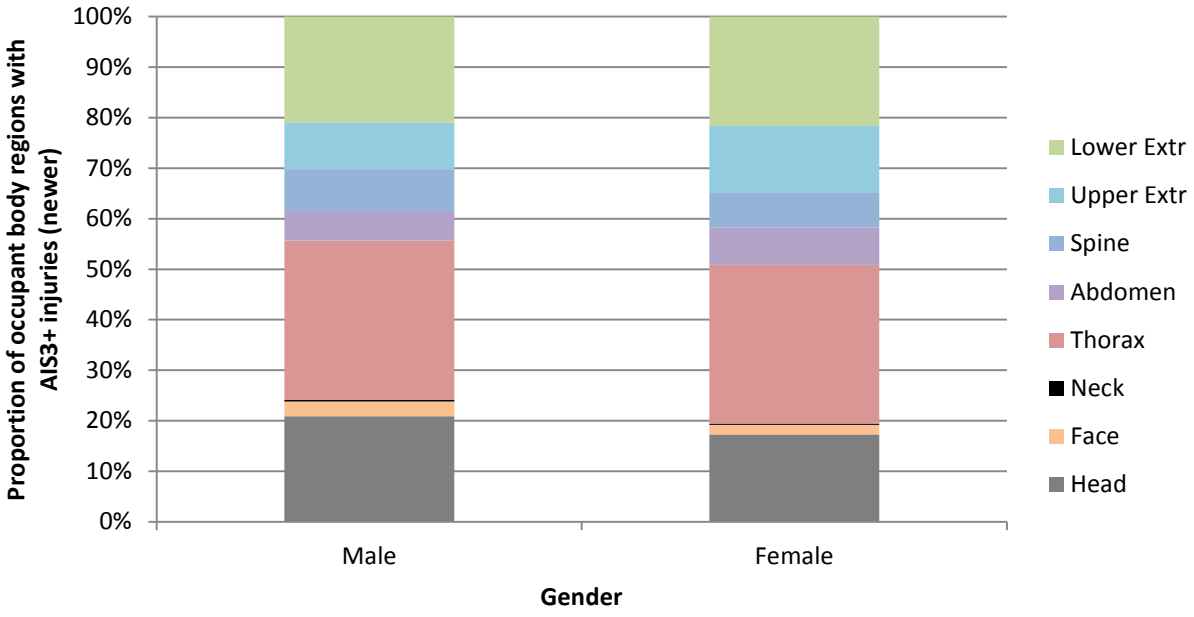


Figure 161. Distribution of occupants with AIS3+ injury by AIS body region for each gender.

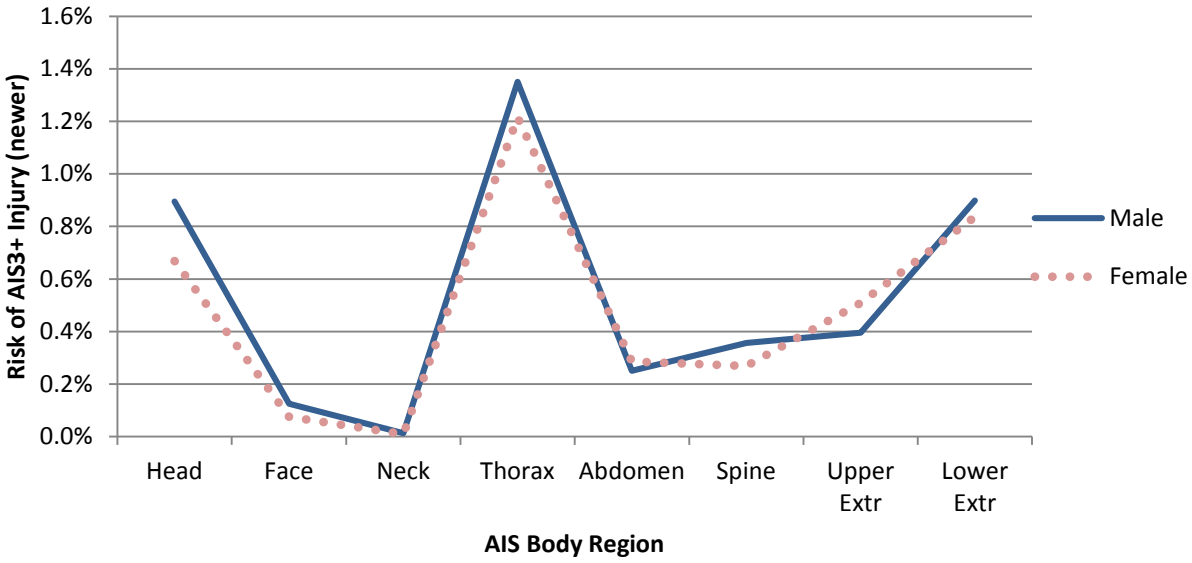


Figure 162. Risk of AIS3+ injury by gender for each AIS body region.

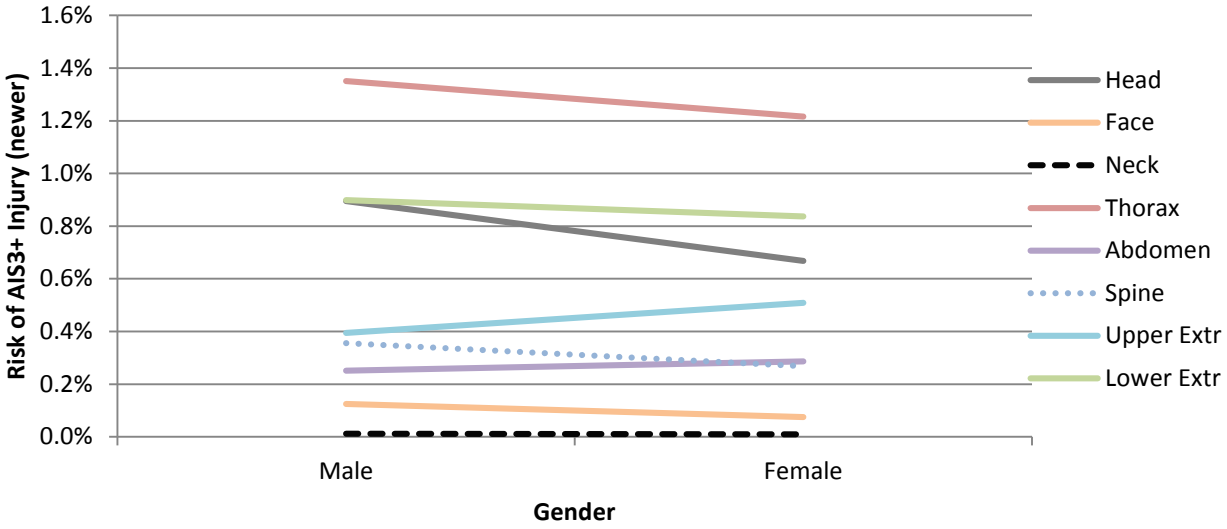


Figure 163. Risk of AIS3+ injury by AIS body region for each gender.

Chapter 9. Injuries by Vehicle Type

- The distribution of occupants in this dataset with known vehicle type and injury level is shown in Figure 164.

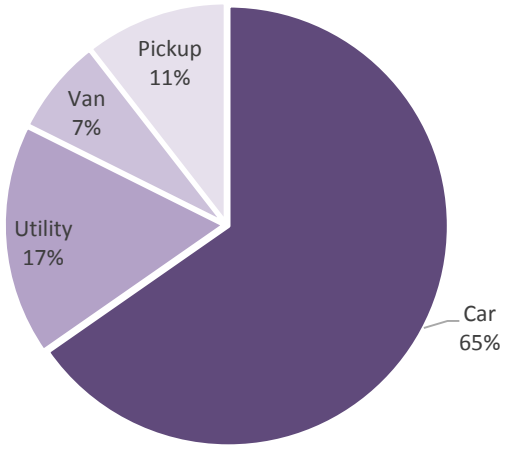


Figure 164. Distribution of occupants by vehicle type.

- There are less than 25 unweighted injured occupants sustaining AIS3+ injuries in rear impacts for all vehicle types except cars. As a result, these categories are marked with an asterisk and are unsuitable for use in analysis of injury trends. The same is true at the AISS2+ and AIS3+ level for most vehicle types in narrow frontals, rear impacts, near L-types, and far L-types, as well as right SOI involving vans.
- Among occupants with AIS2+ or AIS3+ injuries, those in pickups and utilities have the highest proportion of occupants injured in rollovers but the lowest proportion of occupants injured in side and rear impacts.
- Risk of AIS2+ injury is highest in pickup trucks for rollovers, frontal, and near-side impacts, in passenger cars for near and far-side impacts, and utility vehicles in rear impacts.
- Risk of AIS2+ injury is lowest in rear crashes for cars, in utility vehicles for near-side crashes, and in vans for all other crash types.
- Risk of AIS3+ injury is highest in pickup trucks for frontal, near-side, and rear crashes and in passenger cars for far-side and rollovers.
- Risk of AIS3+ injury is lowest in utility vehicles for rollovers and rear impacts and in vans for other crash modes.
- Among occupants with AIS2+ or AIS3+ injury in rollovers, vans have the highest proportion of occupants injured in 1-2 quarter turn and 7+ quarter turn rollovers.
- Passenger cars and vans have the highest risk of AIS2+ injury in 7+ quarter turn rollovers, while pickup trucks and cars have the highest risk in 3-6 and 1-2 quarter turn rollovers.

- Vans have the highest risk of AIS3+ injury in 7+ quarter turn rollovers, while passenger cars have the highest risk in 3-6 quarter turn rollovers.

Crash Mode by Vehicle Type

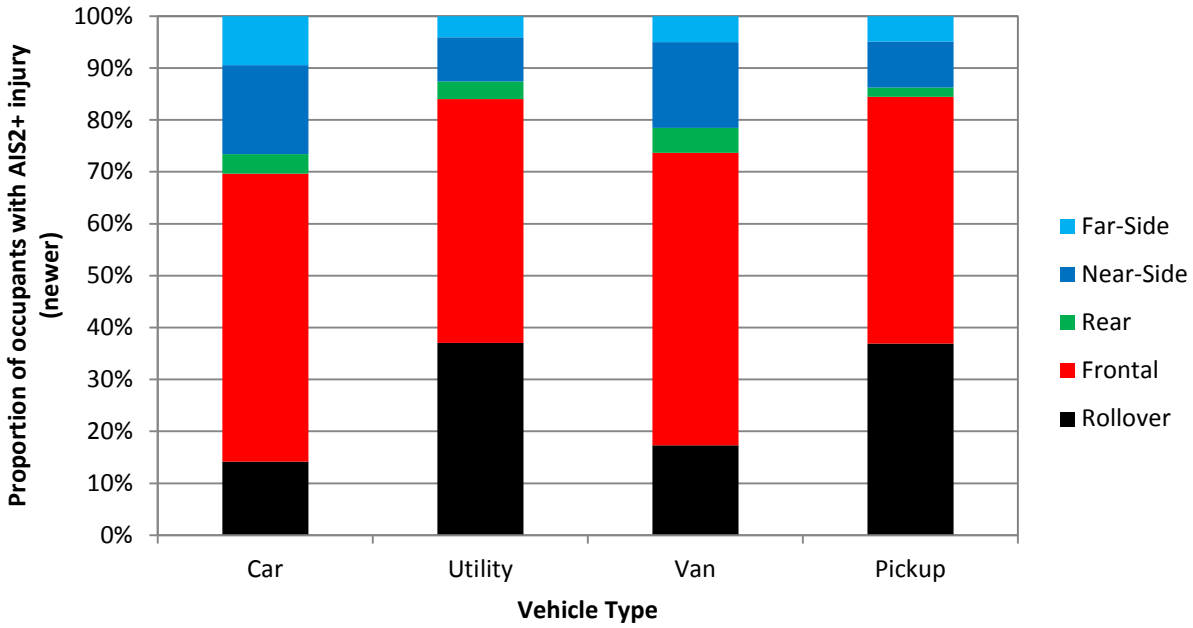


Figure 165. Proportion of occupants with AIS2+ injury by crash mode for each vehicle type.

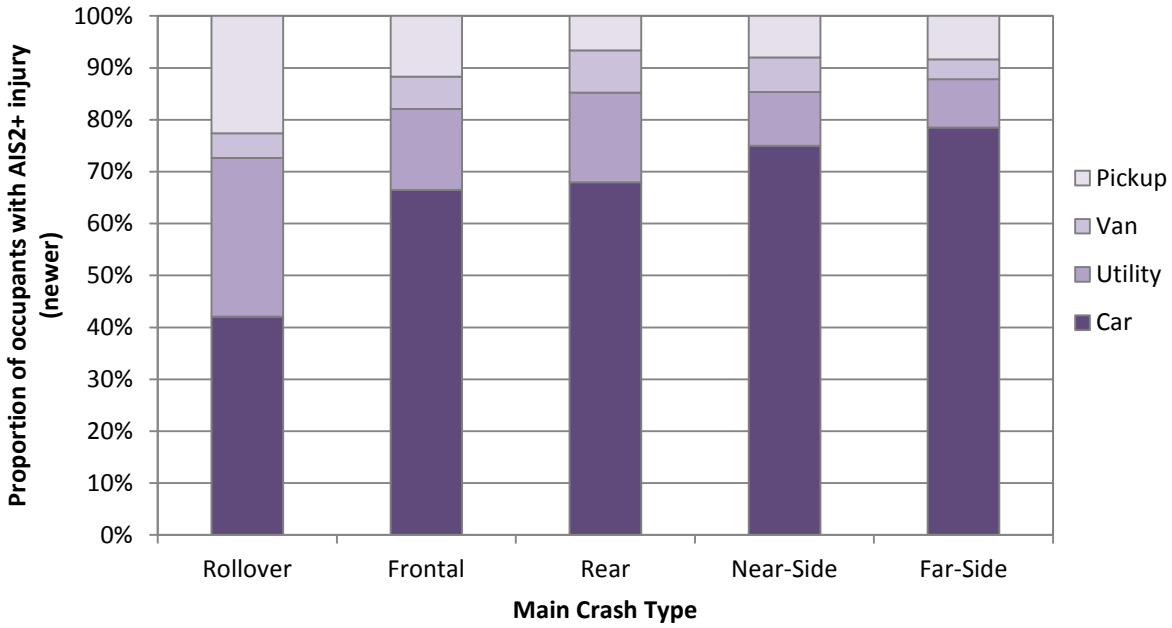


Figure 166. Proportion of occupants with AIS2+ injury by vehicle type for each crash mode.

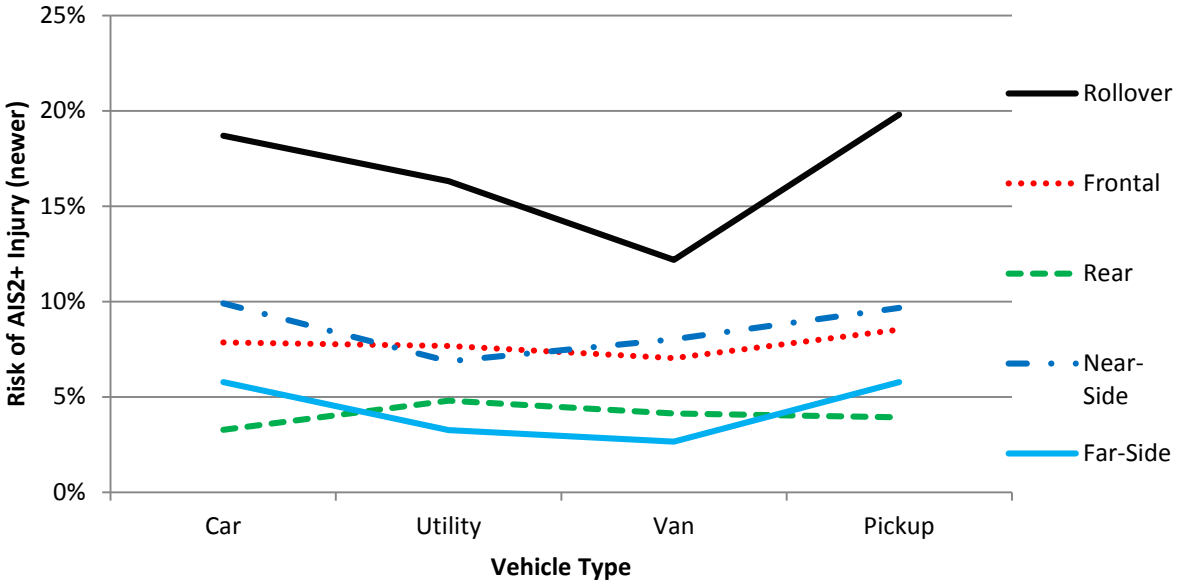


Figure 167. Risk of AIS2+ injury by crash mode for each vehicle type.

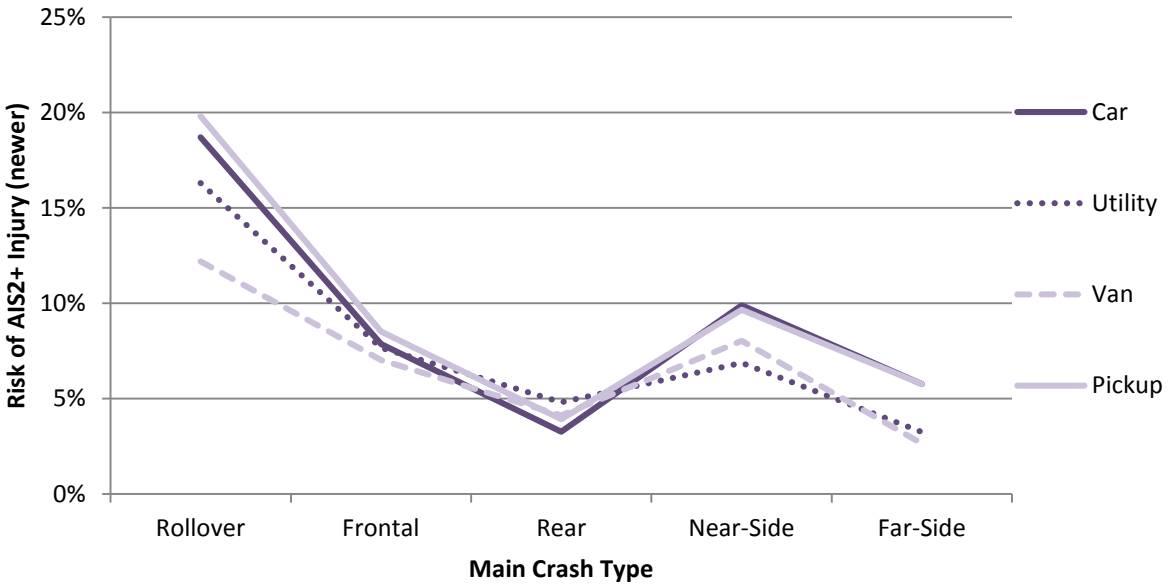


Figure 168. Risk of AIS2+ injury vehicle type for each crash mode.

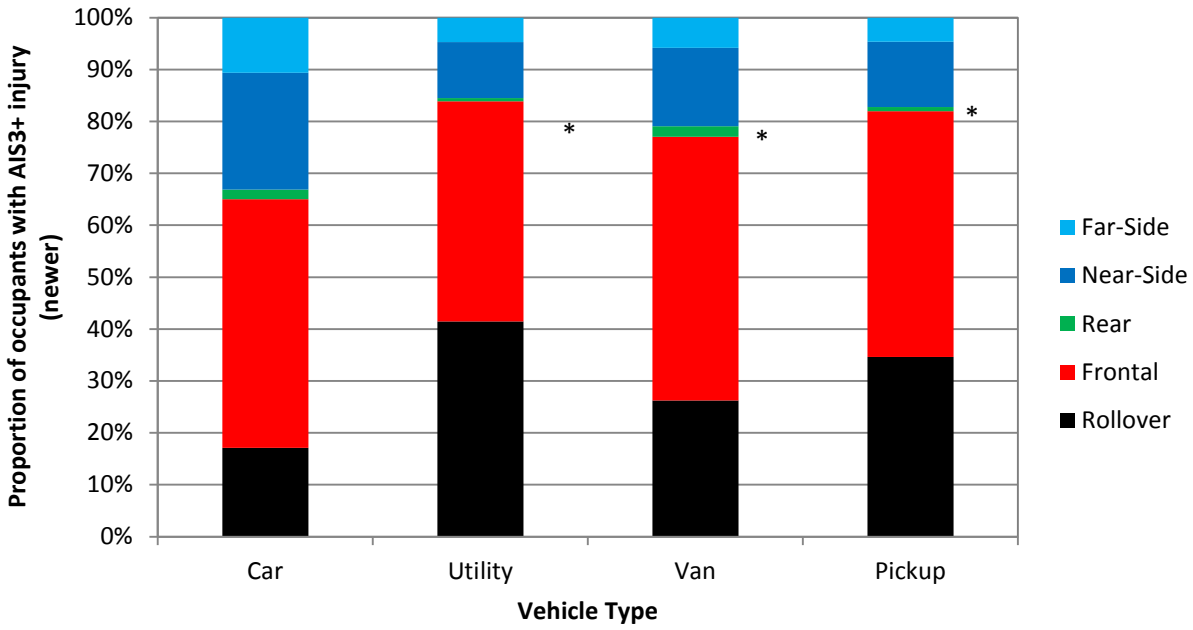


Figure 169. Proportion of occupants with AIS3+ injury by crash mode for each vehicle type.

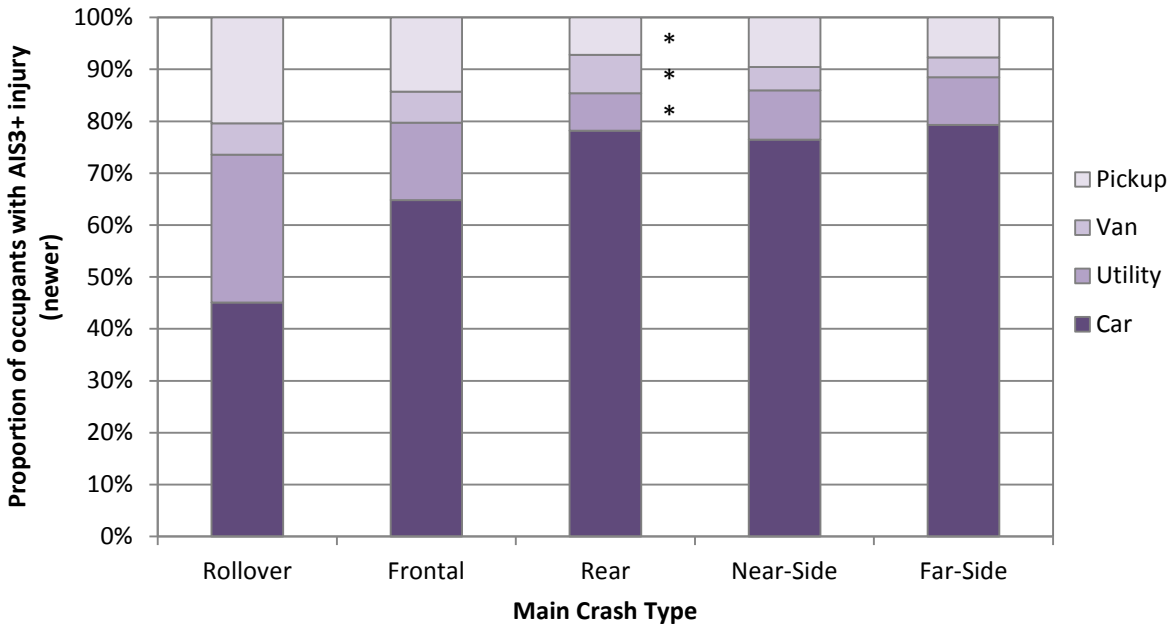


Figure 170. Proportion of occupants with AIS3+ injury by vehicle type for each crash mode.

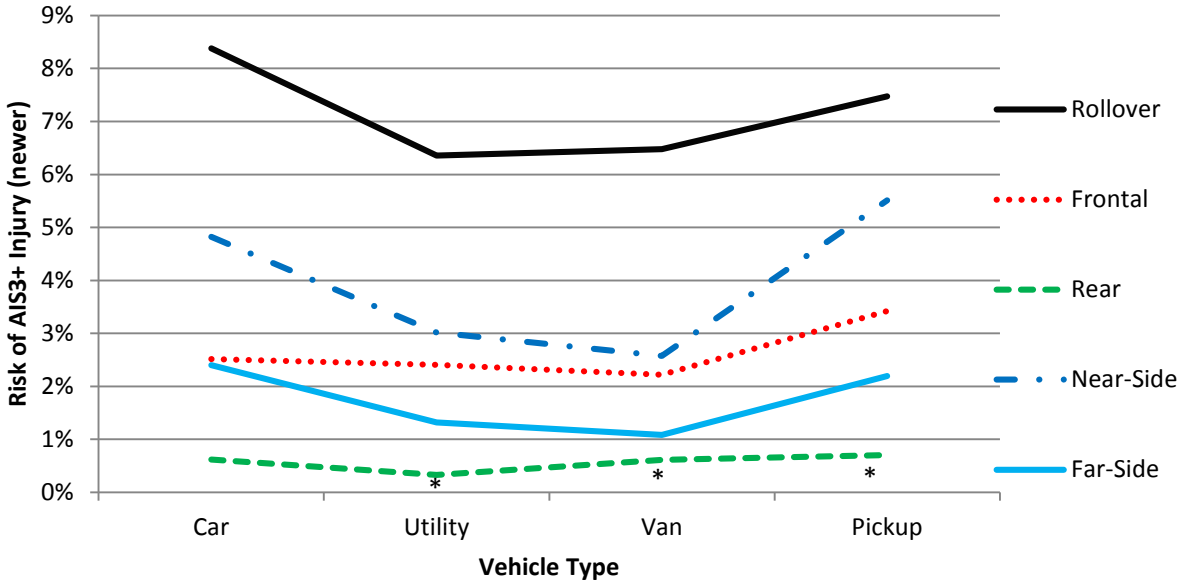


Figure 171. Risk of AIS3+ injury by crash mode for each vehicle type.

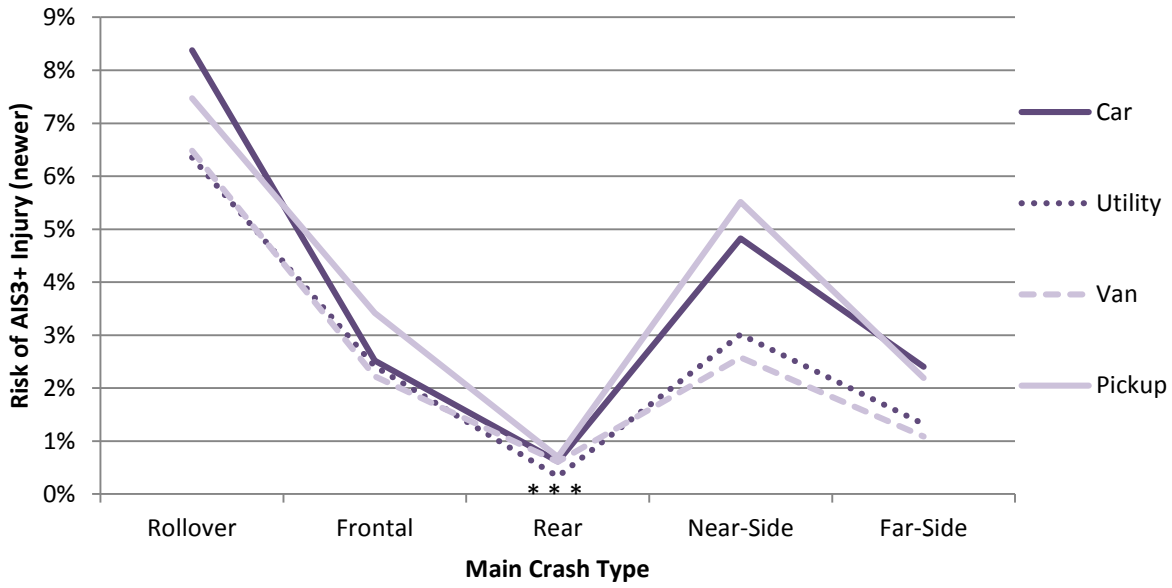


Figure 172. Risk of AIS3+ injury by vehicle type for each crash mode.

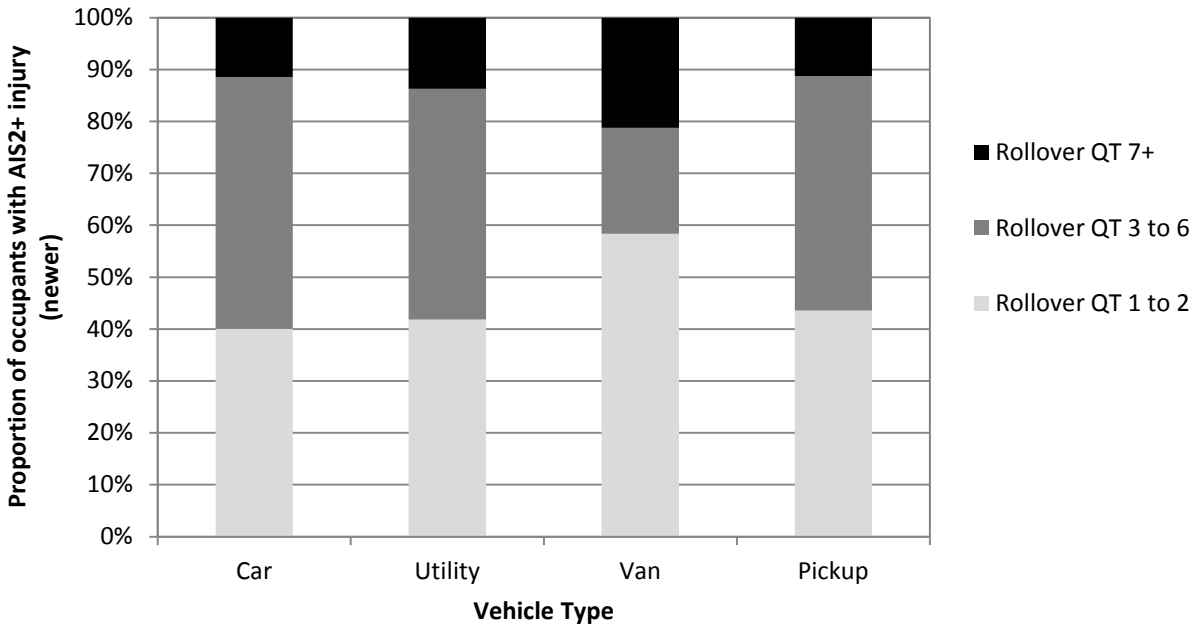


Figure 173. Proporiton of occupants with AIS2+ injury by rollover type for each vehicle type.

