Clinical Study

Health-related quality-of-life outcomes after thoracic (T1–T10) fractures

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Abstract

BACKGROUND CONTEXT: The thoracic spine exhibits a unique response to trauma as the result of recognized anatomical and biomechanical differences. Despite this response, clinical studies often group thoracic fractures (T1–T10) with more caudal thoracolumbar injuries. Subsequently, there is a paucity of literature on the functional outcomes of this distinct group of injuries.

PURPOSE: To describe and identify predictors of health-related quality-of-life outcomes and re-employment status in patients with thoracic fractures who present to a spine injury tertiary referral center.

STUDY DESIGN: An ambispective cohort study with cross-sectional outcome assessment.

PATIENT SAMPLE: A prospectively collected fully relational spine database was searched to identify all adult (>16 years) patients treated with traumatic thoracic (T1–T10) fractures with and without neurologic deficits, treated between 1995 and 2008.

OUTCOME MEASURES: The Short-Form-36, Oswestry Disability Index, and Prolo Economic Scale outcome instruments were completed at a minimum follow-up of 12 months. Preoperative and minimum 1-year postinjury X-rays were evaluated.

METHOD: Univariate and multivariate regression analysis was used to identify predictors of outcomes from a range of demographic, injury, treatment, and radiographic variables.

RESULTS: One hundred twenty-six patients, age 36 ± 15 years (mean ± SD), with 135 fractures were assessed at a mean follow-up of 6 years (range 1–15.5 years). Traffic accidents (45%) and translational injuries (54%) were the most common mechanism and dominant fracture pattern, respectively. Neurologic deficits were frequent—53% had complete (American Spinal Injury Association impairment scale [AIS] A) spinal cord deficits on admission. Operative management was performed in 78%. Patients who sustain thoracic fractures, but escaped significant neurologic injury (AIS D or E on admission) had SF-36 scores that did not differ significantly from population norms.

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Introduction

Thoracic (T1–T10) fractures are a distinct group of injuries. The thoracic spine exhibits a unique response to trauma as the result of recognized anatomical and biomechanical differences including the protective presence of the rib cage and sternum, “normal” kyphotic alignment, and an almost 1:1 cord canal ratio. Despite their uniqueness, a paucity of data are available regarding the outcomes of thoracic spine fractures as they are usually grouped with more caudal thoracolumbar injuries.

To date the limited published outcomes following thoracic fractures have focused mostly on neurologic sequelae [1–5]. Functional recovery measured by validated health-related quality-of-life (HRQOL) instruments has been rarely documented [2], especially in patients who do not incur neurologic injury. Consequently, anticipated patient-orientated outcomes and re-employment prospects after thoracic spinal trauma, which is information of significant interest to patients, their families and society, remains poorly understood.

The primary objective of this study is to determine the medium- and long-term generic and disease-specific HRQOL outcomes and re-employment status of patients after contemporary treatment of thoracic (T1–T10) fractures at a spine injury tertiary referral center and to compare these measures with population norms. Given that the goal of treatment of these injuries is to return patients to their status before injury, we hypothesize that the medium- and long-term outcomes will not differ between this population and a healthy sample. The secondary objective is to identify predictors of outcome from a range of patient, injury, radiologic, and treatment variables.

Materials and methods

Study design

The study involved an ambispective (both retrospective outcome collection and prospective patient recruitment) cohort analysis with cross-sectional outcome assessment. Following institutional ethics approval, our spine unit’s prospectively collected fully relational spine database was searched to identify all adult patients (age > 16 years), with traumatic (nonpathologic) thoracic (T1–T10) fractures, with and without neurologic deficit, treated between 1995 and 2008. Our institution is a level-I trauma center serving a population of 4.5 million with acute care for spinal column and cord injuries.

Baseline demographic, injury, and treatment variables collected from the database included age, sex, insurance status, American Spinal Injury Association (ASIA) impairment scale (AIS) [6] (on admission), Injury Severity Score (ISS) [7], injury level, treatment modality (eg, pedicle screws, hooks, brace) and numbers of levels fused during surgical stabilization. Adverse events were identified by retrospective chart review.

