

Early Predictors of Health-Related Quality of Life Outcomes in Polytrauma Patients with Spine Injuries: A Level 1 Trauma Center Study

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Abstract

Study Design Retrospective review on clinical-quality trauma registry prospective data.

Objective To identify early predictors of suboptimal health status in polytrauma patients with spine injuries.

Methods A retrospective review on a prospective cohort was performed on spine-injured polytrauma patients with successful discharge from May 2009 to January 2011. The Short Form 12-Questionnaire Health Survey (SF-12) was used in the health status assessment of these patients. Univariate and multivariate logistic regression models were applied to investigate the effects of the Injury Severity Score, age, blood sugar level, vital signs, brain trauma severity, comorbidities, coagulation profile, spine trauma-related neurologic status, and spine injury characteristics of the patients.

Results The SF-12 had a 52.3% completion rate from 915 patients. The patients who completed the SF-12 were younger, and there were fewer patients with severe spinal cord injuries (American Spinal Injury Association classifications A, B, and C). Other comparison parameters were satisfactorily matched. Multivariate logistic regression revealed five early predictive factors with statistical significance ($p \leq 0.05$). They were (1) tachycardia (odds ratio [OR] = 1.88; confidence interval [CI] = 1.11 to 3.19), (2) hyperglycemia (OR = 2.65; CI = 1.51 to 4.65), (3) multiple chronic comorbidities (OR = 2.98; CI = 1.68 to 5.26), and (4) thoracic spine injuries (OR = 1.54; CI = 1.01 to 2.37). There were no independent early predictive factors identified for suboptimal mental health-related quality of life outcomes.

Conclusion Early independent risk factors predictive of suboptimal physical health status identified in a level 1 trauma center in polytrauma patients with spine injuries were tachycardia, hyperglycemia, multiple chronic medical comorbidities, and thoracic spine injuries. Early spine trauma risk factors were shown not to predict suboptimal mental health status outcomes.

Keywords

- ▶ health-related quality of life (HRQoL)
- ▶ health status
- ▶ functional outcome
- ▶ SF-12
- ▶ spine trauma
- ▶ spinal cord injury
- ▶ predictive variables
- ▶ prognosis

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Introduction

Decision making with regards to the definitive management of severely injured polytrauma patients with spine trauma is a field with significant variation in practice. The definitive management of these patients should include consideration of not only the spine injury characteristics such as the injury morphology, discoligamentous integrity, and neurologic status but also quantifiable parameters of the patient's clinical state such as comorbidities, coagulation status, age of the patient, and the overall polytrauma severity.

Despite spine trauma involving both the spinal cord and spine column, research on spinal cord injuries is more prevalent than research on spine column trauma. The annual incidence of spine column trauma is 640 cases per million compared with 14 to 51 cases per million for spinal cord injuries.¹⁻⁷ Prior studies have attempted to describe early independent predictive variables of spine trauma mortality. One recent study investigated the association between spine trauma mortality and its independent early predictive factors, and subdivided its predictive variables into two types, "irreversible" and "reversible" variables.⁸ Irreversible variables are variables that are innate characteristics of the patient or primary injuries that have already taken place, and reversible variables are those that can be normalized or treated with active management. Using multivariate analysis, this study identified elderly age group, multiple comorbidities, and severe polytrauma as irreversible independent predictors of mortality in polytrauma patients with spine injuries. It also identified coagulopathy, hypoxia, and hemodynamic instability as reversible independent predictors of mortality in the same patient cohort. Interestingly, it showed that spine injury variables had no independent effect on the mortality of these patients.

Our study aimed to identify independent early predictive variables associated with suboptimal physical and mental patient-reported outcomes in polytrauma patients with spine injuries. This has not previously been reported and may assist in the understanding and definitive management of these patients.

Methods

Definition

The term *early* is defined in our study as a 48-hour period commencing from admission and treatment at a level 1 state-designated trauma institution.

