The Interactive Effects of Age and Sex on Injury Patterns and Outcomes in Elderly Motor Vehicle Crash Occupants

CIREN CONFERENCE

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Introduction

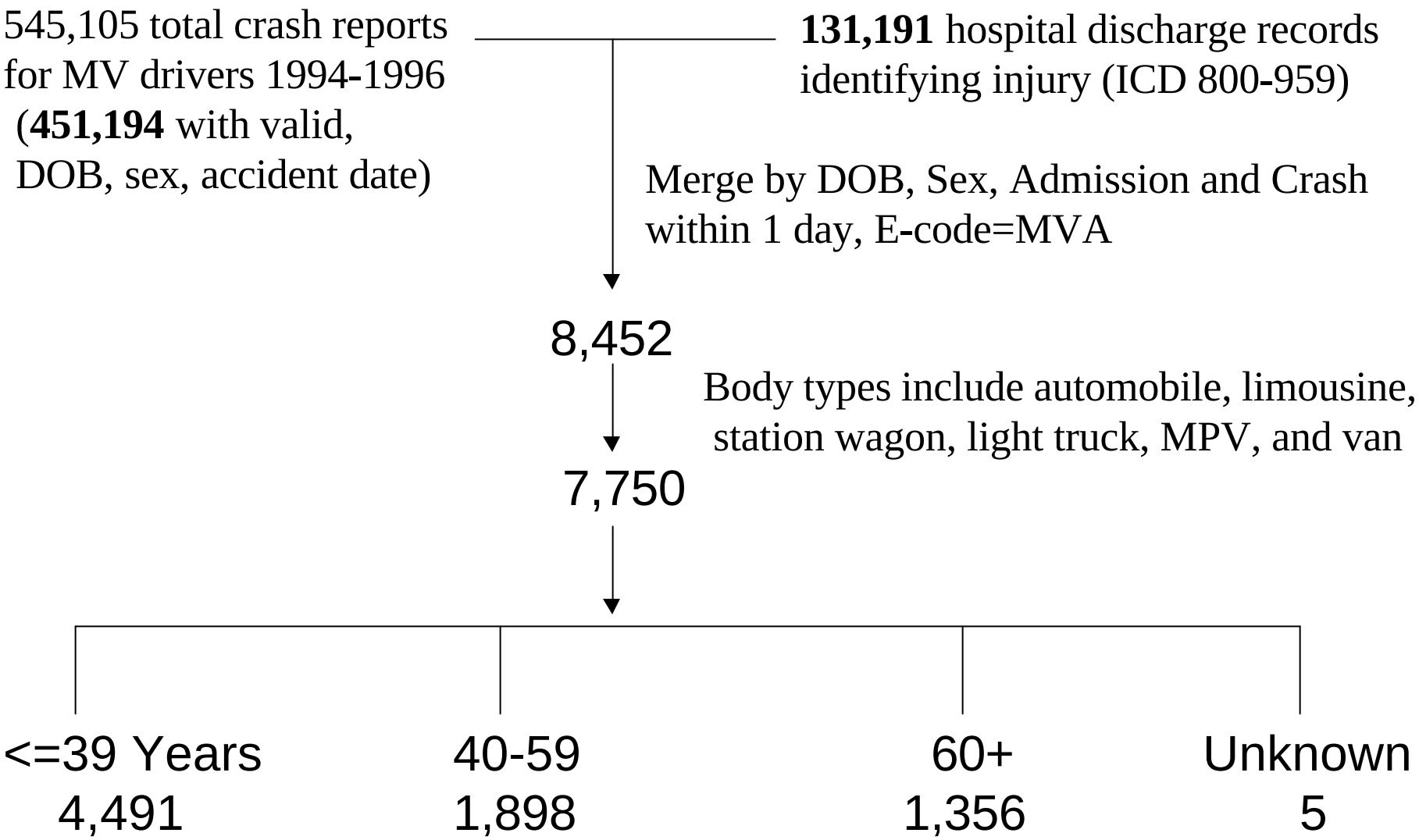
The studies of Fife, Barancik and Chatterjee (1) of a sample of emergency department outcomes in northeast Ohio strongly suggest that although motor vehicle crash injuries are most prominent in young males, that as aging occurred in the population, injury rates leading to hospital admission or fatality rates have tended to rise in the aged population with a somewhat higher increase found in aged females

This study was challenged by the study of evidence in reference to risk of fatality from physical trauma versus sex and age, by Evans (2) who found that there was no substantial sex difference on the death rates of older age crash victims in his study on data from the Fatal Accident Reporting System (FARS) for 1975 through 1983, comprising 52,514 males, and 29,480 females. However, Evans noted the spread of data was such that the delineation of increased risk of death as a function of the sex of the trauma patient at the higher age ranges contained a moderate degree of uncertainty.

However, the issue that needs to be addressed is related more to the nature and pattern of injuries, since these tend to require hospital admission and increase both cost, as well as the allocation of medical resources(3,4). To examine these issues, three studies comprising data available to the members of the Crash Injury Research Engineering Network (CIREN) were compiled. These studies represent data obtained at the National Study Center for Trauma and EMS of the University of Maryland, the University of Michigan Trauma Burn Center, and the New Jersey Medical School-UMDNJ. They represent examinations of somewhat different but mainly urban-suburban populations, but have been coordinated through the CIREN interactive process that involves the sharing of information and collaborative data analysis.

In looking at the broader population, the group from the National Study Center - University of Maryland examined 545,105 total crash reports from motor vehicle drivers for the period 1994-1996, of which 451,194 had validated information concerning age, sex, and accident characteristics. These were compared to 131,191 Maryland hospital discharge records identifying the injury and its ICD-9 code. Of these 8,452 contained information concerning the nature of the crash, and the automotive body type and weight. They were then divided with regard to age into three groups, those #39 years, those between 40-59, and those $60 years, as shown in the accompanying diagram (Figure 1).