Pretreatment, immediate posttreatment (after surgery or application of a brace) and minimum 1-year postinjury plain radiographs and/or computed tomography and/or magnetic resonance imaging scans were used to assign fracture type (compression, burst, flexion-distraction, hyperextension, translation/rotational injury) and to calculate kyphotic deformity using the Cobb angle method. This angle was measured from the inferior endplate of the adjacent normal vertebra below the fracture site and the superior end plate of the adjacent normal vertebra above the fracture site on lateral plain radiographs or reconstructed sagittal computed tomography images.

Consenting patients were contacted by mail to complete the Short Form (SF)-36v2 health survey, the Prolo Economic Scale [8], the Charlson Comorbidity Index [9] and, if neurologically intact (AIS E) on admission, the Oswestry Disability Index (ODI) [10]. Neurologically intact patients admitted between 1995 and 2002 had previously completed the ODI in 2004. These subjects were asked to complete a repeat set of questionnaires (in 2010/11) to obtain longer-term data and to allow comparison with earlier results.

HRQOL outcome instruments

The SF-36v2 is a 36-item measure of generic HRQOL comprising 8 health dimensions. The dimensions of physical

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functioning, role-physical, bodily pain, and general health combine to calculate an aggregate Physical Component Summary (PCS) score, whereas vitality, social functioning, and role emotional and mental health scales combine to create a Mental Component Summary (MCS) score. The questionnaire has been shown to be reliable, valid, and responsive when administered by mail. Norm-based scoring methods were used so that both the PCS and MCS have a population mean of 50±10 SD. Published normative values for the Canadian population exist for comparison [11].

The Prolo Economic Scale [8] offers five occupational “grades” that express the patient’s current employment status ranging from complete inability to work (E1) to ability to work at previous occupation without restrictions (E5). This scale has been viewed favorably as a guide to a patient’s capacity for gainful employment.

The ODI [10] assesses disability caused by back pain by the use of 10 sections representing everyday activities. Answers are translated into a quantitative score on a scale of 0 to 100, with greater scores reflecting more disability. It has been widely used and thoroughly validated as a functional outcome instrument in spine care assessment [12].

To understand which variables independently influenced selected outcomes, multiple regression analysis was performed of varying patient, injury, radiologic, and treatment factors.

**Statistical analysis**

The means of the dependent variables (SF-36 MCS, PCS, and subscale scores, ODI) were compared with their respective normative population means [11] using a 2-sided t test (SAS/Stat PROC TTEST). The null hypothesis was that the mean value of the outcome scores (dependent variable) was equal to the normative mean for that variable. The alternative hypothesis was that the mean dependent variable value was less than the normative mean.

Univariate regressions of the dependent variables (SF-36 MCS, PCS, Physical Functioning subscale, Bodily Pain subscale, Prolo Economic Scale) were completed for each independent variable with the use of SAS/Stat PROC GLM. Multiple regressions were calculated against the selected independent variables using SAS/Stat PROC GLM. For each of the dependent variables, a multivariate linear regression was used to assess the association of the independent variables. The independent variables included in the regression analyses were selected by the level of significance (p<.05) in the univariate regressions.

**Results**

**Cohort characteristics**

A total of 321 patients fulfilled the inclusion criteria. One hundred twenty-six patients completed the health outcome questionnaires, for a response rate of 39%. Demographic, injury, and treatment variables of those that declined to participate were compared with the consenting group (Table 1). Statistically significant differences were noted with the study cohort involving greater numbers of translational injury patterns, greater rates of serious neurological deficits (AIS A, B, or C) and surgical intervention.

**Context**

Thoracic and lumbar fractures are often lumped together when assessing outcomes. The authors specifically set out to look at thoracic fractures in isolation.

**Contribution**

Using validated outcome measures and a prospectively established database, the authors assessed outcomes in 126 patients with an average age of 36 who had fractures from T1 to T10. They found that at six years patients who initially presented with good neurological function generally did quite well, while those with significant neurological injury at presentation had inferior outcomes and employment issues.