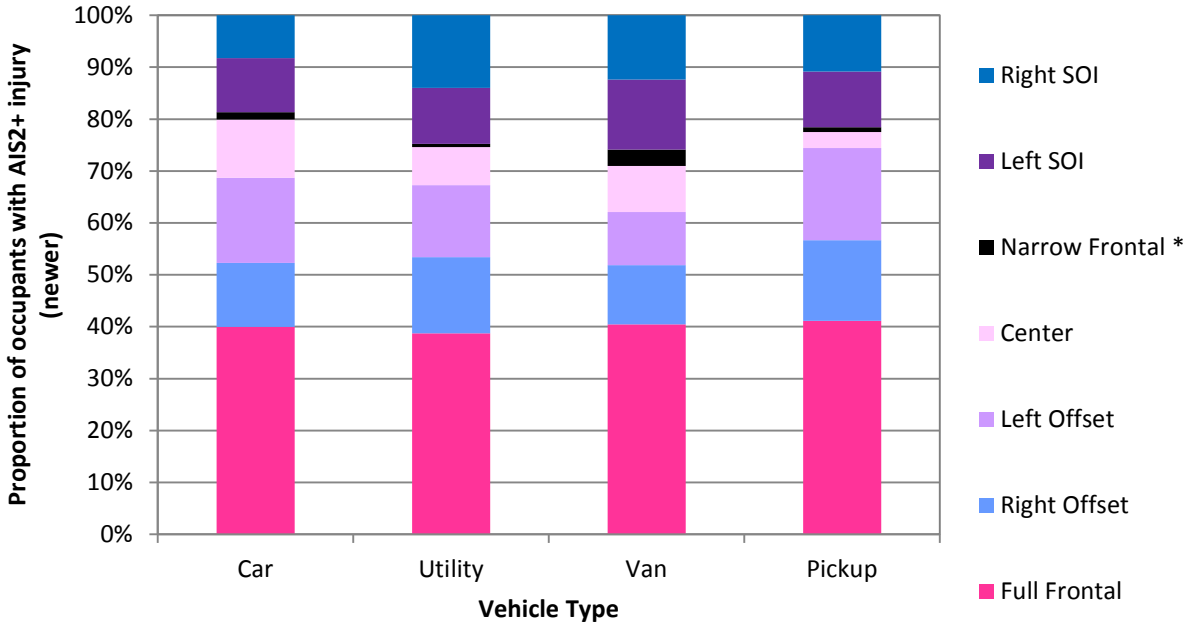


Figure 174. Proportion of occupants with AIS2+ injury by frontal subcrash type for each vehicle type.

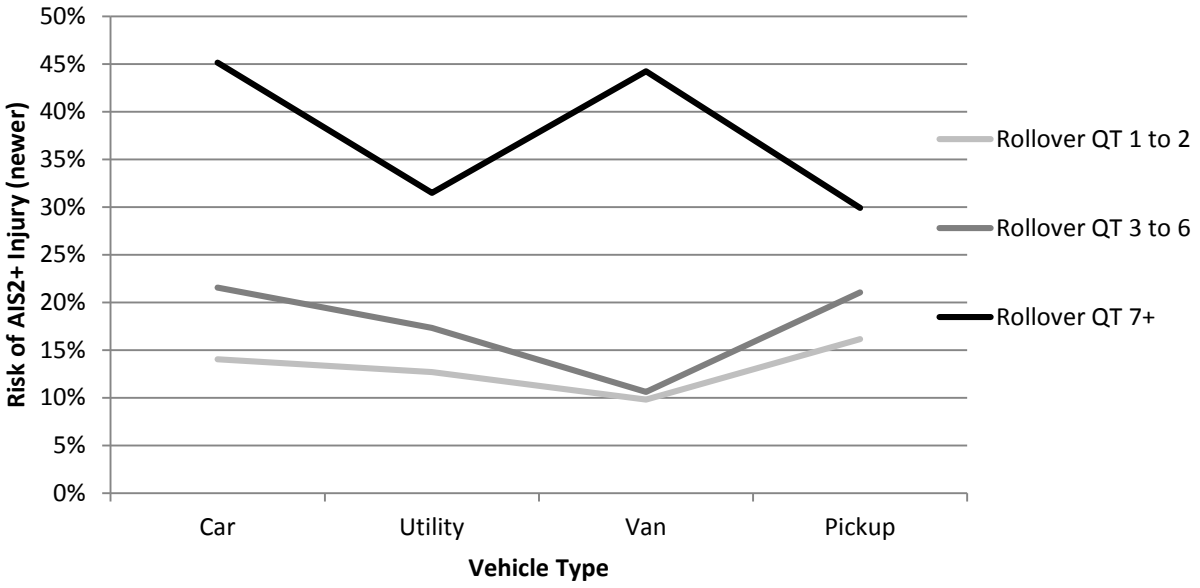


Figure 175. Risk of AIS2+ injury by rollover type for each vehicle type.

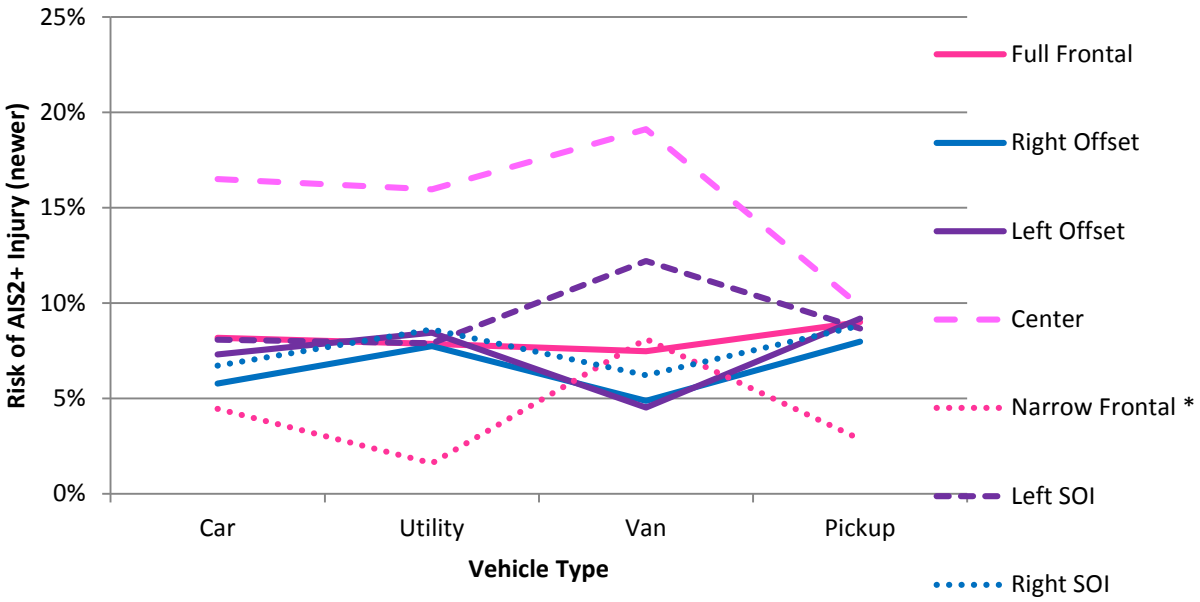


Figure 176. Risk of AIS2+ injury by frontal subcrash type for each vehicle type.

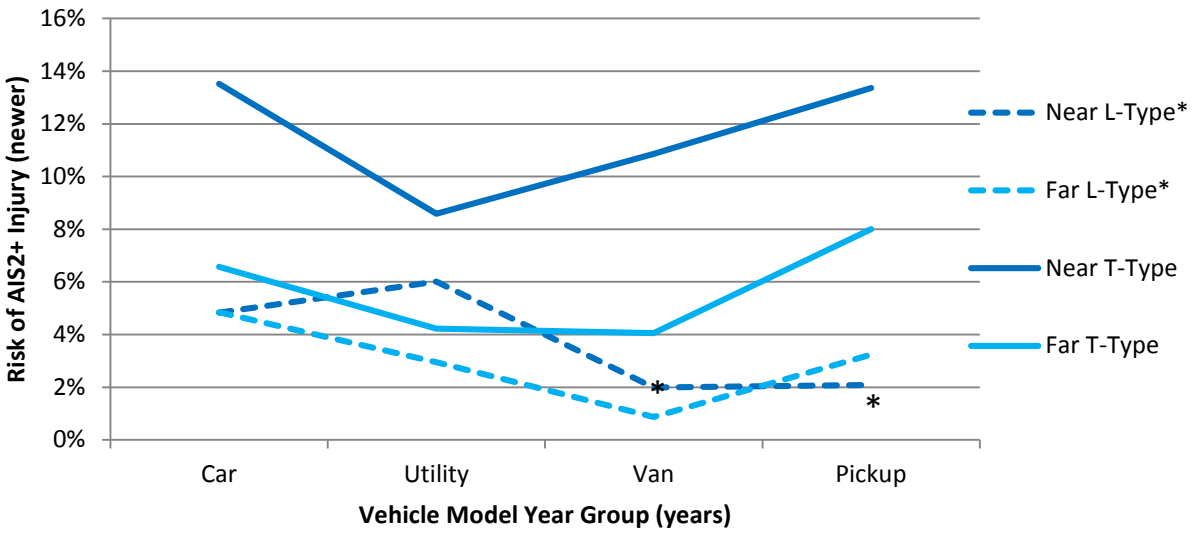


Figure 177. Risk of AIS2+ injury by side subcrash type for each vehicle type.

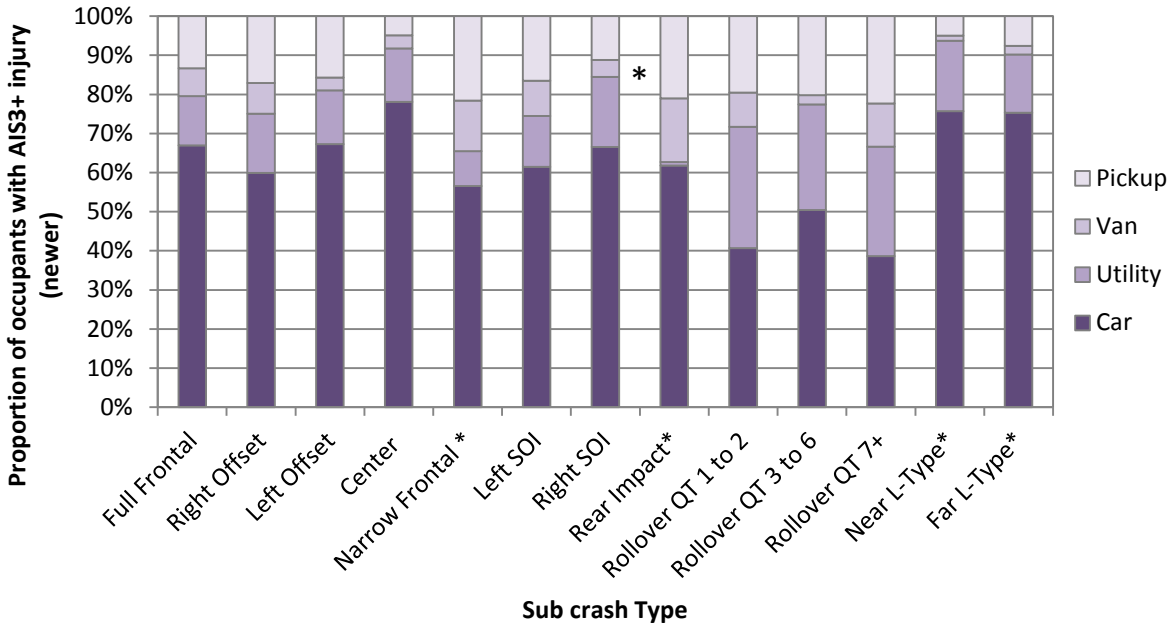


Figure 178. Distribution of occupants with AIS3+ injury by vehicle type for each subcrash type.

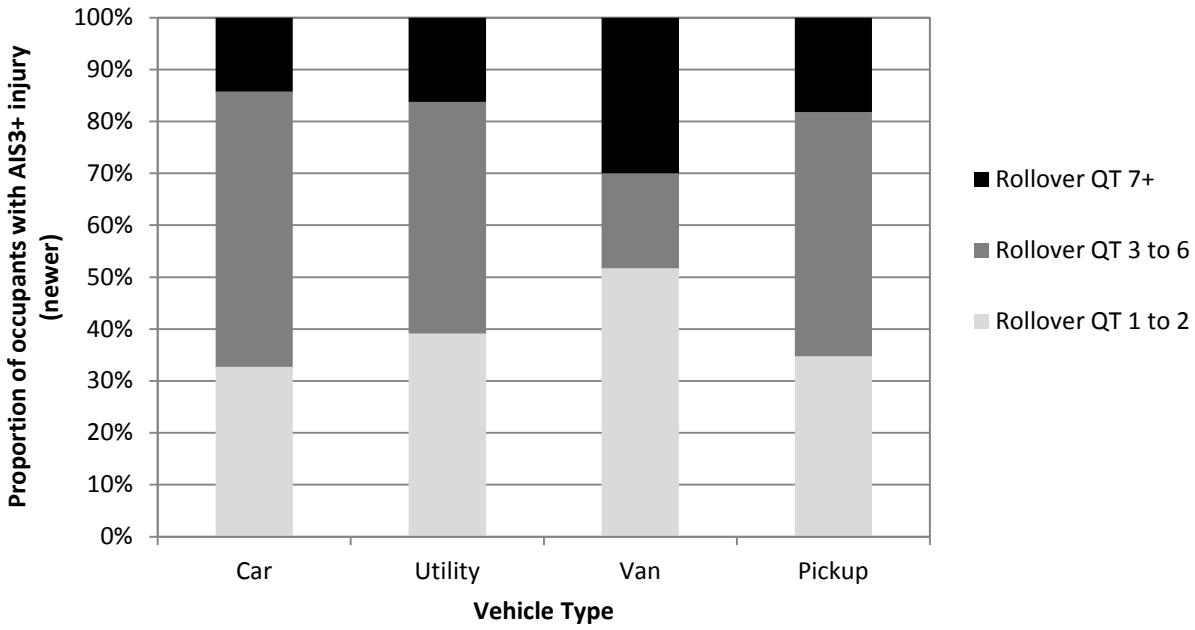


Figure 179. Distribution of occupants with AIS3+ injury by rollover type for each vehicle type.

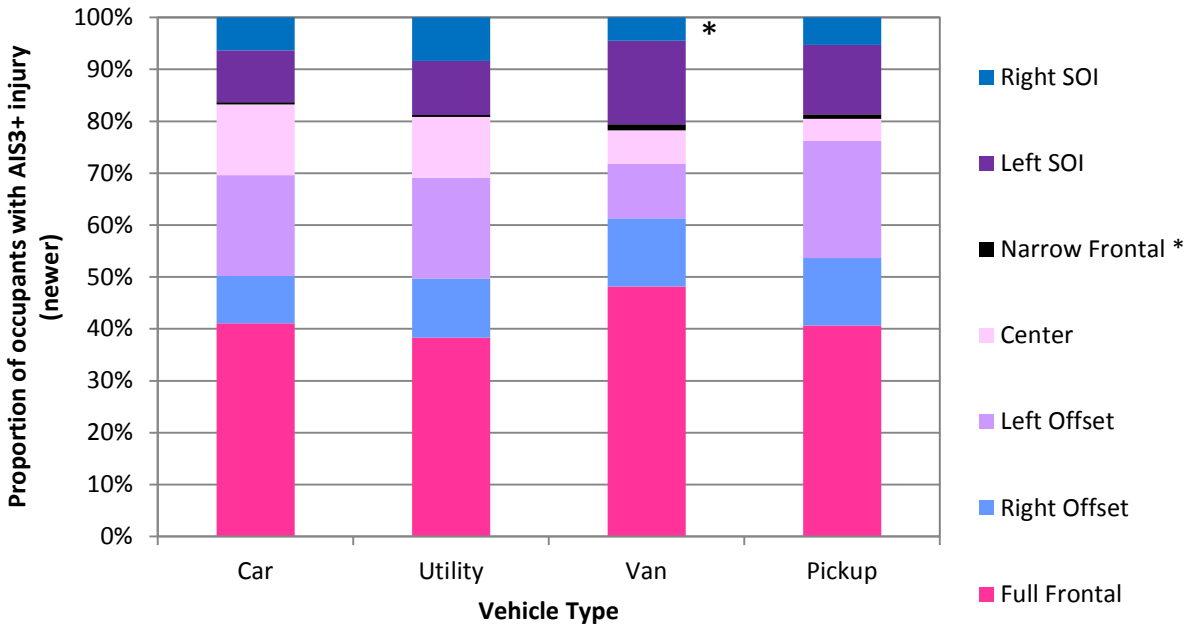


Figure 180. Proportion of occupants with AIS3+ injury by frontal subcrash type for each vehicle type.

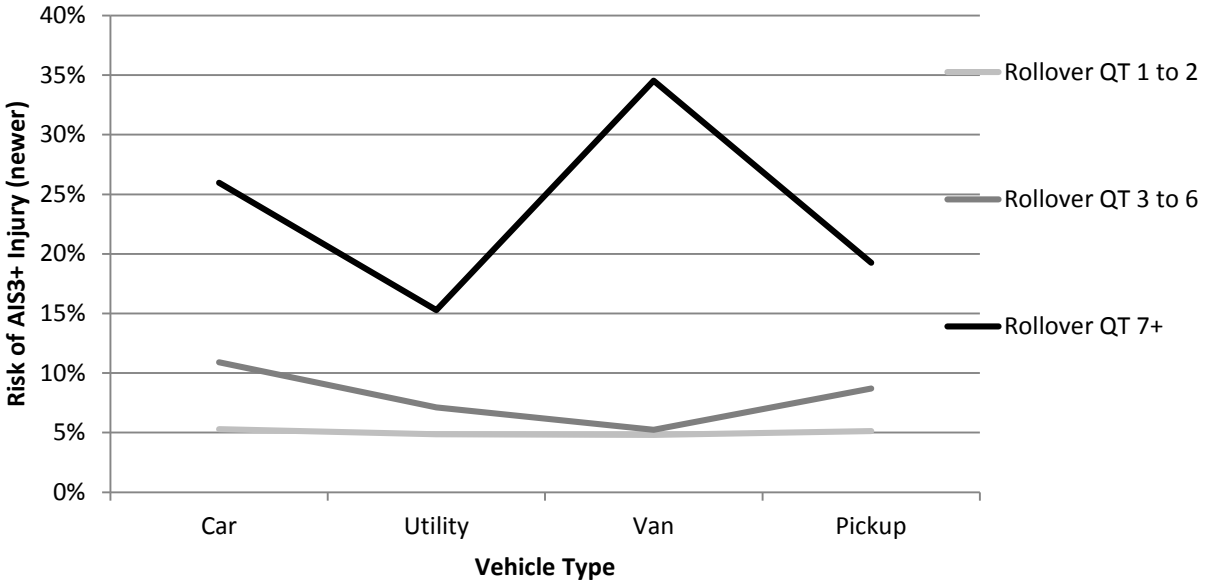


Figure 181. Risk of AIS3+ injury by rollover type for each vehicle type.

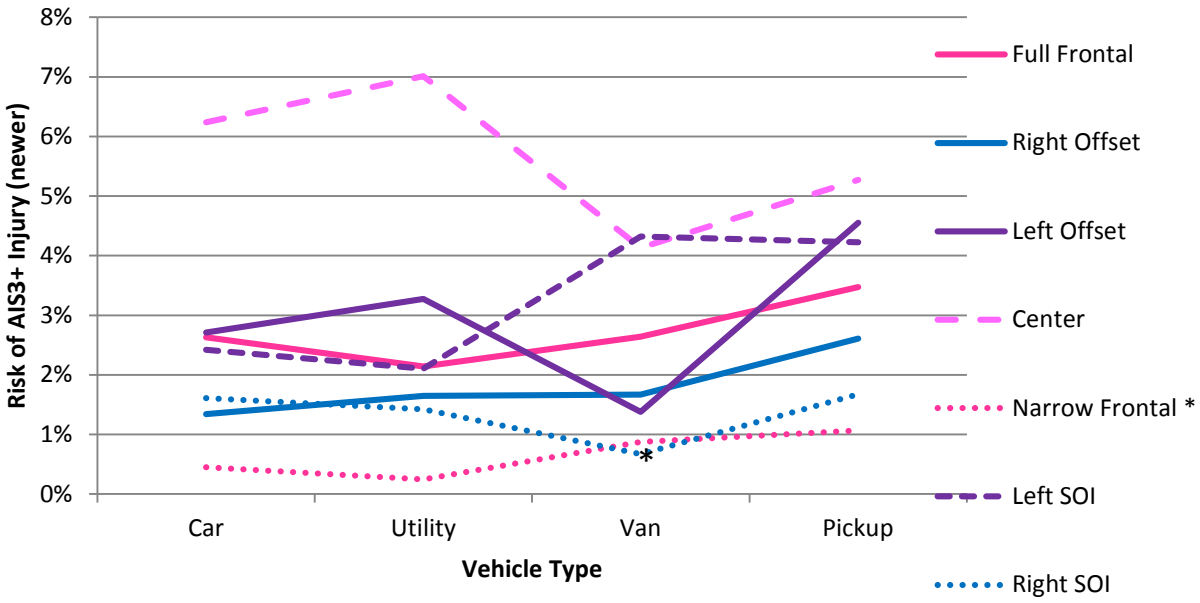


Figure 182. Risk of AIS3+ injury by frontal subcrash type for each vehicle type.

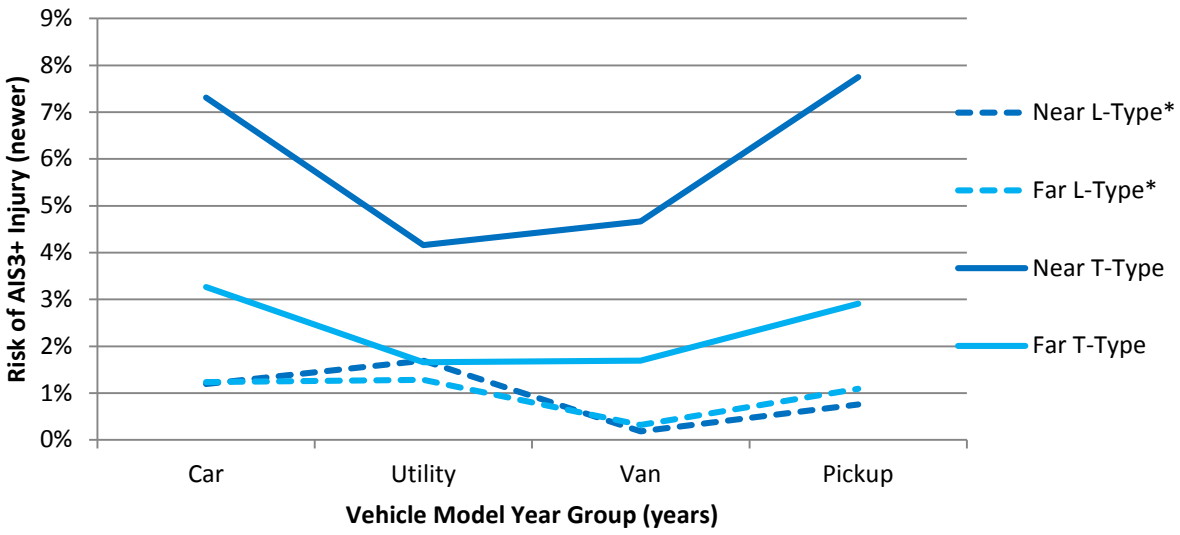


Figure 183. Risk of AIS3+ injury by side subcrash type for each vehicle type.

Body Region by Vehicle Type

- There are less than 25 unweighted injured occupants sustaining AIS2+ or AIS3+ neck injuries in most vehicle types, as well as face injuries in vans. As a result, these categories are marked with an asterisk and are unsuitable for use in analysis of injury trends.
- The distribution of occupants with AIS2+ or AIS3+ injuries to different body regions does not vary substantially with vehicle type.
- Risk of AIS2+ and AIS3+ injury is highest in pickup trucks for all AIS body regions.

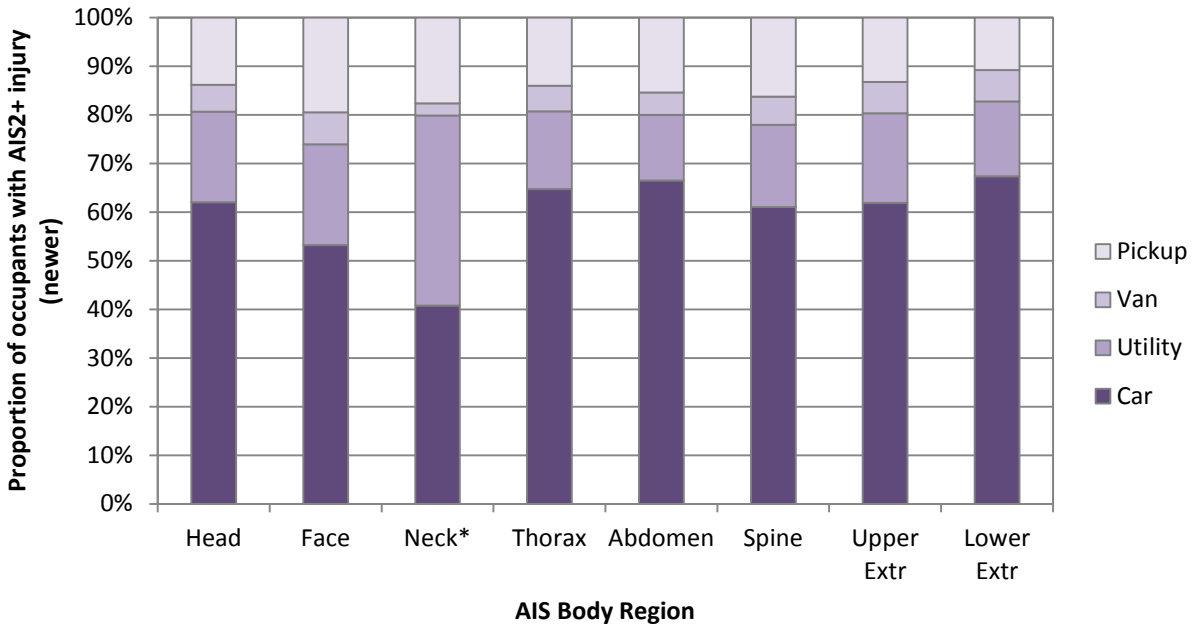


Figure 184. Proportion of occupants with AIS2+ injury by vehicle type for each AIS body region.

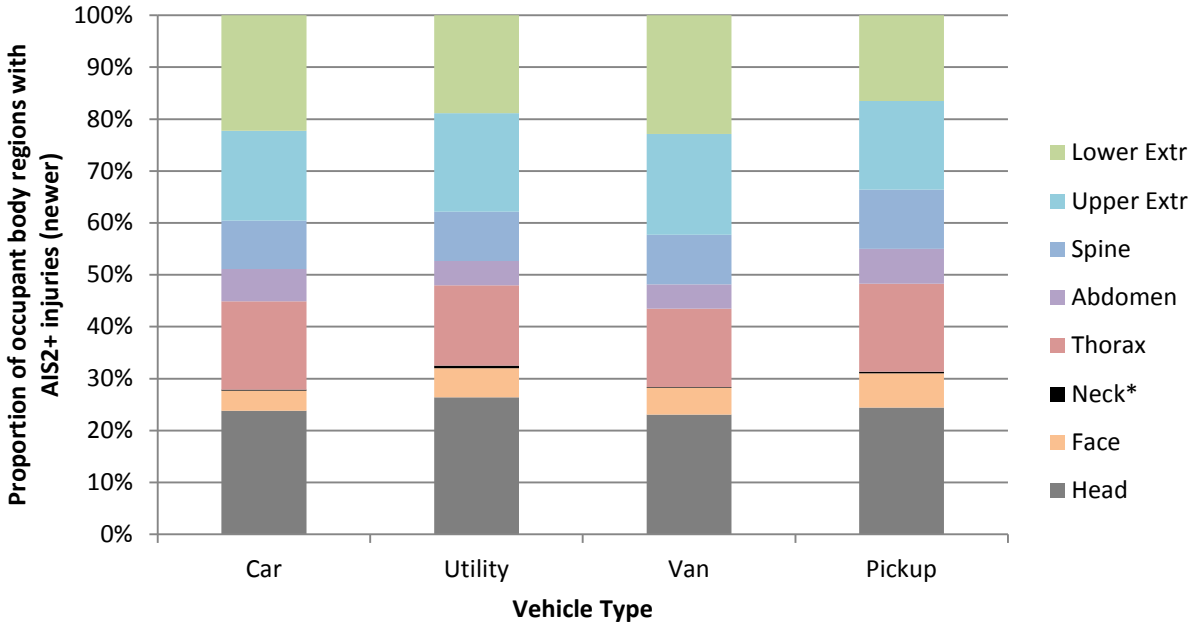


Figure 185. Proportion of occupant body regions with AIS2+ injury by AIS body region for each vehicle type.

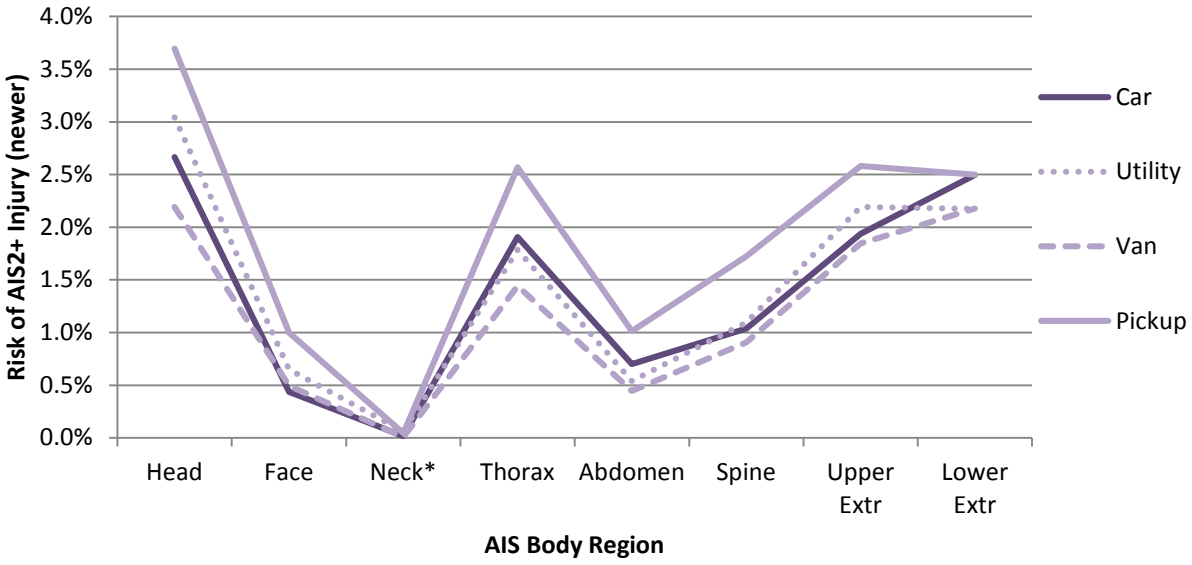


Figure 186. Risk of AIS2+ injury by vehicle type for each body region.

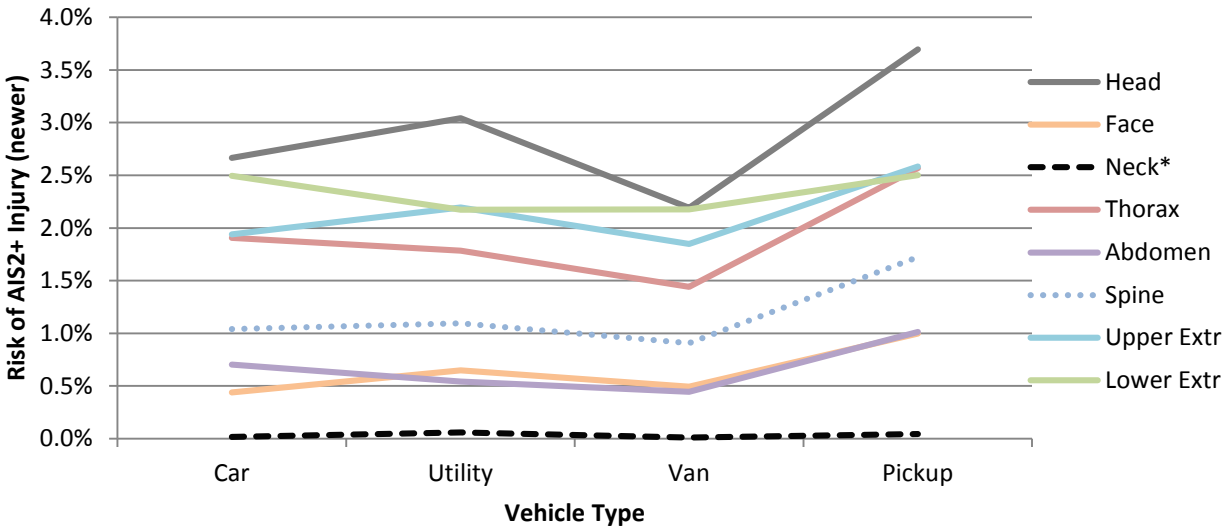


Figure 187. Risk of AIS2+ injury by AIS body region for each vehicle type.