Site and Study Groups

The Alfred Trauma Service consistently treats 55% of major trauma cases per year in the state of Victoria, Australia.^{9,10} The Alfred Trauma Service admits on average 1,200 severe polytrauma patients per year, with 300 to 350 severe polytrauma patients suffering spine trauma with 30% of these patients requiring spine surgery.

The Alfred Trauma Registry and in-hospital database were used to identify all spine trauma patients admitted for spine trauma management at the Alfred Hospital, Melbourne,

Australia with successful discharge between May 1, 2009, and January 1, 2011. The Victorian Orthopaedic Trauma Outcomes Registry was used for provision of Short Form 12-Questionnaire Health Survey (SF-12) 1-year outcome data.^{11,12}

Standard Data Set and Data Set Variable Definitions

The Alfred Spine Trauma Registry minimum data set was used for data collection and has been described previously.^{13,14} Mild, moderate, and severe polytrauma was defined as Injury Severity Score (ISS) < 9, ISS 9 to 15, and ISS > 15, respectively.¹⁵ Mild, moderate, and severe traumatic brain injury (TBI) was defined as Glasgow Coma Scale (GCS) of 13 to 14, GCS of 9 to 12, and GCS of 3 to 8, respectively, all with radiographic evidence of brain injury. Coagulation profile was deranged with pretrauma consumption of antiplatelet or anticoagulation medication, elevated international normalized ratio of >1.3 or activated partial thromboplastin time of >38 seconds within the first 48 hours of injury. Recorded blood sugar levels were defined as normal with levels between 4 to 8 mmol/L and high with levels of >8 mmol/L. The value recorded was the highest value obtained within the first 48 hours of injury. ► **Table 1** lists the definitions of vital sign anomalies. The recorded vital sign values were the most deranged values documented either by paramedics at the scene of injury or by emergency department staff. Spine trauma neurologic deficits are defined as patients suffering nerve root injuries only or spinal cord injuries. Spinal cord injuries were graded using the American Spinal Injury Association (ASIA) classification. Retrospective clinical data and radiographic review was performed for both groups with patient data acquired from The Alfred's acute care electronic medical record (PowerChart, Cerner Solutions, Kansas City, Missouri, United States).

Potential Early Predictors of Spine Trauma Health-Related Quality of Life Outcomes

Age, Premorbid Medical Conditions, Coagulation Profile, and Mechanism of Injury

Elderly is defined as 65 years and above.¹⁶ Elderly patients often have chronic comorbidities, which may reduce life span and complicate the surgical decision making and intensive care treatment. These patients are also often on antiplatelet and anticoagulation agents. Injury mechanism in spine trauma has been well described with high-impact injury mechanisms leading to more severe polytrauma.

Table 1 Vital signs and their definitions

Vital sign	Definition
Hypoxia	Oxygen saturation < 95%
Hypotension	Systolic blood pressure < 100 mm Hg
Hypothermia	Temperature < 36.5°C
Hypertension	Systolic blood pressure > 160 mm Hg
Bradycardia	Heart rate < 60/min
Tachycardia	Heart rate >100/min

Neurologic Status, Injury Segment, Total Injury Levels, and Injury Morphology

The assessment of injury morphology, discoligamentous integrity, and neurologic status are crucial determinants in the management of a spine trauma patient.^{17,18}

Although the relationship between spine injury characteristics and early spine trauma mortality predictive variables has been elucidated, its relationship with early spine trauma HRQoL predictive variables has not.⁸

Injury Severity Score

The ISS is an internationally validated and accepted trauma score, which allows for direct comparison between polytrauma patients. It has been shown to be a good predictor of survival and mortality.¹⁹

Severity of Traumatic Brain Injury

TBI is common in a polytrauma patient.²⁰ An elderly patient with TBI has poorer functional outcome than a young patient despite suffering less severe polytrauma.²¹

Vital Signs

These parameters form the basis of patient assessment and are important markers of a trauma patient's medical stability and convalescence.

