Research Article

Sex-related discrepancies in the epidemiology, injury characteristics and outcomes after acute spine trauma: A retrospective cohort study*

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Context/Objective: The potential effects of sex on injury severity and outcomes after acute spine trauma (AST) have been reported in pre-clinical and clinical studies, even though the data are conflicting. This study compared females and males regarding the epidemiology, injury characteristics, and clinical outcomes of AST.
Design: Retrospective cohort study.
Setting: Acute spine care quaternary center.
Participants: All consecutive cases of AST admitted from January/1996 to December/2007 were included.
Interventions: None.
Outcome Measures: The potential effects of sex on the epidemiology, injury characteristics, and clinical outcomes of AST were studied.
Results: There were 504 individuals with AST (161 females, 343 males; mean age of 49.44 ± 0.92 years). Sex was not associated with age or pre-existing co-morbidities as assessed using the Charlson Co-morbidity Index, however, females had a greater number of International Classifications of Diseases (ICD) codes at admission and higher Cumulative Illness Rating Scale (CIRS) than males. Over the 12-year period, the male-to-female ratio has not significantly changed. Although there were significant sex-related discrepancies regarding injury etiology, level and severity of AST, males and females had similar lengths of stay in the acute spine center, in-hospital survival post-AST, and need for mechanical ventilation and tracheostomy.
Conclusion: This study suggests that females with AST present with a greater number of pre-existing co-morbidities, a higher frequency of thoraco-lumbar trauma, less severe neurological impairment and a greater proportion of MVA-related injuries. However, females and males have a similar length of stay in the acute spine center, and comparable in-hospital survival, need for mechanical ventilation, and tracheostomy after AST.

Keywords: Spinal cord injury, Acute spine trauma, Neurotrauma, Age, Sex

Introduction

The incidence and prevalence of acute spine trauma (AST) remain relatively modest, despite its significant personal impact and its substantial economic impact upon society.[1,2] In the United States, the estimated lifetime costs per individual with traumatic spinal cord injury (SCI) onset at the age of 25 years, vary from $1.65 million (incomplete paraplegia) to $4.7 million (complete high tetraplegia) in 2017 USD.[3] Moreover, the epidemiology of traumatic SCI has been changing over the past three decades.[4,5] The aging of the population has resulted in a boom of fall-related SCIs in the geriatric population around world.[2,4–8] Nonetheless, traumatic SCI continues to predominantly affect males with male-to-female ratios varying from 1.6:1 to 8.1:1 across the world.[2]

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The effect of sex on outcomes after traumatic SCI remains unclear. Most prior pre-clinical experimental and clinical studies have shown conflicting findings as to whether females have more favorable outcomes in terms of locomotor recovery than males.[9–11] In a recent preclinical experimental study, Datto *et al.* concluded that female sex favors better tissue preservation and functional recovery over males after studying a larger sample size of animals, adjusting the data analysis for weight and age, and using a wide variety of locomotion tests.[9] However, clinical studies have not shown a convincing female sex advantage over males. A retrospective study of individuals in the acute stage after SCI documented that females may be more susceptible to post-traumatic depression and deep venous thrombosis, but there were no other significant sex-related disparities with regards to clinical outcomes, including other clinical secondary complications, length of stay, mortality, and discharge disposition from an acute spine center.[12] Using data from 14,433 individuals with traumatic SCI who were registered in a large database in the United States, Sipski *et al.* reported that females and males had slight differences in neurologic and functional recovery following SCI, but both sexes had some distinct advantages.[10] For instance, females were more likely to improve neurologically based on changes in the initial AIS; however, for a given level and severity of SCI, males tend to have better functional performance than females at time of discharge from rehabilitation.[10] Cardenas *et al.* studied 7,379 people with traumatic SCI who mostly developed persistent pain (81% at 1 year post-injury and 82.7% at 25 years), but there were no significant sex-related differences noted.[11] Although there is no definite explanation for the sex-related discrepancies in prior studies, the current understanding is that multiple factors related to female sex beyond estrogen are involved.[9]

Given this background, we examined a single-institution large database in order to test the hypothesis that individual's sex can influence injury characteristics (*i.e.* causes, level and severity of AST), and clinical outcomes (*i.e.* length of stay in the acute spine trauma center, in-hospital survival, need for mechanical ventilation and need for tracheostomy) after AST when data analyses are adjusted for major potential confounders (*i.e.* age at the time of AST, pre-existing medical co-morbidities, and injury characteristics). Because the performance of the measures of pre-existing co-morbidities varies according to the outcome of interest, we used multiple evaluations of the pre-existing co-morbidities in order to clarify which one(s) are more sensitive to the AST population.[13–16] While the data used in this study were collected between 1996 and 2007, this represents a large case series from a single institution where the treatment protocol has not significantly changed when compared to the current practice. Therefore, the results are still relevant and valid for comparisons with current management of AST after accounting for potential epidemiological differences in other jurisdictions.

