Comparison of rehabilitation outcomes following vascular-related and traumatic spinal cord injury

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Background: Previous studies have noted similar outcomes between vascular-related spinal cord injury (VR-SCI) and those with traumatic SCI (T-SCI), despite significant difference in their demographics and clinical presentation (age, level of injury (LOI), and degree of incompleteness).
Objectives: To review demographic and clinical presentation of VR-SCI and to compare outcomes with a matched group with T-SCI.
Design: Analysis of 10-year prospective data collection including 30 consecutive patients admitted to an SCI rehabilitation unit with VR-SCI and comparison with 573 patients with T-SCI. Outcomes were further analyzed comparing VR-SCI to T-SCI ($n = 30$), matched for age, LOI, and ASIA (American Spinal Injury Association) Impairment Scale (AIS).
Setting: A level 1 tertiary university trauma center.
Main outcome measures: Functional independence measure (FIM) score changes from admission to discharge. Secondary outcome measures included admission and discharge FIM scores, FIM efficiency, rehabilitation length of stay (LOS), and discharge disposition.
Results: Overall, individuals with VR-SCI were more likely ($P < 0.0001$) to be older (mean age 57.2 vs. 40.0 years) and have paraplegia (87 vs. 48%) than those with T-SCI. Common etiologies for VR-SCI were post-surgical complication (43%), arteriovenous malformation (17%), aortic dissection (13%), and systemic hypotension (13%). Common region of injury and AIS classification in VR-SCI was thoracic (73%) and AIS C (33%). Common SCI-related complications in VR-SCI included neurogenic bowel/bladder (93%), urinary tract infection (73%), pain (67%), pressure ulcers (47%), and spasticity (20%). Matched-group outcome comparisons did not reveal significant differences in FIM change, FIM efficiency, LOS, or disposition between VR-SCI and T-SCI.
Conclusion: VR-SCI leads to significant disability and is associated with common secondary SCI complications as well as medical co-morbidities. This study notes differing demographic and injury characteristics between VR-SCI and T-SCI groups. However, when matched for these differences, rehabilitation functional outcomes were not significantly different between the two groups.

Keywords: Spinal cord injuries, Vascular, Traumatic, Spinal cord ischemia, Aortic dissection, Post-surgical ischemia, Vascular embolism, Arteriovenous malformation, Systemic hypotension, Functional independence measure

Introduction

Vascular-related spinal cord injury (VR-SCI), a subgroup of non-traumatic spinal cord injury (SCI), can lead to significant neurological sequelae consistent with weakness, sensory loss, and bowel and bladder dysfunction. While the majority of SCI (and its related literature) is secondary to traumatic etiologies (such as motor vehicle accident, falls, and violence), non-traumatic SCI (such as those secondary to vascular events, cancer, multiple sclerosis, spinal stenosis, or infection) has been reported to represent nearly one-third of SCI rehabilitation admissions, with about 3–5% secondary to VR-SCI.[1,2] In general, studies comparing non-traumatic with traumatic SCI have revealed that patients with non-traumatic injury tend to be older, married, female, retired, paraplegic, and often have incomplete injuries.[2–4]

Vascular supply to the spinal cord is formed by 31 segmental (or radicular) spinal arteries originating from the

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aorta and vertebral arteries.[5] Of note, blood supplied to the lower thoracic and lumbar region of the cord originates from a single large radicular artery, the artery of Adamkiewicz. Watershed ischemia has been reported in this region secondary to compromise in this artery. These arteries then give rise to the anterior spinal artery (which supplies the anterior two-thirds of the spinal cord) and two posterior spinal arteries (which supply the posterior cord) via penetrating septal vessels. Spinal infarction syndromes, including anterior and posterior artery syndromes, refer to compromise of the respective arteries and lead to distinct patterns of neurological presentation.

