Research Article

Malunions following lower extremity fractures in veterans with a spinal cord injury/disorder

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Background: Nearly 50% of all persons with a spinal cord injury/disorder (SCI/D) will sustain an osteoporotic fracture sometime in their life, with lower extremity fractures being the most common. There are a number of complications that can occur post fracture, including fracture malunion. To date, there have been no dedicated investigations of malunions among persons with SCI/D.

Objectives: The primary objective of this study was to identify risk factors associated with fracture malunion among fracture-related (type of fracture, fracture location, initial fracture treatment) and SCI/D-related factors. Secondary objectives were to describe treatment of fracture malunions and complications following these malunions.

Methods: Veterans with SCI/D with an incident lower extremity fracture and subsequent malunion from Fiscal Year (FY) 2005–2015 were selected from the Veteran Health Administration (VHA) databases using International Classification of Diseases, 9th edition (ICD-9) codes for lower extremity fractures and malunion. These fracture malunion cases underwent electronic health record (EHR) review to abstract information on potential risk factors, treatments and complications for malunion. Twenty-nine cases were identified with a fracture malunion with 28 of them successfully matched with Veterans with a lower extremity fracture during FY2005-FY2014 without a malunion (matched 1:4) based on having an outpatient utilization date of care within 30 days of the fracture case. There was trend towards more nonsurgical treatment in the malunion group ($n = 27$, 96.43%) compared to the control group ($n = 101$, 90.18%) ($P = 0.05$), though fracture treatment proved not to be not associated with developing a malunion in univariate logistic regression analyses (OR = 0.30; 95% CI: 0.08–1.09). In multivariate analyses, Veterans with tetraplegia were significantly less likely (approximately 3-fold) to have a fracture malunion (OR = 0.38; 95% CI: 0.14–0.93) compared to those with paraplegia. Fracture malunion was significantly less likely to occur for fractures of the ankle (OR = 0.02; 95% CI: 0–0.13) or the hip (OR = 0.15; 95% CI: 0.03–0.56) compared to femur fractures. Fracture malunions were rarely treated. The most common complications following malunions were pressure injuries (56.3%) followed by osteomyelitis (25.0%).

Conclusions: Persons with tetraplegia as well as fractures of the ankle and hip (compared to the femur) were less likely to develop a fracture malunion. Attention to prevention of avoidable pressure injuries following a fracture malunion is important.

Keywords: Spinal cord injury, Fracture, Malunion

Introduction

Osteoporotic fractures contribute to significant morbidity and mortality in persons with a spinal cord injury/disorder (SCI/D). Nearly 50% of the SCI/D population

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will incur a fracture sometime during their life, with lower extremity fractures being the most common. Persons with a SCI/D with lower extremity fractures who are treated in the Veterans Healthcare Administration (VHA) healthcare system have largely been managed non-surgically with the use of casts, braces, and splints (1). However, some studies have suggested that nonsurgical treatment of fractures is associated with an increased risk for fracture malunions (2, 3). Moreover, in one report, Veterans with a lower extremity fracture indicated that they would have preferred surgical treatment for their fracture but did not feel that they were actively involved in the decision making process for fracture treatment (4). However, a systematic review of outcomes following surgical and nonsurgical management of lower extremity fractures reported there was weak evidence for recommending surgical treatment (5).

The primary objective of this study was to identify risk factors associated with fracture malunion in persons with a SCI/D including fracture-related (type of fracture, fracture location) and SCI/D -related characteristics. The association of primary treatment for the fracture (surgical vs. nonsurgical) with the development of a fracture nonunion was examined. Secondary objectives included describing the treatments of fracture malunions and complications following these malunions.