**Implications**

The information is helpful prognostically, allowing patients to have more accurate (and realistic) expectations regarding expected outcomes.

—The Editors

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<table>
<thead>
<tr>
<th>Table 1</th>
<th>Patient demographics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographic variables</strong></td>
<td><strong>Cohort</strong></td>
</tr>
<tr>
<td>N (total number of fractures)</td>
<td>126 (132)</td>
</tr>
<tr>
<td>Age (mean±SD years)</td>
<td>35.7±14.5</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>102 (81%)</td>
</tr>
<tr>
<td>Female</td>
<td>24 (19%)</td>
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<td>Fracture type</td>
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<td>Translational</td>
<td>68 (54%)</td>
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<td>Burst</td>
<td>32 (25%)</td>
</tr>
<tr>
<td>FDI</td>
<td>18 (14%)</td>
</tr>
<tr>
<td>Compression</td>
<td>6 (5%)</td>
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<tr>
<td>Hyperextension</td>
<td>2 (2%)</td>
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<tr>
<td>Level of injury</td>
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<tr>
<td>T1–T4</td>
<td>33 (24%)</td>
</tr>
<tr>
<td>T5–T10</td>
<td>102 (76%)</td>
</tr>
<tr>
<td>AIS</td>
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<tr>
<td>A, B, and C</td>
<td>85 (67%)</td>
</tr>
<tr>
<td>D and E</td>
<td>41 (33%)</td>
</tr>
<tr>
<td>Treatment</td>
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<tr>
<td>Surgical</td>
<td>97 (78%)</td>
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<tr>
<td>Nonsurgical</td>
<td>28 (22%)</td>
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</table>

AIS, American Spinal Injury Association impairment scale; FDI, flexion distraction injury.

* Significant (p<.05) differences between the two groups were noted.
The study cohort comprised 135 fractures in 102 male and 24 female patients with a mean age of 35.7 years (range, 16–77 years). Common mechanisms of injury included traffic accidents (45%), sports participation (29%), and falls (24%). Although injuries at all levels of the thoracic spine were noted, fractures to the upper region were uncommon (Fig. 1).

Injuries were classified as anterior compression (5%), burst (25%), flexion-distraction (14%), hyperextension (2%), or translational/rotational (ie, fracture/dislocations: 54%) type patterns. Nine patients had multiple fractures. All involved anterior compression fractures at other levels in addition to the dominant fracture morphology for which they were categorized.

On admission, complete spinal cord deficits (AIS A) were confirmed in 53% of patients (Fig. 2). Twenty-nine percent of patients presented neurologically intact (AIS E), including 11% of patients with translational injury morphology (Fig. 3).

The ISS was used to quantify the associated injuries and severity of trauma sustained by each patient. The mean ISS of the cohort was 27. Polytrauma has been defined as an ISS > 18 [13]. This criterion was reached in 98 (78%) patients.

Ninety-eight (78%) patients were treated surgically. All compression fractures were treated nonoperatively. For other injury patterns, surgical stabilization was selected by the use of criteria included in the Thoracolumbar Injury Classification and Severity Score system [14]. All procedures were performed via a posterior approach, with transpedicular instrumentation used in 92 (73% of the total population) and hooks or hybrid fixation in 6 (5% of the total population). Conservative management (either bed rest/Jewett brace/thoracolumbosacral orthosis) was prescribed for the remaining 28 (22%).

Adverse events were experienced by 62 (49%) patients, with 15 (12%) considered major. Nine (7%) required revision surgery (excluding simple hardware removal). Indications included debridement of deep infection (4), revision fixation for loss of alignment (4), and decompression of a posttraumatic syrinx (1). Pulmonary embolism occurred in 6 (5%). Minor adverse events included urinary tract infection (10%), pneumonia (13%), superficial wound infection (2%), unintended durotomy (2%), and deep vein thrombosis (4%).