Etiologies of VR-SCI are most often secondary to aortic dissection, post-surgical ischemia, vascular embolism, arteriovenous malformation, and systemic hypotension.[3,6–9] The most common type of VR-SCI is secondary to aortic aneurysms, usually occurring in the thoracic region. In patients undergoing thoracoabdominal aneurysm repair, the incidence of spinal cord ischemia varies from 4 to 16%, depending on the type of aneurysm and repair.[10] Repair of recurrent aneurysms of the descending aorta, however, was not found to increase the risk of SCI above baseline.[11] Several techniques have been studied to reduce the risk of spinal cord ischemia during aneurysm surgical repair, including the use of certain medications, draining of cerebrospinal fluid, preoperative spinal angiography, distal aortic perfusion, monitoring evoked potentials, and cooling.[12] Hemorrhages that damage the spinal cord most often are due to anticoagulant medication, arteriovenous malformations, or coagulopathy, and occur most often in the cervical region.

Outcomes in VR-SCI have not been studied as often as those with traumatic SCI (T-SCI). In general, non-traumatic SCI has been associated with shorter rehabilitation length of stay (LOS) and lower discharge functional independence measure (FIM) scores, as compared to T-SCI.[2,4] Older age, higher neurological level of injury (LOI), and completeness of injury have been shown to correlate with poorer outcomes.[9–13] VR-SCI outcome studies have noted recovery of motor function more than sensory or sphincter function and poor ambulation potential in those without early lower-extremity movement.[9,14,15] Older individuals with VR-SCI have shown worse outcomes.[9,13] Common SCI-related secondary medical complications such as neurogenic bladder and bowel, neuropathic pain, and spasticity are seen in relation to VR-SCI.[3,16]

This investigation will study the demographics, injury characteristics and functional outcomes of patients with VR-SCI and compare these to those with T-SCI. We believe that patients with VR-SCI will present with significantly different age and injury characteristics as compared with those with T-SCI. We will match the two groups for these variables (age and injury characteristics) and further compare functional outcomes between the groups. It is hoped that results of this study may better assist in describing this patient population and with outcome prediction.

Methods

Data were collected from consecutive admissions of individuals with a diagnosis of SCI to a level-one tertiary care rehabilitation medicine center over a 10-year period. Thirty patients were identified with VR-SCI etiology and a comparison group included 573 patients with SCI of a traumatic etiology (i.e. fall, motor vehicle accident, gunshot wound, etc.) admitted during the same period. Demographic characteristics collected included age, race, gender, and marital status. Clinical data included neurological LOI, ASIA (American Spinal Injury Association) Impairment Scale (AIS),[17] etiology of injury, pre-injury medical disorders, and SCI-related medical complications. The AIS scale denotes completeness of injury from A to E, with A representing a complete injury and B through E representing incomplete injuries. For outcome comparisons and to control for potential confounding variables, the two groups (VR-SCI and T-SCI) were matched one-to-one for age (within 10 years for those <67 years, within 21 years for those ≥ 67), AIS, and neurological LOI. All 30 patients with VR-SCI were successfully matched with T-SCI patients (Table 1). One matched patient with VR-SCI was missing FIM outcome measure scores and was not included in the FIM outcome analyses.

Outcome measures collected include acute and rehabilitation hospital LOS, FIM Scores, FIM change (measured as a difference between discharge and admission FIM), FIM efficiency (FIM change per day), and discharge disposition.[18] Patients were evaluated with the FIM at admission to rehabilitation (within 72 hours) and again within 24 hours of discharge. To ensure inter-rator reliability, all FIM ratings were obtained by Uniform Data systems certified rehabilitation professionals. The FIM is composed of scores within six categories of function: self-care, sphincter control, mobility, locomotion, communication, and social cognition. Within each category, two or more specific functional areas are evaluated (total of 18 areas). Each of the 18 areas is evaluated in terms of level of functional dependence, using a seven-point scale, with the higher number indicating increased level of independence.