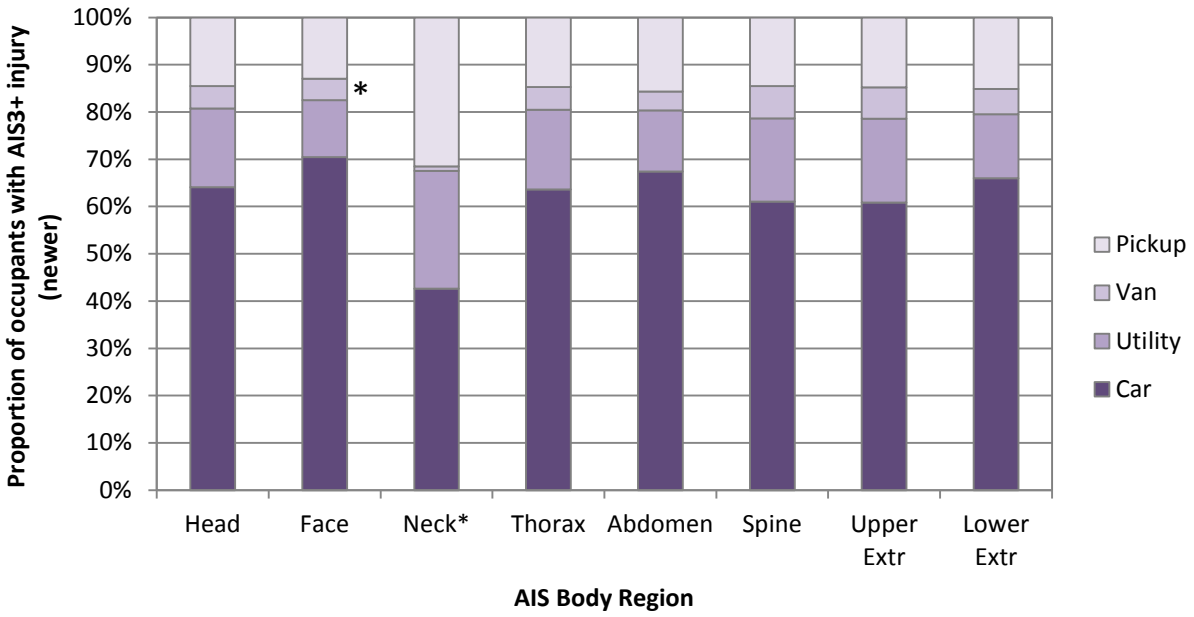


Figure 188. Proportion of occupants with AIS3+ injury by vehicle type for each AIS body region.

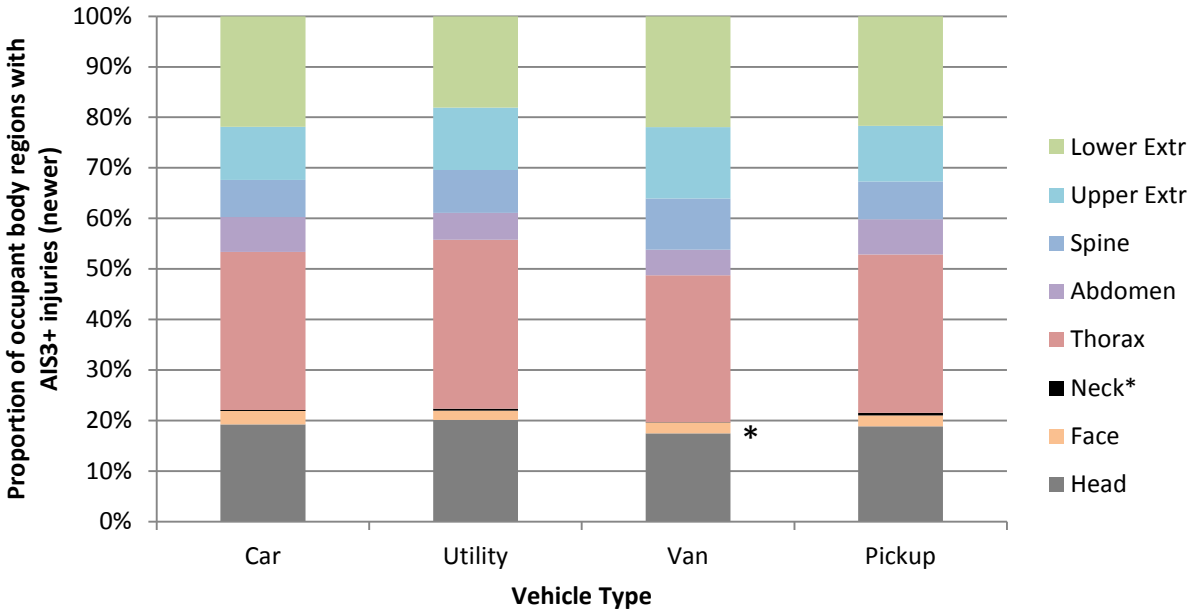


Figure 189. Proportion of occupants with AIS3+ injury by AIS body region for each vehicle type.

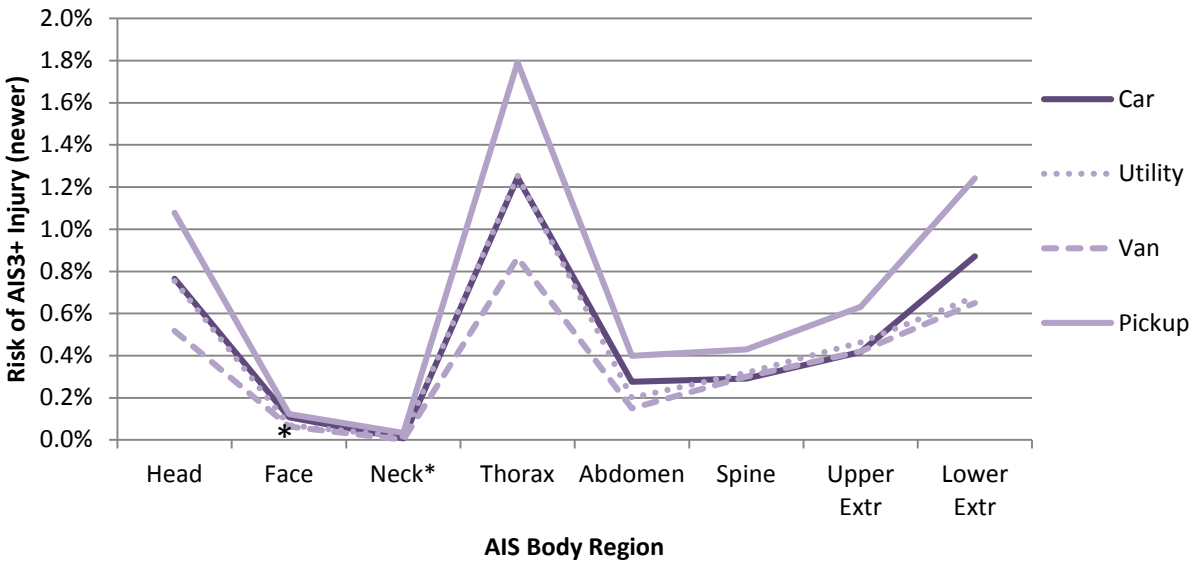


Figure 190. Risk of AIS3+ injury by vehicle type for each AIS body region.

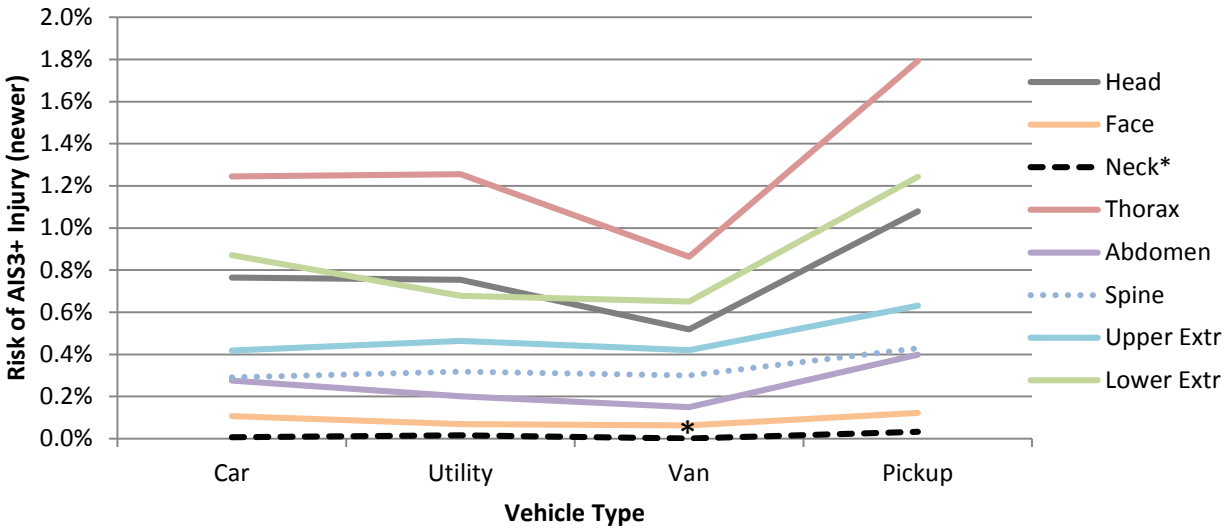


Figure 191. Risk of AIS3+ injury by body region for each vehicle type.

Chapter 10. Injuries by Vehicle Model Year

Injuries by Crash Mode and Vehicle Model Year

- There are less than 25 unweighted injured occupants with AIS3+ injuries in rear impacts in vehicle model years 2008-2010. In addition, there are less than 25 unweighted injured occupants in most categories of subcrash for 2008-2010 for both AIS2+ and AIS3+ injuries, as well as narrow frontal, near- and far-side L-type, and rear impacts for all vehicle model year groups. This makes analysis of injury trends for these groups unreliable; they are indicated on the plots with an *.
- The proportion of occupants with AIS2+ or AIS3+ injuries from different model years fluctuates but does not show clear trends.
- AIS3+ injury risk in rollovers is fairly constant.
- The proportion of occupants with AIS3+ injury from rollovers increases with model year group for 1-2 quarter turn rollovers and decreases for 3-6 quarter turn rollovers.

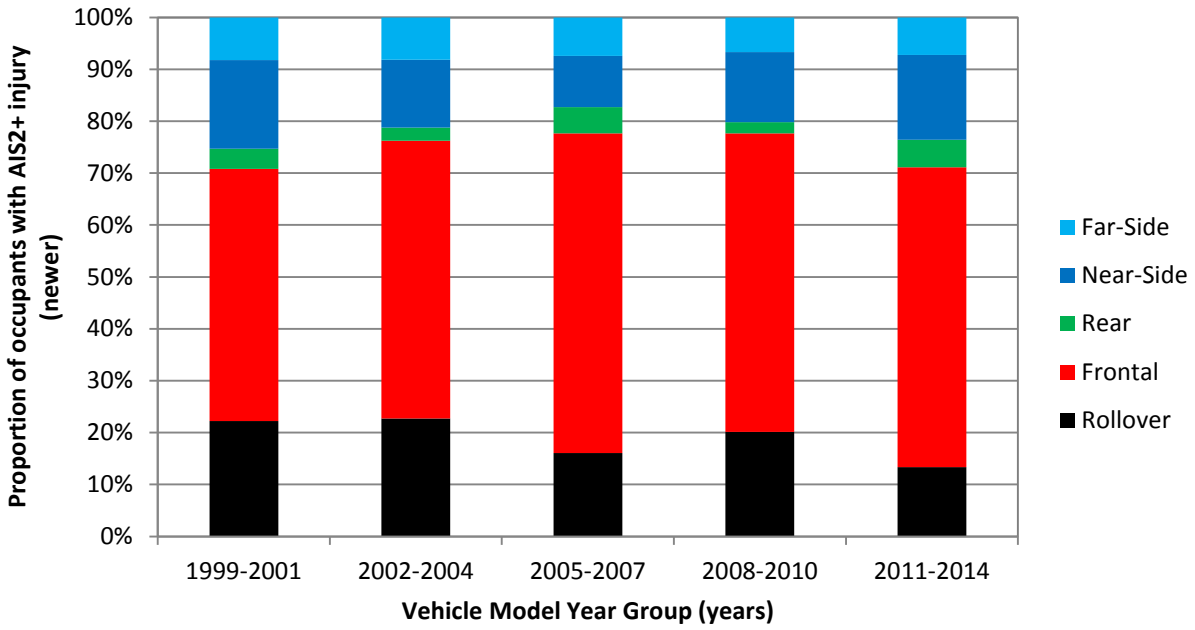


Figure 192. Distribution of occupants with AIS2+ injury by crash type for each vehicle model year group.

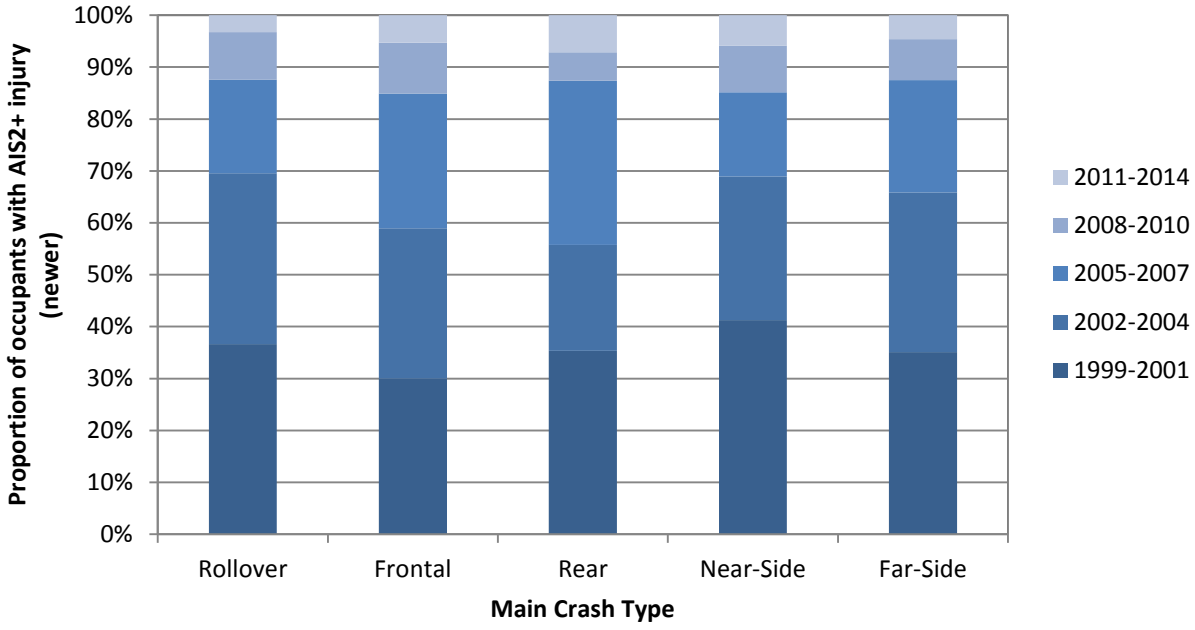


Figure 193. Distribution of occupants with AIS2+ injury by vehicle model year group for each crash type.

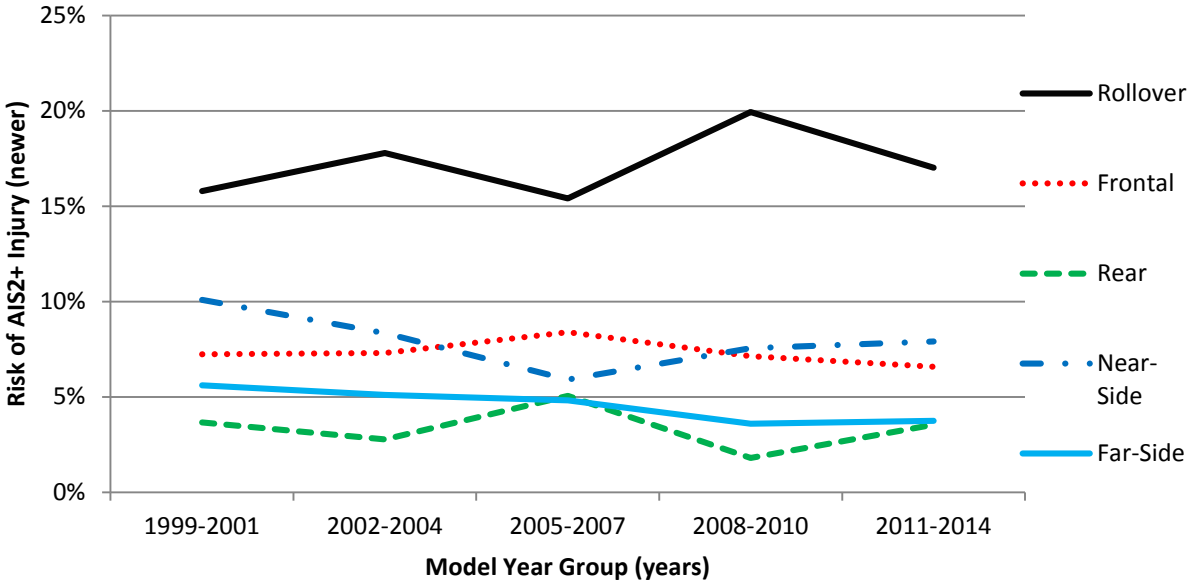


Figure 194. Risk of AIS2+ injury by crash type for each vehicle model year group.

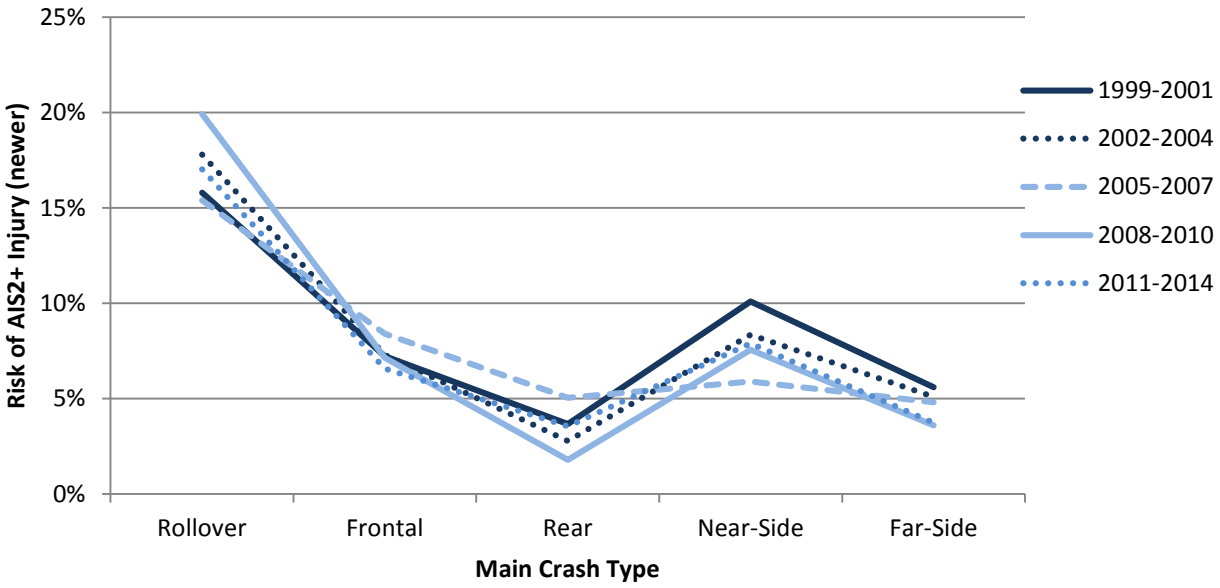


Figure 195. Risk of AIS2+ injury by vehicle model year group for each crash type.

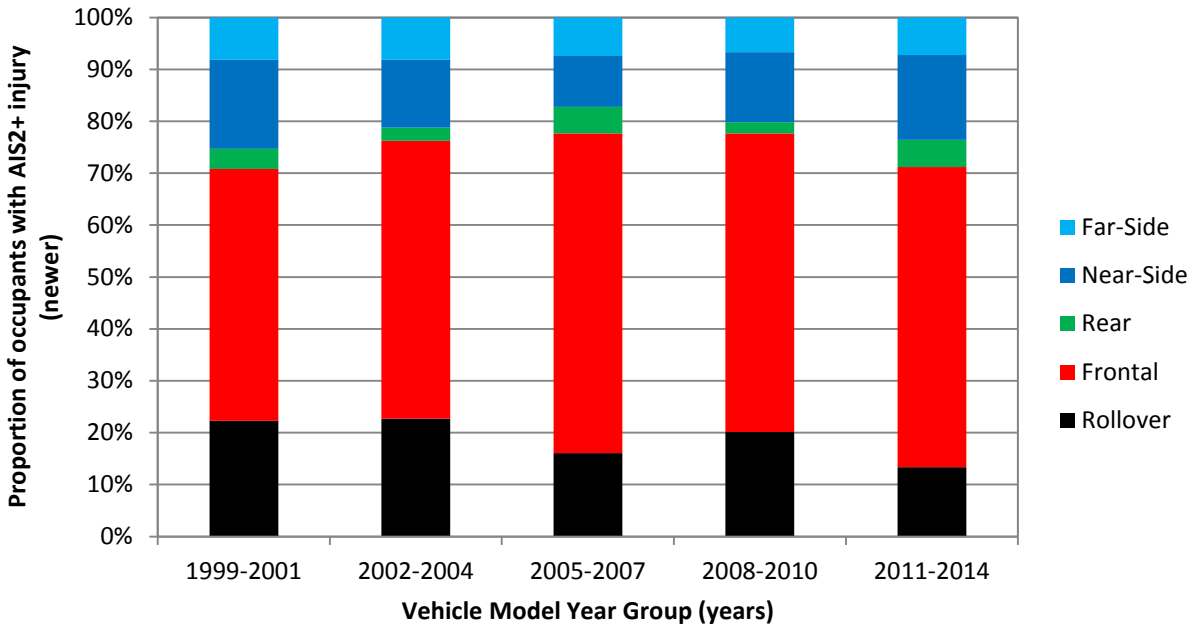


Figure 196. Distribution of occupants with AIS3+ injury by crash type for each vehicle model year group.

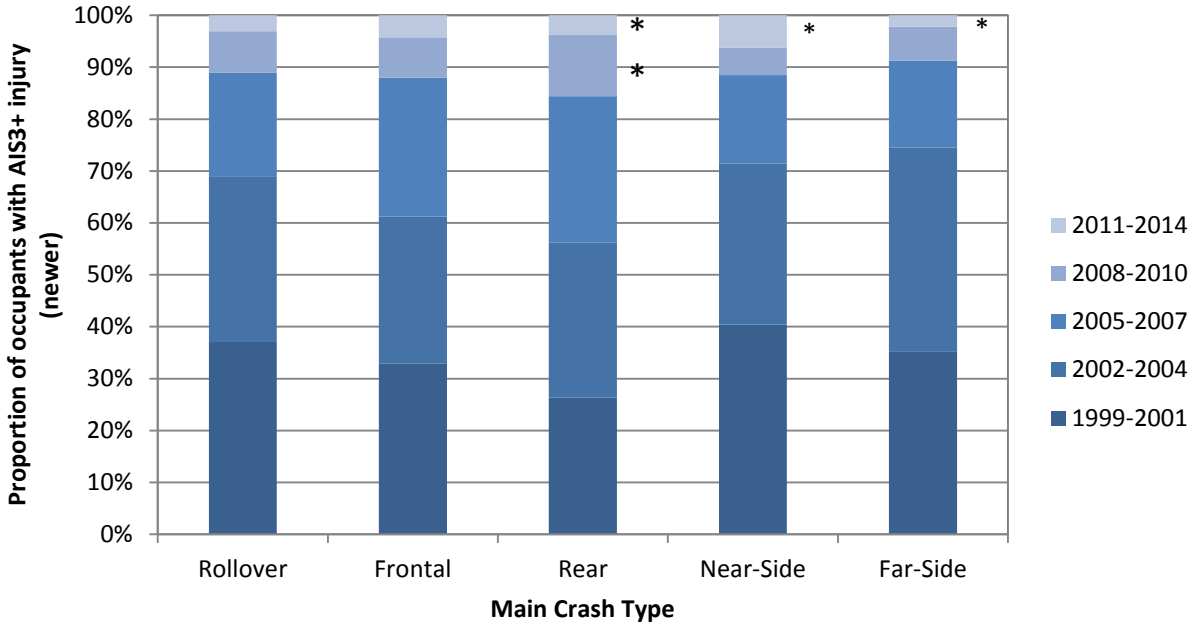


Figure 197. Distribution of occupants with AIS3+ injury by vehicle model year group for each crash type.

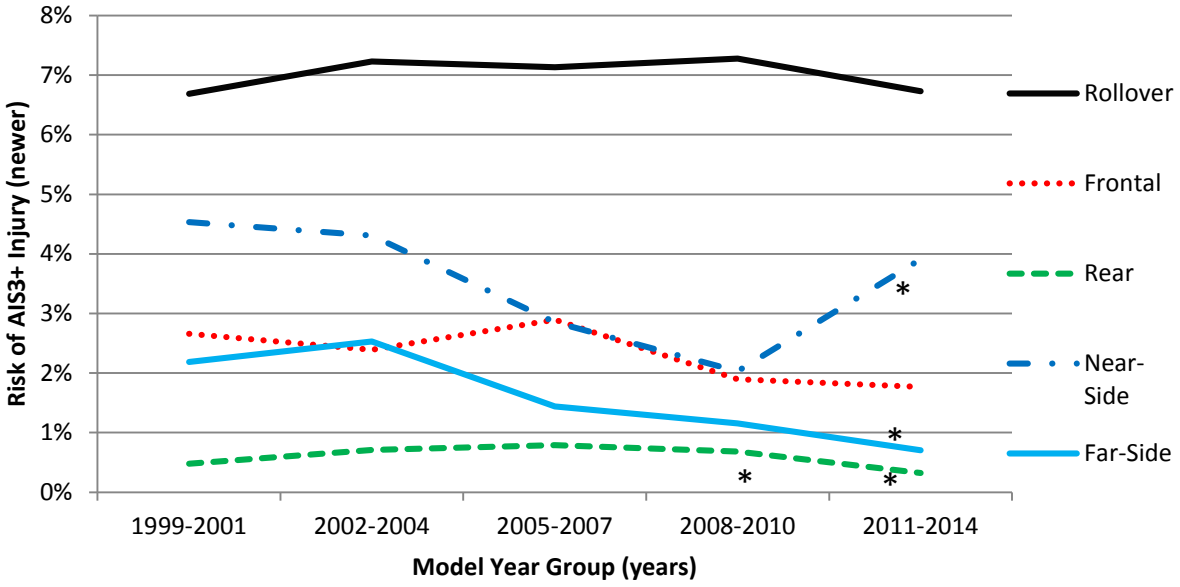


Figure 198. Risk of AIS3+ injury by crash type for each vehicle model year group.

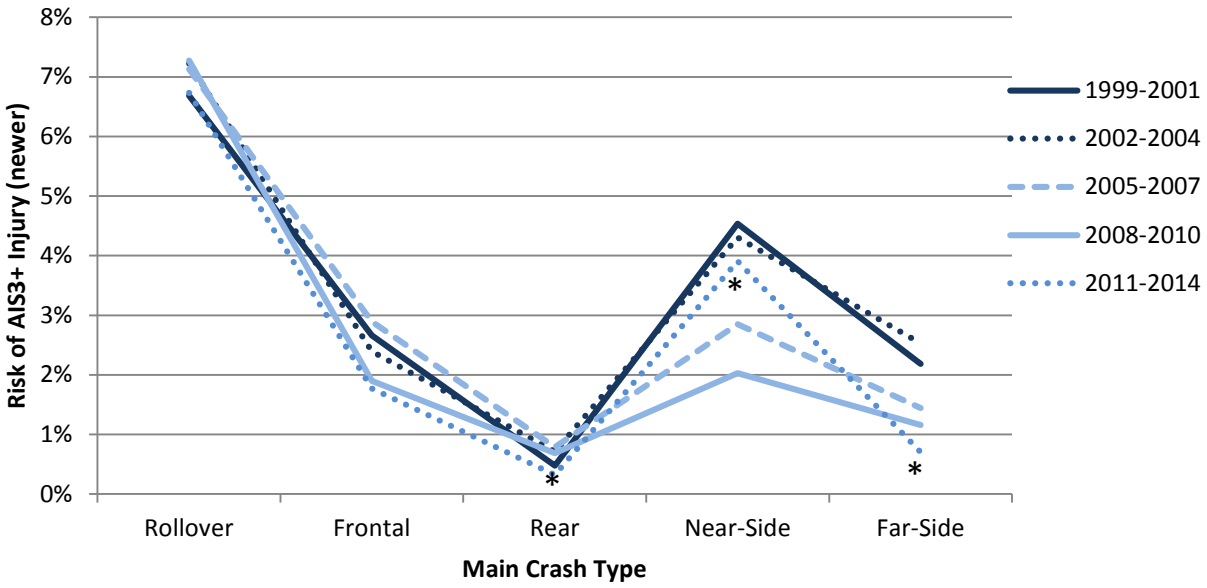


Figure 199. Risk of AIS3+ injury by vehicle model year group for each crash type.

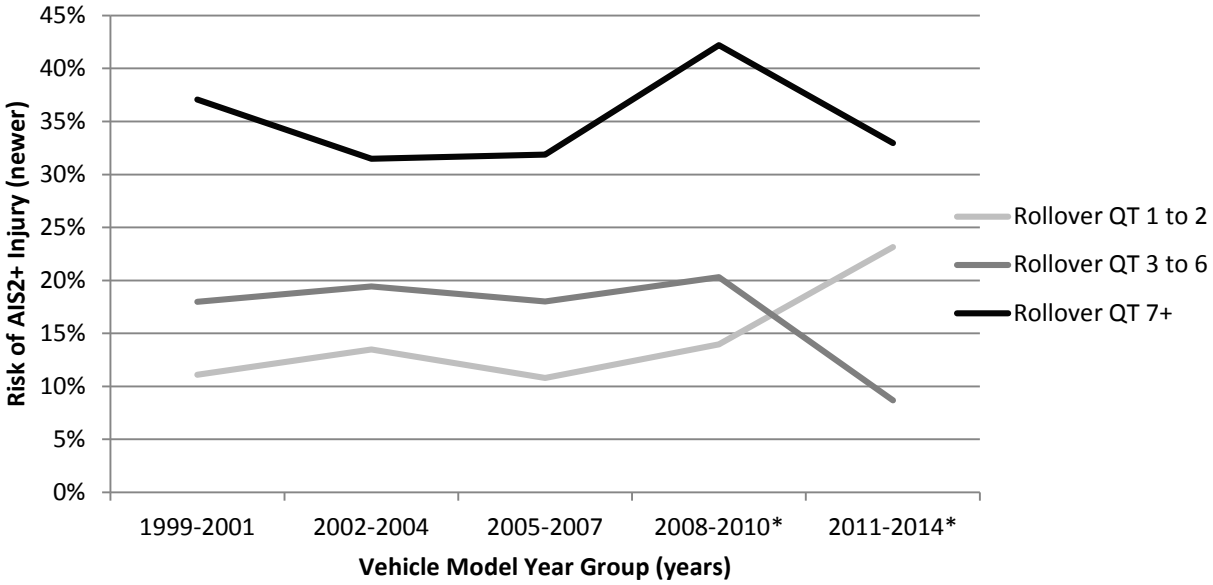


Figure 200. Risk of AIS2+ injury by rollover type for each vehicle model year group.