Blood Sugar Level

It has been shown that hyperglycemia at trauma admission is associated with overall morbidity (greater infection rate and hospital length of stay) and mortality.^{22–26}

Short Form 12-Questionnaire Health Survey

The SF-12 assesses health-related quality of life (HRQoL) and measures health status in a generic fashion and thus allows comparison across different populations. The Short Form Health Survey has been studied extensively in many trauma subgroups and has been recommended for use in trauma registries.²⁷ This health survey has two versions, 36 questionnaires or SF-36 and 12 questionnaires or SF-12. The SF-12 has been validated for use in Europe, United States, and Australia.^{28–30} The SF-12 has two summary scales: (1) Physical Composite Score (PCS) describing physical well-being and (2) Mental Composite Score (MCS) describing mental well-being. The SF-12 regards people with scores of more than 50 as not disabled, 40 to 49 as mildly disabled, 30 to 39 as moderately disabled, and below 30 as severely disabled.³⁰ In this study, patients with satisfactory outcome have PCS and MCS composite scores of ≥ 50 as they have no HRQoL disability, and patients with scores < 50 have varying degrees of disability and thus, suboptimal outcome.

Statistical Analyses

Health-Related Quality of Life Predictive Factors—Physical Domain

Group demographics were summarized using frequencies and percentages for all continuous variables and categorical variables except for the ISS, which was summarized using

median and frequency values. Only variables that showed a trend toward suboptimal PCS outcomes (PCS score < 50) were selected for univariate analysis.

All predictive univariate associations with outcome were investigated using simple linear regression analysis and unadjusted odds ratios (ORs) to identify independent spine trauma HRQoL suboptimal predictive factors. Corresponding 95% confidence intervals (CIs) and significant p values of ≤ 0.05 were used to select predictive variables for multiple logistic regression analysis. As the dependent variable was dichotomous, a binary logistic regression model was utilized for data analysis. Model fit was assessed using the omnibus test of model coefficients and Hosmer and Lemeshow test. The model's Classification table was used to ensure satisfactory accuracy in classification. A binary logistic regression model identified statistically significant independent suboptimal HRQoL predictor variables. This was performed using estimate adjusted ORs, significant p values of ≤ 0.05 and 95% CIs. All analyses were performed using the Statistical Package for the Social Sciences program (Version 20, SPSS Inc., Chicago, Illinois, United States).

Health-Related Quality of Life Predictive Factors—Mental Domain

The statistical method described above was repeated for analysis of the study population using the MCS of the SF-12.

Results

General Cohort Characteristics

The general cohort consisted of 915 spine trauma patients. ►Table 2 shows the general cohort baseline demographics: 68.1% were male, mean age was 50.3 years (SD = 21.9 years), and 28.2% were elderly (≥ 65 years). The median ISS was 14 with 45.9% suffering severe polytrauma (ISS > 15). Motor vehicle accidents (44.3%) and falls from more than 1 m (19.5%) were the most common injury mechanisms; 16.7% of the patients suffered TBI. ►Table 3 shows the general cohort spine injury characteristics. The majority suffered no spinal neurologic deficit (93%); 42% suffered injury at a single spinal level; and 20.9% suffered spine injury at four or more levels. From a total of 2,191 spine injury levels suffered, the thoracic spine was the most injured (39%).

Cohort Comparison Characteristics—Completed SF-12 versus Uncompleted SF-12

There was a 52.3% completion rate of the SF-12 for the general cohort. ►Table 2 shows the baseline demographics, and ►Table 3 shows the spine injury characteristics of the two comparison cohorts.

Out of 479 patients, the completed SF-12 cohort had 71.8% males, mean age of 47.5 years (standard deviation [SD] = 19.1 years) and 21.7% elderly (≥ 65 years). The median ISS was 14 with 48.6% suffering severe polytrauma (ISS > 15). Motor vehicle accidents (46.8%) and falls from more than 1 m (20.7%) were the most common injury mechanisms; 16.7% suffered TBI. In terms of spine injury characteristics, the majority suffered no spinal neurologic deficit (92.9%); 3.5% suffered nerve root injuries, of which 2.9% were ASIA D and

Table 2 Demographics and clinical characteristics of the general cohort and the cohorts with completed and uncompleted SF-12 Health Surveys