Table 2
SF-36 Physical Component and Mental Component Summary scores

<table>
<thead>
<tr>
<th>SF-36</th>
<th>Admission AIS (A+B+C)</th>
<th>Admission AIS (D+E)</th>
<th>Population norms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Component Summary</td>
<td>38.7±8.4*</td>
<td>47.5±11.9</td>
<td>50.5±9.0</td>
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<tr>
<td>Mental Component Summary</td>
<td>46.9±9.9*</td>
<td>48.7±12.1</td>
<td>51.7±9.1</td>
</tr>
</tbody>
</table>

AIS, American Spinal Injury Association impairment scale.

Short-Form (SF) 36 Component Summary Scores (Physical and Mental) for thoracic fractures with significant (AIS A+B+C) or no or minimal (AIS D+E) neurological deficit on admission. Comparison to Canadian population norms.

* Significant (p<.05) difference from population norms.
Outcome analysis

Mean survey follow-up for the entire cohort averaged 6 years (range, 1–15.5 years). At final follow-up SF-36 PCS (p=.12) and MCS (p=.13) scores in patients with minimal or no neurologic deficit (AIS D and E) were not significantly different to Canadian population norms [11]. In patients with more profound neurologic deficits (AIS A, B, and C) SF-36 PCS (p<.0001), MICS (p<.1) scores remained significantly inferior to normative data (Table 2).

Dividing the complete study cohort according to fracture type revealed mean SF-36 PCS scores at final follow-up remained significantly depressed compared with population norms for burst (44.3±10.8, p=.003), flexion/distraction (42.1±11.6, p=.001) and translational fracture types (39.2±9.3, p=.001). Mean SF-36 MCS outcomes were likewise significantly inferior to normative data for flexion distraction (47.2±12.0, p=.035) and translational injuries (46.3±12.2, p=.0006) but not burst fractures (49.3±9.3, p=.16). Subdividing the various fracture types into those with and without neurologic deficits resulted in groups with insufficient numbers of patients to allow additional data analysis.

Predictors of outcome (regression analysis)

Regression analysis was used to identify predictors of outcomes from a range of study variables, including age, sex, comorbidity, insurance status, fracture type, fracture level, admission AIS, ISS, adverse events, numbers of levels fused during surgical stabilization, and kyphosis (Cobb angle) pretreatment, posttreatment (initial X-ray postsurgery or application of a brace) and at final follow-up. The outcomes analyzed included SF-36 PCS, MCS, Physical Functioning, and Bodily Pain subscale scores.

Multivariate regression using an analysis of covariance model was run that included those variables that were significant to 0.05 in univariable analysis (R-square=0.238, coefficient of variation=22.33). Comorbidity (as measured by the Charlson Comorbidity Index [9]) was the only independent predictor of SF-36 PCS (p=.0011) for the complete cohort (other variables significant in univariable analysis included AIS, Fracture Type, ISS, Adverse Events, Numbers of Levels Fused), AIS on admission (p=.0001) and number of adverse events (p=.0481) were identified as independent predictors of SF-36 Physical Functioning outcomes (other variables significant in univariable analysis included ISS, fracture type). No predictors of SF-36 Bodily Pain scores were identified.

Employment status (Prolo Economic Scale)

Current employment status, as measured using the Prolo economic scale, reveal that 88% of patients who escaped major neurological injury (AIS D or E) had returned to the workforce, with 71% returning to their previous level with or without limitations. In contrast 57% of those with significant neurologic deficits on presentations (AIS A, B or C) were re-employed, 25% in their previous job type with or without limitations. Univariate analysis identified AIS, fracture type, final kyphosis, and ISS as predictors of re-employment status, with AIS on admission the only significant (p=.0048) independent predictor on multivariate analysis.

Oswestry Disability Index

Disease-specific HRQOL outcomes, specifically disability due to back pain, were assessed in neurologically intact (AIS E, n=37) patients using the ODI. At a mean follow-up of 5.4 years, scores averaged 16.1. These outcomes compare to published mean scores in healthy subjects of 10.19 [12].