Methods

This retrospective cohort study included all consecutive adults with AST who were admitted to an acute spine trauma center (Level I center that has 12 beds for AST) in Canada from January 1996 to December 2007 inclusive. Relevant clinical data were retrieved including demographics (age and sex), injury characteristics (cause, level and severity of injury), pre-existing medical co-morbidities, and clinical outcomes (survival and length of stay in the acute spine center). Data used in this research project were collected according to a protocol approved by the Research Ethics Board from University Health Network.

For the purpose of this study, AST was defined as a trauma at any level of the spine (C1 to S5) that resulted in hospital admission regardless of the severity of the spine trauma. Severity of AST was classified according to the American Spinal Injury Association [ASIA] Impairment Scale (AIS) as follows: (i) motor and sensory complete SCI (AIS A); (ii) motor complete but sensory incomplete SCI (AIS B); (iii) motor incomplete SCI where the majority of the key muscles below the neurological level have muscle grade < 3 (AIS C); and (iv) motor incomplete SCI where the majority of the key muscles below the neurological level have muscle grade ≥ 3 (AIS D).[17] For the purpose of data analyses using multiple logistic regression, the individuals were further grouped into motor complete SCI (AIS A or B), motor incomplete SCI (AIS C or D), and normal neurological examination or minor neurological deficits after spine trauma (AIS E) according to severity of AST. Additionally, the study population was grouped into individuals with tetraplegia (cervical AST) and individuals with paraplegia (thoracic, lumbar or sacral AST).

Pre-existing medical co-morbidities at admission were quantified according to their severity as assessed using the Charlson Co-morbidity Index and Cumulative Illness Rating Scale (CIRS), as well as the number of codes from the International Classifications of Diseases (ICD), 9th revision.[18–20]

The standard of care in this acute spine trauma center at the time of data collection included: (i) the

administration of methylprednisolone as a neuroprotective agent according to recommendations of the Second National Acute Spinal Cord Injury Study;[21] (ii) hemodynamic and cardiac monitoring with intravenous administration of crystalloids (*i.e.* 0.9% NaCl solution) and vasopressive agents (*i.e.* dopamine) as required to maintain a mean blood pressure at 85–90 mmHg as a neuroprotective measure;[22] and, (3) spinal cord decompression and spine stabilization with realignment at the earliest feasible time according to the clinical conditions.[23]

Data analysis

The appropriate parametric or nonparametric descriptive statistics were used to characterize the demographics and injury characteristics of the cohort. Data were analyzed using the Mann Whitney U test for continuous variables, and Fisher exact test for categorical variables. Survival data were analyzed using a Kaplan-Meier curve and log-rank test. Multiple logistic regression analysis was used to examine the potential associated or confounding factors associated with binary clinical outcomes. All data analyses were performed using SAS version 9.4 (SAS Institute Inc., NC, USA). Significance level of 5% was assumed for univariate analysis with a minimum power level of 80%. Bonferroni correction was used for multiple comparisons.

Results

There were 504 individuals with AST (161 females and 343 males; age range from 15 to 102 years with a mean age of 49.44 ± 0.92 years) who were admitted to the acute spine trauma center. The majority of the individuals (55.02%) had minor or no spinal cord impairment (AIS E), followed by incomplete, milder impairment (AIS D) SCI (30.12%) complete (AIS A) SCI (7.63%), incomplete moderate impairment (AIS C) SCI (4.82%), and motor complete (AIS B) SCI (2.41%). Most of the individuals sustained a cervical spine trauma (58.98%) followed by lumbar spine trauma (28.60%), thoracic spine trauma (11.75%) and sacral spine trauma (0.67%). Falls were the most common cause of AST (54.17%) followed by motor vehicle accidents (25.60%), sports-related accidents (8.73%), diving accidents (4.17%), bicycle accidents (2.98%), assaults (1.79%), work-related accidents (0.98%), self-inflicted injuries (0.60%), and unknown (0.98%).