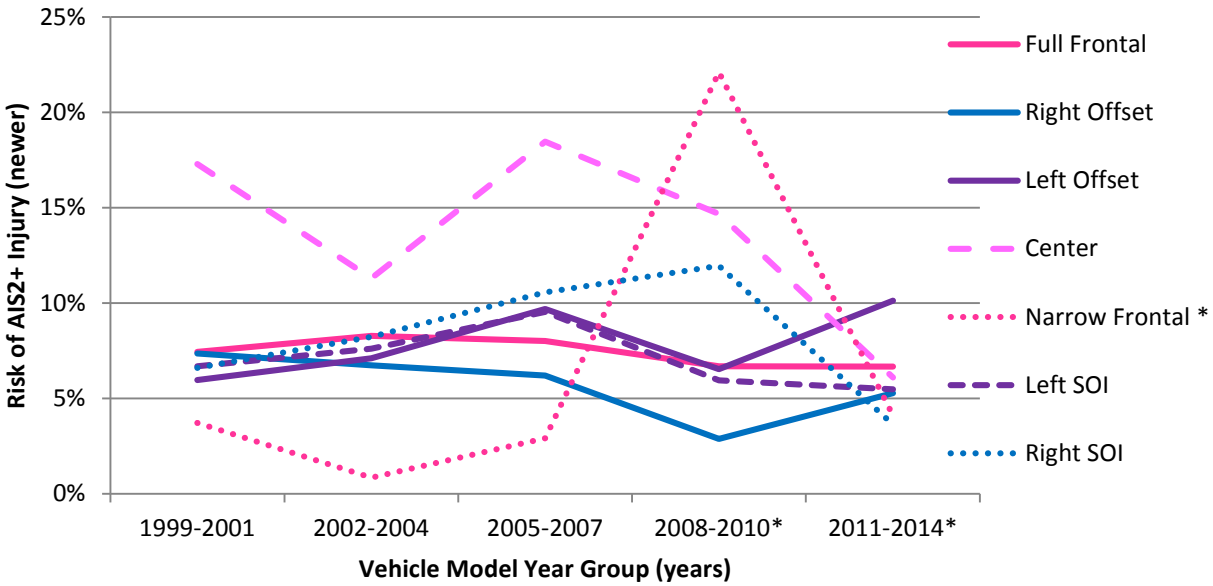


Figure 201. Risk of AIS2+ injury by frontal subcrash type for each vehicle model year group.

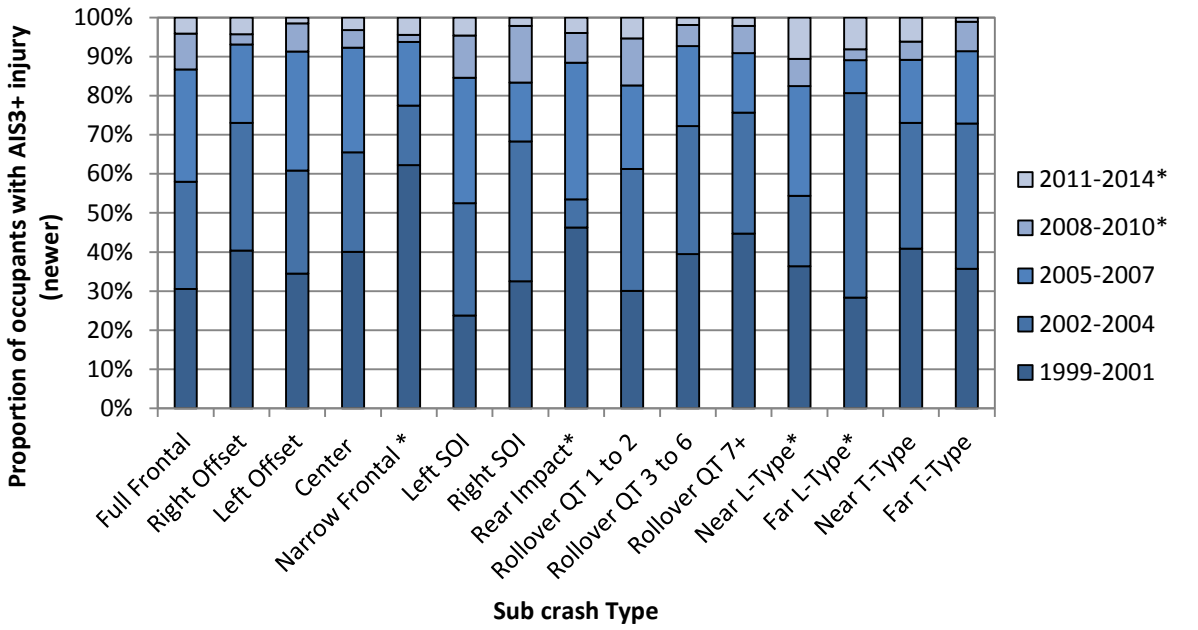


Figure 202. Proportion of occupants with AIS3+ injury by vehicle model year group for each subcrash type.

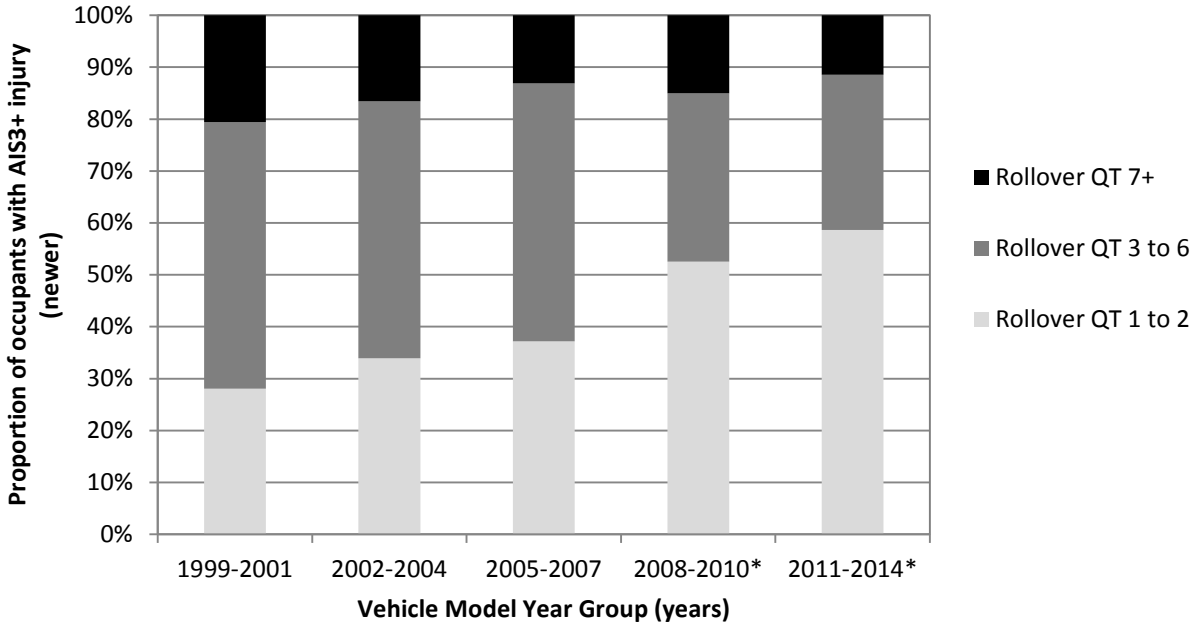


Figure 203. Proportion of occupants with AIS3+ injury by rollover type for each vehicle model year group.

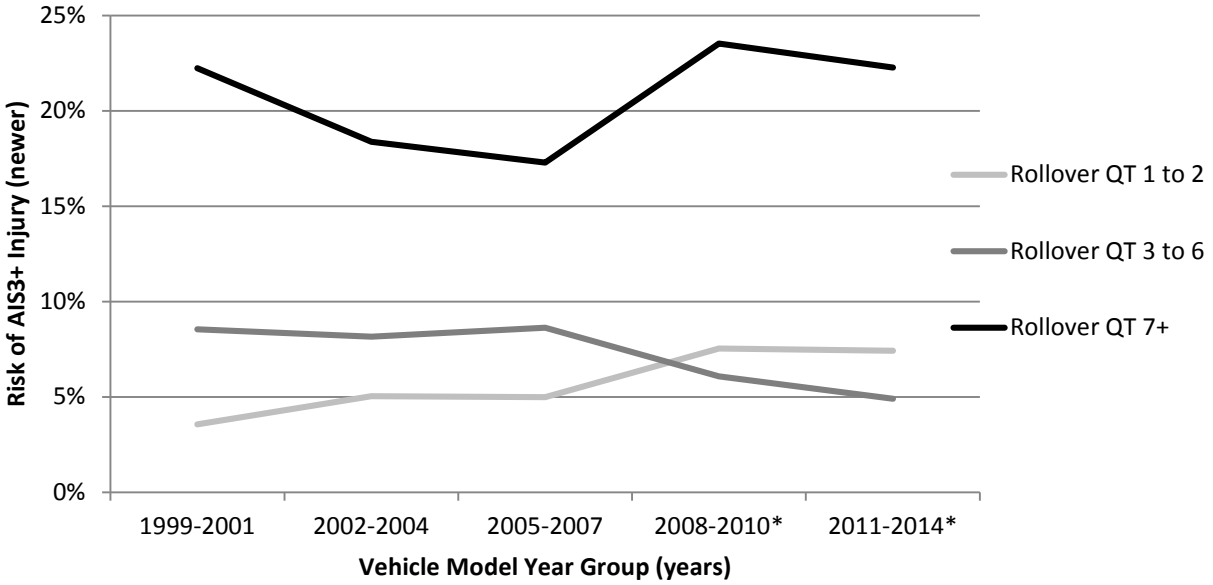


Figure 204. Risk of AIS3+ injury by rollover type for each vehicle model year group.

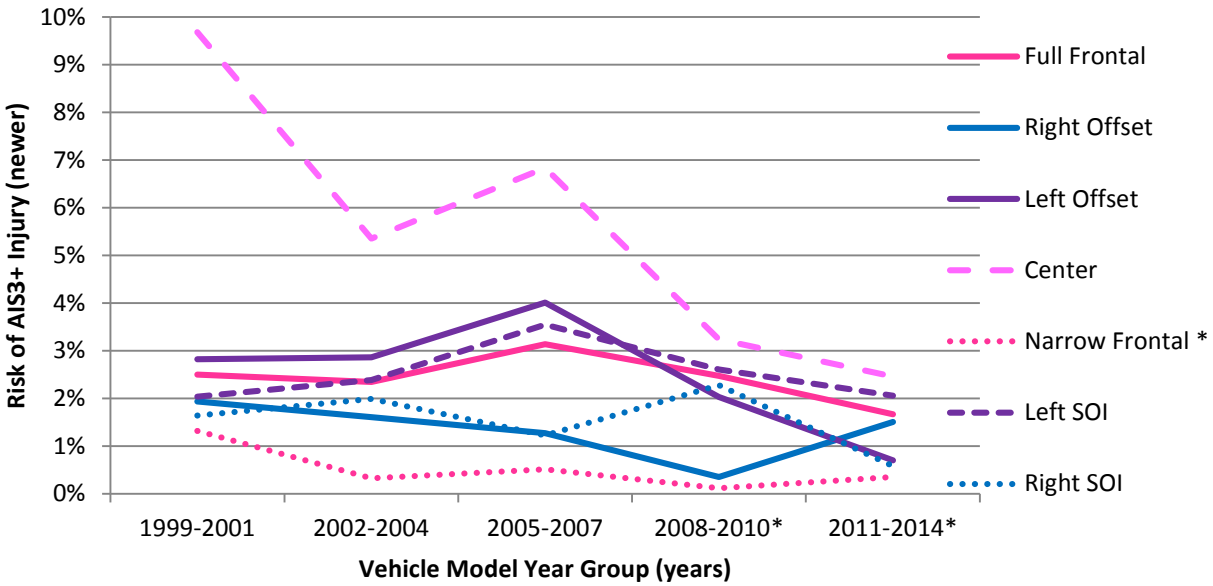


Figure 205. Risk of AIS3+ injury by frontal subcrash type for each vehicle model year group.

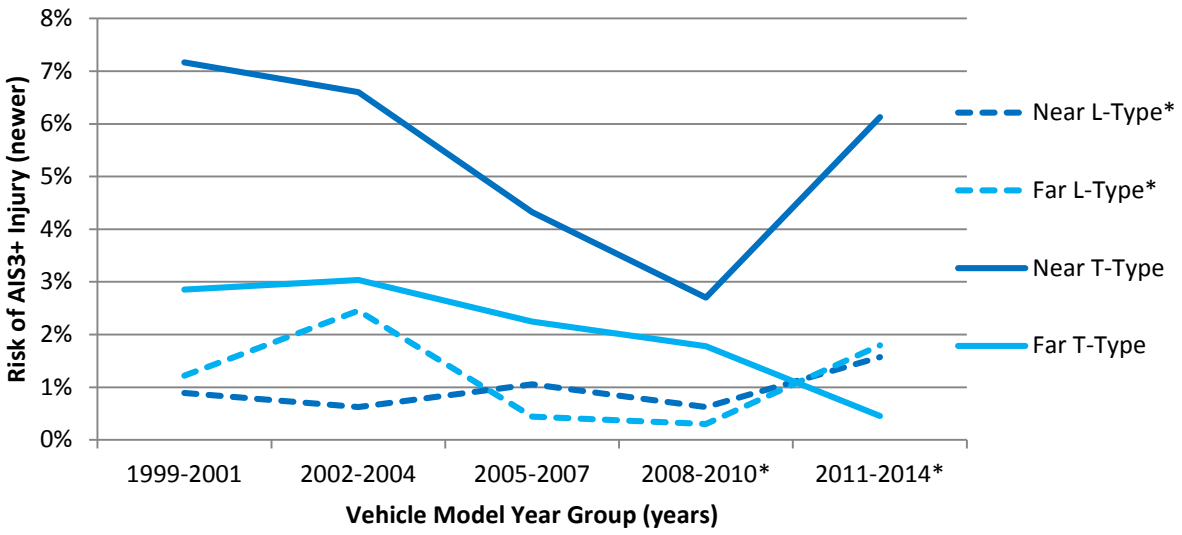


Figure 206. Risk of AIS3+ injury by side subcrash type for each vehicle model year group.

Injuries by Body Region and Vehicle Model Year

- The neck has less than 25 unweighted occupants with AIS2+ injury for most vehicle model year groups. As a result, analysis of injury trends for these groups is unreliable.
- The proportion of occupants with AIS2+ lower extremity injuries decreases with vehicle model year. The proportion of occupants with head injury is highest for the most recent two model year groupings.
- The risk of AIS2+ face, abdomen, and lower extremity injury decreases steadily with vehicle model year group. Spine, thorax, and upper extremity have lower injury risk in the newest two model year groups compared to the two oldest model year groups.
- All body regions except for the spine show a general decrease in AIS3+ injury risk from the oldest to newest vehicle model year groups.

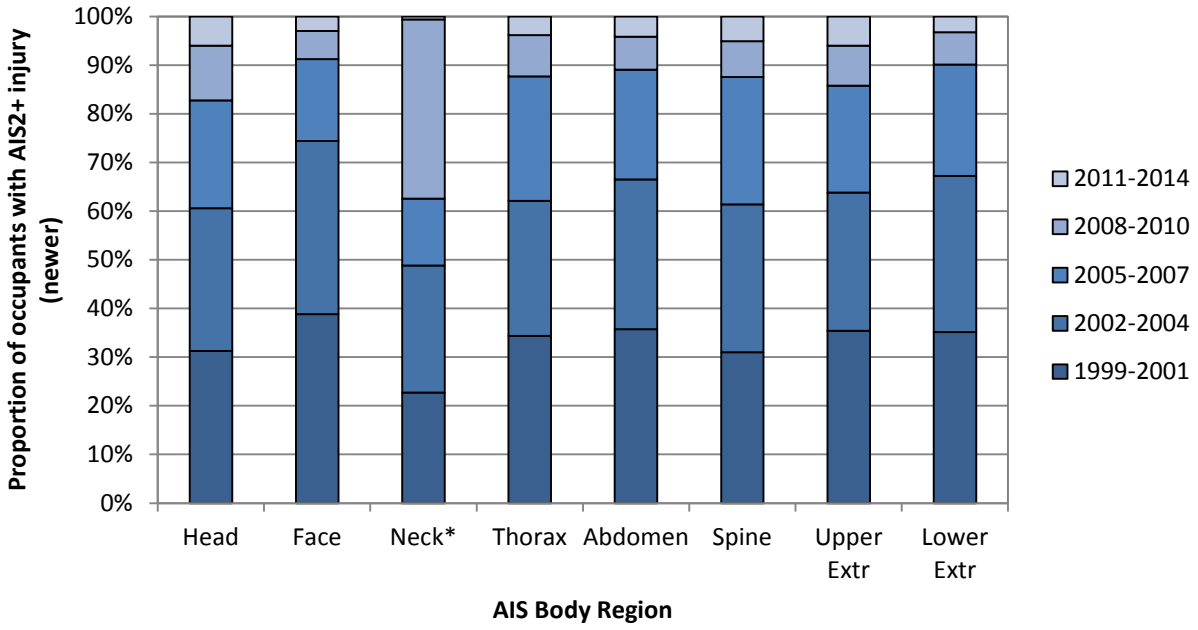


Figure 207. Distribution of occupants with AIS2+ injury by vehicle model year group for each AIS body region.

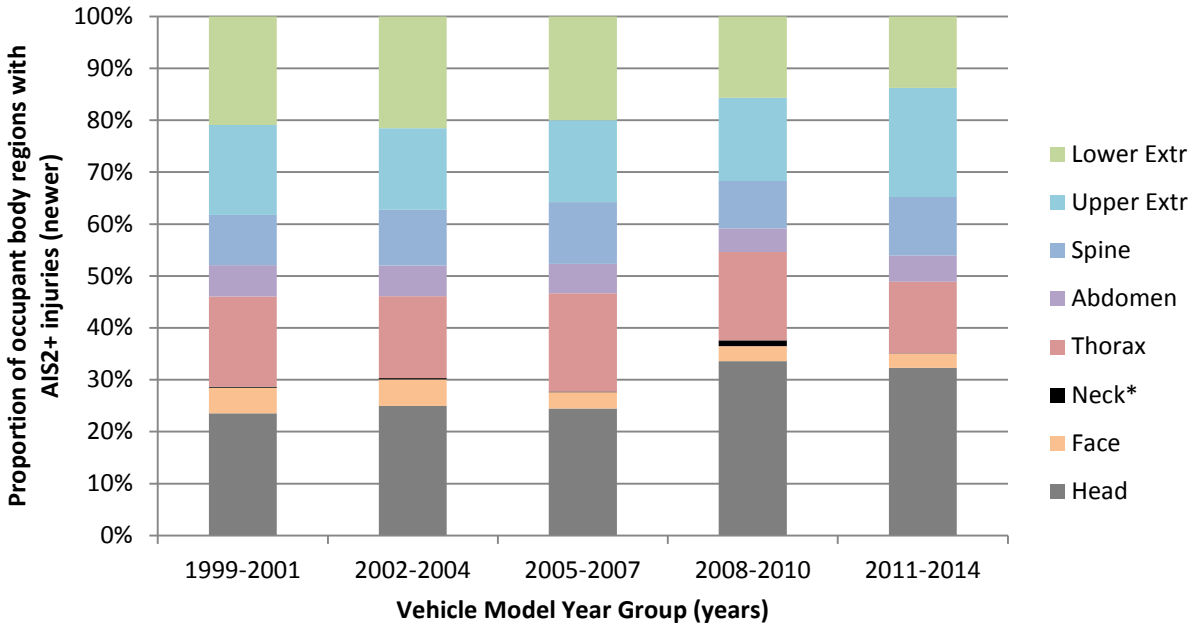


Figure 208. Distribution of occupant body regions with AIS2+ injury by AIS body region for each vehicle model year group.

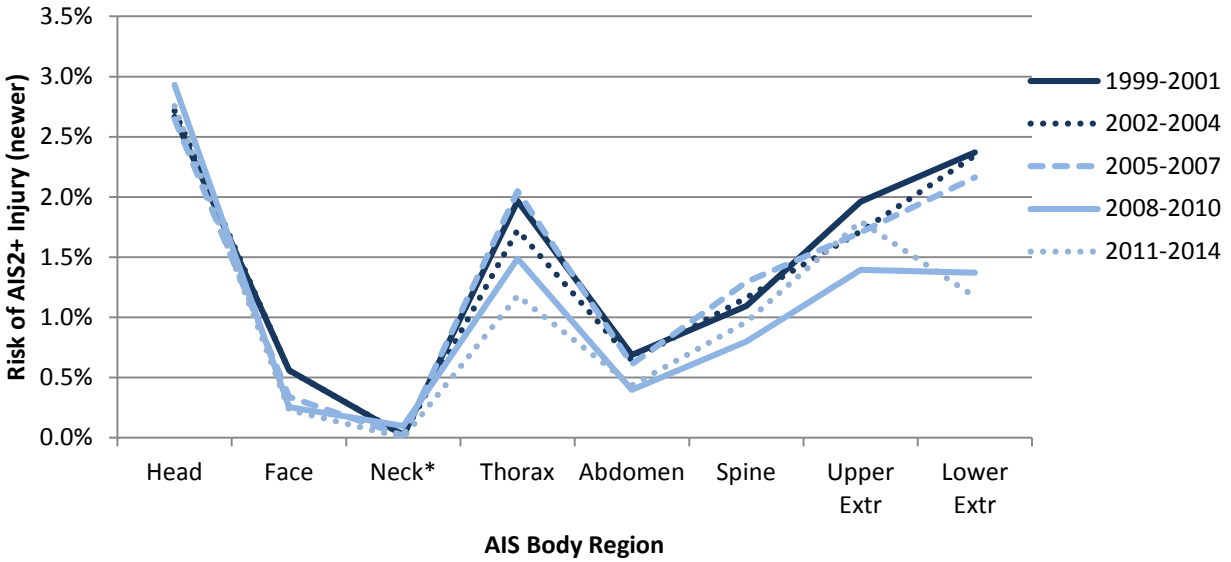


Figure 209. Risk of AIS2+ injury by vehicle model year group for each AIS body region.

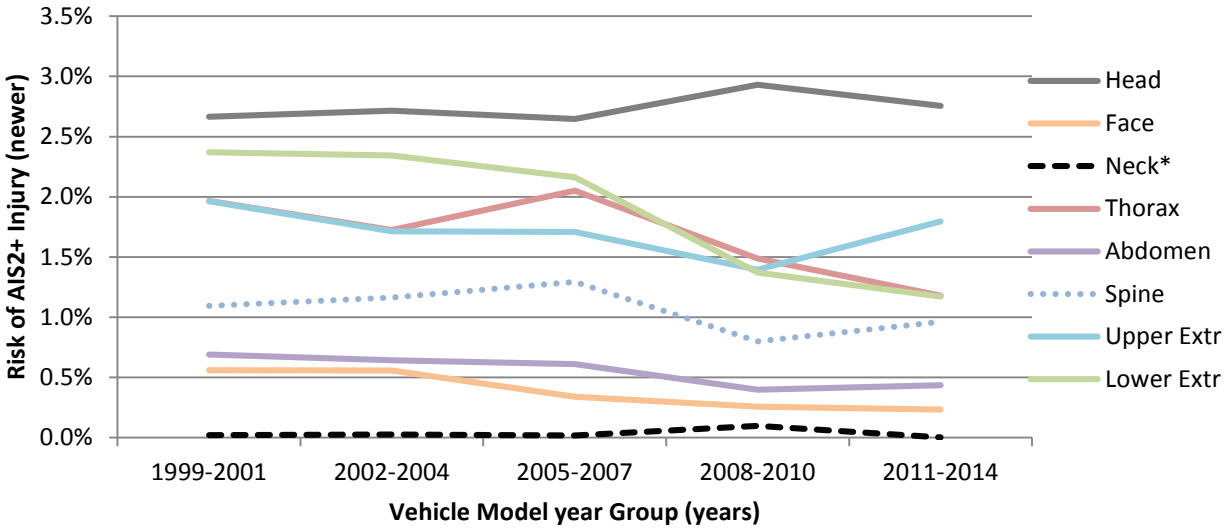


Figure 210. Risk of AIS2+ injury by AIS body region for each vehicle model year group.

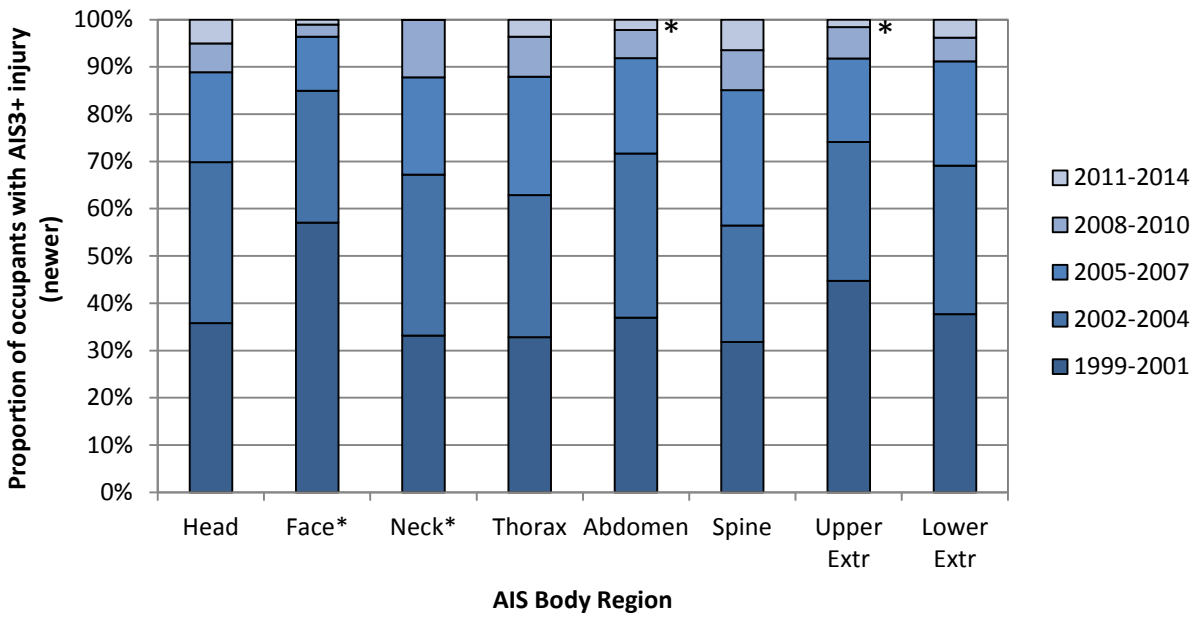


Figure 211. Distribution of occupants with AIS3+ injury by vehicle model year group for each AIS body region.

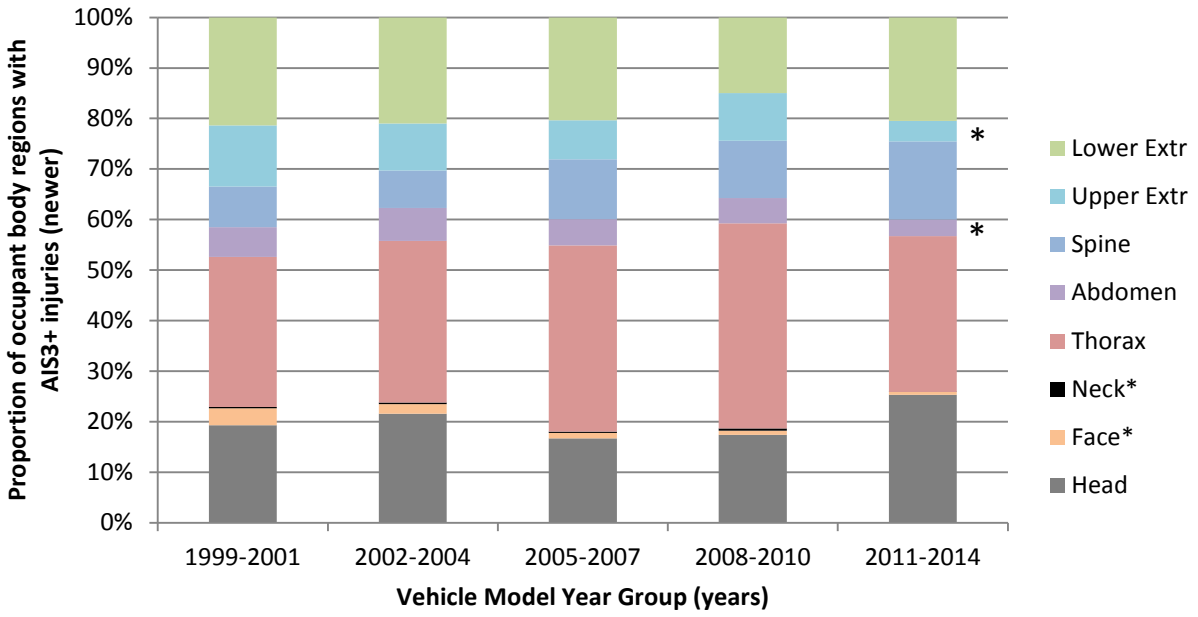


Figure 212. Distribution of occupant body regions with AIS3+ injury by AIS body region for each vehicle model year.

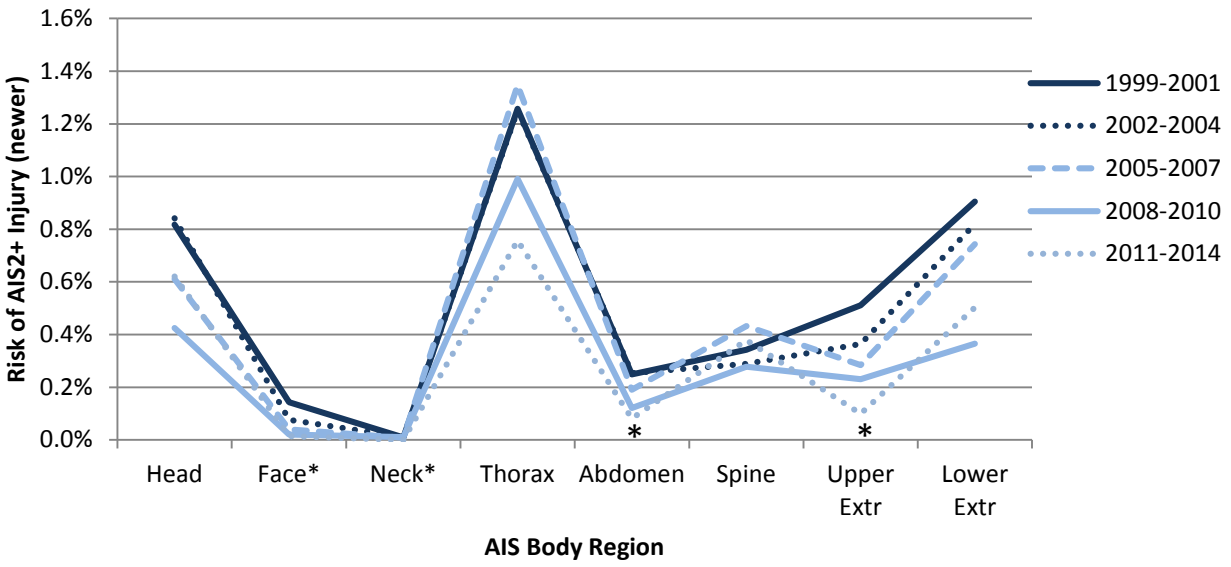


Figure 213. Risk of AIS3+ injury by body region for each vehicle model year group.