Table 1 Matching for VR-SCI and T-SCI

Patient munber	AIS	LOI (VR/T)	Age (VR/T)
23	A	T10	58/55
19	A	T12	75/80
4	A	T4	34/32
14	A	T5	41/43
25	A	T5	46/47
3	A	T6	50/45
24	A	T6	52/49
27	A	T7/T8	63/57
18	A	T8	47/48
2	B	C4	26/30
9	B	L1/L2	82/72
13	B	T1	62/55
12	B	T12/T11	43/38
8	B	T12	57/53
22	B	T12/T11	57/54
1	B	T4/T5	44/52
15	B	T4/T11	62/68
10	B	T6/T1	50/54
28	C	C5	38/38
30	C	C5	42/45
5	C	C8	69/69
17	C	T1/T12	72/65
26	C	T6/T12	67/53
6	C	T7/T8	45/39
29	C	T9/T12	73/80
20	D	L1	64/68
11	D	L1	75/68
21	D	L1/L4	84/70
16	D	L2	64/65
7	D	T11/T7	75/54

Data analyses were conducted using SAS v.9.2.[19] The sample with vascular SCI was compared with the matched sample with traumatic SCI using paired *t*-tests for continuous variables (acute and rehabilitation LOS, admission and discharge FIM, FIM change, FIM efficiency) and McNemar's test for categorical variables (discharge disposition). Total FIM scores as well as the motor and cognitive domains were examined. A matched sample of 30 pairs has 80% power to detect an effect size of 0.53 or larger using a two-sided paired *t*-test with a significance level of 0.05, where the effect size is defined as the difference in means divided by the standard deviation.

Results

Study population

The demographic and injury characteristics of the matched VR-SCI and T-SCI samples of 30 as well as the entire T-SCI sample of 573 are summarized in Table 2. When compared with all patients admitted with T-SCI ($n = 573$), patients with VR-SCI ($n = 30$) were older (mean age 57.2 vs. 40.0 years, $P < 0.001$) and more often presented with paraplegia (87 vs. 48%, $P < 0.0001$). Although not significant, VR-SCI patients had a nominally higher percentage of incomplete SCI (70 vs. 58%, $P = 0.20$).

Table 2 Demographic and injury characteristics

	VR-SCI ($n = 30$)	T-SCI ($n = 30$)	T-SCI ($n = 573$, all subjects)
		Mean (SD)	
Age*	57.2 (14.9)	54.9 (13.4)	40.0 (16.7)
		n (%)	
Gender			
Male	19 (63%)	25 (83%)	470 (82%)
Female	11 (37%)	5 (17%)	103 (18%)
Ethnicity			
White	17 (57%)	12 (40%)	263 (46%)
Black	13 (43%)	18 (60%)	309 (54%)
Marital status			
Married	16 (53%)	15 (50%)	193 (34%)
Single	4 (13%)	8 (27%)	270 (47%)
Divorced	4 (13%)	5 (17%)	60 (10%)
Widowed	5 (17%)	2 (7%)	23 (4%)
Separated	1 (3%)	0 (0%)	26 (5%)
AIS*			
Complete	9 (30%)	9 (30%)	239 (42%)
Incomplete	21 (70%)	21 (70%)	331 (58%)
Level of injury*			
Paraplegia	26 (87%)	26 (87%)	272 (48%)
Tetraplegia	4 (13%)	4 (13%)	297 (52%)

SD, standard deviation.
*Indicates matching variables.

Specific VR-SCI characteristics

Common etiologies for the VR-SCI group included: Aortic aneurysm-related complications such as surgical, post-surgical, or dissection (57%), arteriovenous malformation (17%), and systemic hypotension (13%). Others included idiopathic (6%), and embolic and coagulopathy (3% each). Pre-injury medical disorders most commonly identified for the VR-SCI group included: hypertension (63%), cardiovascular disease (53%), diabetes (30%), and atrial fibrillation (10%). Neurological levels of injury in VR-SCI were noted to be thoracic in 73%, lumbosacral in 17%, and cervical in 10%. AIS classifications included: AIS C (23%), AIS A and AIS B (30% each), and AIS D (17%). Common SCI-related complications in VR-SCI included neurogenic bowel/bladder (93%), urinary tract infection (73%), pain (67%), pressure ulcers (47%), spasticity (20%), and deep venous thrombosis and neuropathic pain (10% each).