Data Linkage

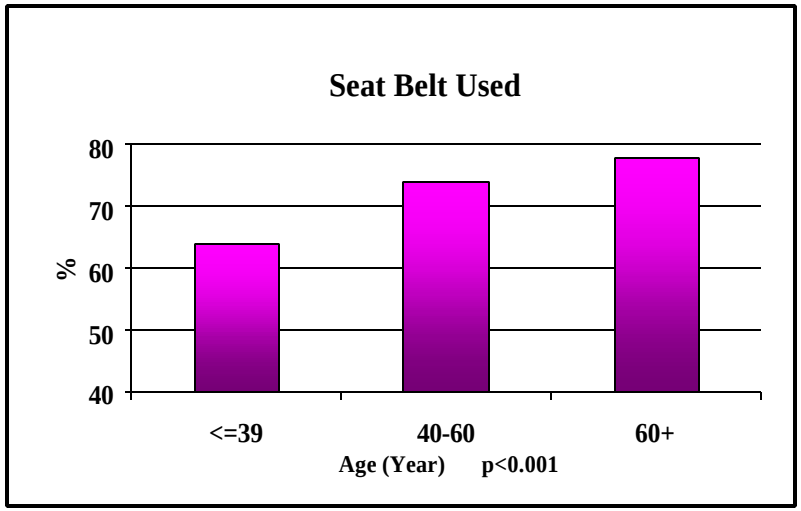


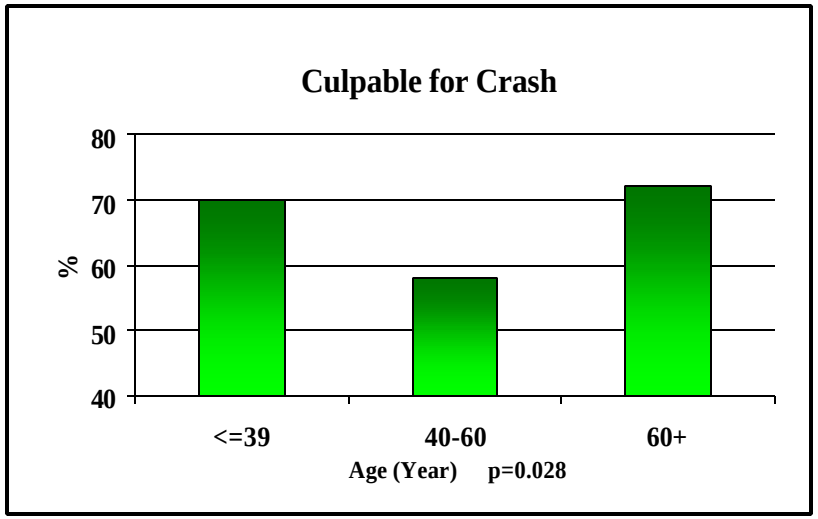
Maryland CODES

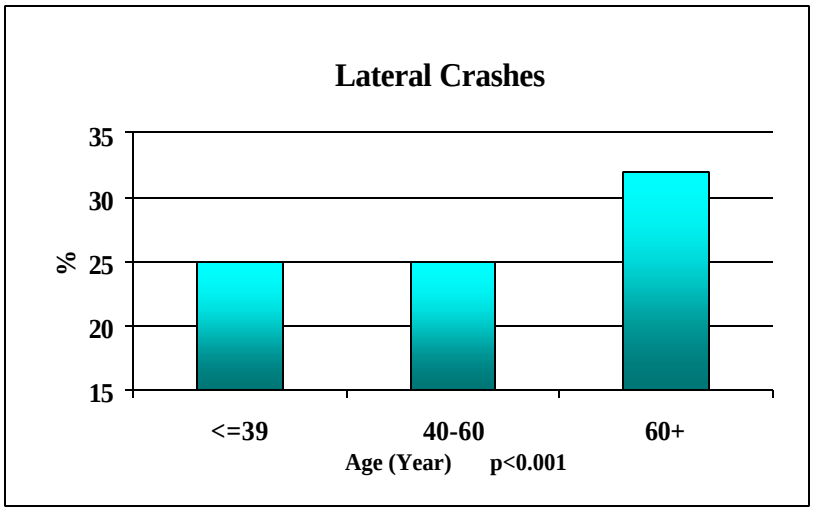
figure 1

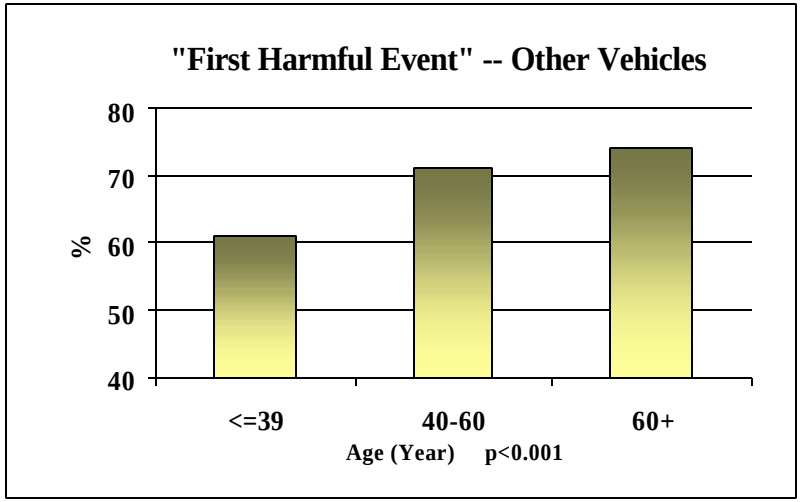
The characteristics of the crash involving an injured driver are shown in (Figure 2), which demonstrates that there was a progressive increase in seat belt utilization, as the age of the patient population increased and a disproportionate increase in the incidence of lateral crashes in the $60 years age population. Of considerable interest was the fact that the culpability for the crash was highest in the $60 age group, next in #39 years, and lowest in the middle age group between 40-59 years. In addition, with regard to the first harmful event, this again increased as a function of age with the highest incidence being in the $60 patients (Figure 2.)

Driver / Crash Characteristics









Figures (3 & 4) demonstrate the distribution of culpability by preexisting disease condition, showing that the involvement of pre-morbid chronic disease process as a causal factor for the motor vehicle crash was most significant in the older age group. Cardiorespiratory diseases and those of the arterial vascular and urinary tract systems, were significant pre-morbid disease process effects in the crash dynamics with regard to culpability for the $60 age group (Figures 3 & 4). In contrast, mental disorders were one chronic disease process which appeared to be relatively uniformly distributed across all age groups.

Distribution of Culpability by Diseases

% Culpable

Diseases	<=39 years		40-59		60+	
Mental Disorders						
Yes	82.4		71.9		83.1	
No	65.6	p<0.001	53.7	p<0.001	69.8	p<0.001
Diabetes						
Yes	73.3		66.2		72.8	
No	70.5	NS	57.4	p<0.05	71.4	NS
Blood						
Yes	73.8		63.9		78.4	
No	70.1	NS	57.4	NS	70.2	p<0.02

Figure 3

Distribution of Culpability by Diseases

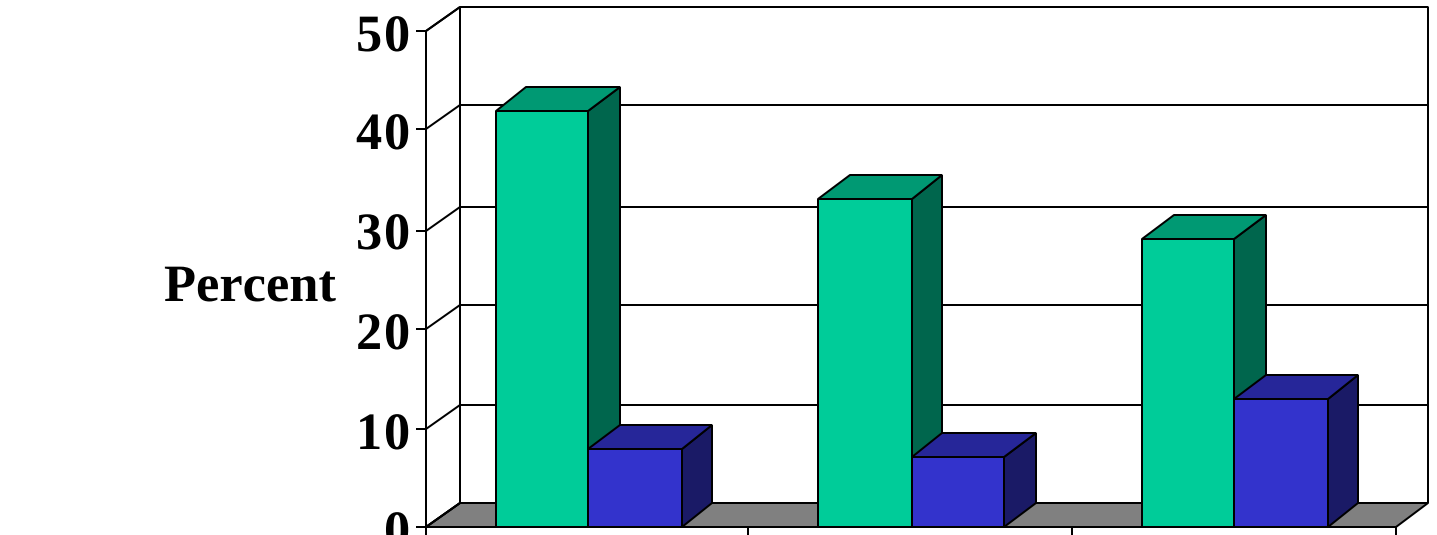
% Culpable

Diseases	<=39 years		40-59		60+	
Respiratory						
Yes	75.3		63.4		75.2	
No	69.9	p<0.02	57.0	p<0.05	70.2	p<0.08
Conduction Dysfunction						
Yes	78.3		61.2		76.4	
No	70.3	p<0.06	57.9	NS	70.4	p<0.06
Arterial						
Yes	88.9		60.0		82.9	
No	70.4	NS	58.1	NS	70.9	p<0.03
Genitourinary System						
Yes	72.4		58.5		79.6	
No	70.4	NS	58.0	NS	70.4	p<0.02

Figure 4

With regard to injury severity, it can be seen, that while the incidence and severity of brain injury (Figure 5) decreases as a function of age, as did the incidence and severity of abdominal injury (Figures 6), and of lower extremity injuries (Figure 7) but thoracic injuries increased proportionate to age being most striking for thoracic injuries in the $60 group (Figure 8). These data also demonstrate that the average hospital cost increased as a function of age, even though the mean ISS remained unchanged (Figure 9). Moreover, the in-hospital death rate increased as a direct function of age, 3.3% in those #39 years, 4.5%in those between 40-59 , and 7.7% in those $60 years, with a corresponding increased requirement for post-hospital rehabilitation as a function of age.