Temporal pattern of HRQOL outcome recovery

In a subcohort of 17 neurologically intact (AIS E) patients, ODI scores were available at two time points in their recovery, with mean scores demonstrating significant clinical [15] improvement from 32.9 at mean follow-up of 3.0 years to 17.3 at mean 6.7 years postinjury (p=.004).

Discussion

Thoracic fractures (T1–T10) are common, comprising 24% of all thoracic and lumbar injuries [16]; however, they have received little specific attention in the contemporary spinal literature and often are grouped inappropriately with other thoracolumbar injuries, despite characteristics unique to this region of the spine. This homogeneous cohort of 135 thoracic fractures managed using contemporary methods, to our knowledge, is the largest, with the longest follow-up reported in the literature.

In contrast to the lumbar region, the thoracic spine is characterized by its kyphotic posture, thinner and less mobile discs, and facet joints orientated such that less sagittal movement but greater axial rotation is possible. However, the dominant distinction of the thoracic region centers on the additional support imparted by the rib cage and sternum. Using human cadavers, Watkins et al. [17] reported that an intact rib cage and sternum increases the stability of the thoracic spine in flexion/extension, lateral bending, and axial rotation by 31% to 40%. These quantities substantiate the opinion of Berg who, referencing Denis three-column model of spinal stability, proposed the sternum and ribs represent an additional “fourth” column of stability [18].

The inherent stability of the thoracic spine suggests that, compared with the thoracolumbar junction and lumbar regions, greater energy is necessary to create thoracic fractures [1,19,20]. In support of this notion is the recognition of a high proportion of polytrauma patients (mean ISS = 27), typically young men involved in traffic accidents, in this study and others [3,21–24]. Recently, an association between severe thoracic fractures and air bags also has been reported [25].

A significant percentage of associated severe neurologic deficits with thoracic fractures is also consistent with earlier
In this series, 68% presented with AIS A, B, or C neurology. Contributing factors include the limited space for the spinal cord within its osseous surroundings coupled with high-energy mechanisms frequently resulting in translational injury patterns (41% of injuries in this study). It is also appreciated that injury to the thoracic spinal cord has reduced recovery potential compared with injury to the conus medullaris and cauda equina.

Associated multisystem injuries often make nonoperative treatment of thoracic injuries, with an orthosis or prolonged recumbency, undesirable, if not unsafe. In our cohort treatment involved surgical stabilization in 78% of cases with the adoption of pedicle screw instrumentation reflecting the evolving acceptance that this technique can be performed accurately and safely for thoracic spine injuries.

Thoracic fracture functional outcomes

So far, only a handful of studies in the English literature have reported outcomes in cohorts of solely thoracic fractures. Most of these have focused on neurologic results, with little attention given to other patient-oriented functional outcomes. Dai reported “pain localized to the site of fracture” in 13 of 37 neurologically intact patients at a follow-up of 2–15 years. McLain et al. noted recovery of full-time employment status in 12 (75%) of 16 surgically stabilized patients, whereas Krengel et al. reported 5 (36%) of 14 patients returned to work full-time after thoracic injuries with associated incomplete neurological deficits. Place et al. showed a reduced length of initial rehabilitation but increased complications in operatively managed thoracic fractures associated with complete paraplegia, compared with those managed nonoperatively.

The distinctive characteristics of thoracic injuries and the lack of published outcome data suggest greater assessment is necessary to accurately prognosticate and favorably influence management of these injuries.

To assess outcomes in a more reliable and patient-oriented way, validated generic and disease-specific HRQOL instruments increasingly are being used. These standardized scoring systems enable comparisons with other spinal injuries, different medical and surgical conditions, and can be referenced against population norms. To date, only Fisher et al. specifically has detailed validated HRQOL outcomes after thoracic fractures. In a select group of 27 patients with upper thoracic (T1–T5) fractures, they noted inferior SF-36 health survey scores compared with normative data at a mean 3.2 years after transpedicular stabilization. By detailing validated outcome measures in 126 thoracic fracture patients, this study has started to address a significant knowledge void.