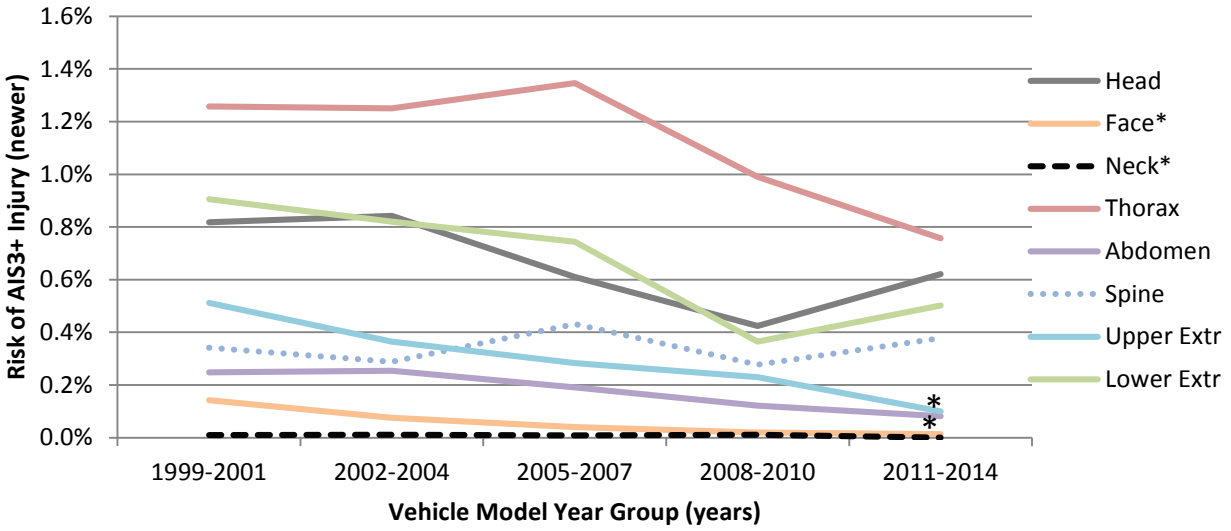


Figure 214. Risk of AIS3+ injury by AIS body region for each vehicle model year group.

Chapter 11. Analysis of specific injuries and body components

In this chapter, specific injuries, specific organs, or specific body components were identified as being clinically significant and occurring frequently enough to analyze. Analysis was performed to examine the distribution and risk of AIS2+ or AIS3+ injuries to these components or organs relative to the overall body region as a function of the same dependent variables analyzed previously. Plots in this chapter are included if the injury trends for a specific component or organ differ from those of the overall body region.

Head Injury

For the head, the distributions and risks of subdural hematomas (SDH), subarachnoid hemorrhages (SAH), and cerebral contusions were compared to the overall injury distributions and risks for the head. Because these three injury types would all be coded as AIS3 or higher, the plots for AIS2+ and AIS3+ would be the same. Cases where the injury patterns for these injuries differ from the overall trends for the head are:

- Occupants in rear crashes with AIS3+ head injury have lower proportions of cerebral contusions and higher proportions of SDH than occupants in other crash types. This is associated with cerebral contusions having the lowest AIS3+ injury risk of the three injury types for rear impacts.
- Occupants in rollovers with cerebral contusions have the lowest proportion of injuries in 7+ quarter turn rollovers and the highest proportion of injuries in 3-6 quarter turn rollovers.
- Risk of cerebral contusions is substantially higher for rear passengers compared to front occupants, whereas risk is more similar for SDH and SAH.
- Crash years 2011-2014 have the lowest proportion of occupants with cerebral contusion and the highest proportion with SAH. This is likely associated with a decrease in risk of cerebral contusion.
- The proportion of occupants with cerebral contusion decreases with vehicle model year. This is likely associated with a decrease in risk of cerebral contusion.
- Occupants age 46 and over have a higher risk of SAH than cerebral contusion, while occupants younger than 46 have higher risk of cerebral contusion. The proportions of occupants with cerebral contusion vary in the same way.

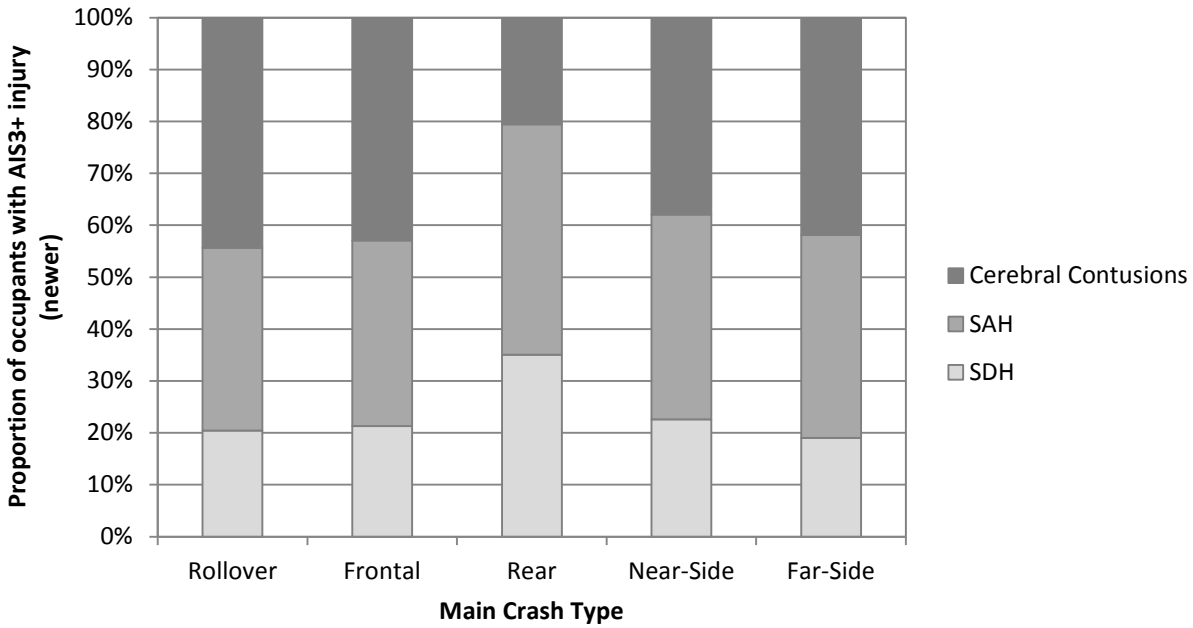


Figure 215. Distribution of specific AIS3+ head injuries for each crash type.

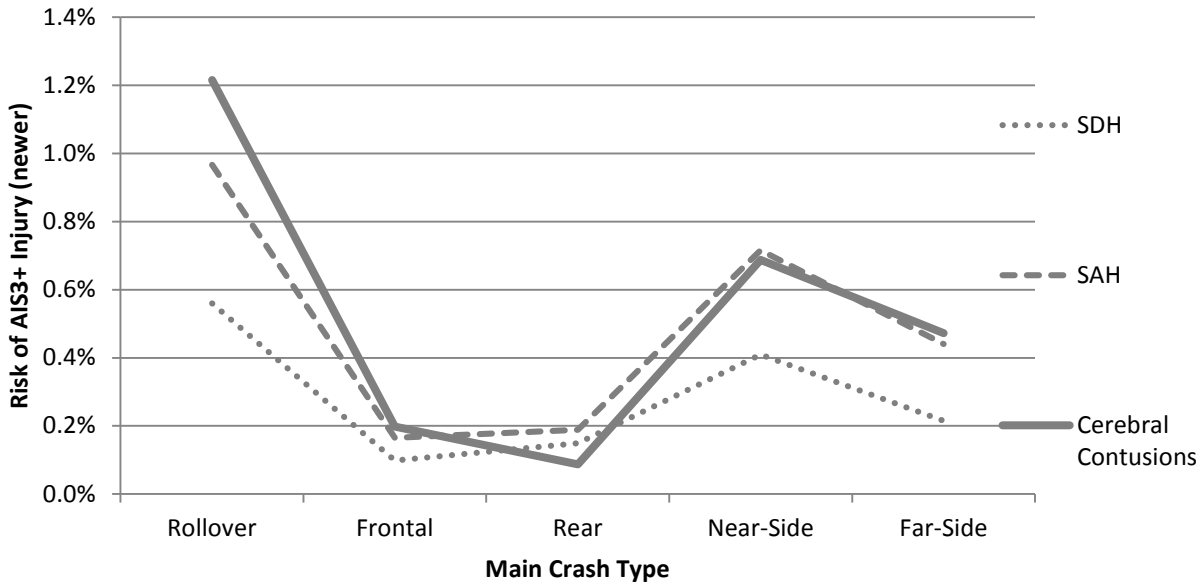


Figure 216. Risk of specific AIS3+ head injuries for each crash type.

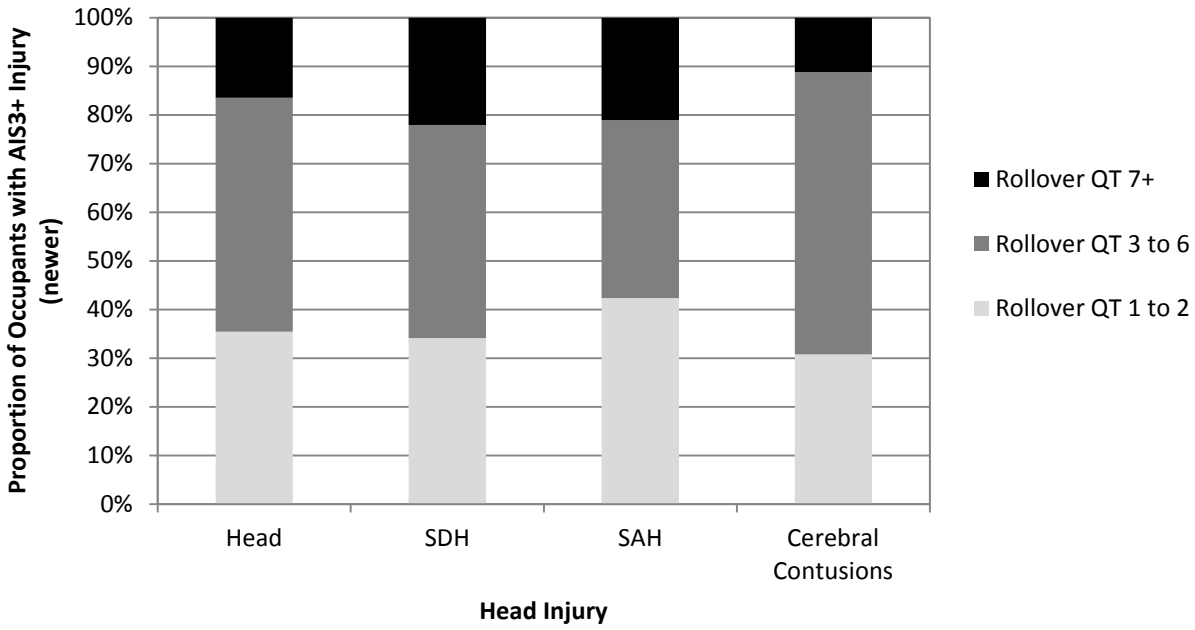


Figure 217. Distribution of occupants by rollover type for specific AIS3+ head injuries.

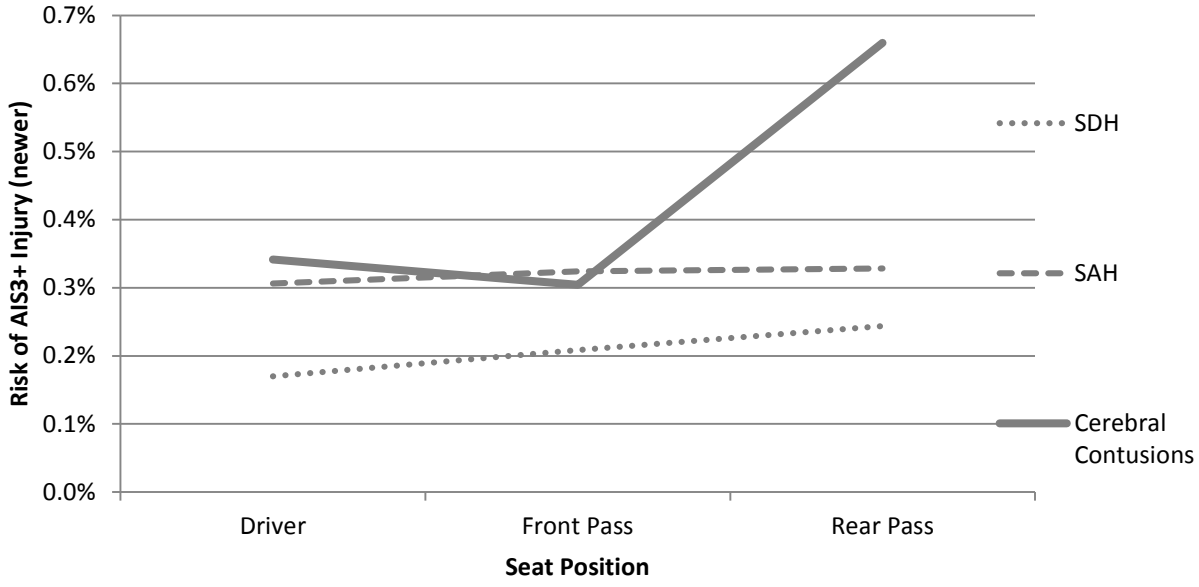


Figure 218. Risk of specific AIS3+ head injuries for each seating position.

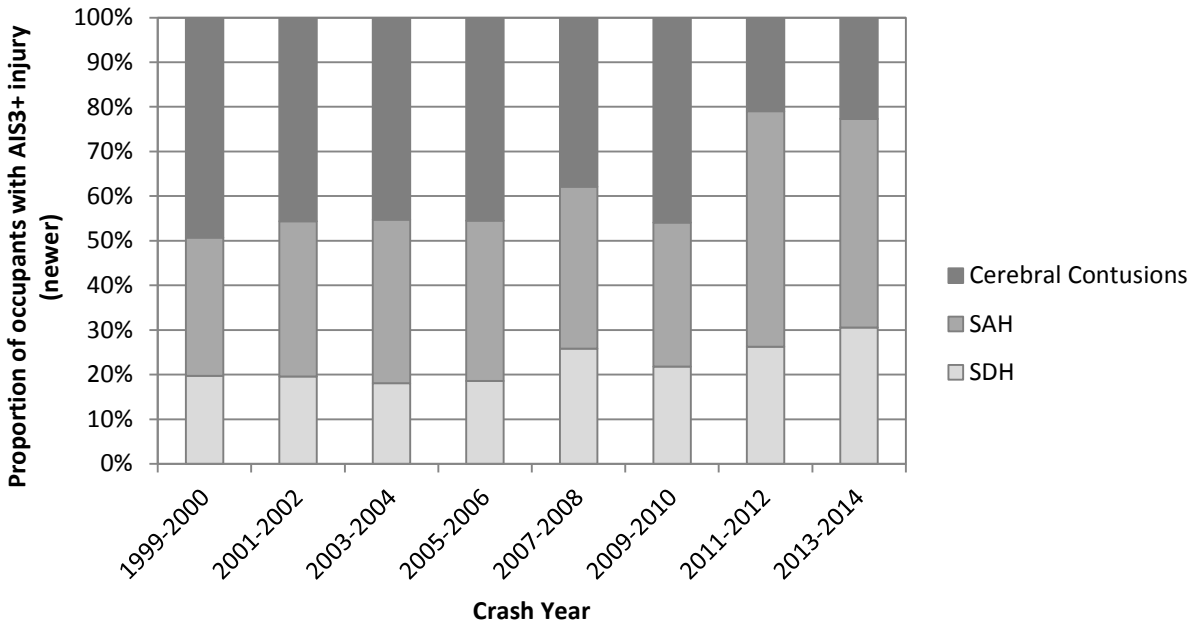


Figure 219. Distribution of occupants by crash year group for specific AIS3+ head injuries.

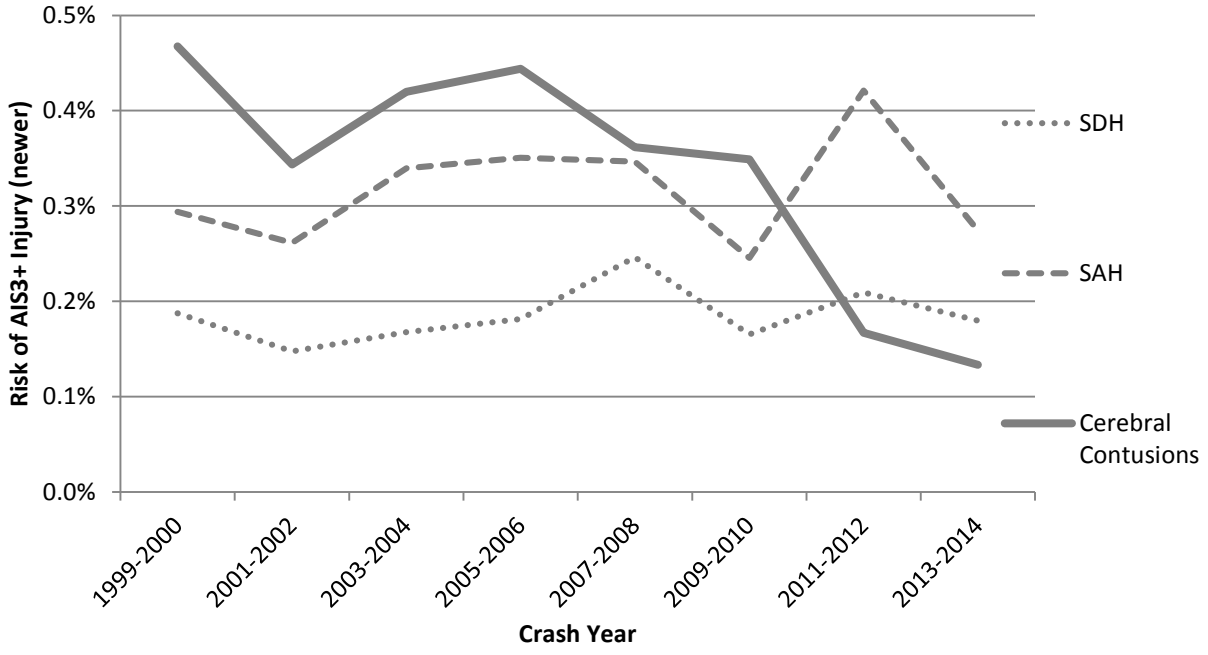


Figure 220. Risk of AIS3+ injury by specific head injuries for each crash year group.

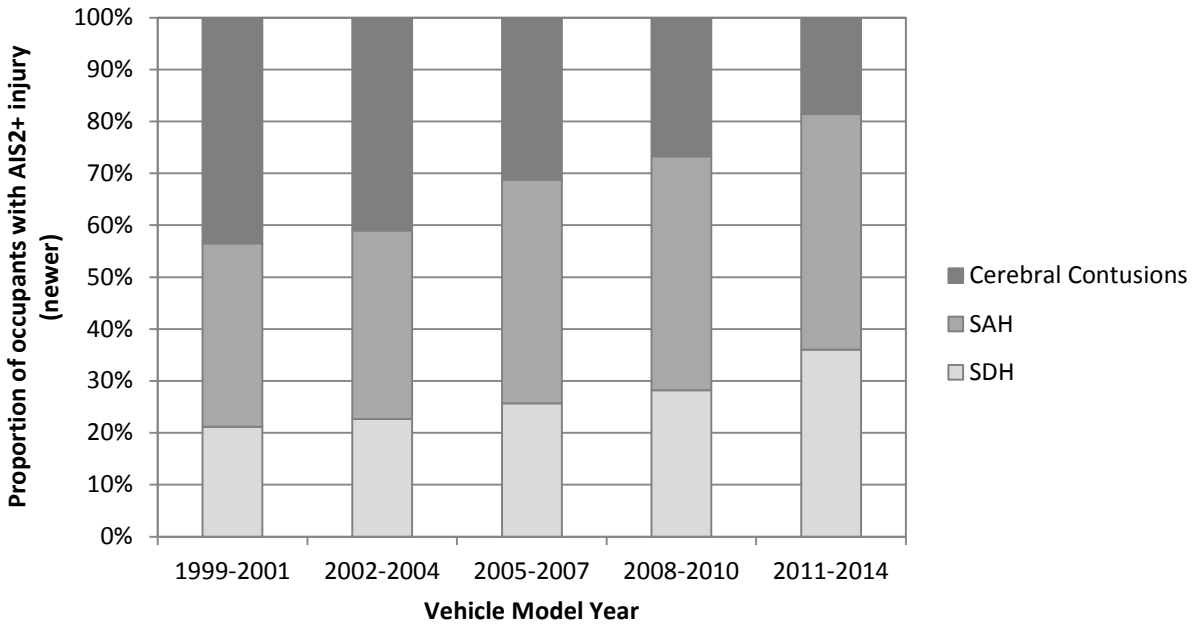


Figure 221. Distribution of occupants by vehicle model year for specific AIS3+ head injuries.

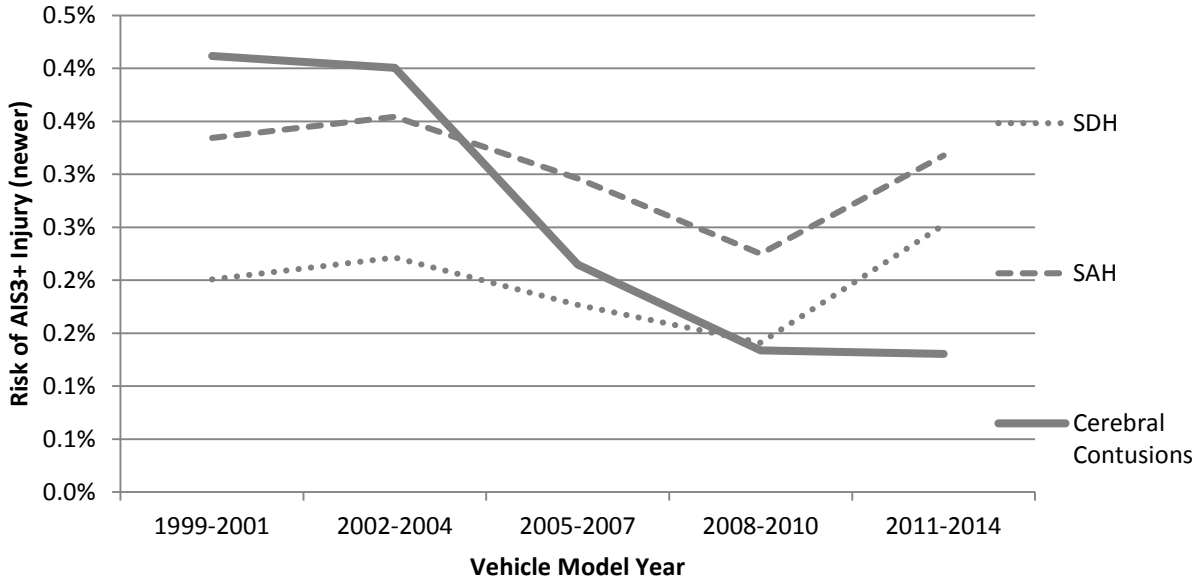


Figure 222. Risk of AIS3+ injury by specific head injuries for each age group.

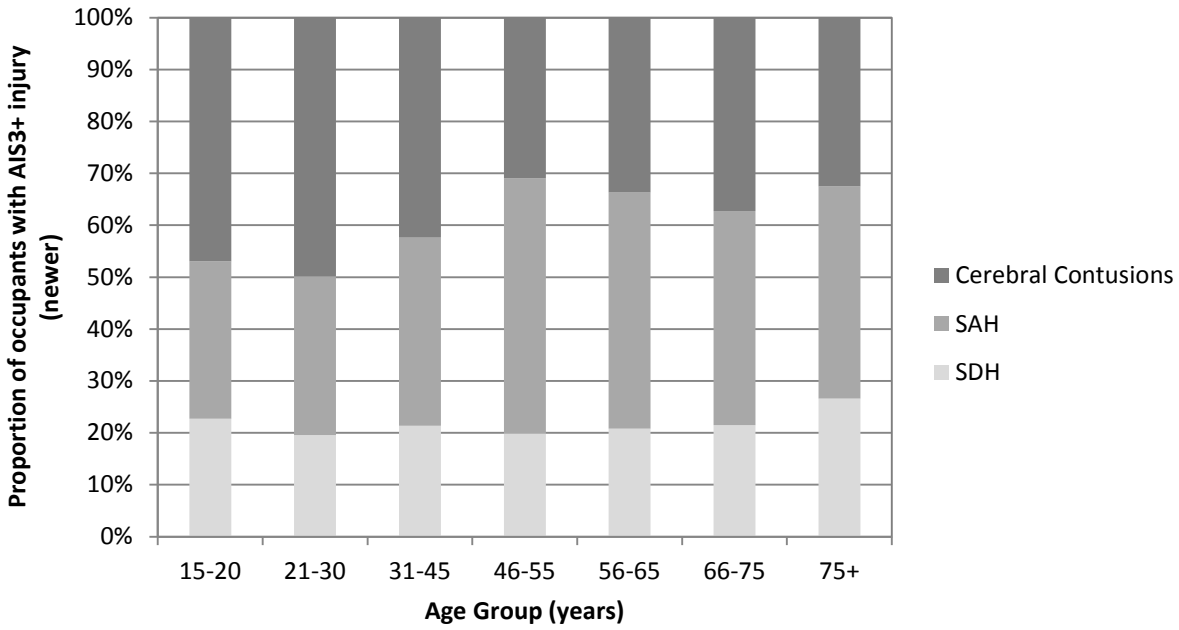


Figure 223. Distribution of occupants by age group for specific AIS3+ head injuries.

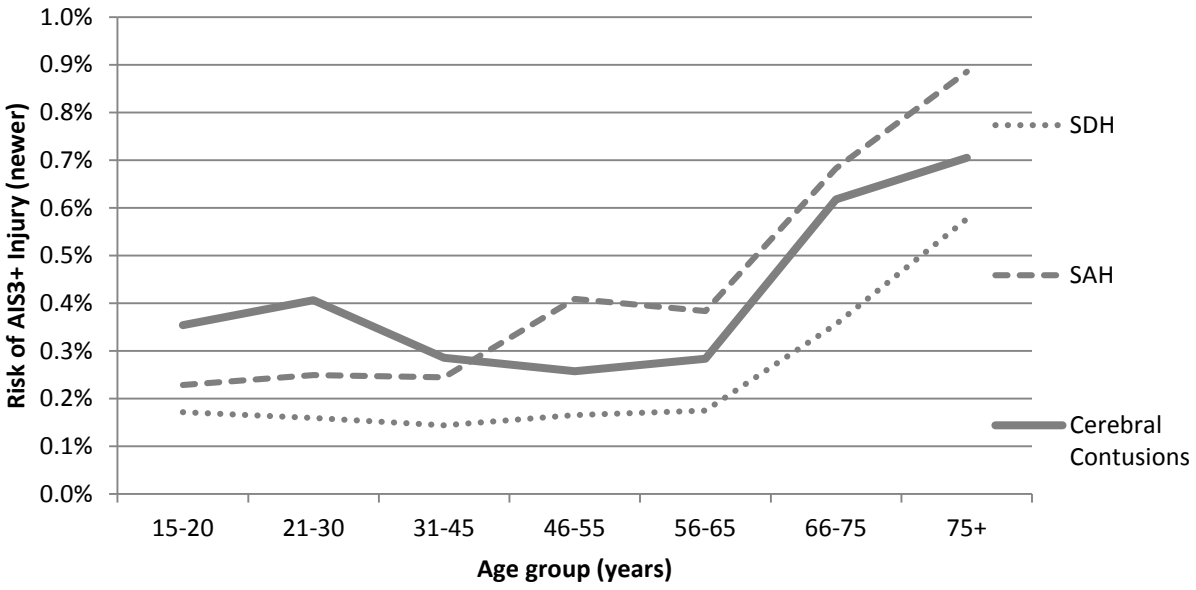


Figure 224. Risk of AIS3+ injury by specific head injuries for each age group.

Thorax Injury

Pulmonary contusions (PC) and rib fractures were compared to overall trends in thorax injury. Trends that differed from those of overall thorax injury include:

- The risk of AIS3+ rib fracture is higher in 2007 and later vehicles compared to PC.
- The proportion of occupants with AIS3+ rib fractures increases with age, because the risk of AIS3+ rib fracture increases with age while the risk of AIS3+ PC is relatively constant with age. For occupants under age 30, risk of AIS3+ PC is higher than risk of rib fracture, while it is lower for occupants over 30.
- Men have nearly the same risk of AIS3+ rib fracture and PC, while it is higher for rib fracture among women.
- Occupants with BMI of less than 25 have similar risks of PC and rib fracture, while it is higher for rib fracture among occupants with BMI greater than 25.
- Risk of AIS3+ rib fracture and PC decreases with vehicle model year group, but decreases more for PC.

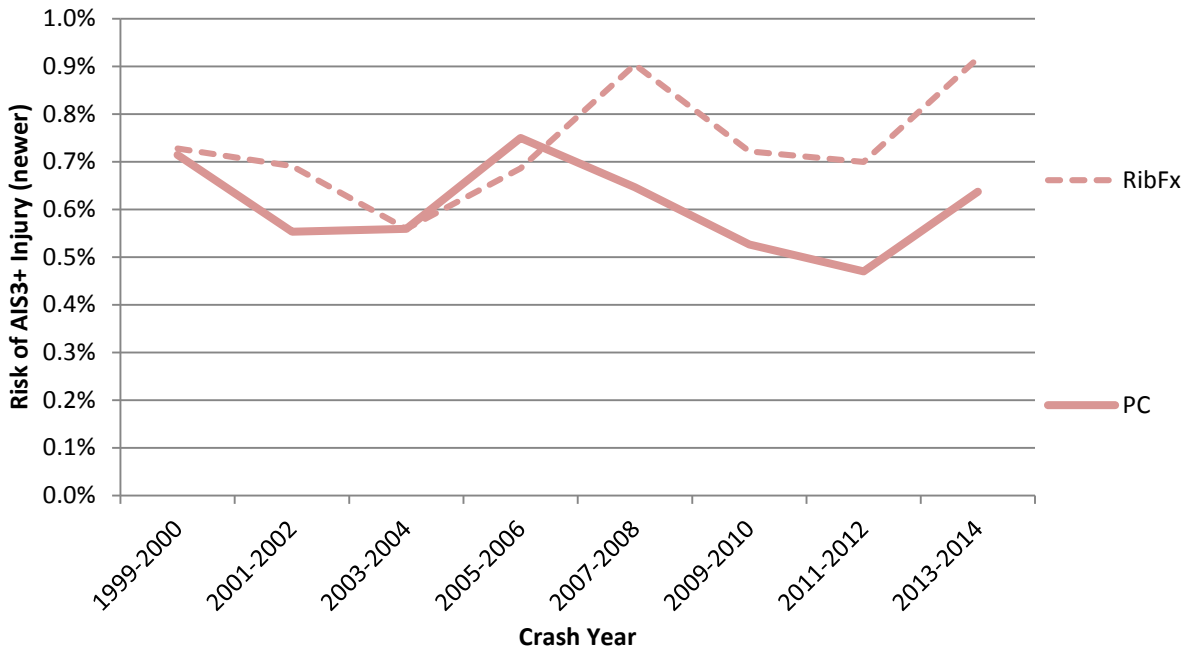


Figure 225. Risk of AIS3+ rib fracture and PC for each crash year.