Methods

Study participants

This was a retrospective case control study of Veterans with SCI/D identified from the VHA Allocation Resource Center (ARC) list using ICD-9 codes for SCI/D. The ARC was subsequently linked to the Spinal Cord Dysfunction (SCD) Registry and/or SCI/D Outcomes (SCIDO) database to confirm SCI status and obtain SCI/D-specific variables (etiology, extent of injury, neurologic level of injury, date of onset), and SCI/D-related healthcare utilization. Etiology was categorized as either traumatic or nontraumatic. Traumatic etiologies of SCI are those secondary to high-impact events, such as a motor vehicle accidents, gunshot wounds or high level falls. Nontraumatic etiologies include those related to cancer, arthritis, infections, ischemia or inflammatory or demyelinating diseases (such as multiple sclerosis, amyotrophic lateral sclerosis). The SCD Registry was created in 1996 as an operational tool to track Veterans with an SCI/D receiving care at the VHA's spinal cord centers. SCIDO later replaced the SCD Registry in 2010 and added clinical outcomes. The study period was defined as Fiscal Year (FY) 2005–2015.

Fracture malunion

A fracture malunion was defined as an encounter with an ICD-9 code for malunion (733.81) within the study period (FY2005–2015) present within the 365 days following an incident lower extremity fracture. An incident lower extremity fracture was defined as an ICD-9 code for a lower extremity fracture present (820–829, 722.14–733.16, 733.19, 733.10) and no other encounters with the same ICD-9 code in the preceding 120 days (6).

The electronic health records (EHR) of Veterans with a fracture malunion identified by ICD-9 codes were manually reviewed by 3 physicians and 3 medical students. The reviewers used a chart abstraction tool that they designed and adjudicated to confirm the fracture malunion and to record details of the characteristics, treatments, and complications associated with the case. A malunion was considered "present" if an ICD-9 code for a malunion was identified, and there was evidence of a malunion by radiographs and/or clinical notes. If an ICD-9 code for a malunion was identified, but there was no documentation of a malunion in either radiographs or clinical notes, these were not considered to be fracture malunions and these cases were excluded.

Comparison group

Controls from our prior study of nonunions was used as the comparison group. The details of their selection are published elsewhere.[2] The comparison group consisted of Veterans with SCI/D who had an ICD-9 code for a lower extremity fracture between FY2005 and FY2014, but no history of either malunion or nonunion by ICD-9 codes. The index date of the control was chosen as having an outpatient clinic encounter within a 30-day period of the fracture case. There were 1,746 Veterans in the comparison group eligible for matching.

Predictors of malunion

Data for possible predictors of malunion were aggregated from administrative database queries and EHR review. Fracture-related variables included fracture location (hip, femur, tibia/fibula, ankle, metatarsal), and type of fracture (open, closed). SCI/D-related characteristics were also examined including the etiology and duration of injury.

Fracture treatment was considered surgical if EHR review identified documentation of a related surgical procedure within 30-days post-fracture or nonsurgical if there was no procedure code or documentation of this in the EHR.

Treatments of malunion

Treatments following malunion were identified from EHR review. Surgical interventions considered were new hardware, hardware revision, osteotomy, open reduction with internal/external fixation, arthroplasty, and amputation. Nonsurgical management included bone stimulators, casts, immobilizing braces, and orthoses.

Complications of malunion

Complications following malunion were obtained from EHR review. These included pressure ulcerations, osteomyelitis, soft-tissue infection, amputations, thromboembolic phenomenon and secondary osteoarthritis. EHR review included the period up to 365 days post-fracture to search for these events and these events were included as a complication only if they were present at or near the fracture site.

Table 1 Baseline characteristics of matched (one to four) malunion study population.