Sex-related differences in the epidemiology of acute spine trauma

The male-to-female ratio has not significantly changed over the 12-year period (Fig. 1). There were no significant differences between males and females with regards to their age at the time of injury and major pre-existing medical co-morbidities as assessed using the Charlson Co-morbidity Index (Table 1). However, females had a greater number of ICD codes and more often had major pre-existing medical co-morbidities as assessed using CIRS than males (Table 1). Females most often sustained a thoracic or lumbar AST, whereas a higher frequency of cervical AST was observed in males (Table 1). With respect to the causes of AST, motor vehicle accidents were more often seen among females than males, while sports-related accidents and bicycle accidents were more

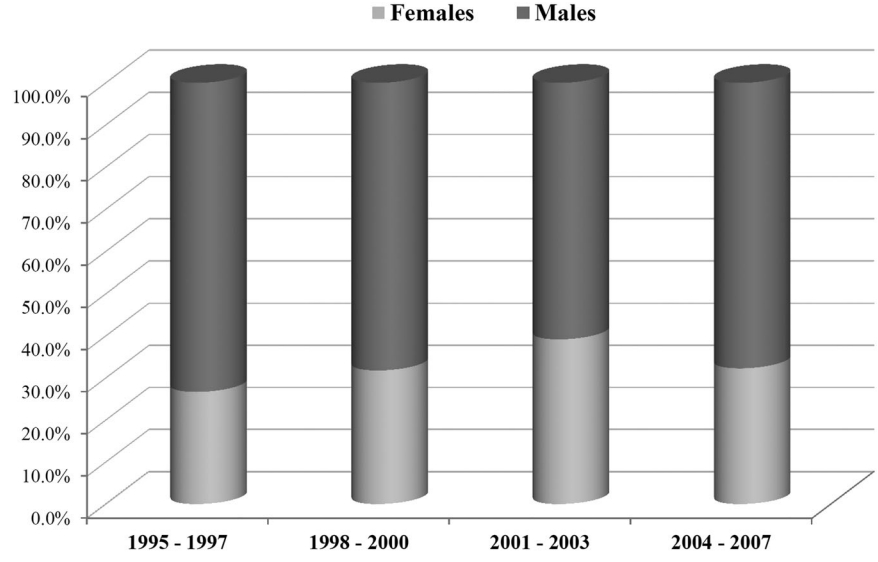

Figure 1 Comparison of male-to-female ratios over the 12-year period among the triennia ($P = 0.1423$).

Table 1 Comparison between females and males with regards to baseline data.

Feature	Females	Males	*P* value
Mean age ± SEM	51.81 ± 1.74 years	48.32 ± 1.08 years	0.1299
Age range	16–91 years	15–102 years	
Level of spine trauma			
Cervical	73 (44.99%)	193 (63.91%)	
Thoracic	23 (15.44%)	30 (9.93%)	
Lumbar	52 (34.90%)	77 (25.50%)	
Sacral	1 (0.67%)	2 (0.66%)	0.0155
Severity of spine trauma			
AIS A	10 (6.37%)	28 (8.21%)	
AIS B	1 (0.64%)	11 (3.23%)	
AIS C	3 (1.91%)	21 (6.16%)	
AIS D	51 (32.48%)	99 (29.03%)	
AIS E	92 (58.60%)	182 (53.37%)	0.0735
Cause of spine trauma			
Fall	86 (53.42%)	187 (55.33%)	
Motor vehicle accident	55 (34.16%)	74 (21.89%)	
Sports-related accident	10 (6.21%)	34 (10.06%)	
Diving accident	5 (3.11%)	16 (4.73%)	
Bicycle accident	1 (0.62%)	14 (4.14%)	
Other causes	4 (2.48%)	13 (3.85%)	0.0154
Charlson Co-morbidity Index			
0	110 (68.32%)	251 (73.39%)	
1	32 (19.88%)	56 (16.37%)	
2	12 (7.45%)	18 (5.26%)	
3 or higher	7 (5.35%)	17 (4.97%)	0.5392
Number of ICD codes			
Mean ± SEM	2.12 ± 0.18	1.50 ± 0.12	0.0003
Range	0–11	0–15	
Cumulative Illness Rating Scale			
Mean ± SEM	4.21 ± 0.38	3.12 ± 0.28	0.0005
Range	0–22	0–42	

SEM, standard error of mean; AIS, ASIA Impairment Scale; ICD, International Classification of Diseases.

common causes of AST among males than females (Table 1). Furthermore, there was a trend towards sex-related discrepancies in terms of the severity of AST. Overall, females appeared to have had less severe AST than males (Table 1).