Demographics and clinical characteristics	General cohort (n = 915)	Completed SF-12 Health Survey cohort (n = 479)	Uncompleted SF-12 Health Survey cohort (n = 436)
Age			
Mean (\pm SD)	50.3 (\pm 21.9)	47.5 (\pm 19.1)	53.4 (\pm 24.1)
Elderly (\geq 65 y)	258 (28.2%)	104 (21.7%)	154 (35.3%)
Gender			
Male	623 (68.1%)	344 (71.8%)	279 (64%)
Female	292 (31.9%)	135 (28.2%)	157 (36%)
Ratio	2.1	2.5	1.8
Mechanism of injury			
Motor vehicle occupants	406 (44.3%)	224 (46.8%)	182 (41.7%)
Unprotected road users	121 (13.2%)	59 (12.3%)	62 (14.2%)
Low falls (<1 m)	138 (15.1%)	52 (10.9%)	86 (19.7%)
High falls (>1 m)	178 (19.5%)	99 (20.7%)	79 (18.1%)
Significant collision (not road related)	61 (6.7%)	40 (8.4%)	21 (4.8%)
Other causes	11 (1.2%)	5 (1%)	6 (1.4%)
Injury Severity Score			
Median	14	14	14
25th/75th percentile	9/22	9/22	9/22
Severe	420 (45.9%)	233 (48.6%)	187 (42.9%)
Traumatic brain injury			
None	762 (83.3%)	399 (83.3%)	363 (83.3%)
Yes	153 (16.7%)	80 (16.7%)	73 (16.7%)

Abbreviations: SD, standard deviation; SF-12, Short Form 12-Questionnaire Health Survey.

0.7% were ASIA A, B, and C. A single spinal level was injured in 38.8% and 22.6% suffered injuries to four or more levels. From a total of 1,101 spine injuries, the thoracic spine was the most commonly injured (38.3%).

Out of 436 patients, the uncompleted SF-12 cohort had 64% males, mean age of 53.4 years (SD = 24.1 years) and 35.3% elderly (\geq 65 years). The median ISS was 14 with 42.9% patients suffering severe polytrauma (ISS > 15). Motor vehicle accidents (41.7%) and falls from less than 1 m (19.7%) were the most common injury mechanisms; 16.7% patients suffered TBI. In terms of spine injury characteristics, the majority suffered no spinal neurologic deficit (93.1%); 3.2% suffered nerve root injuries, of which 1.4% were ASIA D and 2.3% were ASIA A, B, and C. A single spinal level was injured in 46.8% and 17.9% suffered injury to four or more levels. From a total of 1,090 spine injuries, the thoracic spine was the most commonly injured (38.8%).

SF-12 Physical Composite Score Cohort

Cohort Comparison Characteristics—PCS < 50 versus PCS \geq 50

► **Tables 4 and 5** show the study population demographics, clinical characteristics, and spine injury characteristics as

stratified by the SF-12 PCS. Out of 323 patients, the PCS < 50 or suboptimal PCS scores cohort had 68.1% males, mean age of 49.9 years (SD = 18.6 years), 23% elderly (\geq 65 years), and 41.5% with chronic medical comorbidities. The median ISS was 17 with 53% patients suffering severe polytrauma (ISS > 15). Motor vehicle accidents (52.6%) and falls from more than 1 m (18%) were the most common injury mechanisms. In addition, 37.2% had normal vital signs, 38.1% had hyperglycemia, and 29.4% were coagulopathic, and 5.6% patients suffered moderate or severe TBI. In terms of spine injury characteristics, the majority suffered no spinal neurologic deficit (94.1%), and 2.5% suffered nerve root injuries, of which 2.5% were ASIA D and 0.9% were ASIA A, B, and C. In all, 37.2% suffered injury at a single spinal level and 16.4% suffered injury in five or more levels. From a total of 737 spine injuries, the thoracic spine was the most commonly injured (41%).