Variable	Total (*N* = 140)	No Fracture Malunion (*N* = 112)	Fracture Malunion (*N* = 28)	P Value
Sex				
Male	136 (97.14)	110 (98.21)	26 (92.86)	0.06[a]
Female	4 (2.86)	2 (1.79)	2 (7.14)	
Etiology of SCI				
Non-Traumatic	31 (22.14)	23 (20.54)	8 (28.57)	0.16[a]
Traumatic	108 (77.14)	88 (78.57)	20 (71.43)	
Missing	1 (0.71)	1 (0.89)	0 (0)	
Duration of SCI				
Mean	21.64	21.26	23.14	0.35[b]
Std Dev	14.97	15.11	14.55	
Median	20.73	20.73	21.00	
Extent of SCI				
Incomplete	57 (47.11)	49 (48.04)	8 (42.11)	0.99[a]
Complete	64 (52.89)	53 (51.96)	11 (57.89)	
Neurologic Level of SCI				
Tetraplegia	55 (41.98)	50 (45.87)	5 (22.73)	0.001[a]
Paraplegia	76 (58.02)	59 (54.13)	17 (77.27)	
Fracture Treatment				
No	128 (91.43)	101 (90.18)	27 (96.43)	0.05[a]
Yes	12 (8.57)	11 (9.82)	1 (3.57)	
Fracture				
Ankle Fracture	26 (18.57)	25 (22.32)	1 (3.57)	0.0002[a]
Femur Fracture	33 (23.57)	22 (19.64)	11 (39.29)	
Hip Fracture	30 (21.43)	27 (24.11)	3 (10.71)	
Metatarsal Fracture	6 (4.29)	5 (4.46)	1 (3.57)	
Tibia/Fibula Fracture	45 (32.14)	33 (29.46)	12 (42.86)	
Open vs Closed Fracture				
Closed	139 (99.29)	111 (99.11)	28 (100)	N/A[c]
Open	1 (0.71)	1 (0.89)	0 (0)	

[a]McNemar's Test.
[b]Paired T-Test.
[c]P value could not be calculated as there was only 1 open fracture.

Statistical analyses

Each case was matched to four different controls, where a different control was used with each match to produce a sample without replacement. Cases were matched to controls based on date of incident fracture. There were 28 cases that were successfully matched within 30 days. One case could only be matched up to a minimum of 3334 days and was excluded from further analyses. This excluded case was a malunion which followed a surgically treated femur fracture in a male Veteran with a traumatic SCI. Baseline characteristics of the matched study population were examined using McNemar's Statistic or Paired T-Test when appropriate at a type I error of $\alpha = 0.05$ (Table 1).

Univariate and multivariate conditional logistic regression models were considered. Conditional, rather than unconditional, logistic regression was used because this was matched case–control data, with cases being matched to controls by exposure (that is, by incident fracture) (7). Univariate and multivariate conditional regression analyses with Odds Ratio's and 95% Confidence Intervals are shown in Table 2.

Table 2 Predictors of fracture malunion in those with lower extremity fractures (Matched Analyses 1 case to 4 controls).

Predictors	Fracture Malunion (Univariate) OR (95% CI)	Fracture Malunion (Multivariate) OR (95% CI)
Demographics		
Sex (Female vs Male)	4.0 (0.85–18.84)	
Fracture Treatment		
Surgical vs Non-Surgical	0.30 (0.08–1.09)	
SCI-Related Factors		
Etiology (Non-Traumatic vs Traumatic)	1.56 (0.83–2.93)	
Extent (Complete vs Incomplete)	1.00 (0.51–1.96)	
Neurologic Level (Tetraplegia vs Paraplegia)	0.32 (0.16–0.66)	0.38 (0.14–0.93)
Duration of Injury	1.01 (0.99–1.03)	
Fracture Related Characteristics		
Ankle vs Femur	0.06 (0.02–0.23)	0.02 (0–0.13)
Hip vs Femur	0.19 (0.07–0.50)	0.15 (0.03–0.56)
Metatarsal vs Femur	0.49 (0.11–2.10)	1.12 (0.10–16.32)
Tibia/Fibula vs Femur	0.61 (0.29–1.28)	0.58 (0.20–1.59)

Independent variables considered in univariate analyses included sex, SCI-related characteristics (etiology, duration, extent, level of injury), and fracture-related characteristics (fracture treatment and site of fracture). Sex and SCI-related characteristics were selected based on their associated risks for fracture in persons with SCI as well as with nonunion (2, 8–10). Fracture-related characteristics were chosen as fracture management and localization have been found to be independent predictors for nonunion (2, 8). Fracture type (closed vs. open) was not included because the majority of fractures were closed. Femur fractures were chosen as the referent group a previous study indicated these were the most frequent lower extremity site to incur a fracture nonunion (2). In multivariate conditional logistic regression only those variables significant in univariate analyses ($P < 0.05$) were entered into the model.