Our study reports that patients who sustain thoracic fractures, but escape significant neurological injury (AIS D or E on admission), had generic HRQOL scores (SF-36 PCS and MCS) that did not differ significantly from population norms at a mean follow-up of 6 years. In addition, 88% of this cohort was re-employed. Interestingly, greater disability caused by back pain, accessed via the ODI, remains compared with healthy subjects. Of note ODI scores in the same neurologically intact patients were significantly lower...
superior at a mean follow-up of 6.7 years compared with the earlier 3-year time-point, challenging the prevailing opinion that after spinal trauma all recovery parameters plateau within 1 to 2 years of injury.

Our data suggest outcomes after thoracic fractures are favorable compared with other spinal injuries with minimal or no neurologic deficits when assessed with the same generic scoring instrument (Fig. 4) [33–40]. SF-36 scores have been reported to be inferior to population norms for cohorts of thoracolumbar (T11-L2) burst fractures managed nonoperatively [33,39], flexion distraction injuries (T11-L2) [35], Jefferson fractures [34], C2 injuries (including type II and II odontoid fractures) [36], and subaxial cervical injuries treated with either anterior decompression, fusion and plating [37,40] or posterior instrumented fusion [40], albeit at varying follow-up intervals. To our knowledge, only unilateral cervical facet injuries have recorded superior SF-36 PCS scores at the final follow-up [38].

The outcomes for thoracic fractures with associated neurologic sequelae were less favorable. SF-36 PCS and MCS scores were significantly lower than population norms, with an inferior re-employment rate of 57%.

Using multiple regression analysis, comorbidity status (measured by the Charlson Comorbidity Index) was the only independent predictor of generic HRQOL (SF-36 PCS and MCS). Neurologic impairment (AIS) and adverse events were independent predictors of the SF-36 physical functioning subscale only. This adverse events burden should prompt interest in strategies to avoid and optimally treat these potentially avoidable events in the quest for better outcomes following spinal trauma.

Sagittal mal-alignment, either before or after treatment, was not an independent predictor of outcome, a result that is consistent with literature on the thoracolumbar spine. We did not find an association with outcomes and the numbers of levels fused, in keeping with the common practice of placing less emphasis on limiting the extent of fixation in the thoracic region compared with the more mobile portions of the spine.

Although this study provides impactful information to the published literature, limitations exist. The low response rate (39%) is somewhat typical of trauma cohorts and somewhat expected with long-term follow-up. Statistical analysis of those eligible but who did not participate showed the study group to be a cohort of relatively more severe injuries. As such, these outcome measures should be interpreted as reflecting baseline or conservative recovery expectations. This only strengthens our contention that patients with thoracic fractures who remain neurologically intact can expect to recover a generic HRQOL equivalent to that enjoyed by the general public. Our cohorts characteristics, such as the proportion of patients in whom surgical treatment is indicated and the number presenting with associated neurologic injury, is likely to be influenced by the referral pattern to our institution, a spine injury tertiary referral center. Limited numbers of thoracic fractures with no or minor neurological deficits precluded subgroup analysis of the effect of different fracture types on outcomes. An a priori decision was made to analyze AIS D and E patients together. Incomplete spinal cord injury patterns are uncommon with thoracic injuries and the minor neurological deficits characteristic of this subgroup have a favorable prognosis. As anticipated our cohort included few AIS D patients (n=4). Regardless, the HRQOL scores for AIS E patients only may be better than our combined results indicate.

Conclusions

At mean follow-up of 6 years, patients who presented with thoracic fractures and AIS D or E neurologic status recover a general health status (SF-36 PCS and MCS) not significantly inferior to population norms and have a favorable prognosis compared with other spinal injuries. Almost 90% of patient had returned to the workforce.

In contrast, the generic HRQOL outcomes for patients that present with AIS A, B, or C neurology do not return to levels seen in the normal population. Only 57% regained employment. Comorbidity profile was the only independent predictor of generic SF-36 PCS outcomes, with AIS on admission the only independent predictor of re-employment status. ODI scores after thoracic fractures with no neurology continue to improve beyond 3 years.

References