Out of 156 patients, the PCS \geq 50 or optimal PCS scores cohort had 79.5% males, mean age of 42.4 years (SD = 19.3 years), 19% elderly (\geq 65 years), and 17.9% with chronic medical comorbidities. The median ISS was 13 with 39.7% patients suffering severe polytrauma (ISS > 15). Motor vehicle accidents (34.6%) and falls from more than 1 m

Table 3 Spinal injury characteristics of the general cohort and the cohorts with completed and uncompleted SF-12 Health Surveys

Spinal injury characteristics	General cohort (n = 915)	Completed SF-12 Health Survey cohort (n = 479)	Uncompleted SF-12 Health Survey cohort (n = 436)
Neurologic status			
Intact	851 (93%)	445 (92.9%)	406 (93.1%)
NRI only	31 (3.4%)	17 (3.5%)	14 (3.2%)
SCI	33 (3.6%)	17 (3.5%)	16 (3.7%)
ASIA D	20 (2.2%)	14 (2.9%)	6 (1.4%)
ASIA A, B, and C	13 (1.4%)	3 (0.7%)	10 (2.3%)
Injury levels per patient			
Mean	2.4	2.6	2.2
1	384 (42%)	186 (38.8%)	204 (46.8%)
2	222 (24.3%)	116 (24.2%)	106 (24.3%)
3	117 (12.8%)	69 (14.4%)	48 (11%)
4 or more	191 (20.9%)	108 (22.6%)	78 (17.9%)
Total injury levels	2191	1101	1090
Spine injury by segments			
C0–C2	172 (7.9%)	72 (6.5%)	100 (9.2%)
C3–C7	460 (21%)	235 (21.3%)	225 (20.6%)
T1–T12	845 (39%)	422 (38.3%)	423 (38.8%)
L1–L5	656 (30%)	346 (31.4%)	310 (28.4%)
Sacrococcygeal	58 (2.1%)	26 (2.5%)	32 (3%)

Abbreviations: ASIA, American Spinal Injury Association classification of spinal cord injury; NRI, nerve root injury; SCI, spinal cord injury; SF-12, Short Form 12-Questionnaire Health Survey.

(26.3%) were the most common injury mechanisms. In all, 56.4% had normal vital signs, 13.5% had hyperglycemia, and 14.1% were coagulopathic; 1.9% patients suffered moderate or severe TBI. In terms of spine injury characteristics, the majority suffered no spinal neurologic deficit (90.4%). In addition, 5.8% suffered nerve root injuries, of which 3.8% were ASIA D and none were ASIA A, B, or C. In all, 41% suffered injury at a single spinal level and 11.5% suffered injury to five or more levels. From a total of 364 spine injuries, the lumbar spine was the most commonly injured (34.6%).

Physical Domain: Univariate Analysis

–Tables 4 and 5 show the univariate associations of spine trauma predictive variables based on the SF-12 PCS. Nine univariate predictors of suboptimal physical functional outcome with statistical significance ($p \leq 0.05$) were identified. They were severe ISS (OR = 1.71; CI = 1.16 to 2.51), hypoxia (OR = 1.73; CI = 1.06 to 2.82), hypotension (OR = 1.97; CI = 1.08 to 3.61), hypertension (OR = 2.72; CI = 1.45 to 5.11), tachycardia (OR = 2.42; OR = 1.53 to 3.82), hyperglycemia (OR = 3.95; CI = 2.37 to 6.60), coagulopathy (OR = 2.54; CI = 1.52 to 4.23), multiple chronic comorbidities (OR = 0.54;

CI = 0.31 to 0.92), and thoracic spine injuries (OR = 1.41; CI = 1.08 to 1.84).

Physical Domain: Multivariate Regression Analysis

Model Selection and Design

The Hosmer and Lemeshow test and omnibus test of model coefficients confirmed the model fit. Four independent spine trauma risk factors predictive of suboptimal physical HRQoL outcomes were identified (–Table 6). The final multivariate regression model correctly classified 69.9% of cases overall. The sensitivity and specificity of the model was 87.9 and 32.7%, respectively. Its positive predictive and negative predictive values were 73 and 56.7%, respectively.