Incidence and Severity of Brain Injury By Age



* p<0.001, ** p<0.01

Figure 5

Incidence and Severity of Abdominal Injury By Age

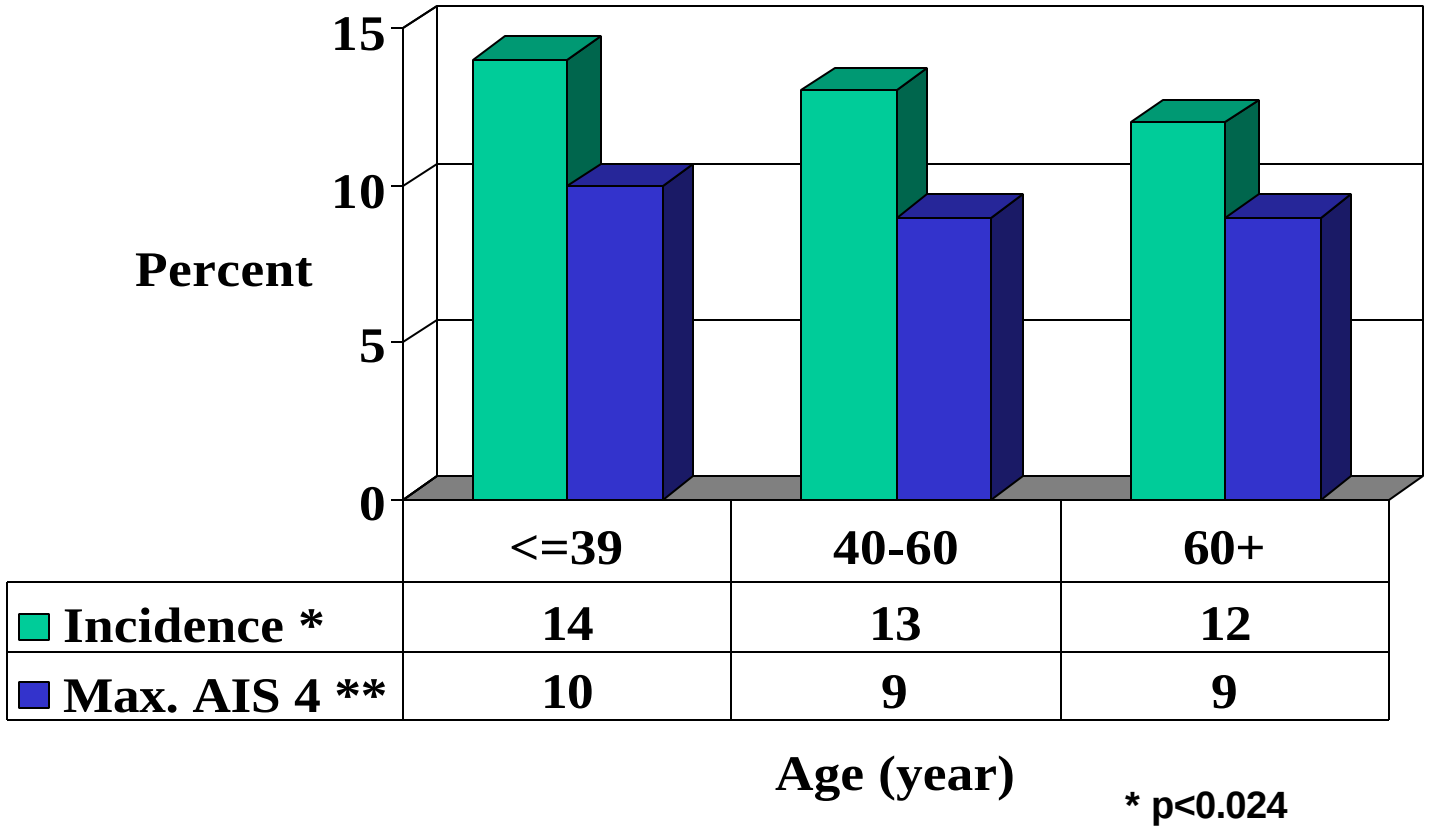


Figure 6

Incidence and Severity of Lower Extremity Injury By Age

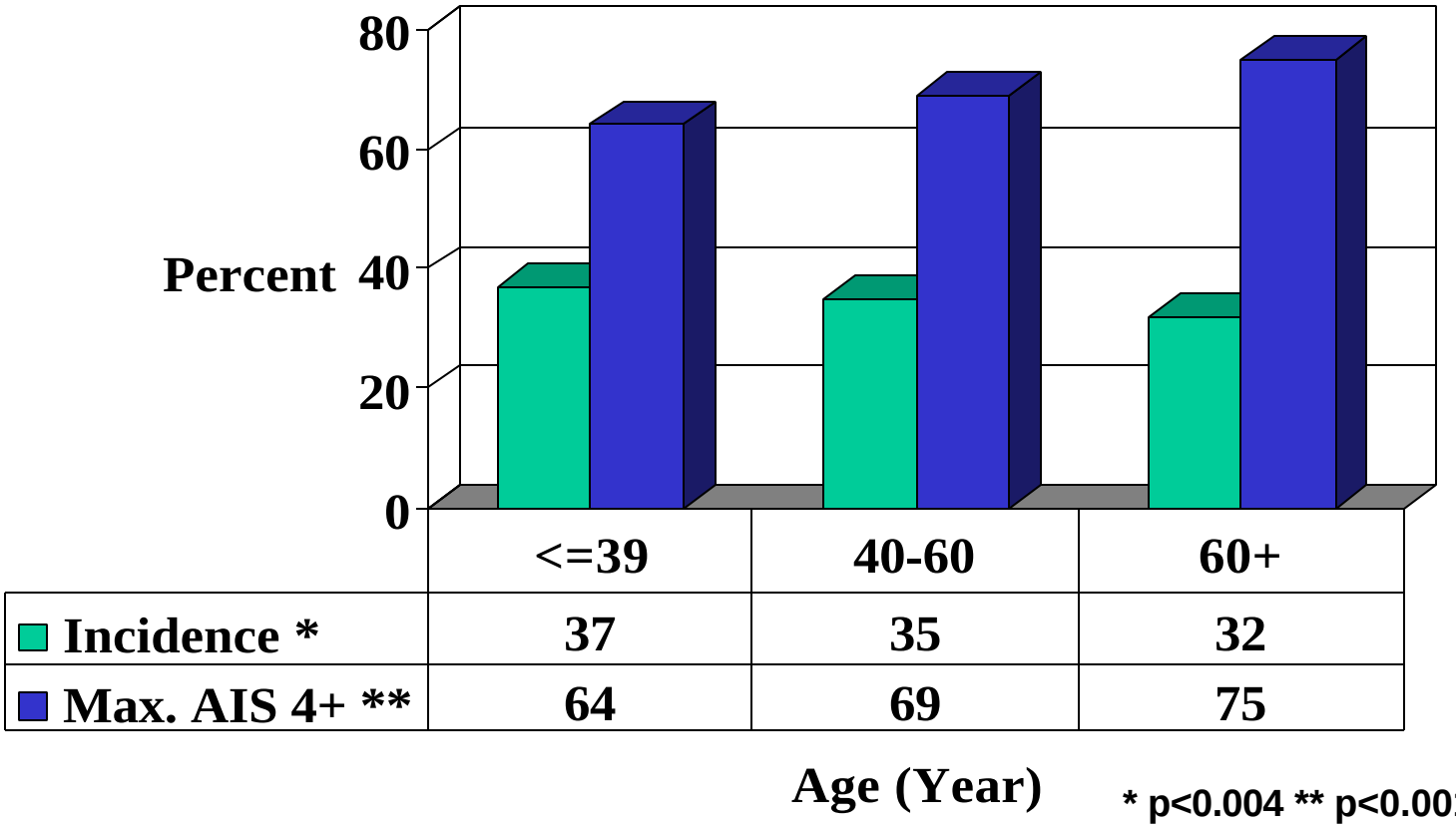
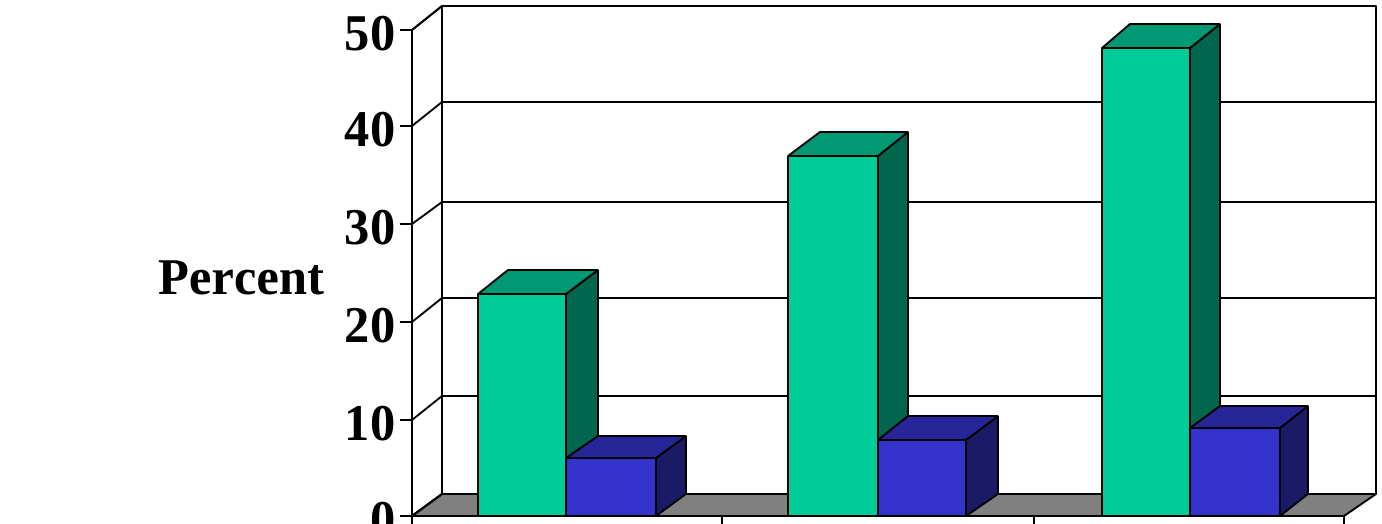


Figure 7

Incidence and Severity of Thoracic Injury By Age



	<=39	40-60	60+
Incidence *	23	37	48
Max. AIS 4+ **	6	8	9

Age (Year)

* p<0.001, ** p<0.007

Figure 8

ISS, LOS And Hospital Cost by Age

Medians and 25th-75th Percentile Ranges

	Age Group			
	<=39	40-59	60+	p
ISS	9 (4-14)	9 (4-14)	9 (4-16)	0.06
LOS	2 (1-4)	2 (1-5)	3 (1-7)	<0.001
Hospital Cost	$3,231 (2,063-7,688)	$3,582 (2,216-7,726)	$4,458 (2,456-10,892)	<0.001

Figure 9

Following up on this type of broad based demographic data the CIREN-University of Michigan group analyzed CIREN and National Automotive Sampling System (NASS formerly National Accident Sampling System) data. This data was confined to frontal and side crashes with the elimination of rollover crashes. Three hundred cases cases were examined with regard to the patterns of injury. In their study, they observed a 40% in-hospital mortality rate in the elderly $60 age group compared to only a 19% mortality in those admitted in-patients <60 years of age. Of these, 73% of the elderly cases had fractures of the skeleton or extremities. Out of these, 58% of the elderly patients had thoracic injuries, while only 30% had head injuries. Moreover, of the elderly fatalities, chest injuries were present in 86%, whereas head injuries were only observed in 38%. It was felt that chest injury was a major contributory cause of death in 71% of these older patient fatalities. All of the patients with thoracic injuries had multiple rib fractures, although there was a high incidence of cardiac, pulmonary, or major vascular injuries and noted as well. However, 8 of their 21 fatal cases were noted to have only rib fractures, with no other chest region visceral injury. Older age patients ($60 years) injured in frontal motor vehilce crashes showed a marked increase in multiple rib fractures compared to younger patients (20-39 years) (Figure 10). Moreover, this study suggested that the side impact crash produced an ever greater over representation of thoracic injuries in the over 60 year age group (Figure 11). This was in contrast to the reduction in femoral fractures comparing the $ 60 year age group to the #40 year old patients (Figure 12).

Figure 10 - Age Distribution of Rib Fractures in Frontal Crash Occupants aged 20-79, NASS 1993-1996