Outcomes after acute spine trauma: females versus males

Females did not significantly differ from males with regards to the length of stay in the acute spine trauma center (Fig. 2.A). Similarly, there were no significant sex-related discrepancies in the in-hospital survival after AST (Fig. 2.B). The need for mechanical ventilation was associated with a greater number of major pre-existing medical co-morbidities (as assessed using the number of ICD codes) and tetraplegia, but not related to individuals' sex and age at the time of trauma onset (Table 2). A tracheostomy was more often required in those individuals with a motor complete (AIS A or B) SCI, but was not related to the individuals' sex or age at the time of trauma onset (Table 3).

Discussion

The results of this retrospective cohort study in 504 individuals with AST suggest that sex was not associated with age at the time of trauma or major pre-existing medical co-morbidities as assessed using Charlson Co-morbidity Index. However, females presented with a greater number of ICD codes and more often had major pre-existing medical co-morbidities as assessed using CIRS than males with AST. While females most often had a thoracic or lumbar AST, males showed a higher frequency of cervical AST than their female counterparts. Motor vehicle accidents as a cause of AST were more often seen among females than males, while sports-related accidents and bicycle accidents were less common causes of AST among females. Also, females appeared to have had less severe AST than males. Over the 12-year period, the ratio of males to females has not significantly changed. Females did not significantly differ from males with regards to the length of stay in the acute spine trauma center and in-hospital survival after AST. The need for mechanical ventilation was significantly associated with greater number of major pre-