Early Spine Trauma Suboptimal Physical HRQoL Predictive Variables (Adjusted)

Variables shown to be independent spine trauma predictors of suboptimal physical HRQoL with statistical significance ($p \leq 0.05$) were tachycardia (OR = 1.88; CI = 1.11 to 3.19), hyperglycemia (OR = 2.65; CI = 1.51 to 4.65), multiple chronic comorbidities (OR = 2.98; CI = 1.68 to 5.26), and thoracic spine injuries (OR = 1.54; CI = 1.01 to 2.37).

Table 4 Comparison of demographics and clinical characteristics using the SF-12 PCS and its associated univariate analysis

Demographic and clinical characteristics	PCS < 50 (n = 323)	PCS ≥ 50 (n = 156)	Odds ratio; 95% CI	p value
Age				
Mean (± SD)	49.9 (± 18.6)	42.4 (± 19.3)	–	–
Elderly	74 (23%)	30 (19%)	1.25; 0.78–2	0.36
Gender				
Male	220 (68.1%)	124 (79.5%)	–	–
Female	103 (31.9%)	32 (20.5%)	–	–
Ratio	2.1	3.9	–	–
Mechanism of injury				
Motor vehicle occupants	170 (52.6%)	54 (34.6%)	–	–
Unprotected road users	41 (12.7%)	18 (11.5%)	–	–
Low falls (<1 m)	33 (10.2%)	19 (12.2%)	–	–
High falls (>1 m)	58 (18%)	41 (26.3%)	–	–
Significant collision (not road related)	19 (5.9%)	21 (13.5%)	–	–
Other causes	2 (0.6%)	3 (1.9%)	–	–
Injury Severity Score				
Median	17	13	–	–
25th/75th percentile	10/24	9/21	–	–
Severe	171 (53%)	62 (39.7%)	1.71; 1.16–2.51	<0.01
Vital signs				
Normal	120 (37.2%)	88 (56.4%)	–	–
Hypoxia	83 (25.7%)	26 (16.7%)	1.73; 1.06–2.82	0.03
Hypotension	56 (17.3%)	15 (9.6%)	1.97; 1.08–3.61	0.03
Hypertension	64 (19.8%)	13 (8.3%)		<0.01
Bradycardia	9 (2.8%)	5 (3.2%)	2.72; 1.45–5.11	–
Tachycardia	118 (36.5%)	30 (19.2%)	2.42; 1.53–3.82	<0.01
Hypothermia	24 (7.4%)	5 (3.2%)	2.42; 0.91–6.48	0.08
Blood sugar level (mmol/L)				
< 8	200 (61.9%)	135 (86.5%)	–	–
≥ 8	123 (38.1%)	21 (13.5%)	3.95; 2.37–6.60	<0.01
Coagulation profile				
Normal	228 (70.6%)	134 (85.9%)	–	–
Deranged	95 (29.4%)	22 (14.1%)	2.54; 1.52–4.23	<0.01
Traumatic brain injury				
None	264 (81.7%)	135 (86.5%)	–	–
Mild	41 (12.7%)	18 (11.5%)	1.11; 0.62–2.01	0.72
Moderate/severe	18 (5.6%)	3 (1.9%)	3.0; 0.87–10.38	0.08
Chronic comorbidities				
None	127 (39.3%)	90 (57.7%)	–	–
1	62 (19.2%)	38 (24.4%)	0.74; 0.47–1.17	0.19
2 or more	34 (41.5%)	28 (17.9%)	0.54; 0.31–0.92	0.02

Abbreviations: CI, confidence interval; PCS, Physical Composite Score; SD, standard deviation; SF-12, Short Form 12-Questionnaire Health Survey. Note: Variables in **bold** demonstrate trend toward suboptimal SF-12 PCS scores.