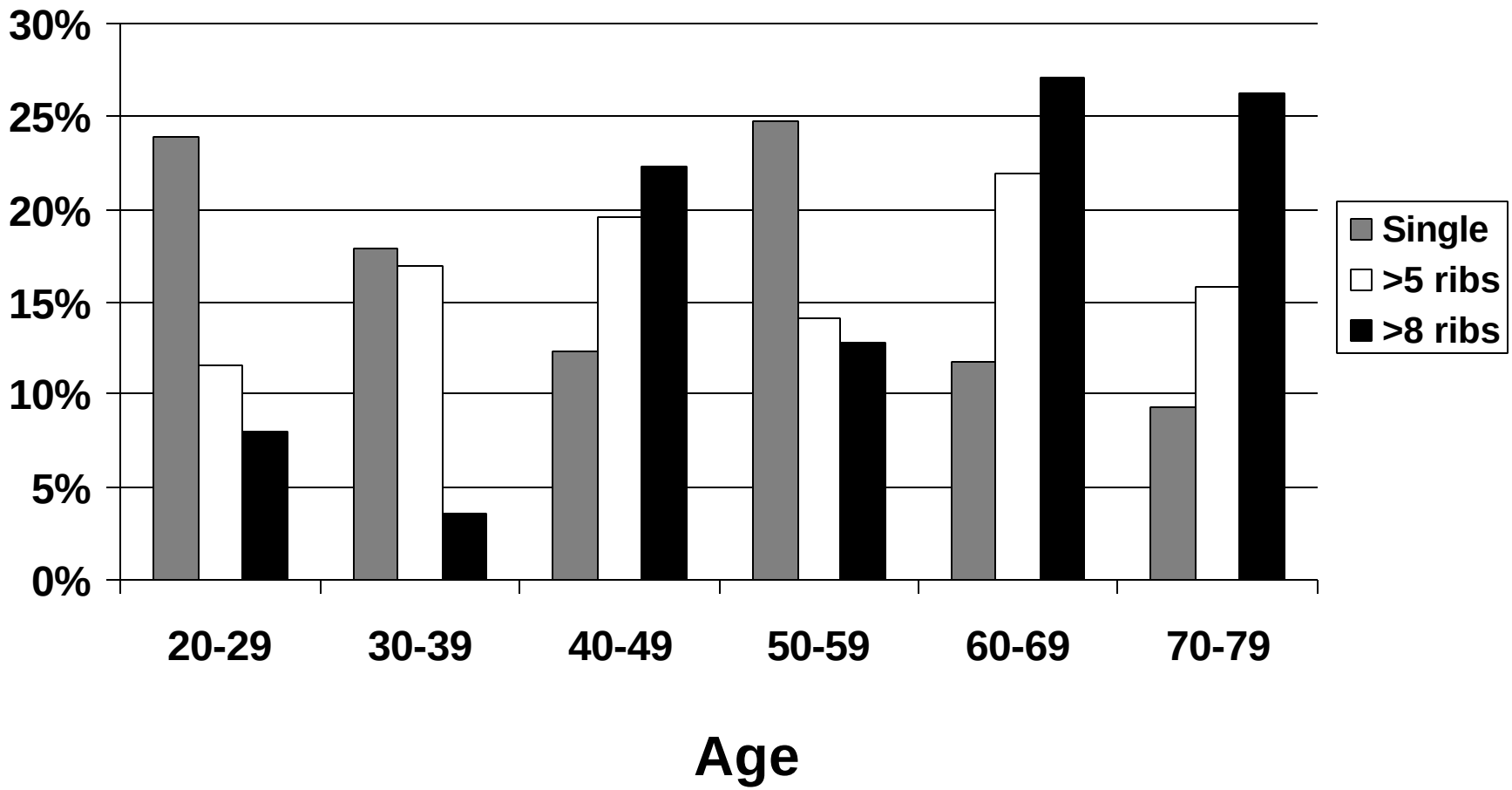


Figure 11 - Age Distribution of Rib Fractures in Side Crash Occupants aged 20-79, NASS 1993-1996

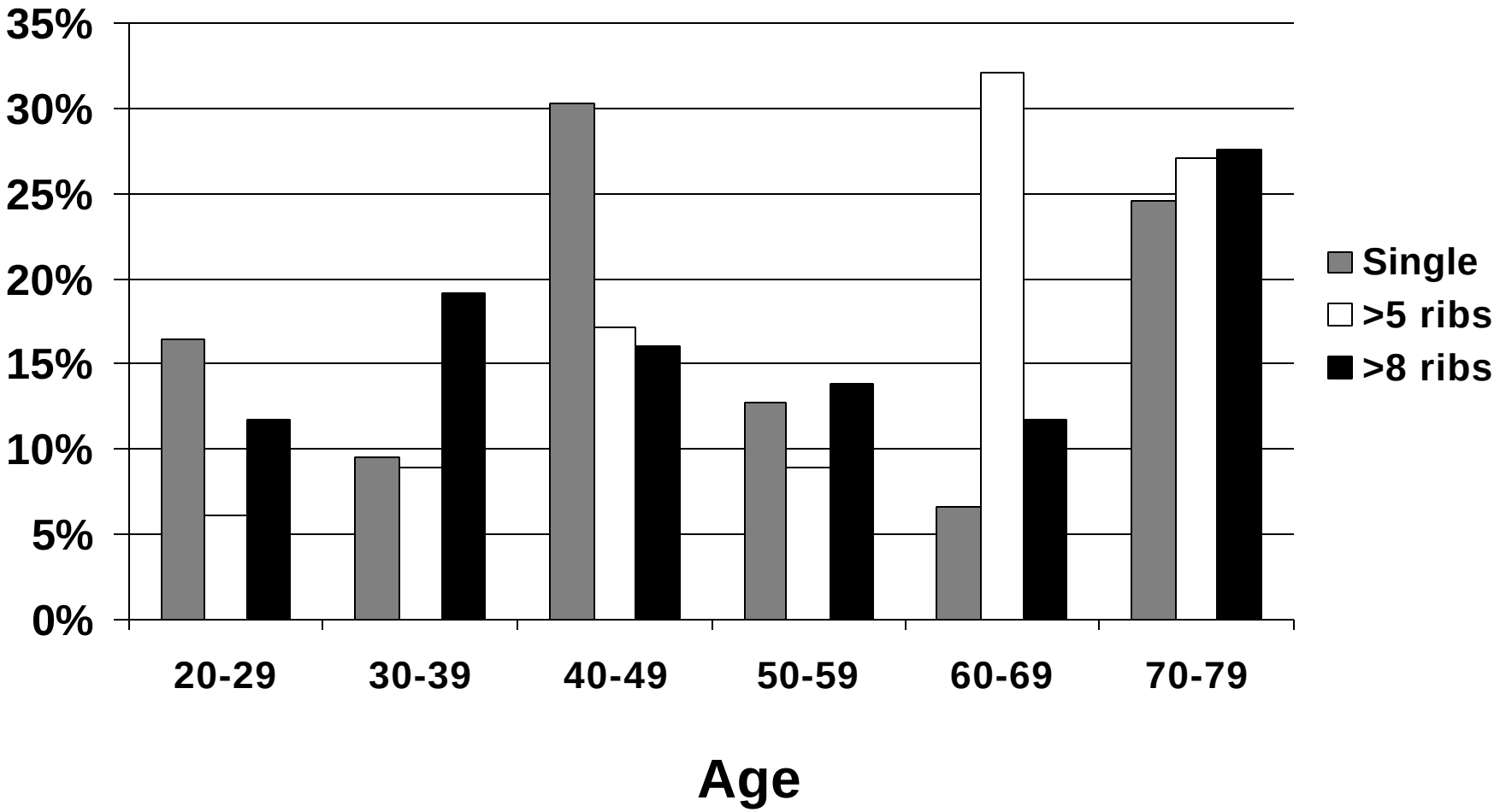
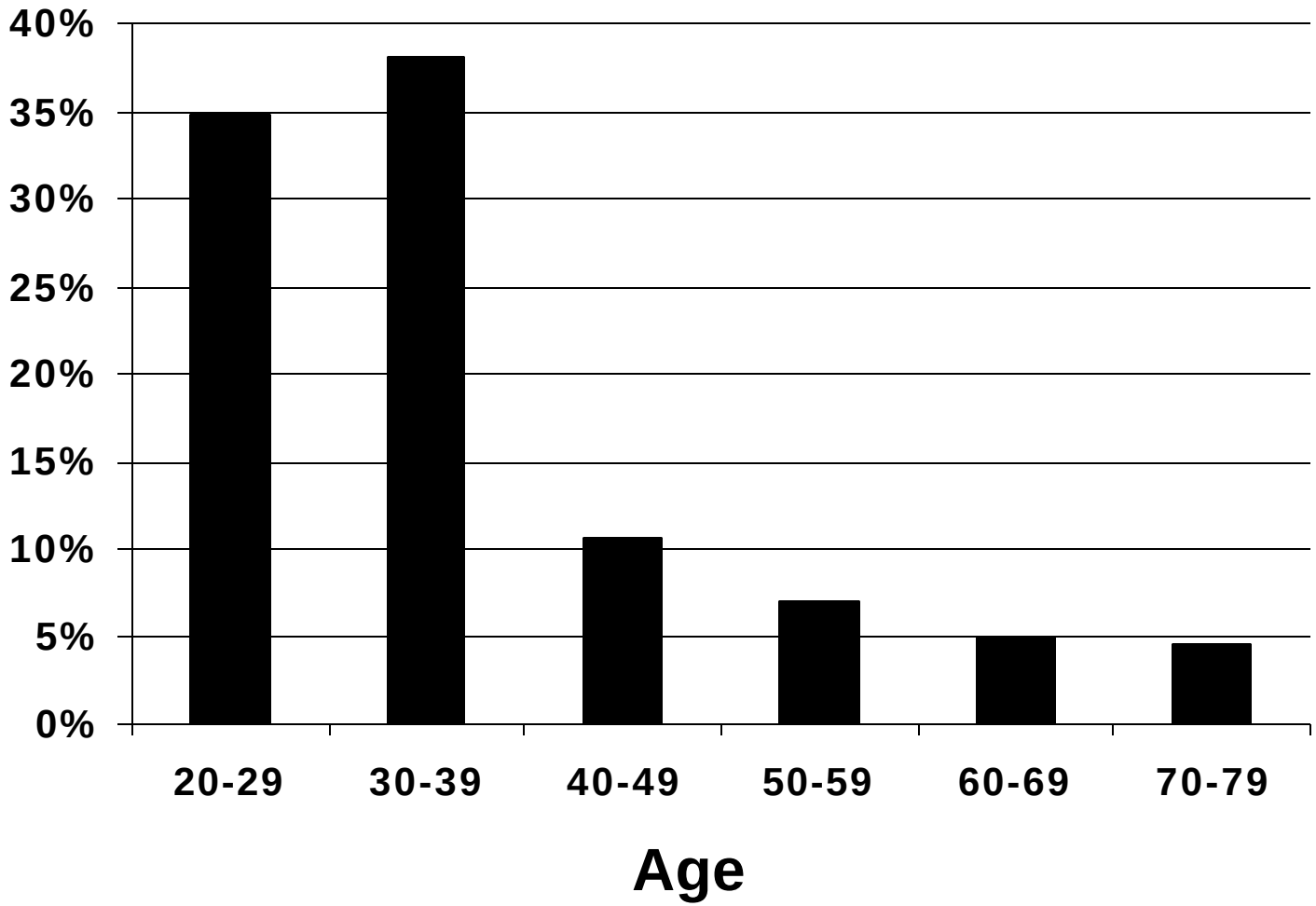