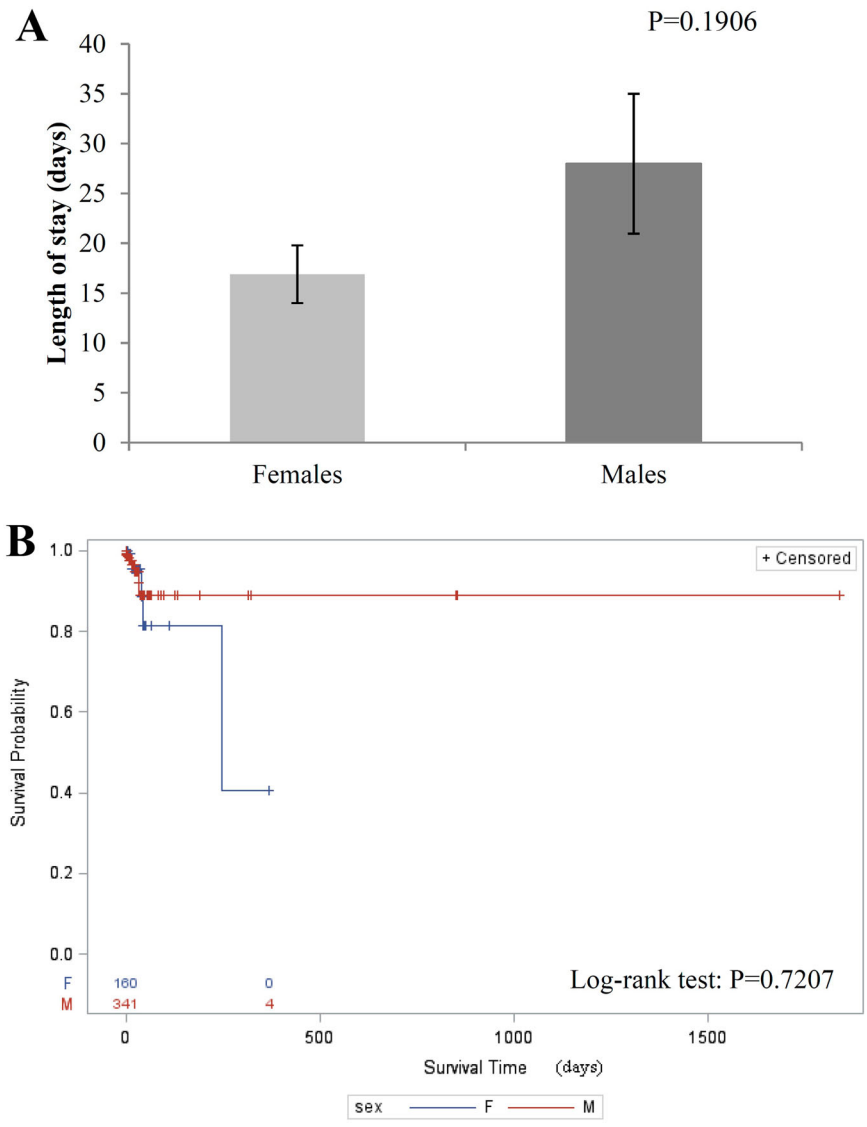

Figure 2 Comparisons between females and males regarding the outcomes after acute spine trauma: (A) Length of stay in the acute spine trauma center; (B) In-hospital survival using Kaplan–Meier curves.

existing medical co-morbidities (as assessed using the number of ICD codes) and tetraplegia, but not related to individuals' sex and age. A tracheostomy was more often required in those individuals with a motor complete (AIS A or B) SCI, but was not related to the individuals' sex and age.

Sex and epidemiology of acute spine trauma

The results of our study revealed no significant changes in the male-to-female ratio over the 12-year period. Similarly, the vast majority of the prior studies have shown no significant changes in the male-to-female ratio over the past two decades, even though the results of a few population-based studies suggested that the proportion of females has increased relative to the proportion of males in some jurisdictions.[2,4–8]

In our study, sex distribution was found to be unrelated to the age at the time of trauma. Contrary to the belief that elderly patients inevitably have poorer recovery than younger adults after traumatic SCI, the most recent clinical studies suggest that age at the onset of SCI is not certainly associated with less favorable outcomes.[24,25] It is commonly reported that, survival in the elderly with SCI is lesser than their younger adult counterparts, even though a prior study indicated that pre-existing medical co-morbidities can have a confounding effect on the reduced survival in the elderly following SCI.[24–27] Among survivors, age at onset of SCI did not significantly influence motor and sensory recovery as well as pain scores within the first year following acute traumatic SCI after adjusting data analyses for major potential confounders.[24,25] However,

Table 2 Results of the multiple logistic regression analysis on the need for mechanical ventilation after acute spine trauma.

Model 1: Need for mechanical ventilation
Model fit statistics: −2 log L = 162.35
Likelihood ratio (chi-square): 72.85 $P < 0.001$
c statistics: 0.882

Co-variants	Odds ratio	95% confidence interval	*P* value
Age at the time of trauma	0.993	0.970, 1.016	0.532
Sex			
Females vs. males	2.033	0.688, 6.006	0.199
Number of ICD codes	0.835	0.707, 0.985	0.032
Level of spine trauma			
Paraplegia vs. tetraplegia	4.576	1.265, 16.554	0.020
Severity of spine trauma			
Incomplete vs. minor or normal	0.358	0.107, 1.205	0.122
Motor complete vs. minor or normal	0.031	0.009, 0.104	< 0.001 (*)

Model 2: Need for mechanical ventilation
Model fit statistics: −2 log L = 163.64
Likelihood ratio (chi-square): 71.55 $P < 0.001$
c statistics: 0.879

Co-variants	Odds ratio	95% confidence interval	*P* value
Age at the time of trauma	0.991	0.968, 1.014	0.449
Sex			
Females vs. males	2.031	0.685, 6.020	0.201
Cumulative Illness Rating Scale (CIRS)	0.939	0.877, 1.006	0.073
Level of spine trauma			
Paraplegia vs. tetraplegia	7.731	1.310, 17.089	0.018
Severity of spine trauma			
Incomplete vs. minor or normal	0.327	0.096, 1.111	0.178
Motor complete vs. minor or normal	0.031	0.009, 0.105	< 0.001 (*)

Model 3: Need for mechanical ventilation
Model fit statistics: −2 log L = 165.97
Likelihood ratio (chi-square): 69.22 $P < 0.001$
c statistics: 0.871

Co-variants	Odds ratio	95% confidence interval	*P* value
Age at the time of trauma	0.978	0.958, 1.001	0.060
Sex			
Females vs. males	2.000	0.682, 5.857	0.207
Charlson Co-morbidity Index	1.135	0.811, 1.589	0.459
Level of spine trauma			
Paraplegia vs. tetraplegia	5.183	1.442, 18.639	0.012
Severity of spine trauma			
Incomplete vs. minor or normal	0.350	0.106, 1.157	0.135
Motor complete vs. minor or normal	0.031	0.009, 0.104	< 0.001 (*)