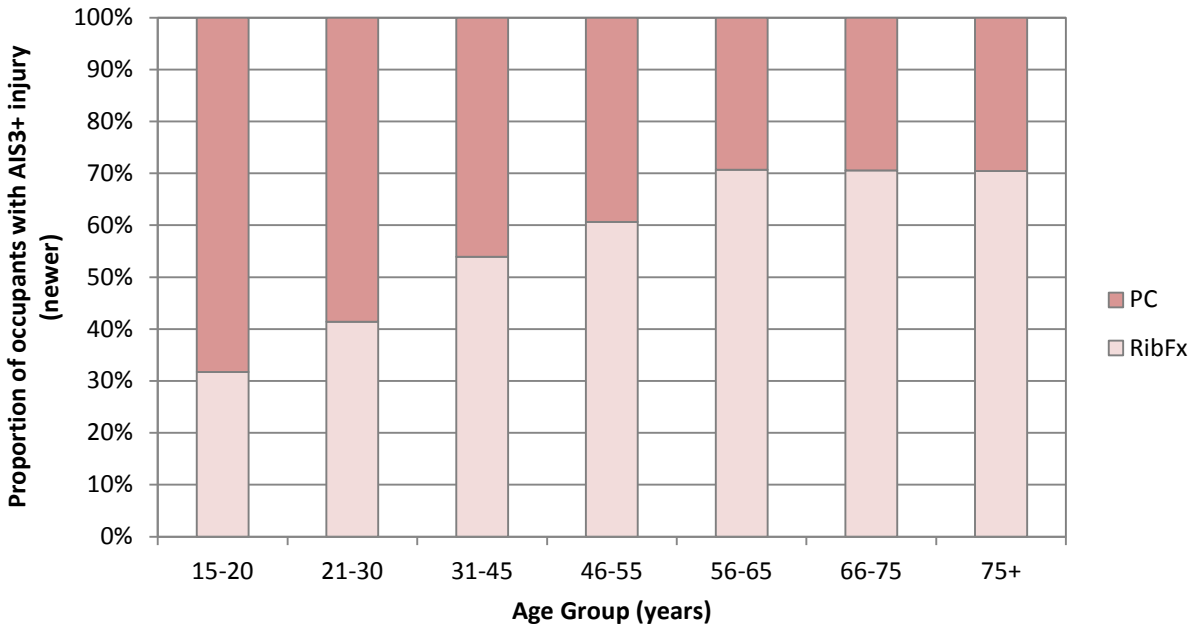


Figure 226. Distribution of occupants with AIS3+ injury by age group for rib and PC injury

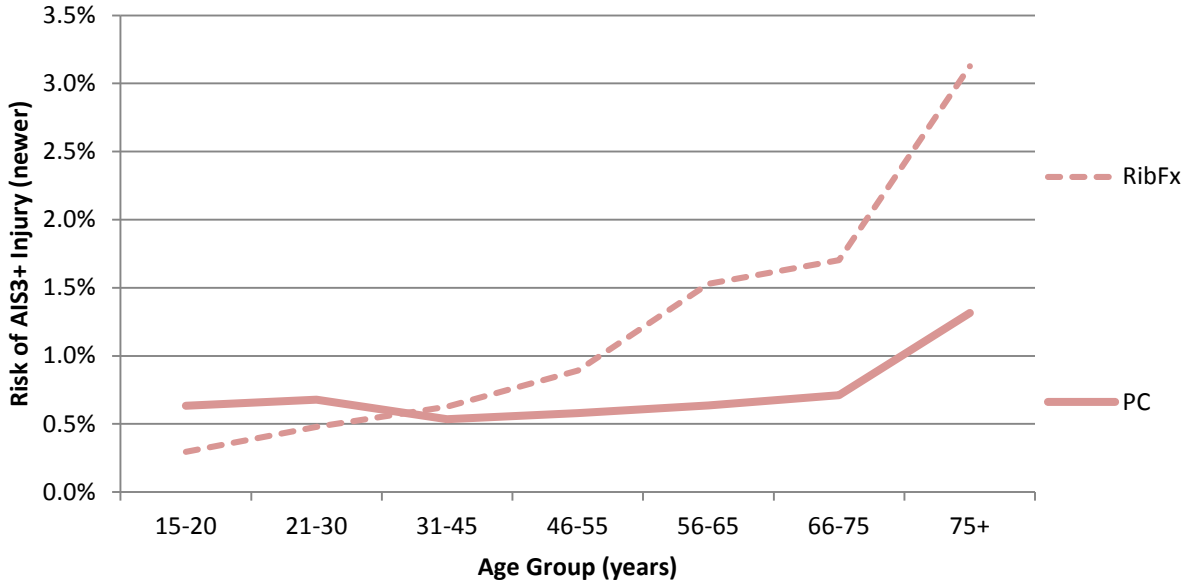


Figure 227. Risk of specific AIS3+ thorax injuries by age group.

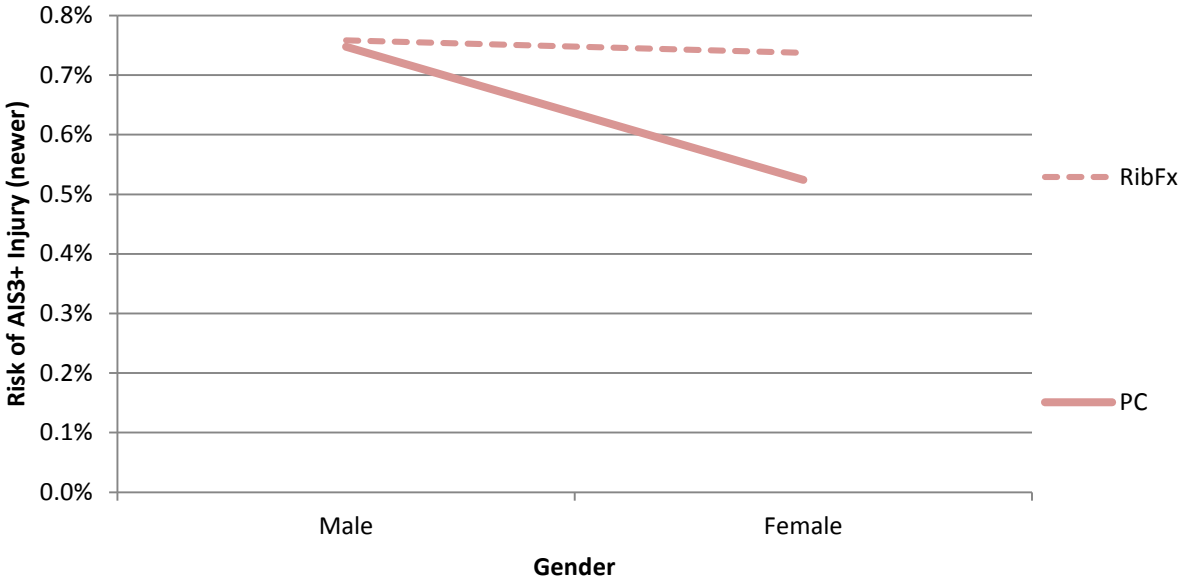


Figure 228. Risk of specific AIS3+ thorax injuries by gender.

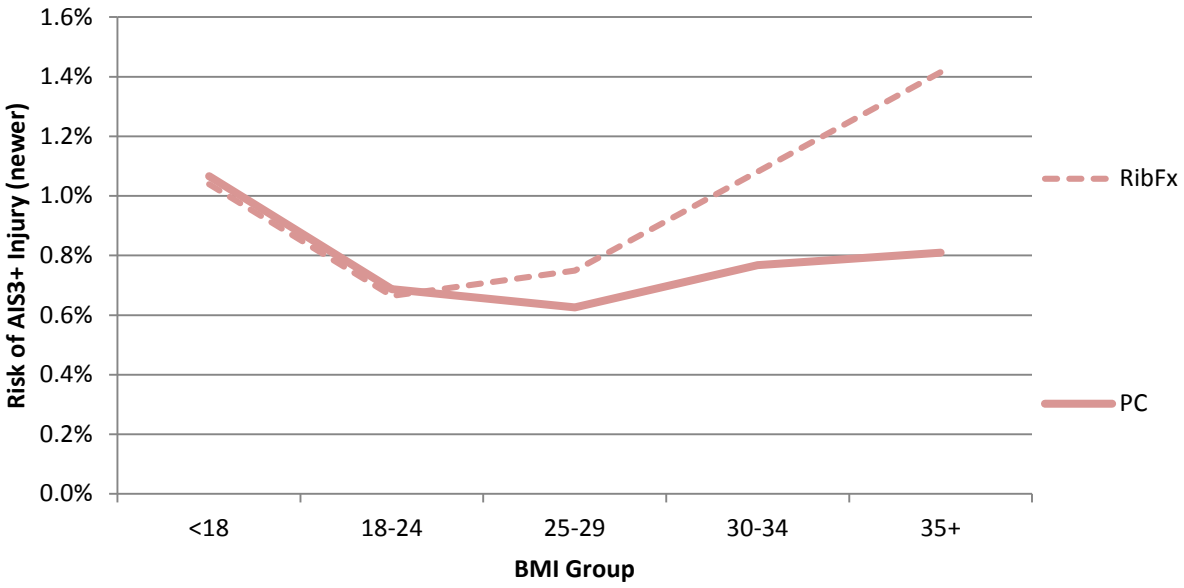


Figure 229. Risk of specific AIS3+ thorax injuries by BMI group.

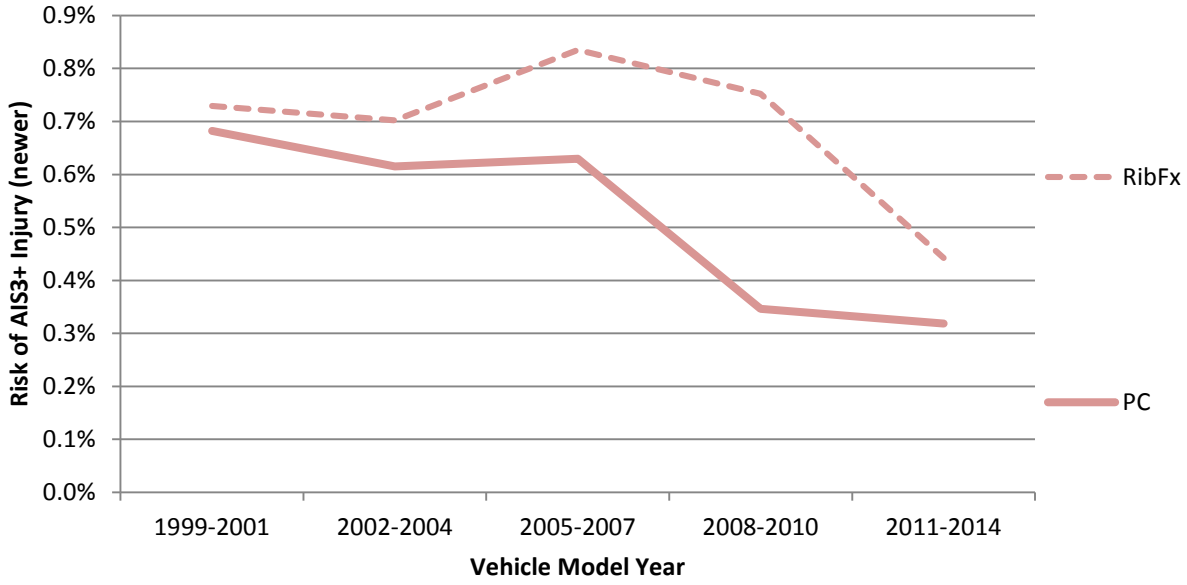


Figure 230. Risk of specific AIS3+ thorax injuries by vehicle model year.

Spine Injury

Differences in the distributions and risks of injury to the cervical, thoracic, and lumbar spine were different from trends for any spine injuries as indicated below:

- The lumbar spine had the highest proportion of AIS3+ injuries to belted occupants.
- Risk of AIS3+ cervical spine injury increases with BMI group, while thoracic and lumbar spine injury risk are fairly constant with BMI group.

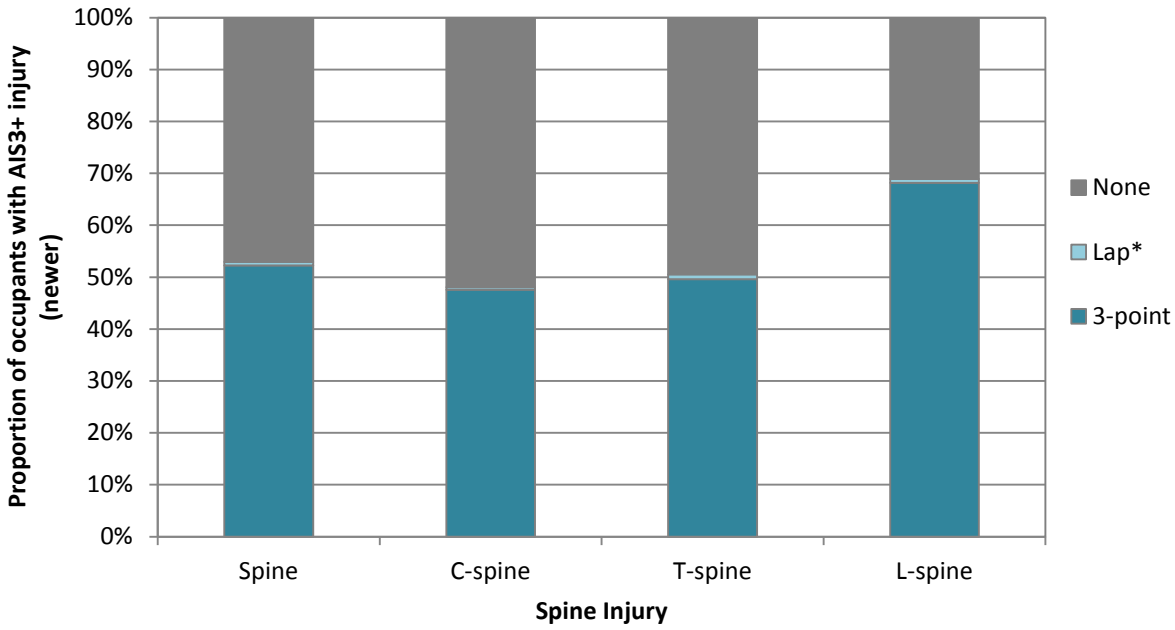


Figure 231. Distributions of occupants with AIS3+ injury by belt restraint for the spine and spinal regions.

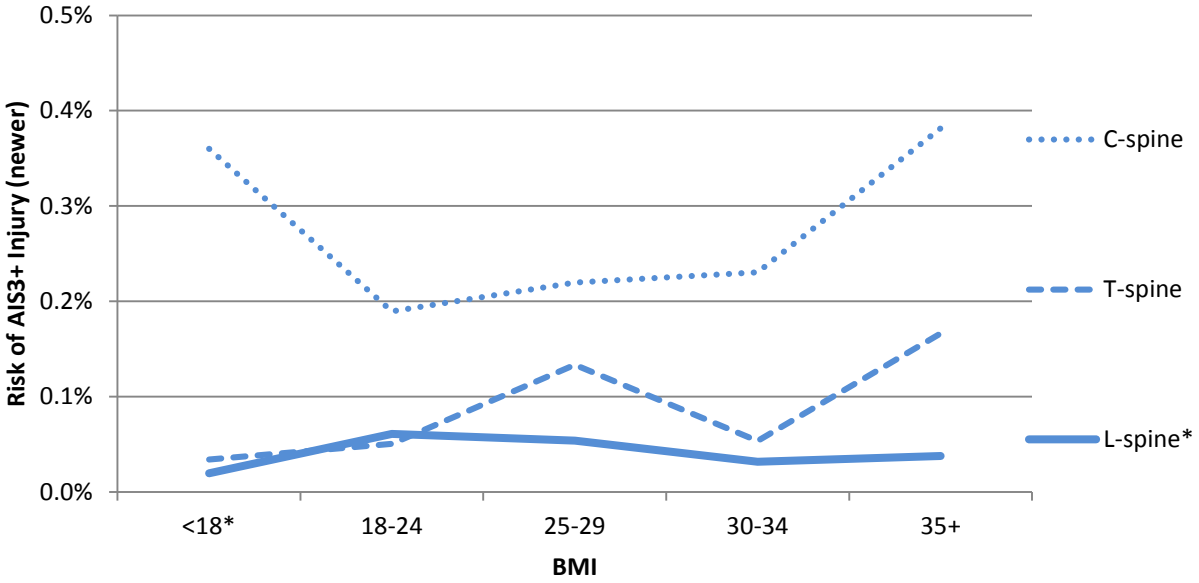


Figure 232. Risk of AIS3+ injury by spinal region for each BMI grouping.

Abdomen Injury

The distributions and risks of injury to the liver and spleen differed from overall abdomen injury patterns as indicated below:

- Occupants with AIS3+ spleen injuries have higher proportions of near-side impacts and lower proportions of frontal and rollover impacts.
- The difference between AIS3+ injury risk for liver and spleen is highest in near-side impacts.
- Among frontal subcrash types, occupants with spleen injury have greater proportions of left offset or left SOI crashes.
- For AIS3+ injured occupants in rollovers, those with spleen injuries have the highest proportion of rollovers with 7+ quarter turns.
- Occupants with AIS3+ liver injuries have a higher proportion of occupants in far-side T-type crashes than those with spleen injuries.
- Occupants with AIS3+ liver injuries have a greater proportion of unbelted occupants than occupants with spleen injury. Risk of AIS3+ liver and spleen injury are similar for 3-point-belted occupants, but higher for liver for unbelted occupants.
- Occupants with BMI 25-29 had a higher proportion of spleen injuries. This group has the highest risk of AIS3+ spleen injury.
- Women have a higher proportion of liver injuries. Their risk of AIS3+ liver injury is higher than the risk of AIS3+ spleen injury, while the opposite is true for men.

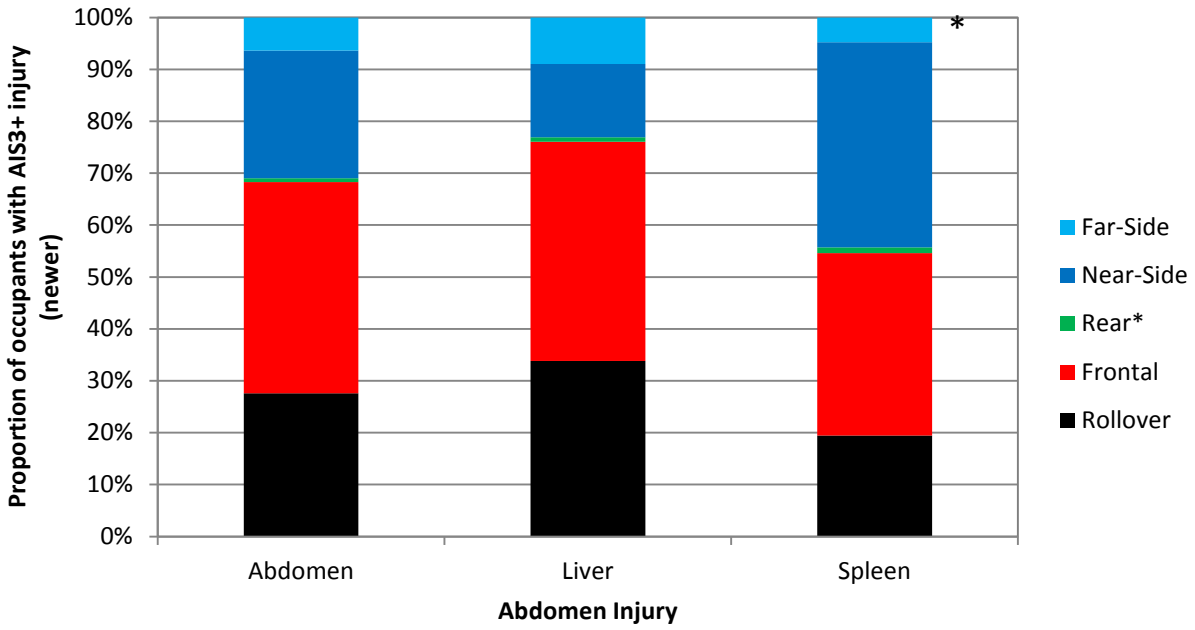


Figure 233. Distribution of AIS3+ injured occupants by crash type for abdomen, liver, and spleen injuries.

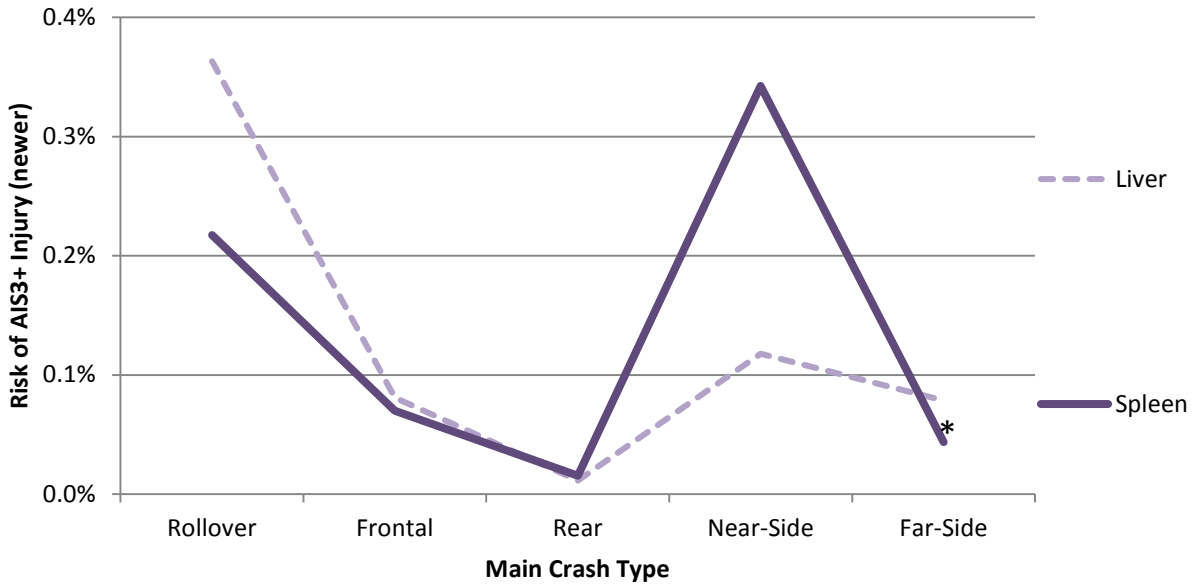


Figure 234. Risk of AIS3+ liver or spleen injury by crash type.

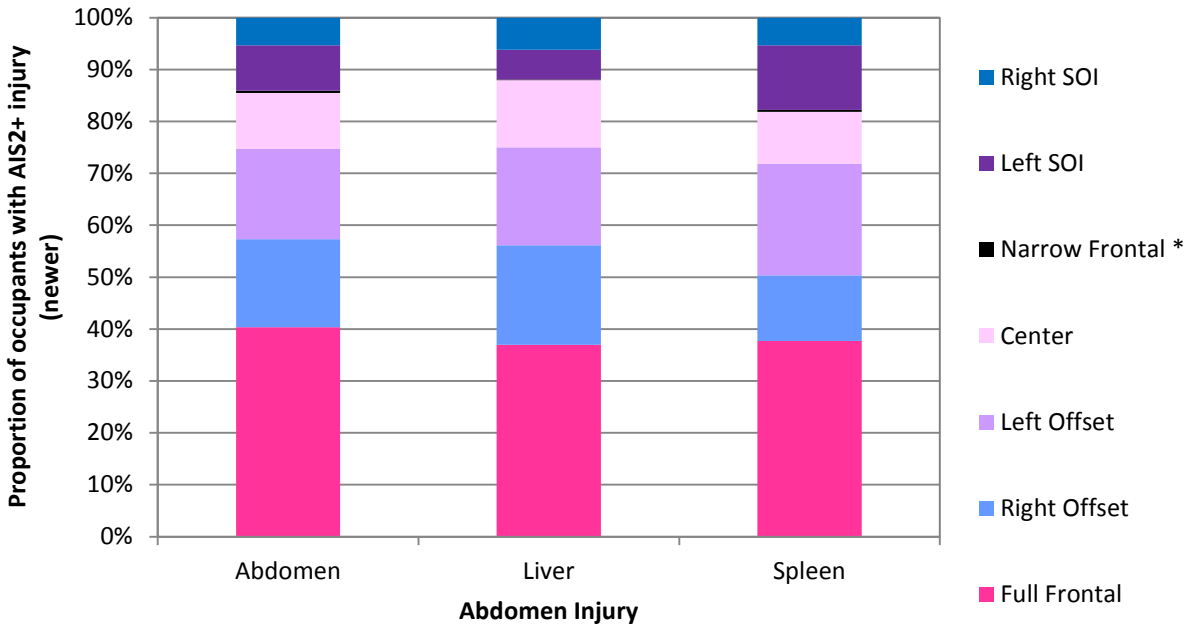


Figure 235. Distribution of AIS3+ injured occupants by frontal subcrash type for those with abdomen, liver, and spleen injuries.

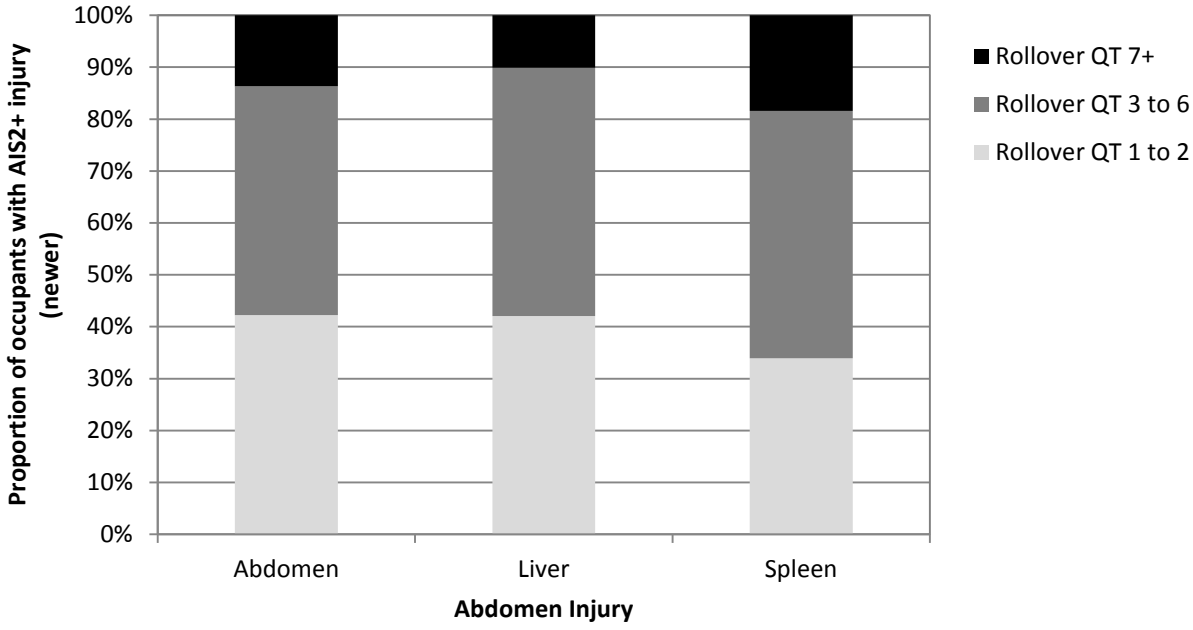


Figure 236. Distribution of AIS2+ injured occupants by rollover crash type with abdomen, liver, or spleen injury.

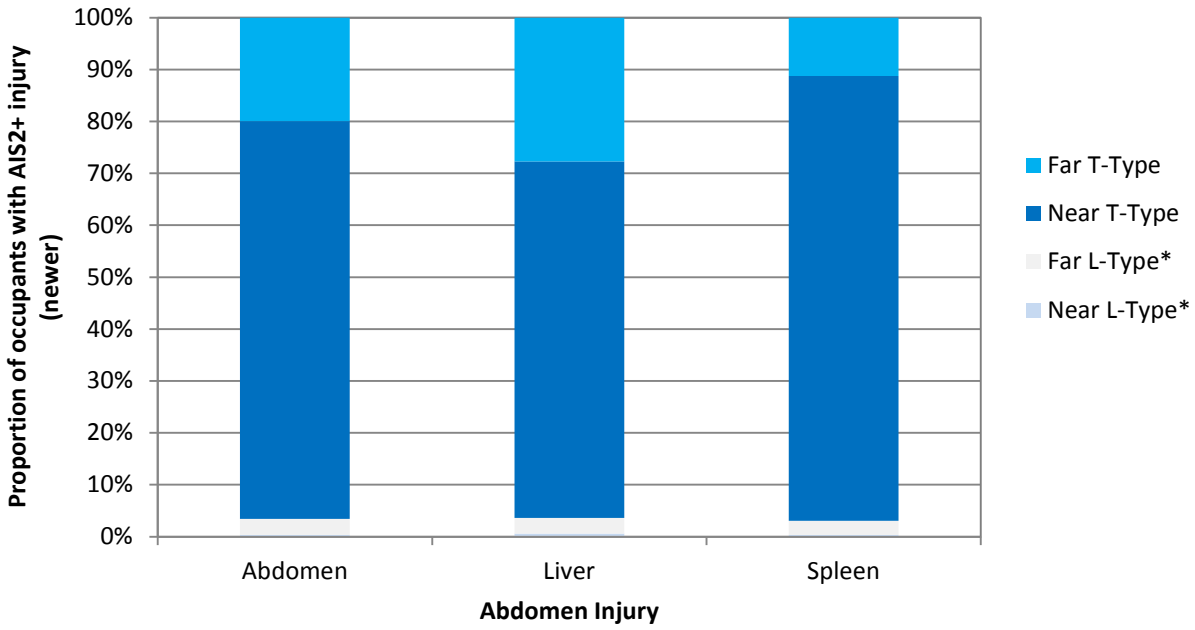


Figure 237. Distribution of AIS2+ injured occupants with abdomen, liver, or spleen injury by side subcrash type.

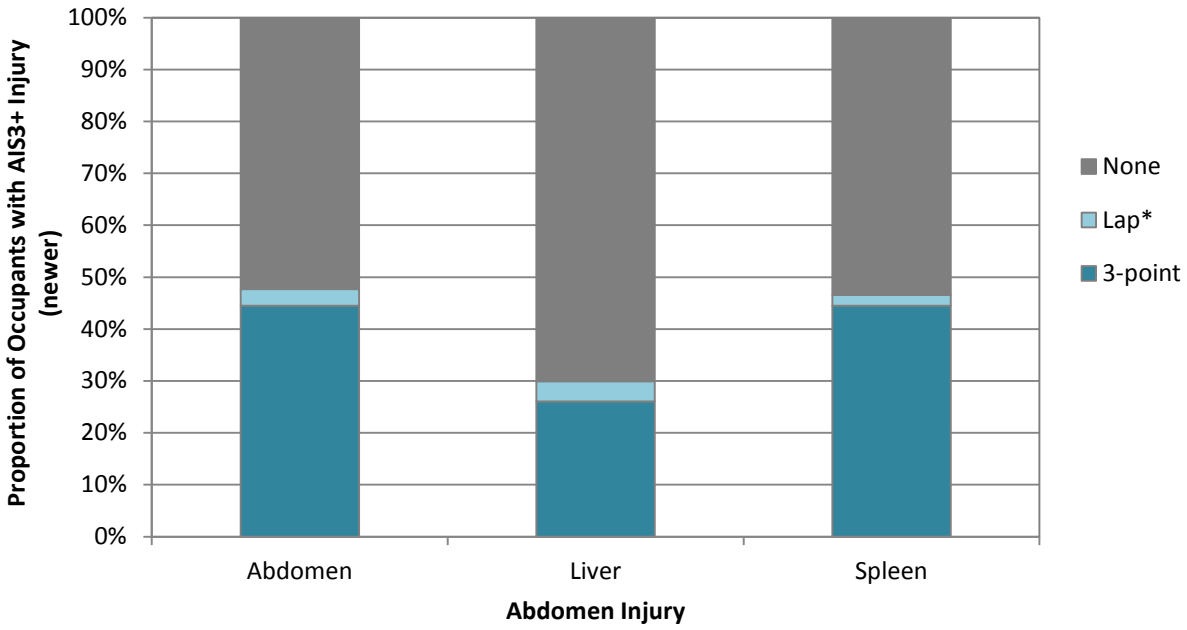


Figure 238. Distribution of AIS3+ injured occupants with spleen or liver injuries by belt restraint.