Figure 12 - Age Distribution of Femur Fractures in Frontal Crash Occupants aged 20-79, NASS 1993-1996



In a companion study carried out by the CIREN-New Jersey Medical School group on data from 412 Motor Vehicle Crash (MVC) patients collected from four CIREN centers, the influence of various crash dynamics in frontal crashes with regard to age and sex, was examined in males versus females. The patterns of injury and shock in aged men and women were compared to frontal crash patterns in males between 15 and 39 years of age as well as in young (15-39 years) and middle (40-59 years) aged females. As seen in Figure 13, compared to the young male reference population (#39 years) the older age females (60-99 years) had a significantly **decreased** survival in spite of the fact that their crashes occurred at a significantly lower DELTA V. Also it can be seen that the height and weight of the elderly females was significantly lower than those of the young males.

CIREN - Motor Vehicle Crash Study
Frontal Crash Age Group Male 15-39 vs. Female 60-99

Patient Dynamics	Fr M15-39	Fr F60-99
N	92	35
Avg Age	26.05	69
ISS	20.35	22.29
GCS	12.38	13.23
Survival % *	86	69
LOS ~	14.5	21.9
ICU Days	5.88	7.7
Height (cm) ***	179.3	161.1
Weight (kg) **	84.1	71.4
Crash Dynamics		
Delta V1 (kph) ***	52.16	36.88
Mass V1 avg.	1316.2	1367.8
Mass V2 avg.	1629.2	1385.9

Wilcoxon (ISS&GCS), Fisher's Exact (survival), t-test (LOS, ICU days, HT, WT, Delta V1)
p-value: '+ ' < 0.05 '++' < 0.01 '+++' < 0.001

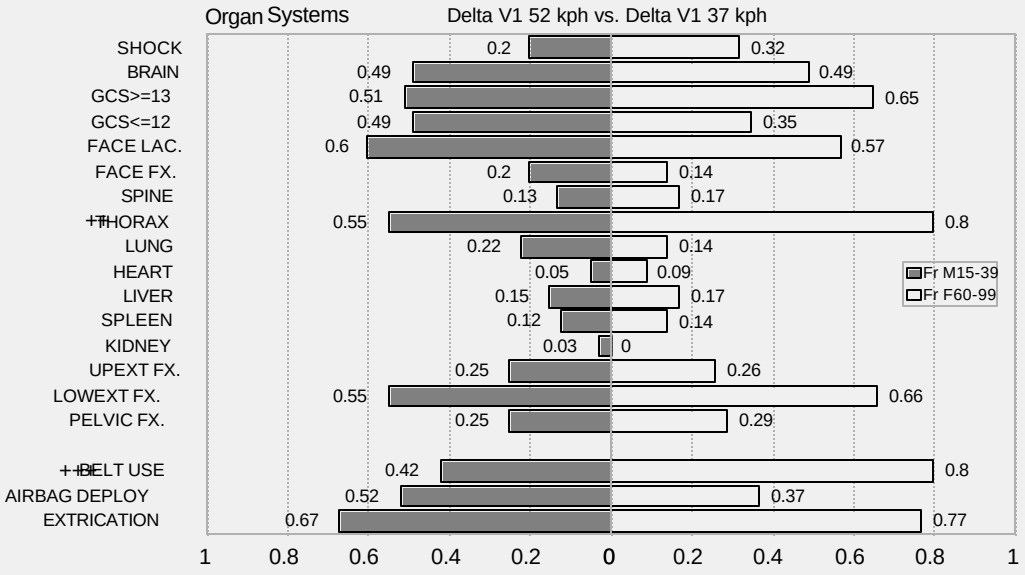
Figure 13

What is also clear is that the while incidence of severe brain injury (defined in this study as Glasgow Coma Scale #12) was reduced in the aged females. There was a significant increase in the aged female incidence of thoracic injuries as noted earlier for the total aged group of patients (Figure 14). This occurred in spite of the fact that these elderly female patients tended to have a significantly higher seat belt use, though with a slightly decreased incidence of airbag deployment (Figure 14). When comparing young females (15-39) versus aged females (60-99 years),as shown in Figure 15, one can see that the older females required a significantly longer length of stay, more ICU days, and had a reduced survival rate. The data also showed that the poorer outcomes occurred in spite of a significantly lower MVC DELTA V, albeit the fact that the measured ISS was not significantly different between the two groups of women.

Examining the pattern of injury between these groups, it can also be seen that there was a significant increase in thoracic injuries in the older aged females (60-99 years) when compared to the young (15-39 years). However, no difference in the incidence of lower extremity fractures was seen between the two age groups of women(Figure 16).

CIREN - Motor Vehicle Crash Study

Frontal Crash Age Group Male15-39 vs. Female 60-99



N: Male =92 Female=35
p-value: '+' < 0.05 '++' < 0.01 '+++' < 0.001

Figure 14

CIREN - Motor Vehicle Crash Study

Frontal Crash Age Group Female 15-39 vs. Female 60-99

Patient Dynamics	Fr F15-39	Fr F60-99
N	72	35
Avg Age	26.68	69
ISS	21.01	22.29
GCS	12.94	13.23
Survival %	82	69
LOS **	10.6	21.9
ICU Days *	2.73	7.7
Height (cm)	163.4	161.1
Weight (kg)	69.1	71.4
Crash Dynamics		
Delta V1 (kph) **	47.93	36.88
Mass V1 avg.	1266.9	1367.8
Mass V2 avg.	1437.3	1385.9

Wilcoxon (ISS&GCS), Fisher's Exact (survival), t-test (LOS, ICU days, HT, WT, Delta V1)
p-value: '+ ' < 0.05 '++' < 0.01 '+++' < 0.001

Figure 15

Examining the pattern of injury between these groups, it can also be seen that there was a significant increase in thoracic injuries in the older aged females (60-99 years) when compared to the young (15-39 years). However, no difference in the incidence of lower extremity fractures was seen between the two age groups of women(Figure 16).