ICD, International Classification of Diseases; Bonferroni corrections: * $p < 0.025$.

the potential of elderly individuals to neurologically improve within the first year post-SCI did not translate into functional recovery similar to younger individuals.[24,25,28]

In our study, sex was not associated with major pre-existing medical co-morbidities as assessed using Charlson Co-morbidity Index. However, females had greater number of ICD codes and more often had major pre-existing medical co-morbidities as assessed using CIRS than males. Alike our study, a prior investigation indicated that males with SCI did not differ from females with SCI in terms of the frequency of pre-existing medical comorbidities.[12] The discrepancies of the results on different measures of pre-existing co-morbidities in our study remain to be elucidated. However, several prior studies suggest that the performance of the measures of pre-existing co-morbidities varies according to the outcome of interest.[13–16] This is important because a growing body of evidence has indicated that pre-existing medical co-morbidities can affect the clinical outcomes of individuals with AST.[29–31]

In our study, females most often sustained thoracic or lumbar AST, whereas males had a greater frequency of cervical AST than females. Also, there was a trend for females to have less severe AST than males.

Table 3 Results of the multiple logistic regression analysis on the need for tracheostomy after acute spine trauma.

Model 1: Need for tracheostomy
Model fit statistics: −2 log L = 90.96
Likelihood ratio (chi-square): 33.45 P <0.001
c statistics: 0.883

Co-variants	Odds ratio	95% confidence interval	*P* value
Age at the time of trauma	0.993	0.961, 1.026	0.667
Sex			
Females vs. males	1.838	0.370, 9.134	0.457
Number of ICD codes	0.895	0.689, 1.163	0.407
Level of spine trauma			
Paraplegia vs. tetraplegia	4.989	0.603, 41.277	0.136
Severity of spine trauma			
Incomplete vs. minor or normal	0.231	0.025, 2.122	0.625
Motor complete vs. minor or normal	0.026	0.003, 0.215	< 0.001 (*)

Model 2: Need for tracheostomy
Model fit statistics: −2 log L = 91.526
Likelihood ratio (chi-square): 32.88 P < 0.001
c statistics: 0.879

Co-variants	Odds ratio	95% confidence interval	*P* value
Age at the time of trauma	0.989	0.957, 1.021	0.496
Sex			
Females vs. males	1.875	0.378, 9.299	0.442
Cumulative Illness Rating Scale (CIRS)	0.984	0.870, 1.112	0.794
Level of spine trauma			
Paraplegia vs. tetraplegia	5.226	0.638, 42.823	0.123
Severity of spine trauma			
Incomplete vs. minor or normal	0.225	0.025, 2.057	0.661
Motor complete vs. minor or normal	0.026	0.003, 0.218	< 0.001 (*)

Model 3: Need for tracheostomy
Model fit statistics: −2 log L = 91.585
Likelihood ratio (chi-square): 32.82 P < 0.001
c statistics: 0.880

Co-variants	Odds ratio	95% confidence interval	*P* value
Age at the time of trauma	0.986	0.955, 1.019	0.397
Sex			
Females vs. males	1.866	0.375, 9.294	0.446
Charlson Co-morbidity Index	1.018	0.667, 1.556	0.933
Level of spine trauma			
Paraplegia vs. tetraplegia	5.338	0.652, 43.713	0.119
Severity of spine trauma			
Incomplete vs. minor or normal	0.225	0.025, 2.061	0.656
Motor complete vs. minor or normal	0.026	0.003, 0.220	< 0.001 (*)

ICD, International Classification of Diseases; Bonferroni corrections: * $p < 0.025$.