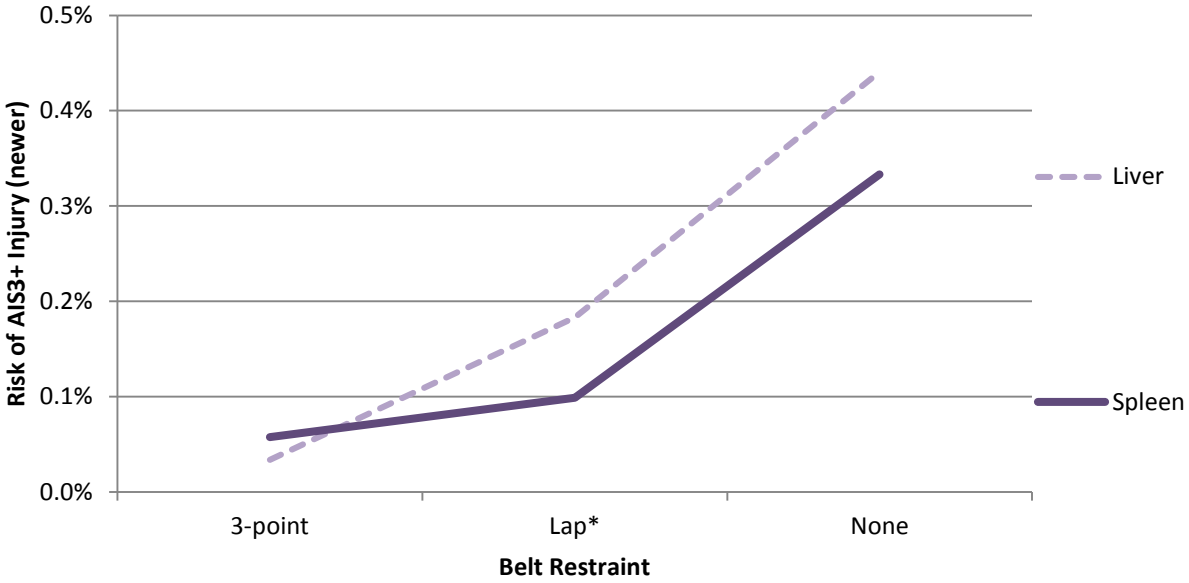


Figure 239. Risk of AIS3+ liver and spleen injury for each belt restraint type.

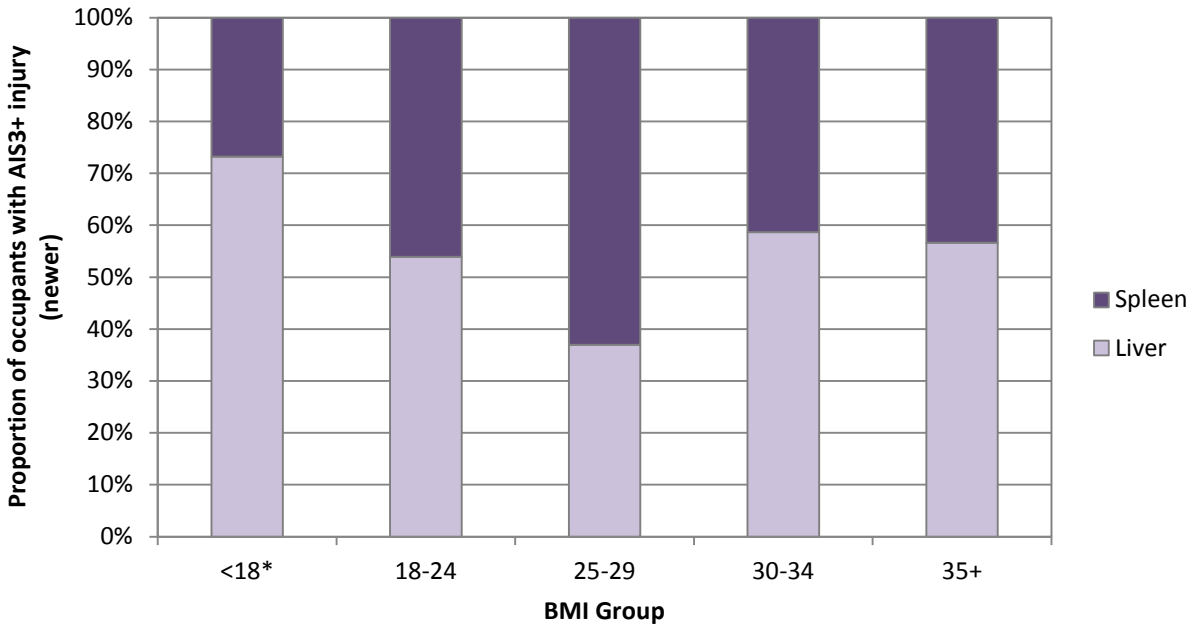


Figure 240. Proportion of occupants by BMI group with AIS3+ abdomen, spleen or liver injury.

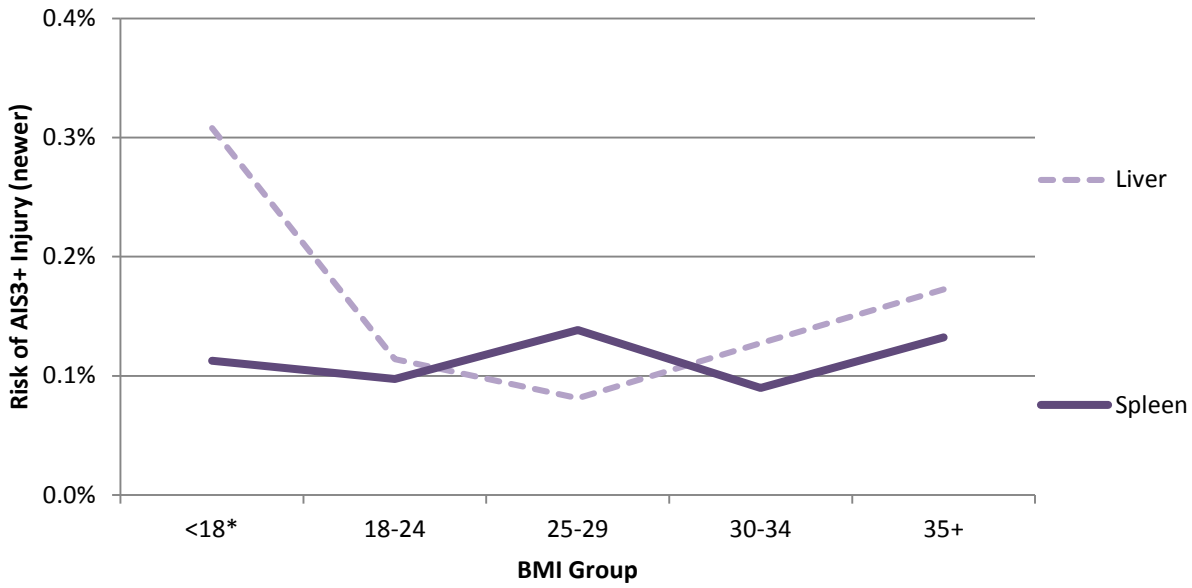


Figure 241. Risk of AIS3+ liver or spleen injury for each BMI group.

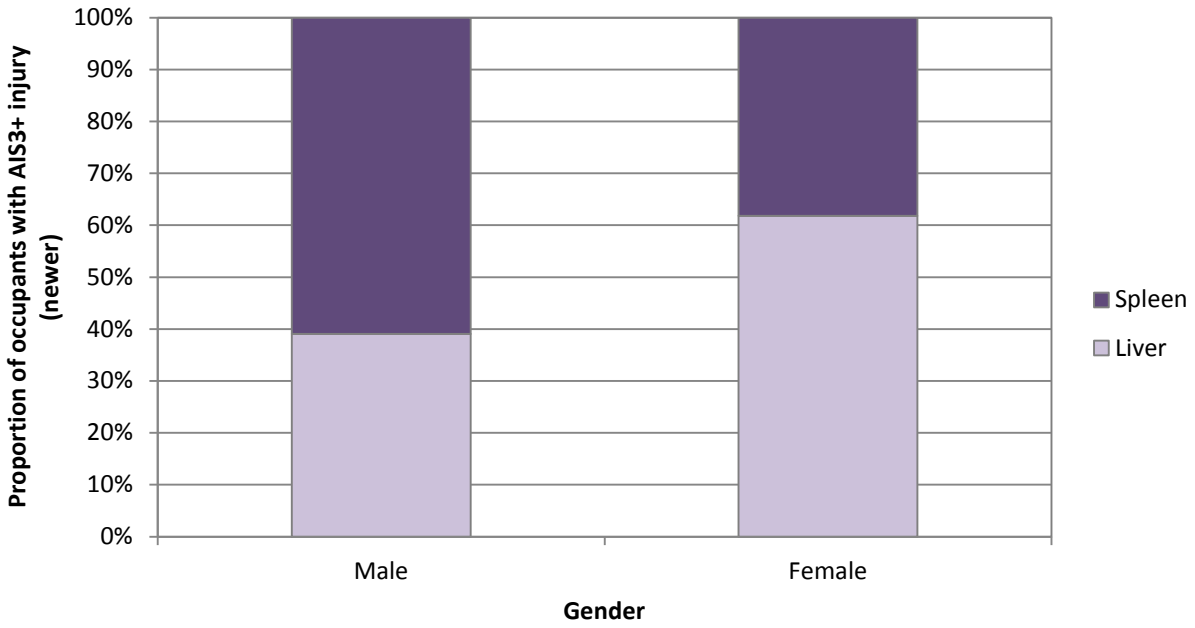


Figure 242. Proportion of occupants with AIS3+ injury to the spleen or liver for each gender.

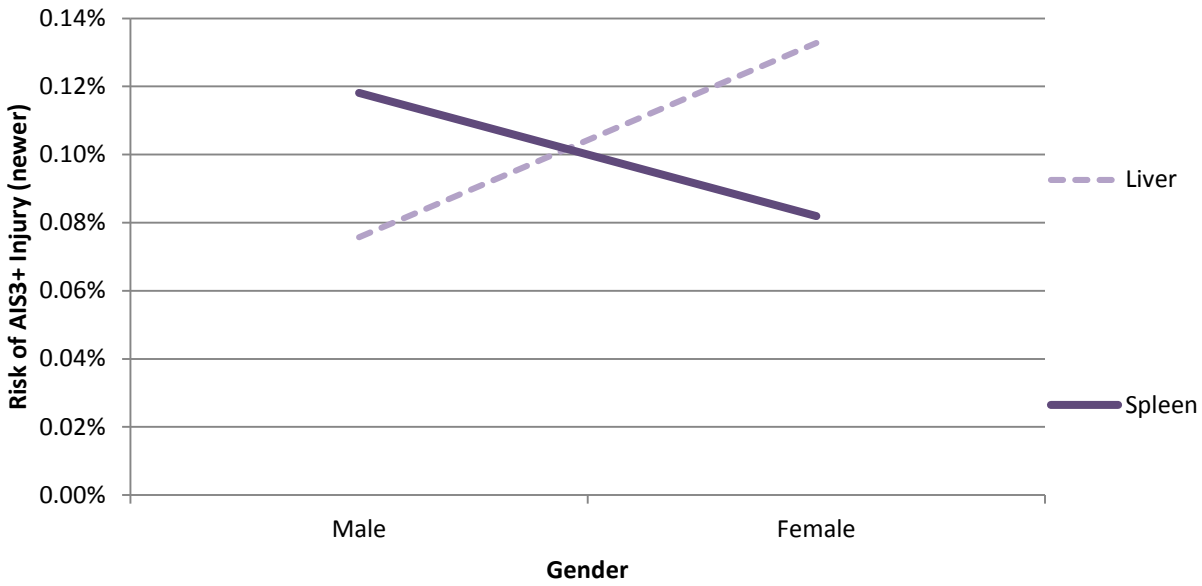


Figure 243. Risk of AIS3+ injury to the liver and spleen for each gender.

Upper Extremity

For the upper extremity, occupants with injuries to the radius, ulna, or humerus were compared to occupants with any upper extremity injury. Atypical injury patterns among the different upper extremity bones are as follows:

- The humerus has greater proportions of occupants in later crash years compared to the radius and ulna (considering AIS3+ injury).
- Humerus has the greatest proportion of occupants in rollovers and far-side impacts.
- Among occupants with AIS3+ upper extremity injuries from rollovers, the ulna has the lowest proportion from 7+ quarter turn rollovers and the largest from 1-2 quarter turn rollovers.
- The humerus has the highest proportion of unbelted occupants.
- The humerus has the lowest proportion of drivers and the greatest proportion of rear seat occupants.
- Risk of AIS3+ injury increases with age for all three upper extremity bones, but the humerus has a large increase in risk at age 75 and the largest proportion of occupants with humerus injuries among those with AIS3+ upper extremity injuries.
- Almost 40% of occupants with AIS3+ humerus injuries have BMI above 30, compared to just over 20% for the radius and ulna.
- The humerus has the greatest proportion of occupants in passenger cars.

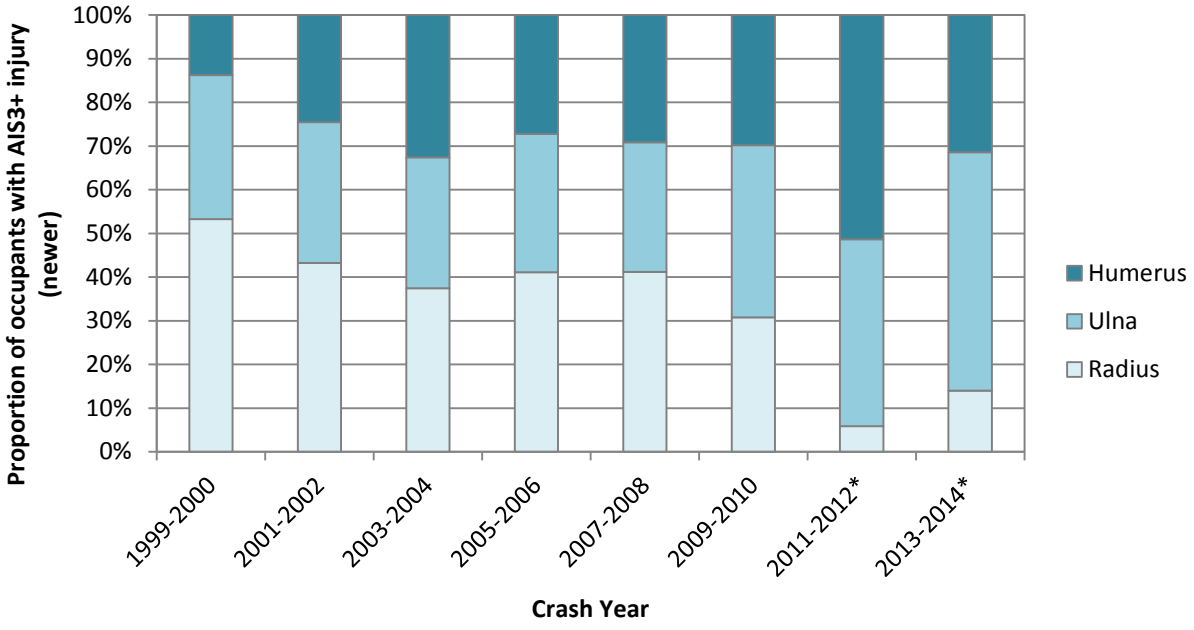


Figure 244. Distribution of AIS3+ injured occupants by crash year for each upper extremity bone and overall upper extremity injuries.

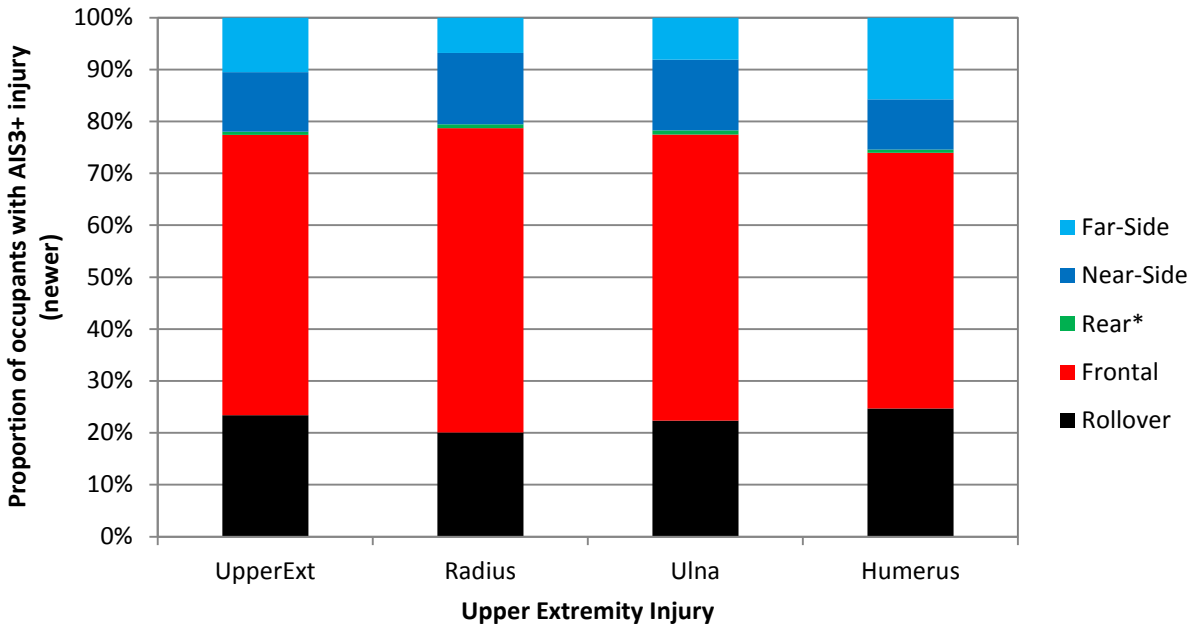


Figure 245. Distribution of AIS3+ injured occupants by crash type for each upper extremity bone injury.

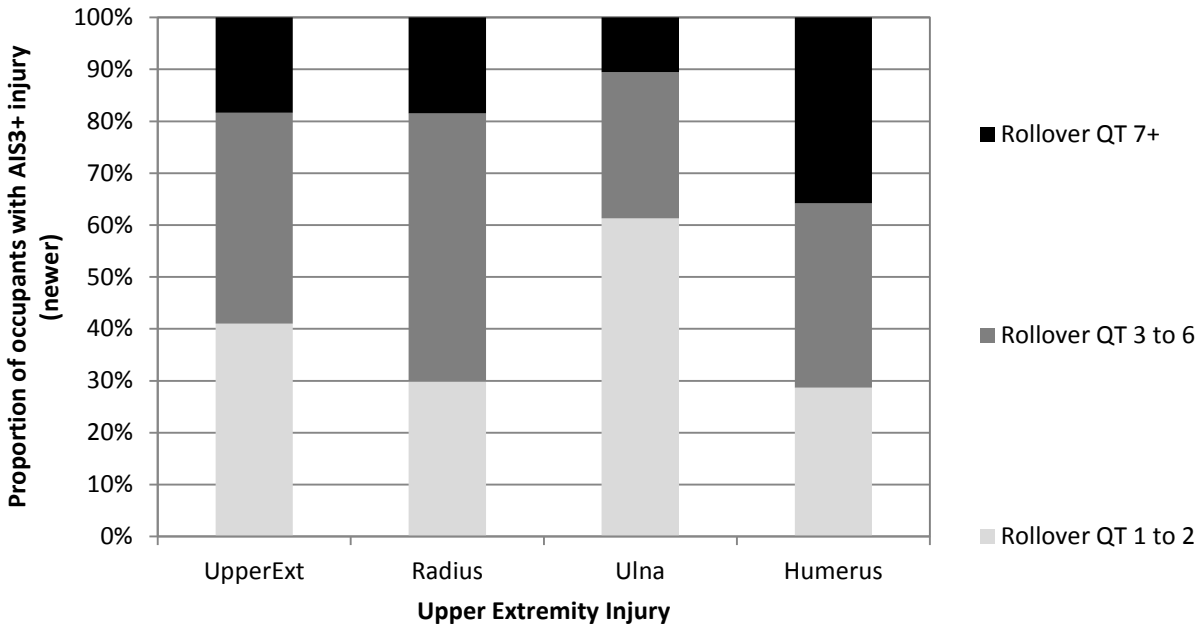


Figure 246. Distribution of AIS3+ injured occupants by rollover type for each upper extremity bone and overall upper extremity injuries.

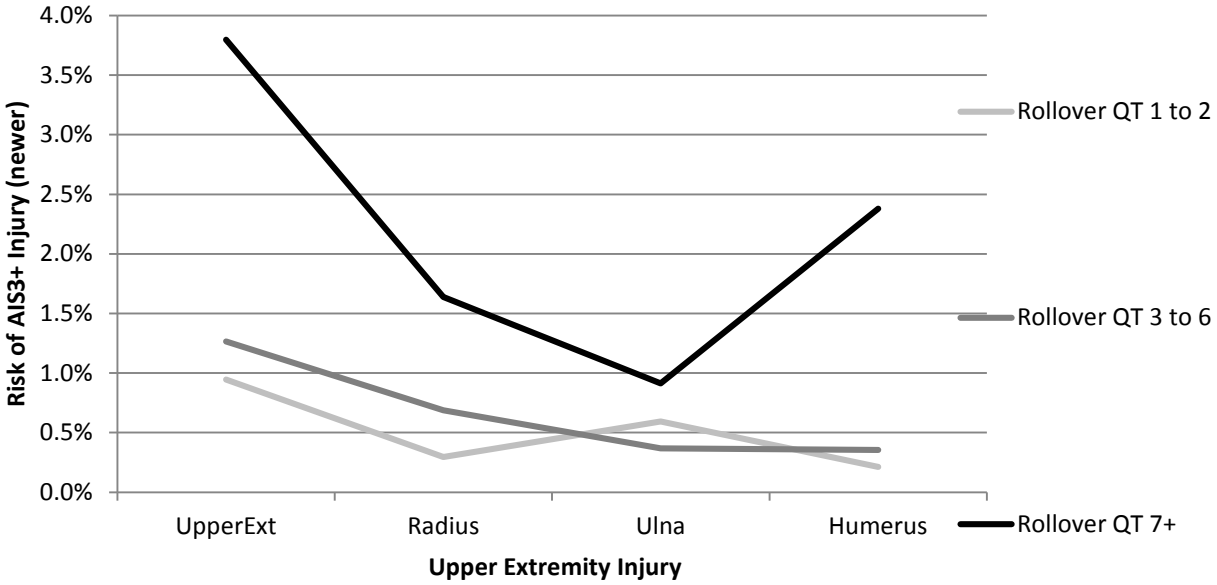


Figure 247. Risk of AIS3+ upper extremity injury by rollover type.

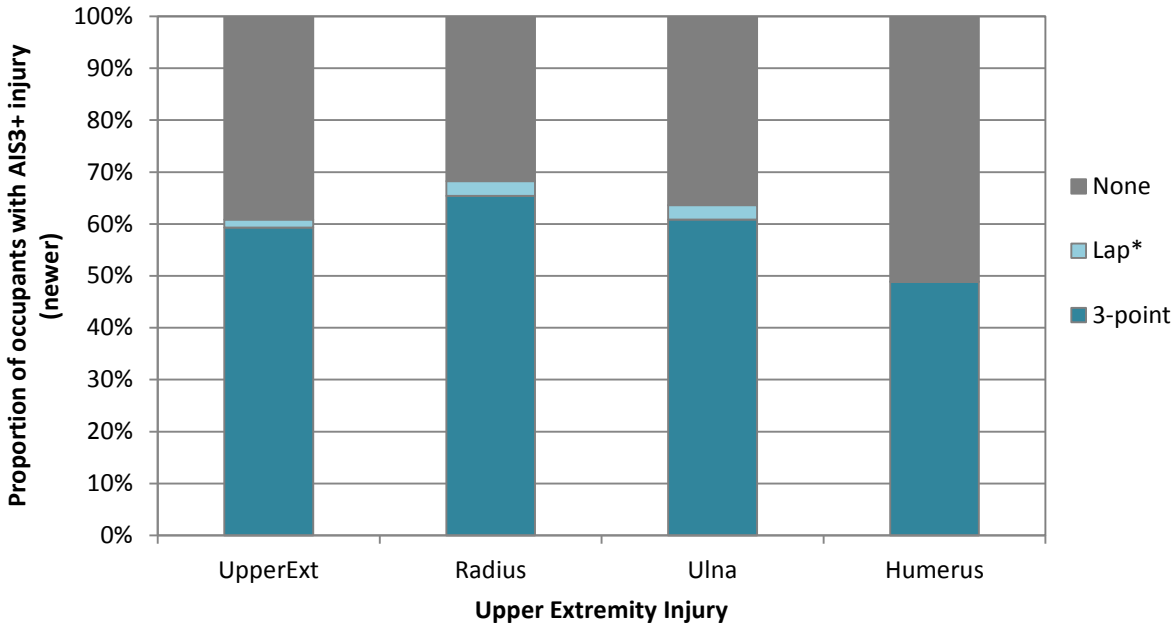


Figure 248. Distribution of AIS3+ injured occupants by belt restraint type for each upper extremity bone injury.

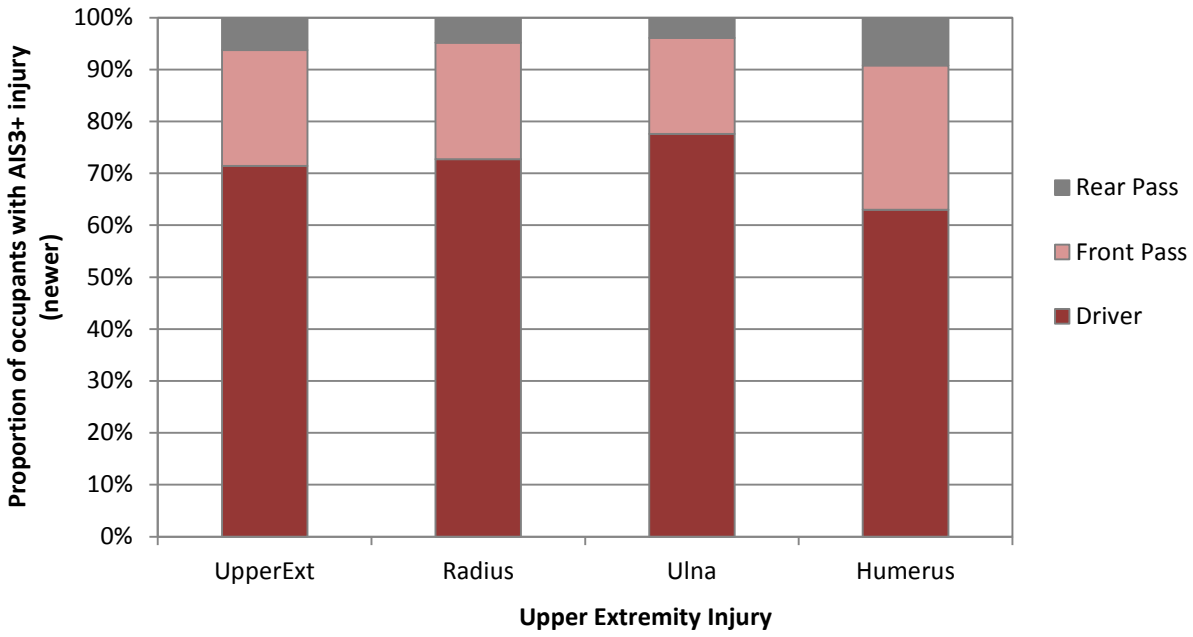


Figure 249. Distribution of AIS3+ injured occupants by seating position for each upper extremity bone and for overall upper extremity injuries.

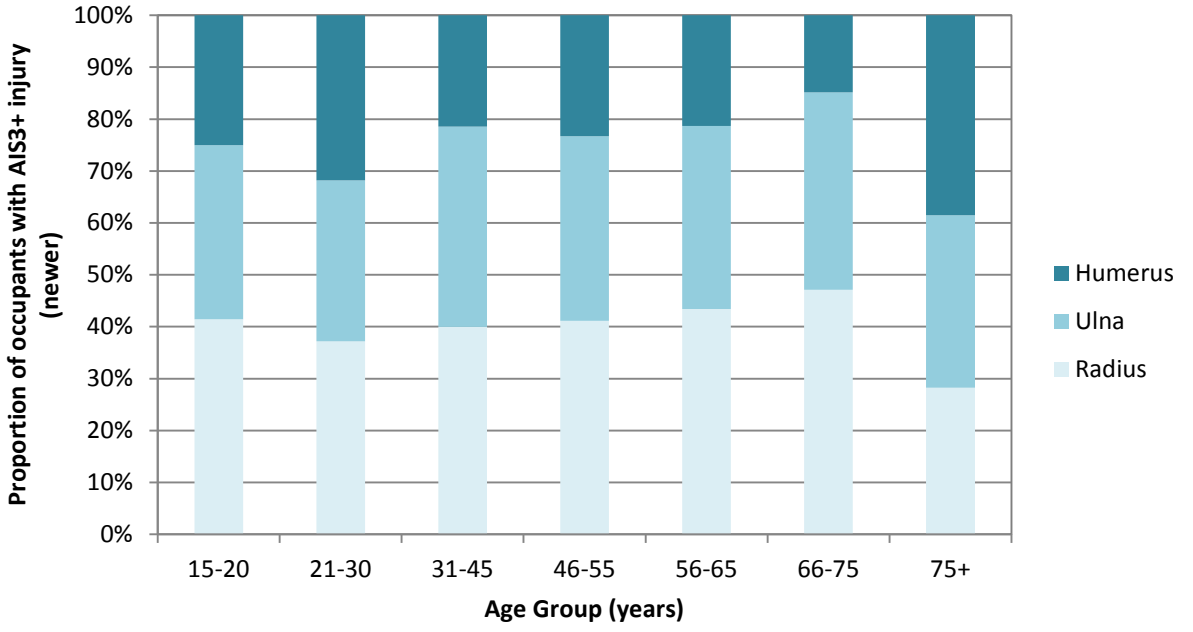


Figure 250. Distribution of AIS3+ injured occupants by age group for each upper extremity bone.