Outcome measures

There were no significant differences between VR-SCI and T-SCI groups with respect to acute LOS (19.8 vs. 17.1 days, $P = 0.60$), rehabilitation LOS (35.3 vs. 36.3 days, $P = 0.76$), or discharge to home rates (80 vs. 67%, $P = 0.21$) (Table 3). Total, motor and cognitive measures of FIM admission, FIM discharge, FIM change, and FIM efficiency were analyzed for the

Table 3 LOS and discharge disposition, VR-SCI vs. T-SCI

	VR_SCI ($n = 30$)	T-SCI ($n = 30$)
	Mean (SD)	
Acute LOS (days)	19.8 (15.8)	17.1 (19.6)
Rehabilitation LOS (days)	35.3 (13.2)	36.3 (16.3)
	n (%)	
Discharge disposition		
Home	24 (80%)	20 (67%)
Nursing facility	2 (7%)	2 (7%)
Skilled nursing facility	3 (10%)	2 (7%)
Rehabilitation facility	1 (3%)	–
Acute unit of own facility	–	3 (10%)
Transitional living	–	1 (3%)
Other	–	2 (7%)

SD, standard deviation.

matched group (VR-SCI = 29 and T-SCI = 29). There was no evidence of significant differences between the VR-SCI and T-SCI groups with respect to any of these measures (Table 4).

Discussion

VR-SCI is an uncommon but disabling type of non-traumatic SCI. Its pathophysiology is most often related to ischemia secondary to arterial flow interruption, systemic hypotension, or vascular malformation, as were the etiologies noted in this study. The most common etiology was aortic aneurysm related, which has often been associated with spinal cord ischemia due to systemic hypotension or indirect occlusion of the radicular arteries. The vascular supply to the spinal cord (comprised of an anastomotic network of radicular arteries) allows for potential watershed ischemia, especially in the lower thoracic or upper lumbar region, which can result in paraplegia.

This study noted significant differences in demographic factors and SCI injury characteristics between VR-SCI and T-SCI groups. Individuals with VR-SCI were older and more often had paraplegia. Co-morbidities for VR-SCI include hypertension, cardiovascular disease, diabetes mellitus, and atrial fibrillation, which are more commonly found in older individuals. Paraplegic status, as mentioned above, relates to the location of spinal cord vascular watershed and ischemia. In addition, although not statistically significant, there was a meaningful trend toward incomplete injuries in the VR-SCI group. As VR-SCI is most often caused by ischemia (which may be transient) it may tend to result in more incomplete SCI. In contrast, T-SCI often results from mechanical disruption of the axons within the spinal cord resulting more often in complete SCI. Both older age, complete injuries, and higher neurological LOI have been shown to adversely affect functional outcomes in patients with SCI.[20–22] By matching the two groups for age, level, and completeness of injury, this study attempted to more adequately compare outcomes in VR-SCI patients to individuals in the more-often studied T-SCI group, by removing these differences from the groups.

This study noted that rehabilitation of the VR-SCI patient can result in improved functional outcomes; however, it did not reveal differences in functional outcome, LOS or disposition between the matched VR-SCI and T-SCI groups. Admission FIM scores between matched groups provided a basis to evaluate functional changes associated with the rehabilitation process. Ultimately, lack of significant difference in FIM change and FIM efficiency between the two groups may indicate that comparable rates of functional improvement were achieved despite differences in etiology of injury and associated medical issues. This suggests that the etiology of SCI (vascular vs. traumatic)