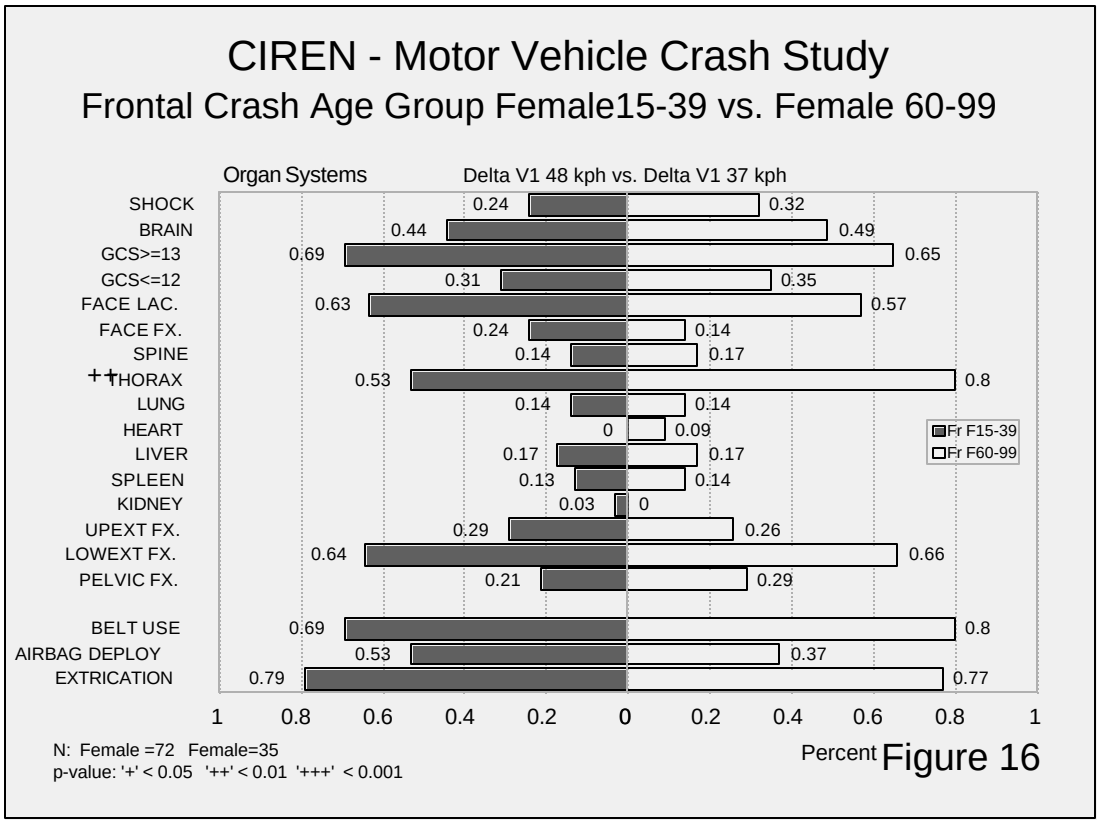


Figure 16

The most interesting comparison appeared when comparing pre-menopausal and early post-menopausal females between 40-59 years with late post-menopausal females between 60 and 99 years (Figure 17). While there are little differences in height and weight between these two groups, the older age late post-menopausal females manifested a lower survival rate and longer length of stay in the hospital in spite of a lower MVC DELTA V.

CIREN - Motor Vehicle Crash Study
Frontal Crash Age Group Female 40-59 vs. Female 60-99

Patient Dynamics	Fr F40-59	Fr F60-99
N	37	35
Avg Age	47.22	69
ISS	19.92	22.29
GCS	13.35	13.23
Survival %	84	69
LOS	15.3	21.9
ICU Days	6.03	7.7
Height (cm)	162.9	161.1
Weight (kg)	72.6	71.4
Crash Dynamics		
Delta V1 (kph)	43.05	36.88
Mass V1 avg.	1415.2	1367.8
Mass V2 avg.	1585.3	1385.9

Wilcoxon (ISS&GCS), Fisher's Exact (survival), t-test (LOS, ICU days, HT, WT, Delta V1)
p-value: '+ ' < 0.05 '++' < 0.01 '+++' < 0.001

Figure 17

In examining the patterns of injury in Figure 18, the post-menopausal women also had a much greater incidence of shock and thoracic injury, and a greater incidence of pelvic fractures. These findings occurred despite the fact that the older women had a higher incidence of seat belt use than the middle-aged females, although with a significantly lower airbag deployment rates. This probably reflects the fact that they tended to drive older pre-airbag era equipped cars (Figure 18). Furthermore, in comparing these pre-menopausal and early post-menopausal females (39-59 years) with the late post-menopausal females, (60-99 years), it can be seen that there were significant differences in thoracic injuries, pelvic fractures, and the resultant shock with a tendency for there to be a greater number of visceral injuries per patient in the older age group (Figure 18).

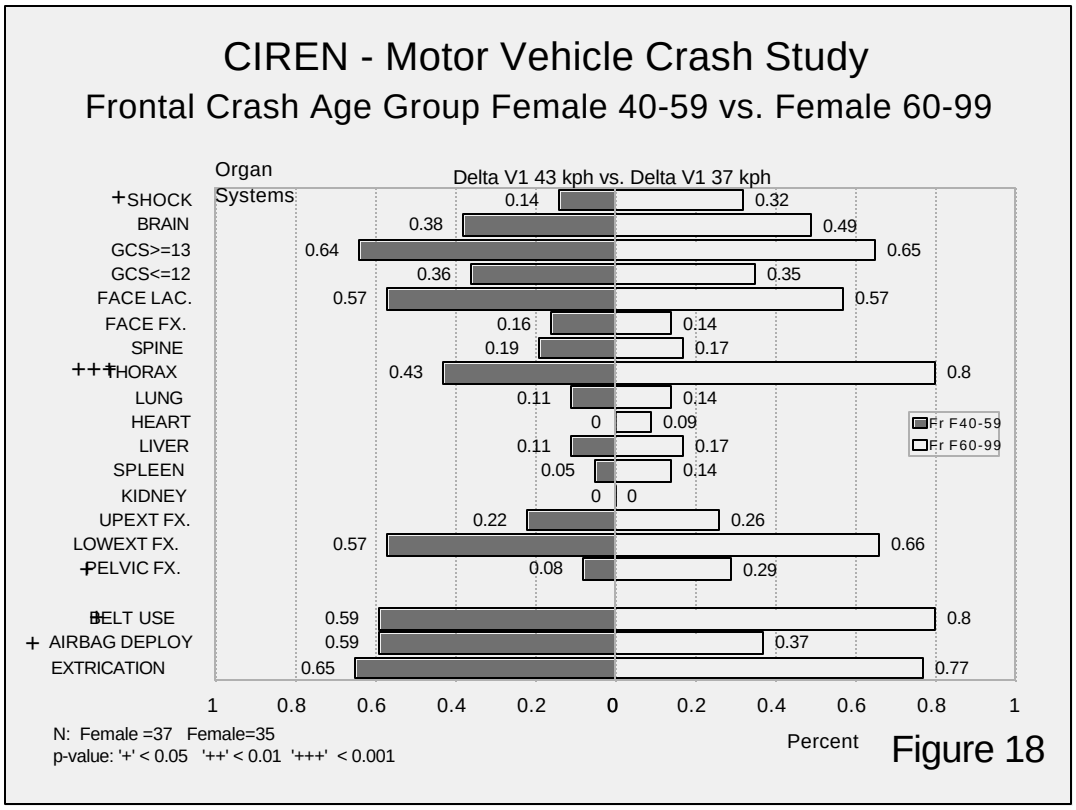


Figure 18

This late post-menopausal difference characteristic of aged women appears to be an important effect dominating the effect of age alone when comparing older age males (60-99 years) to older age females (60-99 years)(Figure 19). While, there was no substantial difference in the incidence of severe brain injury as a function of sex in the increased incidence of thoracic and overall abdominal visceral injuries was greater in the older age females than in the men of similar age and there was a tendency for an increased lower extremity fractures in the female group as well. This is in marked contrast to the reduction in lower extremity fractures found in the males (Figure 14 versus Figure 19) and int the overall statistics Figure 12 which is dramatic by the higher proportion of men. However, there was no difference of significance in the older age related survival between sexes.