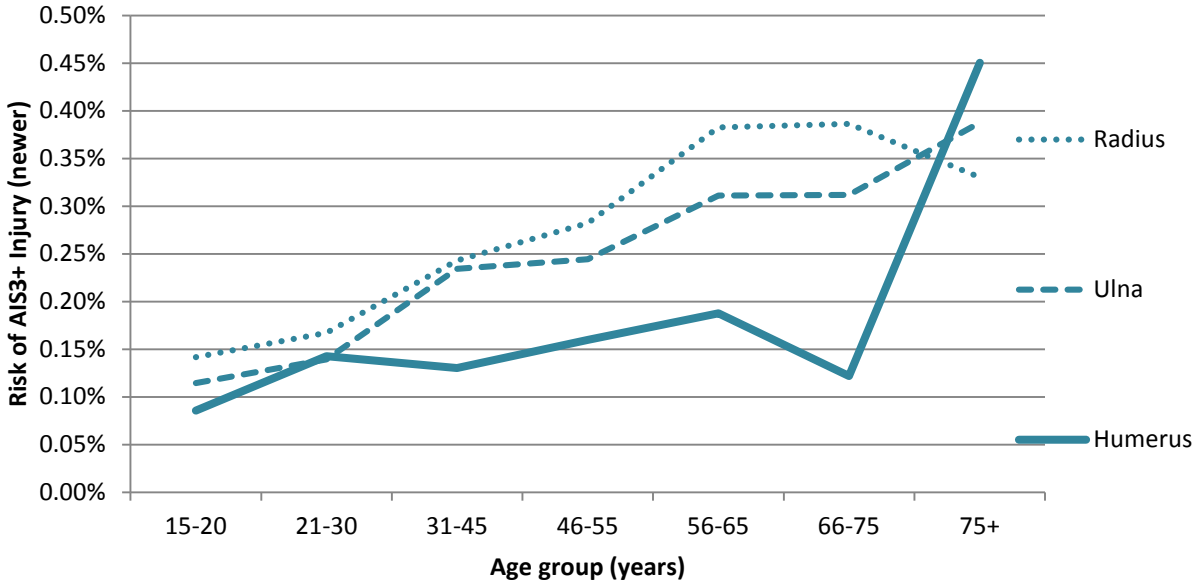


Figure 251. Risk of AIS3+ upper extremity injury by bone for each age group.

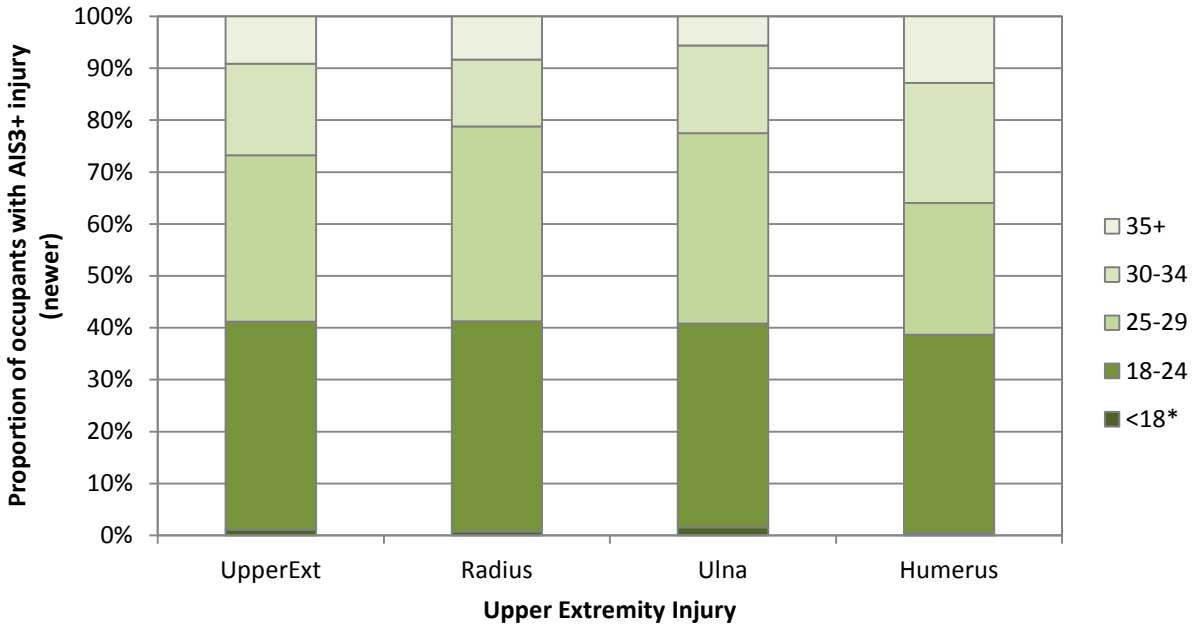


Figure 252. Distribution of AIS3+ injured occupants by BMI group for overall upper extremity and each upper extremity bone injury.

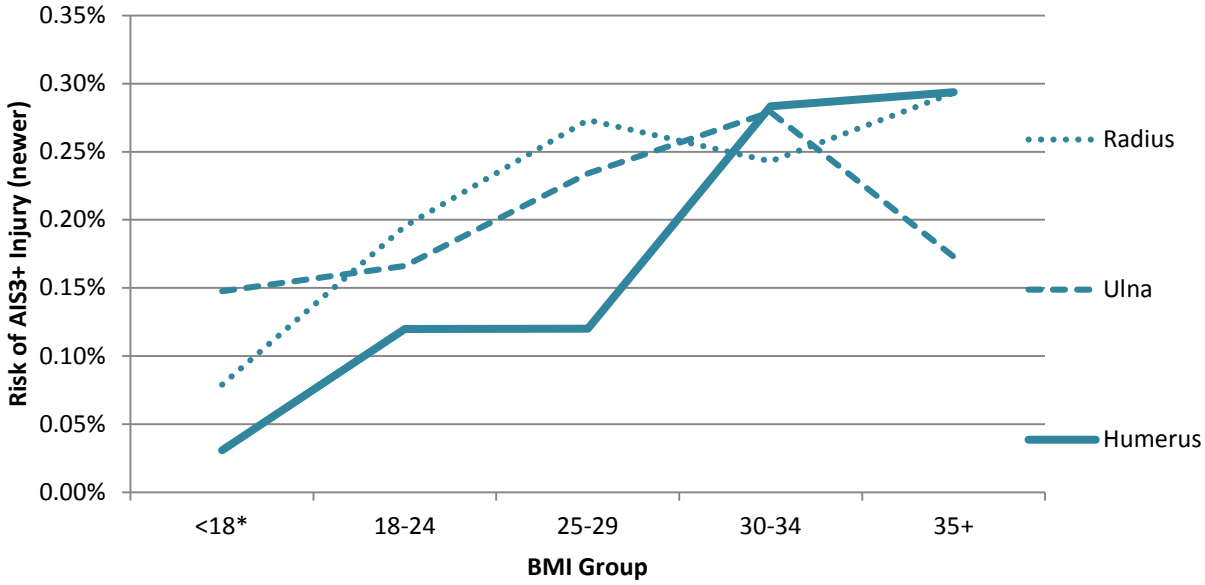


Figure 253. Risk of AIS3+ upper extremity injury by bone for each BMI group.

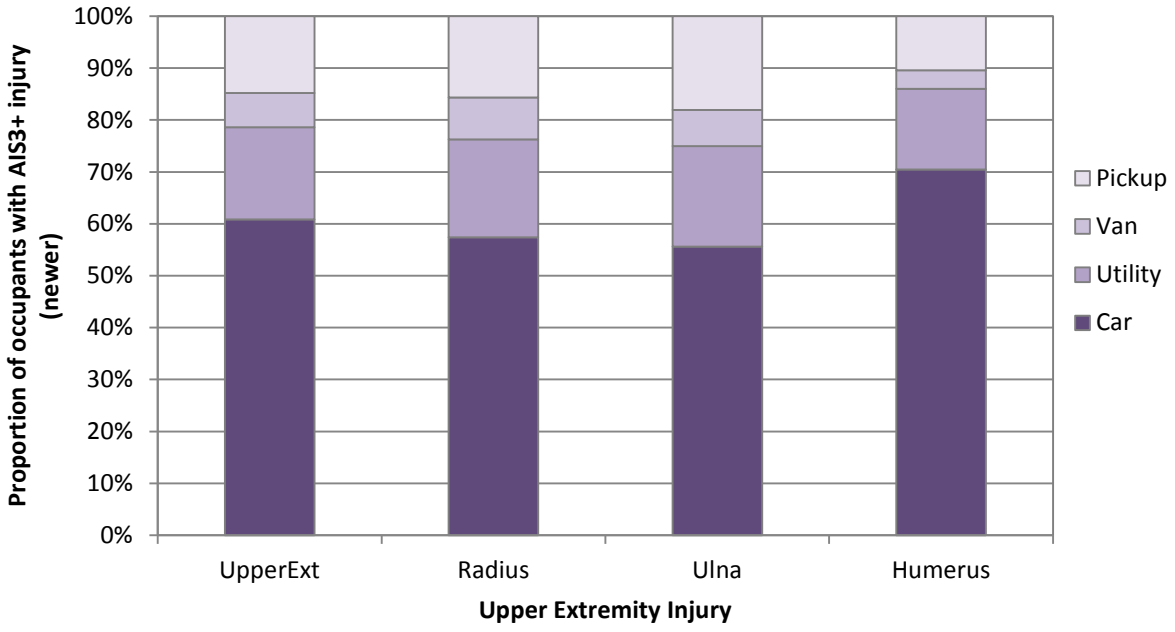


Figure 254. Distribution of AIS3+ injured occupants by vehicle type for each upper extremity bone injury.

Lower Extremity

For the lower extremity, injuries analyzed were those to the pelvis, femur, patella, knee soft tissue, tibia or fibula shaft, and the ankle/heel. Several factors affected lower extremity injury patterns as noted below.

- The pelvis has the greatest proportion of occupants in near-side impacts.
- The femur has the highest risk of AIS3+ injury in all crash types except the pelvis in near-side impacts.
- Women have a greater proportion of AIS3+ injury to the tibia/fibula shaft, knee tissue, and ankle/foot compared to men.
- The femur has the largest difference in injury risk between men (0.6%) and women (0.4%).
- Pickup trucks have the highest risk of AIS3+ injury for the pelvis and femur.
- Risk of AIS3+ injury to the pelvis and femur have dropped substantially since vehicle model years 1999-2004.

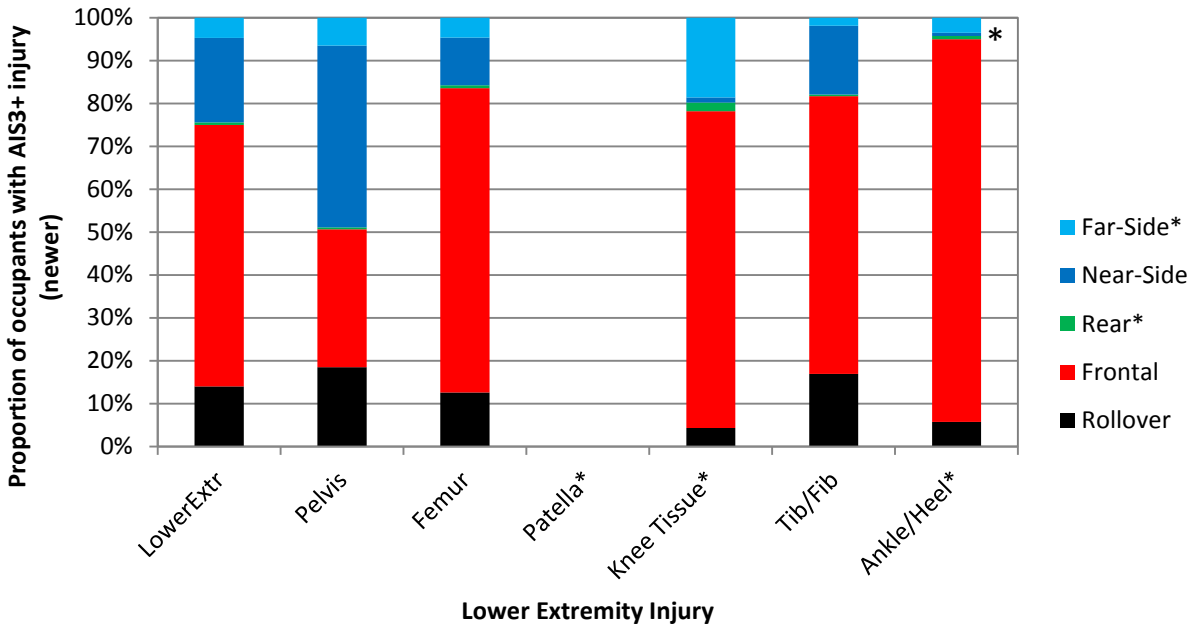


Figure 255. Distribution of AIS3+ injured occupants by crash type for each lower extremity region.

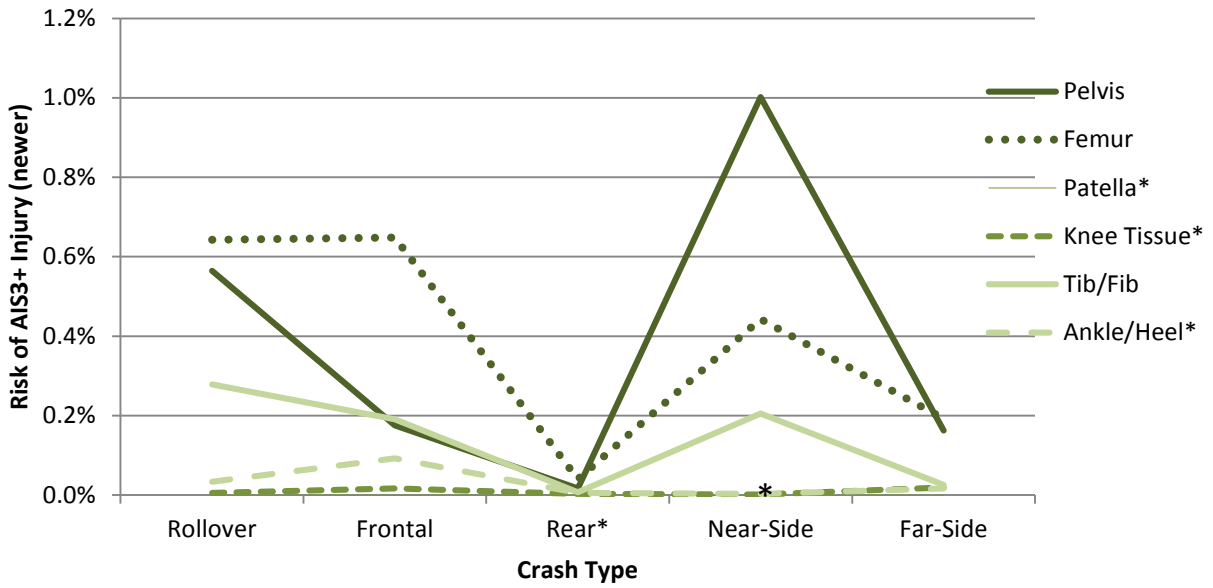


Figure 256. Risk of AIS3+ injured occupants by lower extremity body region for each crash type.

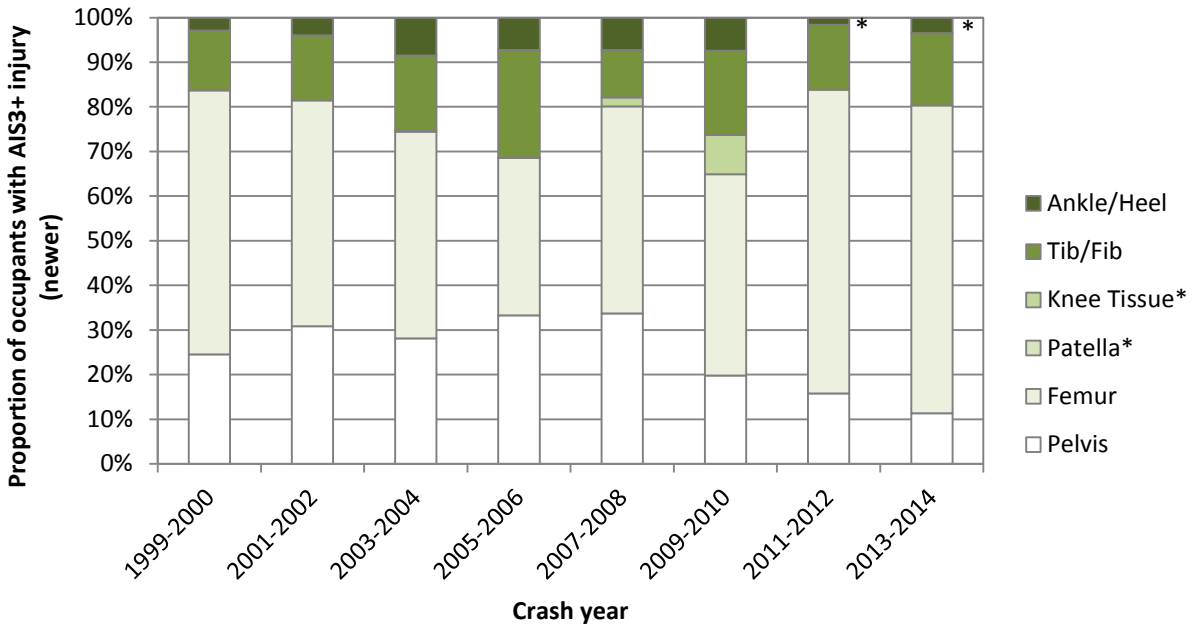


Figure 257. Distribution of AIS3+ injured occupants by crash year for each lower extremity region.

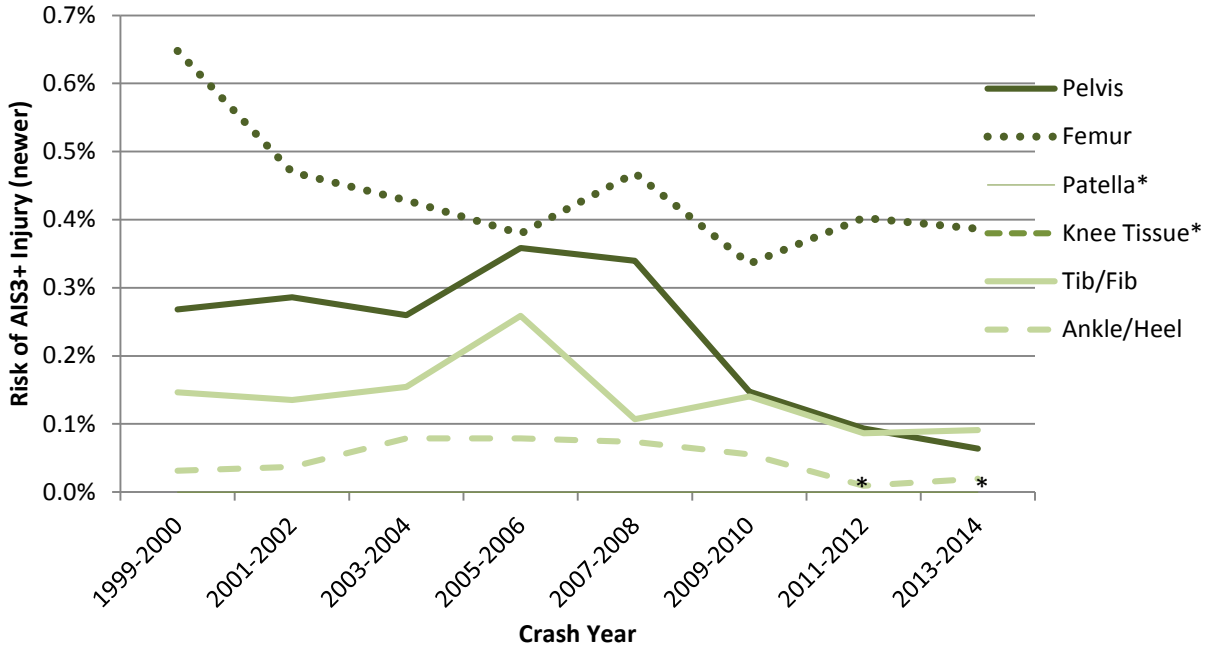


Figure 258. Risk of AIS3+ injured occupants by lower extremity body region for each crash year.

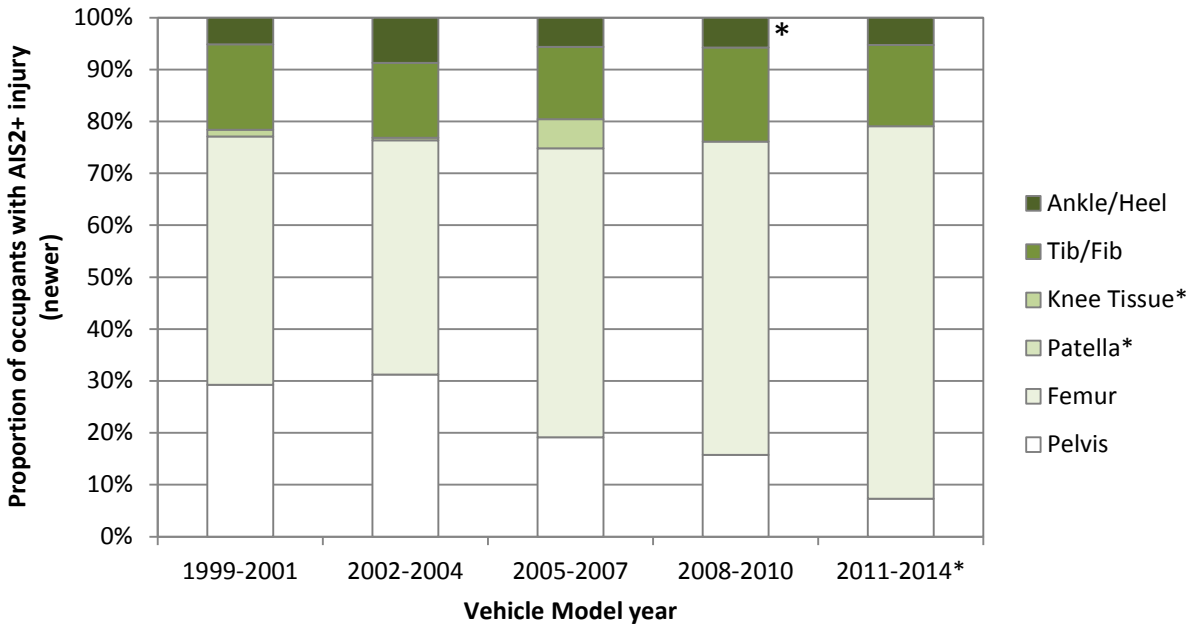


Figure 259. Distribution of AIS3+ injured occupants by vehicle model year for each lower extremity region.

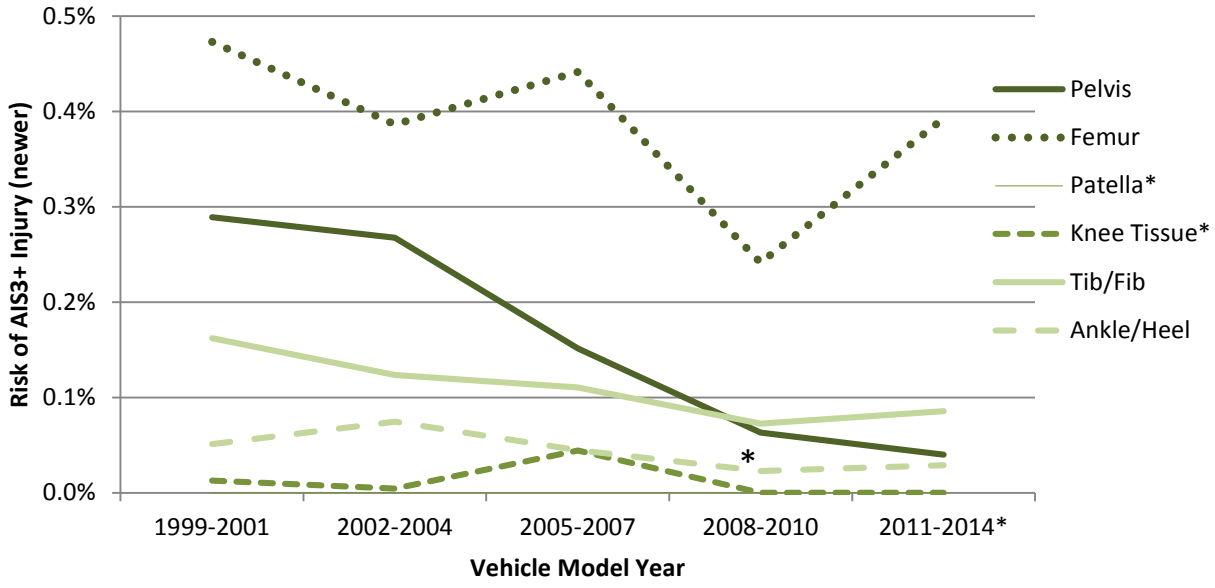


Figure 260. Risk of AIS3+ injured occupants by lower extremity body region for each vehicle model year.

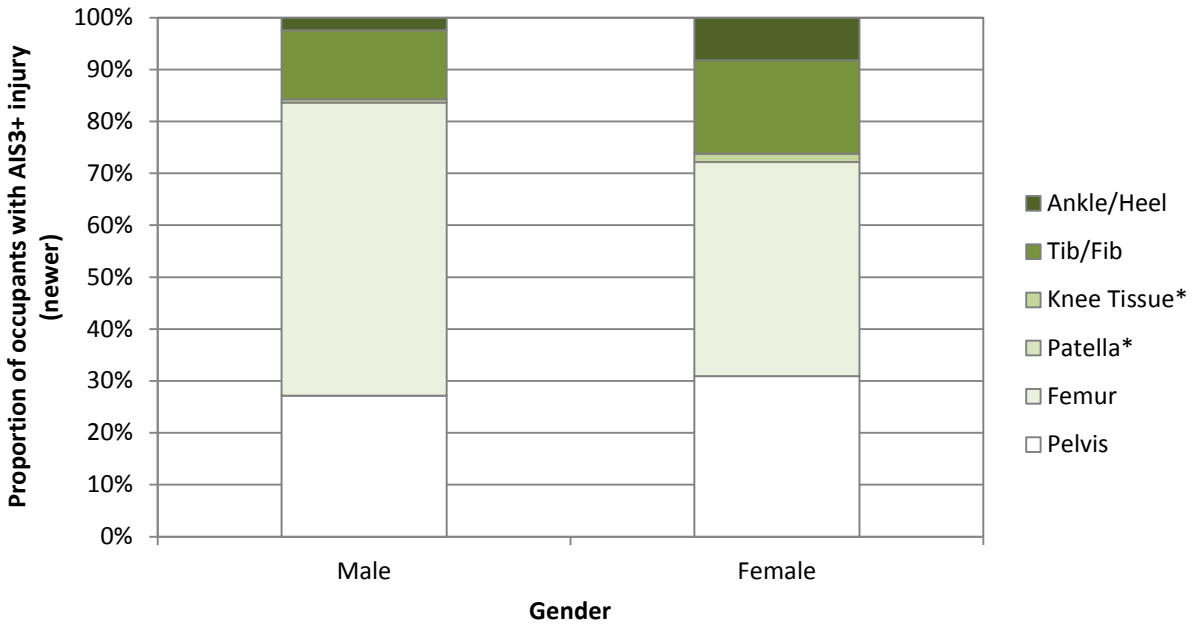


Figure 261. Distribution of occupants with AIS3+ injury by gender for each lower extremity region.

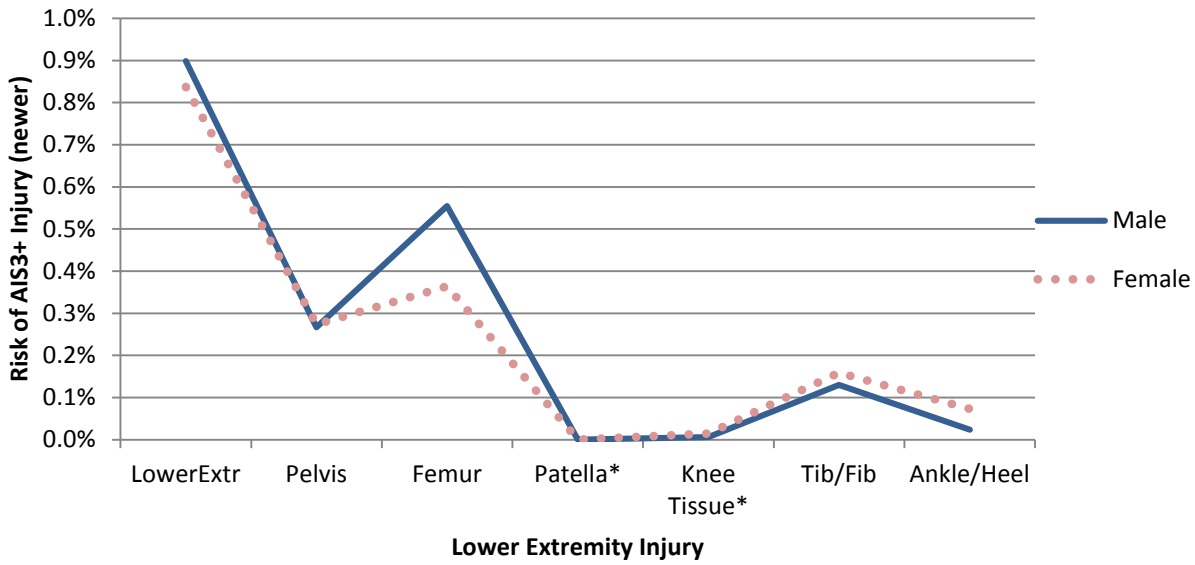


Figure 262. Distribution of AIS3+ injury by gender for each lower extremity region.

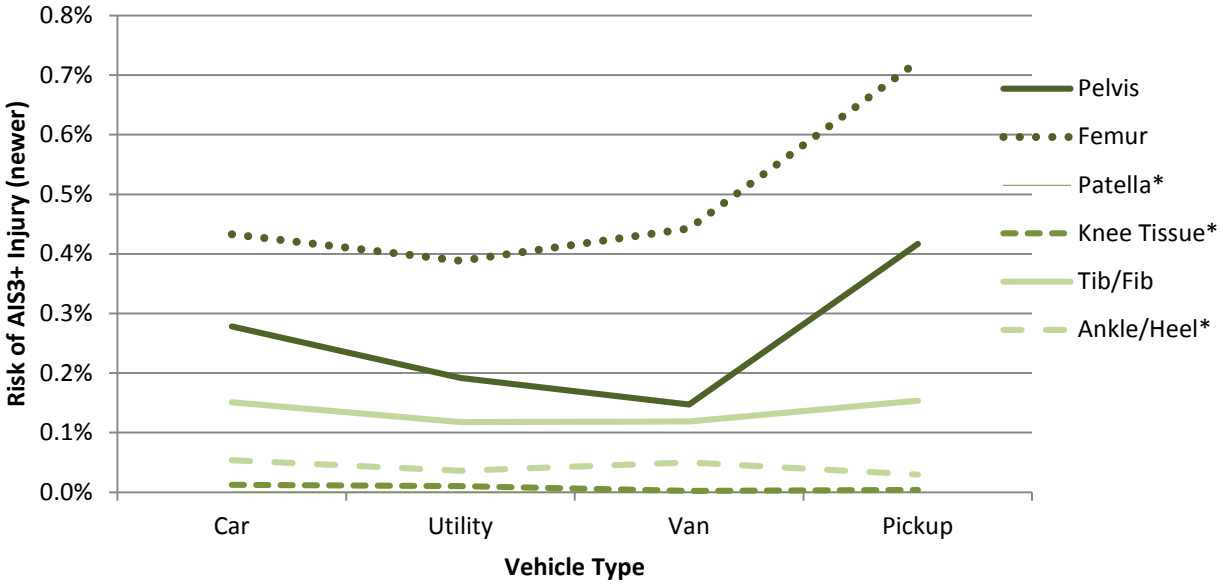


Figure 263. Risk of AIS3+ injury by lower extremity region for each vehicle type.

References

Hallman JJ, Yoganandan N, Pintar FA, Maiman DJ. (2011). Injury differences between small and large overlap frontal crashes. Ann Adv Automot Med. 55:147-57.