Statistical analyses were conducted using SAS release 9.4 (SAS Institute, Cary, NC) with two-sided P values reported.

The VA Institutional Review Boards at the Charlie Norwood VA Hospital, Augusta, Georgia, and the Hines VA Hospital, Hines, Illinois approved the study.

Results

There were 64,811 Veterans with SCI/D in the VHA ARC as of FY2016, with 57,502 Veterans identified in the desired study period between FY2005–2015. Among them, 6,005 Veterans had an ICD-9 code for an incident fracture during the study period. Eighty of these Veterans had an ICD-9 code for a malunion within 365 days of the incident fracture. Following EHR review, 51 Veterans were subsequently excluded due to no malunion ($n = 14$); no SCI ($n = 14$); the malunion resulting from a non-lower extremity fracture ($n = 9$); unknown fracture date or over 1 year prior to the malunion ($n = 5$); insufficient records ($n = 4$); the fracture occurring prior to or at the same time as the SCI ($n = 3$); the fracture being related to diabetes ($n = 1$); and no fracture ($n = 1$). No incident fracture was related to malignant neoplasm or Paget's disease on EHR review. Following all exclusions, there were 29 Veterans in the final study population with fracture malunion.

Baseline characteristics between those with and without a malunion following an incident lower extremity fracture are shown in Table 1. Nontraumatic etiologies included 4 Veterans with multiple sclerosis and another 4 with other etiologies (not shown). There were no significant differences between the matched malunion group and control group in terms of sex, etiology of SCI, duration of SCI, extent of SCI or open vs. closed fractures ($P > 0.16$ for all). There was a trend towards more nonsurgical treatment for fractures in the malunion group ($n = 27$, 96.43%) compared to the control group ($n = 101$, 90.18%) ($P = 0.05$). There was a significantly greater frequency of paraplegia in the malunion group ($n = 17$, 77.27%) compared to the control group ($n = 59$, 54.13%) ($P = 0.01$). Tibia/fibula and femur fractures were more frequent in the malunion group ($n = 12$, 42.86% for tibia/fibula; $n = 11$, 39.29% for femur) compared to the control group ($n = 33$, 29.46% for tibia/fibula, $n = 22$, 19.64% for femur) ($P = 0.0002$).

In multivariate conditional logistic regression analyses, those with a tetraplegia were significantly less likely to have a fracture malunion than those with a traumatic SCI (OR = 0.38; 95% CI: 0.14-0.93). Fracture malunion was significantly less like to occur for ankle and hip fractures in comparison to femur fractures (OR = 0.02, 95% CI: 0–0.13 and OR = 0.15, 95% CI: 0.03–0.56, respectively). The type of fracture treatment namely, surgical vs. non-surgical, was not significantly related to development of a fracture malunion (OR = 0.30; 95% CI: 0.08–1.09) (Table 2).

Treatments for fracture malunions are shown in Table 3. The majority of fracture malunions received no treatment (51.7% of all malunions), followed by surgical (37.9%) and nonsurgical (10.3%) interventions. In the surgically repaired malunion cases, the most common interventions were installation of new hardware (27.2% of all surgical treatments) and amputations

Table 3 Treatment for fracture malunion.