Table 4 FIM outcomes, VR-SCI vs. T-SCI

Variable	Vascular, Mean (SD) ($n = 29$)	Traumatic, Mean (SD) ($n = 30$)	Comparison	
			t (DF)	*P* value
FIM motor admission	29.9 (10.2)	29.2 (11.2)	0.33 (28)	0.7476
FIM Motor Discharge	51.1 (16.3)	53.3 (16.0)	−0.53 (28)	0.5984
FIM Motor Change	21.2 (11.3)	24.0 (12.1)	−1.13 (28)	0.2686
FIM Motor Efficiency	0.7 (0.5)	0.7 (0.5)	−0.26 (28)	0.7985
FIM Cognitive Admission	28.4 (4.6)	28.4 (5.9)	−0.07 (28)	0.9418
FIM Cognitive Discharge	30.7 (4.2)	32.2 (3.4)	−1.95 (28)	0.0608
FIM Cognitive Change	2.3 (2.8)	2.3 (2.8)	−1.44 (28)	0.1609
FIM Cognitive Efficiency	0.1 (0.1)	0.1 (0.2)	−1.44 (28)	0.1599
FIM Total Admission	58.3 (11.4)	57.6 (14.0)	0.23 (28)	0.8180
FIM Total Discharge	81.8 (17.3)	85.4 (18.0)	−0.91 (28)	0.3728
FIM Total Change	23.5 (11.8)	27.8 (13.1)	−1.68 (28)	0.1050
FIM Total Efficiency	0.8 (0.5)	0.8 (0.5)	−0.62 (28)	0.5434

SD, standard deviation; DF, degrees of freedom.

may not be as much of a factor in rehabilitation outcomes as the three criteria that were matched on (age, LOI, and AIS). It should be noted that lack of significant difference in functional outcomes between the two matched groups may represent either true comparability (not different) or lack of power within the study to detect the existing difference. This information may assist health care providers with decisions regarding rehabilitation along with management and prevention of medical complications. Rehabilitation strategies for individuals with VR-SCI should focus on maximizing functional outcomes (such as mobility and self-care), psychosocial adjustment and community reentry while minimizing secondary SCI complications.

Associated medical issues may have affected LOS. Patients with T-SCI often have acute medical issues arising from the trauma itself (such as spinal or hemodynamic instability, concomitant brain, or abdominal injuries or long-bone fractures) that can increase LOS. Similarly, LOS in VR-SCI patients may have been affected by time necessary for concomitant diagnostic procedures or treatment for pre-injury medical disorders (such as cardiovascular disease or diabetes), as were noted in many patients in this study. However, this study noted similarities in acute care and rehabilitation LOS in both VR-SCI and T-SCI matched groups.

This study also revealed that the SCI-related complications found in individuals with VR-SCI are similar to those typically seen in individuals with T-SCI (neurogenic bowel/bladder, urinary tract infection, pain, pressure ulcers, and spasticity). Spasticity had a low incidence in VR-SCI possibly due to lower motor neuron injury patterns that may accompany diffuse watershed ischemic injuries or a prolongation of spinal shock in VR-SCI. The key objectives of a comprehensive inpatient rehabilitation program must be to offer medical management, patient/family education and long-term prevention of future medical issues in order to maximize ongoing health. Future studies are encouraged to examine differences in complication rates, long-term functional outcomes, and mortality between these two SCI populations due to differences in demographics and co-morbidities.

Some limitations of this study deserve mention. The overall sample size of VR-SCI was small and utilized only one tertiary care rehabilitation center which could affect the generalizability of the results. Larger multisite studies are warranted to see if our findings are reproduced. Also, other between-group characteristics that could have affected outcomes may not have been measured or controlled for.

Conclusion

VR-SCI remains a less common presentation to a rehabilitation medicine unit; however, their clinical presentation and SCI-related complications can be similar to the more commonly seen traumatic SCI group. Thus, rehabilitation, to maximize functional and psychosocial outcomes and to address management of SCI-related complications, remains very important. This study notes significant differences in demographic and injury characteristics between VR-SCI and T-SCI groups. However, when matched on age, neurological level, and completeness of injury, rehabilitation functional outcomes were not significantly different between the two groups. Future studies are still recommended to more fully address functional outcomes, medical complications, quality of life, and long-term outcome.

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