Furthermore, females were more likely to be injured by motor vehicle accidents than males, while sports-related accidents and bicycle accidents were less common causes of AST among females. Those sex-related differences in the distribution of mechanisms of injury at least partially explain the discrepancies seen in the level and severity of AST between males and females. For example, incomplete tetraplegia was the top neurological outcome after ASTs related to sports (47.7%), motor vehicle accidents (32.8%), and falls (41.1%) according to most recent data from the National Spinal Cord Injury Statistical Center.[32] Of note, 84.9% of all sports-related injuries resulted in tetraplegia.[32] In addition, the survival after motor accidents in the United States is greater among female drivers in comparison with their counterparts, which could explain the higher frequency of AST related to motor vehicle accidents in the female group. According to recent data from the Fatality Analysis Reporting System from the U.S. Department of Transportation, male drivers were responsible for 71% of all motor vehicle crash deaths in 2017, and males had 1.8–2.6 times *per capita* passenger vehicle occupant death rates from 1975 to 2017 than females.[33]

Similar to our results, most recent data from the National Spinal Cord Injury Statistical Center documented that motor vehicle accident was a more

common cause of SCI among females (47.1%) than males (28.9%), as well as sports-related accidents and bicycle accidents were less common causes of AST in females (5.6% and 1.0%, respectively) when compared with males (11.2% and 1.8%, respectively).[32] In contrast, Scivoletto *et al.* found no sex-related differences in the distribution of levels and causes of traumatic SCI.[34] The authors also reported no significant sex-related discrepancies in the distribution of severity of SCI regarding AIS A, B and D, but the frequency of AIS-C injuries was significantly greater in males than females.[34] In a retrospective case series in Australia, New *et al.* reported no significant correlation of sex with injury severity and neurological level of non-traumatic SCI.[35] Analyzing US data from 1,074 individuals with traumatic SCI, Greenwald *et al.* found no significant sex-related differences in the Functional Independence Measure (FIM) motor scores and ASIA motor scores on admission to the acute spine trauma center and discharge from rehabilitation center.[36]

Sex and outcomes after acute spine trauma

There was no sex-related discrepancy in the length of stay in the acute spine trauma center and in-hospital survival following AST in our study. Similarly, prior studies on unmatched groups of individuals with SCI showed no significant differences between males and females with regards to the mean length of stay.[12,37–39] Greenwald *et al.* documented that females did not differ from males with regards to the length of stay in the acute care facility.[36] By analyzing many predictive variables for a longer stay in the acute care unit, Mylotte *et al.* identified SCI and development of a nosocomial infection as key predictive factors, but sex was not associated with the length of stay in the acute care unit.[40] Scivoletto *et al.* found no significant sex-related differences in terms of the length of stay in a Spinal Cord Unit for rehabilitation of individuals with traumatic or non-traumatic SCI.[34] In contrast, Herren *et al.* reported that males had a longer hospital of stay after lumbar spine surgery for spinal disc herniation, lumbar spinal stenosis and spondylolisthesis than females.[41] Although there is no obvious explanation for the differences in the results between the study by Herren *et al.* and former investigations, one may speculate that methodological differences such as variations in the definition of length of stay may account for those discrepancies.[42]

The results of our study also suggest that females had similar survival to males after AST. Similarly, New and Epi reported no sex-related differences in survival after initial rehabilitation of 70 adult inpatients with nontraumatic SCI in an Australian retrospective case series.[35] In a retrospective cohort study at Spinal Cord Injury Centre of Western Denmark including 665 cases, Noe *et al.* found no significant sex-related differences in mortality at 2, 5 and 10 years after traumatic SCI.[43] In a Swiss observational cohort study including 2,421 individuals with traumatic SCI, Chamberlain *et al.* reported that males had a greater mortality rate than females using Kaplan-Meier curve analysis with univariate analysis hazard ratio of 1.38 (95% CI: 1.10, 1.74).[44] However, sex was not significantly associated with survival after traumatic SCI when using a multivariable analysis with a hazard ratio of 1.0 (95% CI: 0.79, 1.10).[44] In contrast, Hatch *et al.* documented greater mortality among males (hazard ratio: 1.3 [95% CI: 1.0, 1.6]) in an analysis with multiple-variable Cox proportional hazards model in an American retrospective cohort study that included 535 individuals with nontraumatic SCI and 221 individuals with traumatic SCI.[45] Of note, survival was higher in the group of individuals with traumatic SCI than the group of individuals with nontraumatic SCI, and the latter group had greater number of younger males than the former group.[45] In a recent retrospective cohort study including data of 8,069 cases of traumatic SCI from the Japan Trauma Data Bank, Shibahashi *et al.* documented a significantly greater mortality among males (odds ratio: 2.06 [95% CI: 1.44–2.93]) than females using a multivariate logistic regression analysis.[46] Therefore, the results of our study are consistent with many of the prior publications but other investigators found significant sex-related differences in survival after AST. The reasons for those discrepancies may include differences among the studies (*e.g.* methodological variances), among jurisdictions (*e.g.* differences in healthcare systems, healthcare access, and population profile), and others.