Type of Treatment	*n* (%)
Surgical	11 (37.9%)
New hardware (e.g. screws, plates, nails)	3 (10.3%)
Open reduction with internal fixation	1 (3.4%)
Removal of hardware	1 (3.4%)
Osteotomy	2 (6.9%)
Amputation	3 (10.3%)
Unspecified	1 (3.4%)
Nonsurgical	3 (10.3%)
Cast	1 (3.4%)
Brace	2 (6.9%)
No treatment	14 (51.7%)

Table 4 Complications of fracture malunion.

Complication	*n* (%)
Pressure Injury	9 (56.3%)
Osteomyelitis	4 (25.0%)
Thrombosis	1 (6.3%)
Osteoarthritis	1 (6.3%)
Abscess	1 (6.3%)

(27.2%), followed by osteotomy (18.2%), open reduction with internal fixation (9.0%), removal of hardware (9.0%), and an unspecified procedure (9.0%). Among nonsurgical interventions, braces (66.7% of all nonsurgical treatments) were the most common followed by casts (33.3%).

Complications occurred in half of all Veterans following the malunion (55.2%) and are reported in Table 4. The most common complications were pressure injuries (56.3%), followed by osteomyelitis (25.0%), thromboses (6.3%), osteoarthritis (6.3%) and abscess (6.3%). These complications occurred after the malunion had been documented in the EHR; however, three of these complications were those that had either persisted or were exacerbated during the fracture healing time period. There was one case of methicillin-resistant Staphylococcus aureus (MRSA) bacteremia that became an osteomyelitis; one case of a chronic ulcer that became an abscess; and one case of a persistent chronic ulcer that resulted in an amputation. Among Veterans who had surgical intervention for their malunion ($n = 11$, 37.9%), seven (63.6%) of them developed complications following the malunion. Among Veterans who had nonsurgical treatment for their malunion ($n = 18$, 62.1%), seven of them (38.9%) had complications following their malunion.

Discussion

In Veterans with a SCI/D, a significantly higher proportion of Veterans with paraplegia developed a fracture malunion. Fracture site was also significantly different between those with and without a fracture malunion. There were more frequent tibia/fibula and femur fractures in the fracture malunion group, and more frequent hip, ankle, and metatarsal fractures in the control group. In multivariable logistic regression analyses, tetraplegia and ankle and hip fractures (compared to femur fractures) were associated with a decreased risk for developing a malunion. The type of treatment for the initial fracture (surgical vs. nonsurgical) was not a risk factor for a fracture malunion, although more fractures that developed a malunion were treated nonsurgically. More than half of all malunions led to complications, with the most common being pressure injuries (56.3%) and osteomyelitis (25.0%).

To our knowledge, this is the first study to determine risk factors for fracture malunions as an independent event among persons with SCI/D. Existing reports have only accounted for malunions collectively with other complications (3, 8, 11–17), Further, these reports (3, 16) only had a small number of malunions.

In this series, Veterans with tetraplegia had an approximately 3-fold decreased risk for developing a fracture malunion compared to those with paraplegia. There are no studies of fracture malunions among persons with SCI/D for comparison; however, epidemiological studies of fractures in persons with SCI/D suggest that paraplegia (compared to tetraplegia) is associated with an increased risk for fracture (18). A potential explanation for this may be related to greater ambulatory ability among persons with paraplegia. It is possible that forces exerted with standing and walking in paraplegia may result in a greater probability for malalignment during the fracture healing process.

That ankle and hip fractures are associated with a decreased risk for fracture compared to femur fractures are similar to results from our prior study looking at fracture nonunions among Veterans with SCI/D (2). In that study, fractures of the distal femur were associated with an increased risk for fracture nonunion. Considered in tandem, it may be that distal femur fractures are associated with an increased risk for nonunions, and that this location may be more susceptible to the unique biomechanics required of persons with SCI/D and can also result in malignment (such as with ambulation as previously mentioned in paraplegia or with bed-to-wheelchair transfers).