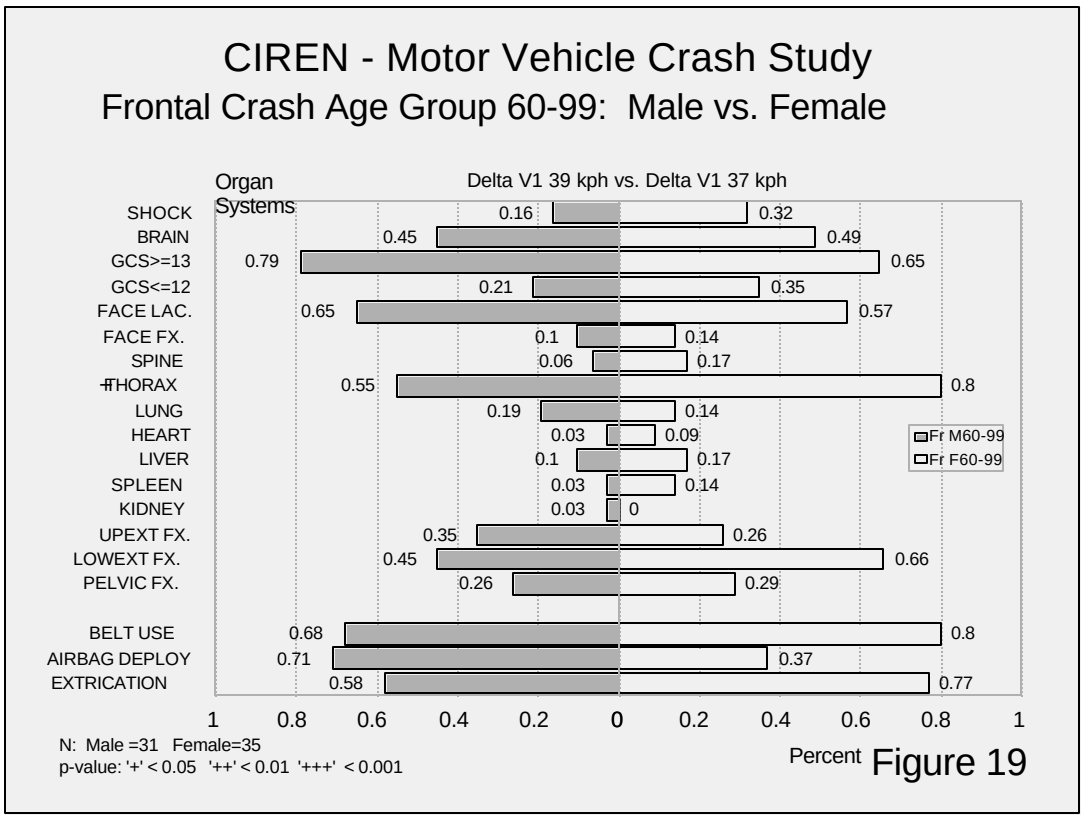


Figure 19

This may be influenced by the fact that the height and weight characteristics of the older age males, were significantly greater than those of the older age females (60-99 years) (Figure 20). Moreover, in spite of the fact that these crashes occurred at essentially the same DELTA V, as shown above the older age females, demonstrated significantly more regional and organ injury differences than the older age males (Figure 21).

CIREN - Motor Vehicle Crash Study
Frontal Crash Age Group 60-99: Male vs. Female

Patient Dynamics	Fr M60-99	Fr F60-99
N	31	35
Avg Age	70.58	69
ISS	22	22.29
GCS	12.52	13.23
Survival %	61	69
LOS	23.6	21.9
ICU Days	11.9	7.7
Height (cm) ***	177.4	161.1
Weight (kg) **	82.2	71.4
Crash Dynamics		
Delta V1 (kph)	39.72	36.88
Mass V1 avg.	1414.3	1367.8
Mass V2 avg.	1476	1385.9

Wilcoxon (ISS&GCS), Fisher's Exact (survival), t-test (LOS, ICU days, HT, WT, Delta V1)
p-value: '+ ' < 0.05 '++' < 0.01 '+++' < 0.001

Figure 20

CIREN - Motor Vehicle Crash Study
Summary Findings

Comparing premenopausal and early postmenopausal females (40-59 yrs) to late postmenopausal females (60-99 yrs) over comparable Delta V (43kph vs. 37 kph) and similar height/weights reveals a greater number of more severe injuries and more shock.

	40-59 years	60-99 years	
Thorax	43%	80%	p<0.0001
Pelvic Fx.	8%	29%	p<0.05
Mean Visceral Injuries per Patient	0.27	0.53	
Shock	14%	32%	p<0.05

Figure 21

DISCUSSION

These data suggest that there is an increased vulnerability of the older age, particularly in the post-menopausal female patient to thoracic injuries. The vulnerability to this specific type of injury may lie in a number of factors related to the sex difference exacerbated by the increased effects of the late post-menopausal state in the aged women.

The first factor is that seriously injured aged women in motor vehicle crashes tend to be smaller in height and lighter in weight than the younger men, for whom most of these vehicles were designed. Consequently, they appear to sit closer to and even partially under the steering wheel. Moreover, in spite of the fact that the motor vehicle crashes in this age group of women tend to occur at lower DELTA V's, (37 kph vs 52 kph for younger men) compared to younger men the aged women tend to have a smaller percentage of air bag deployment, but use their seat belts more often. While the incidence of seat belt use was greater in the older age females the smaller incidence of airbag deployment may reflect the fact that the older age females drive older pre-FMVSS 208 cars rather than newer airbag equipped vehicles. Comparing pre-menopausal or early post menopausal women (40-59 years) to late post-menopausal women (60-99 years), it was noted that the older women had a significantly higher incidence of thoracic injuries, (80% vs 43%), and pelvic fractures (29% vs 8%). There were also greater mean number of visceral organ injuries per patient 0.27 vs 0.53, and a significantly greater propensity for shock (32% vs 14%). As a result the older women's survival rate was lower 69% vs 84%, and they had a longer average hospital stay, (22 vs 15 days). These effects may be a function of the late post-menopausal changes which include a greater degree of osteoporosis. This factor combined with the circumstance that both the body characteristics and the physical habitus of older women may play an important role in their pattern of injuries is suggested by the fact that the older age women were significantly smaller (161 cm vs.177 cm), and significantly lighter, (71 kg vs 82.2 kg) than the older age men and the middle aged women who show little alteration in physical habitus. These physical body changes undoubtedly cause them to sit closer and somewhat under the steering wheel, making them more susceptible to crash induced injuries from the steering wheel, and in some instances from the airbag as well. It also predisposes them to a greater incidence of femoral and pelvic fractures in frontal crashes by virtue of impacts of the femurs and knees with the instrument panel.

Finally, all of these data, suggesting the vulnerability of older age and in particular aged women patients, to a higher incidence of thoracic injuries, and pelvic and lower extremity fractures, strongly suggest that design features in future motor vehicles must take into account the significant age and sex related anatomic and pathophysiologic differences. The U.S. population itself is aging and based on national statistics, the incidence of individuals in the 60+ age group, especially females, is markedly increasing. Moreover, the relative increase in the population of older age women (60-99 years) produces a higher incidence of osteoporosis, especially in these post-menopausal females, which may or may not be correctable by the prophylactic use of estrogen hormones beginning in the early post menopausal period, and carried on into mature life. Long term studies in the value of estrogen supplementation in older age women, as well as other prophylactic measures to control osteoporosis may have an impact in the future (5,6,7). However, in the present generation of older age women the incidence of post-menopausal hormonal therapy and mineral related control of osteoporosis seems not to be very effective in slowing the progression of this disease and therefore an increased set of safety measures may need to be built into the next generation of motor vehicles.

These data demonstrate the importance of the CIREN studies by relating the actual crash dynamics and with the result by their injury producing effects on real human beings to demonstrate the nature and patterns of injuries and their crash related pre-existing disease process or other influences on the crash occupant factors source with regard to vehicle dynamics.

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