Furthermore, our results suggest that individual's sex and age do not influence the need for mechanical ventilation and tracheostomy after AST. In a Spanish retrospective cohort study including 146 individuals, Montoto-Marques *et al.* documented that males more often need mechanical ventilation after traumatic cervical SCI, but the only factor that significantly determined the need for mechanical ventilation was the ASIA motor score at admission.[47]

In a meta-analysis of previous studies on the factors that influence the need for tracheostomy after traumatic cervical SCI, Wang *et al.* reported that males are at a greater risk for prolonged intubation requiring tracheostomy (odds ratio: 1.29 [95%CI: 1.12, 1.49]).[48] However, major potential confounders such as pre-

existing medical co-morbidities were apparently excluded from their data analysis.

Overall, the results of our study indicate that sex does no significant influence on length of stay in the acute spine trauma center and in-hospital survival after AST. While those results are consistent with several of the aforementioned prior studies, there are conflicting results in the literature suggesting that males may have a longer stay in the hospital, and a higher mortality after SCI. Furthermore, individuals' sex does not influence their need for mechanical ventilation and tracheostomy after AST.

Study limitations

This original retrospective cohort study compared females and males with respect to the epidemiology of AST, injury characteristics, and clinical outcomes. However, there are a few limitations that should be considered prior to interpreting and generalizing the results. First, selection bias may occur in any retrospective cohort study. Second, the Spinal Cord Database includes only data with regards to admissions at an acute spine trauma center from January/1996 to December/2007. Given that treatment protocol has not substantially changed in that institution since 1996, this large case series can be considered relevant and valid for comparisons with current management of AST after accounting for potential epidemiological differences. Although the management protocol did not change since 2007, we could not verify whether there has been any significant change over the past 12 years in terms of the sex distribution of individuals with AST. According to the results of a recent study on the epidemiology of traumatic SCI, Jain *et al.* reported an increase of the mean age of individuals with acute traumatic SCI but the sex distribution did not significantly changed from 1993 to 2012 in the United States.[4] Third, this study is based on data from a single institution where four spine surgeons utilize the same treatment protocol and principles that may differ from other jurisdictions. Fourth, data on other potential confounding factors such as secondary complications of AST were not available for further adjusted analyses. Finally, there are likely some important health system confounders we were unable to adjust for using the current model.

Conclusions

This retrospective cohort study using a large single-institution database examined the potential influence of sex on the epidemiology of AST, injury characteristics, and clinical outcomes. Our results suggest that sex is not associated with age at the time of AST and pre-existing medical co-morbidities as assessed using Charlson Co-morbidity Index, but females had greater number of ICD codes and higher CIRS than males. Over the 12-year period, the male-to-female ratio has not significantly changed. Also, there were significant sex-related discrepancies with regards to cause, level and severity of AST. However, there were no significant sex-related differences in terms of length of stay in the acute spine trauma center and in-hospital survival after AST. The need for mechanical ventilation was significantly associated with greater number of major pre-existing medical co-morbidities (as assessed using the number of ICD codes) and tetraplegia, but not related to individuals' sex and age. A tracheostomy was more often required in those individuals with a motor complete (AIS A or B) SCI, but was not related to the individuals' sex and age. Overall, there were some significant differences between females and males with regards to the injury characteristics that did not adversely affect their survival, length of stay in the acute spine trauma center, need for mechanical ventilation and need for tracheostomy after AST. Those results reinforce the current guidelines for acute spine trauma care where individuals' sex is not accounted for as a key determinant of patients' outcomes including in-hospital survival, length of stay in the acute spine trauma center, need for mechanical ventilation and need for tracheostomy after AST for patients with AST. While the severity of neurological impairment is less in females at outset, the greater number of medical co-morbidities (as assessed using CIRS) can challenge the management. It is noteworthy to mention that our data from an acute spine trauma center may not represent the reality of the rehabilitation centers where other outcomes may be affected by the individuals' sex. For instance, sex-related differences in the management of neurogenic bladder after SCI were reported to influence patients' satisfaction and functional outcomes.[49] Further investigations are necessary to determine which measures of pre-existing medical co-morbidities have the best performance when evaluating outcomes after AST.

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