Fracture malunion was not significantly associated with type of initial fracture treatment in this study. This contrasts to several prior retrospective case series which suggest that nonsurgical treatment of lower extremity fractures in SCI/D often leads to more overall complications compared to surgical treatment. One series of 40 patients with SCI/D with 50 lower extremity fractures reported a two-fold higher rate of overall complications following conservative management of these fractures compared to surgical treatment (3). In that series, two malunions were observed among post-fracture complications in the nonsurgical group and none in the surgical group. Other case series also report high rates of complications following fractures treated nonsurgically compared to those treated surgically, though malunions were not specifically reported (8, 11–15, 17). Surgical treatment has also been associated with earlier union and shorter inpatient length-of-stay (19). Despite this, the vast majority of lower extremity fractures in SCI/D at the VA are still treated nonsurgically (1), although some Veterans have reported that they would have preferred surgical management for their lower extremity fracture (4). It is worthy to note that there was a trend towards more nonsurgical interventions among the malunion cases in this investigation. Further studies are needed to determine a more precise relationship between type of initial treatment of fractures to fracture-healing complications, including malunion. Comparing fractures treated surgically and nonsurgically may perhaps be too general. Several case series and reports have been published on different surgical techniques in lower limb fractures with SCI (20–23), and it may be that surgical technique may matter more. In accord, one retrospective study of 58 chronic SCI patients treated surgically concluded that longer implants should be considered in treating lower extremity fractures, that the poor architecture of osteoporotic bone and impaired sensorimotor feedback leading to longer biomechanical momentum in SCI may play important roles in hindering osteosynthesis (18, 23).

We noted in this series that fracture malunions were often left untreated. This is in contrast to practices in the general population in which surgical correction of lower extremity malunions are commonly performed for the restoration of function (24–26). Notably, however, the majority of those with a fracture malunion incurred some sort of complication from their malunions, the most common being pressure injuries and osteomyelitis. Furthermore, a higher proportion of post-malunion complications had their malunions treated surgically. Thus, further studies should explore whether treatment of fracture malunions is associated with an increased risk for developing future complications in persons with SCI/D.

There are some limitations to this study. The sample size for malunions was small (29 cases) which increased the possibility of committing a type II error. Greedy matching algorithms were used to match controls to cases (4:1) where each case was matched to a unique control four times to replicate sampling without replacement and thus mitigate this problem. Nine ICD-9 codes for malunion from our query were excluded because neither the incident fracture nor the malunion could be confirmed or refuted on EHR review. These exclusions may have introduced bias which would have underestimated the effects we observed. Furthermore, one malunion from a surgically-managed femur fracture was unable to be matched; however, we performed additional analyses where we matched this case to four controls by incident fracture date of >30 days (3 different controls at 3,380 days and 1 control at 3,383 days), and fracture treatment still was not a significant predictor for developing a fracture malunion. Additionally, there was also a trend towards nonsurgical treatment for the malunion group, yet this is likely due to the relatively few cases of fractures being treated surgically as historically been done at the VA and is a limitation to using the VA SCD Registry. Thus, this trend needs further exploration. Similarly, there were few female Veterans among our cases, which is also reflective of the VA SCD Registry as it is comprised of predominantly male Veterans (97.6%) (24). As this was a database study, not all malunions may have been correctly coded. Furthermore, while the occurrence of an incident fracture and subsequent malunion could be confirmed by provider notes and radiographic reports, radiographs were not readily available for review. As such, Orthopedic Trauma Association (OTA) fracture classification could not be utilized (27). Further studies should focus on obtaining precise OTA classification for these fractures.

In conclusion, persons with SCI/D with tetraplegia or fractures of the ankle or hip (compared to femur fractures) are less likely to develop a malunion. The occurrence of a malunion is not associated with how a fracture was treated. Fracture malunions are frequently untreated, but often result in secondary complications, most commonly pressure injuries. Future studies should explore whether interventions to correct malunions can reduce complications and improve function.

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