Table 5 Comparison of spine injury characteristics using the SF-12 PCS and its associated univariate analysis

Spine injury characteristics	PCS < 50 (n = 323)	PCS ≥ 50 (n = 156)	Odds ratio; 95% CI	p value
Neurologic status				
Intact	304 (94.1%)	141 (90.4%)	–	–
NRI only	8 (2.5%)	9 (5.8%)	–	–
SCI	11 (3.4%)	6 (3.8%)	–	–
ASIA D	8 (2.5%)	6 (3.8%)	–	–
ASIA A, B, and C	3 (0.9%)	0	3.42; 0.18–66.69	0.42
Injury levels per patient				
1	120 (37.2%)	64 (41%)	–	–
2	76 (23.5%)	38 (24.4%)	–	–
3	45 (13.9%)	24 (15.4%)	–	–
4	29 (9%)	12 (7.7%)	1.18; 0.59–2.39	0.64
5 or more	53 (16.4%)	18 (11.5%)	1.50; 0.85–2.67	0.16
Total injury levels	737	364	–	–
Spine injury by segments				
C0–C2	42 (5.7%)	30 (8.2%)	–	–
C3–C7	156 (21.2%)	79 (21.7%)	–	–
T1–T12	302 (41%)	120 (33%)	1.41; 1.08–1.84	0.01
L1–L5	220 (29.9%)	126 (34.6%)	–	–
Sacroccoccygeal	17 (2.3%)	9 (2.5%)	–	–

Abbreviations: ASIA, American Spinal Injury Association classification of spinal cord injury; CI, confidence interval; NRI, nerve root injury; PCS, Physical Composite Score; SCI, spinal cord injury; SF-12, Short Form 12-Questionnaire Health Survey.

Note: Variables in **bold** demonstrate trend toward suboptimal SF-12 PCS scores.

SF-12 Mental Composite Score Cohort

Cohort Comparison Characteristics—MCS < 50 versus MCS ≥ 50

► **Tables 7** and **8** show the study population demographics, clinical characteristics, and spine injury characteristics as stratified by the SF-12 MCS. Out of 193 patients, the MCS < 50 or suboptimal MCS scores cohort had 67.9% males, mean

age of 46.4 years (SD = 17.5 years), 16.1% elderly (≥65 years), and 36.8% with chronic medical comorbidities. The median ISS was 17 with 54.9% patients suffering severe polytrauma (ISS > 15). Motor vehicle accidents (56.5%) and falls from more than 1 m (13.5%) were the most common injury mechanisms. Overall, 38.3% had normal vital signs, 35.8% had hyperglycemia, and 22.8% were coagulopathic; 4.7% patients suffered moderate or severe TBI. In terms of spine

Table 6 Binary logistic regression analysis of early spine trauma health-related quality of life predictive variables using the SF-12 Physical Composite Scale

Predictive variables	OR	95% CI	p value
Severe polytrauma (ISS ≥ 15)	1.11	0.70–1.77	0.65
Hypoxia	0.89	0.51–1.58	0.70
Hypotension	1.77	0.88–3.54	0.11
Hypertension	1.60	0.83–3.12	0.16
Tachycardia	1.88	1.11–3.19	0.02
Hyperglycemia (>8mmol/L)	2.65	1.51–4.65	<0.01
Coagulopathy	1.13	0.62–2.05	0.69
Multiple comorbidities	2.98	1.68–5.26	<0.01
Thoracic spine injuries	1.54	1.01–2.37	0.05

Abbreviations: CI, confidence interval; ISS, Injury Severity Score; OR, odds ratio; SF-12, Short Form 12-Questionnaire Health Survey.

Note: Variables in **bold** are independent early spine trauma physical Health-Related Quality of Life predictive variables.

Table 7 Comparison of demographics and clinical characteristics using the SF-12 MCS and its associated univariate analysis

Demographic and clinical characteristics	MCS < 50 (n = 193)	MCS ≥ 50 (n = 286)	Odds ratio; 95% CI	p value
Age				
Mean (± SD)	46.4 (± 17.5)	48.2 (± 20.2)	–	–
Elderly	31 (16.1%)	73 (25.5%)	–	–
Gender				
Male	131 (67.9%)	213 (74.5%)	–	–
Female	62 (32.1%)	73 (25.5%)	–	–
Ratio	2.1	2.9	–	–
Mechanism of injury				
Motor vehicle occupants	109 (56.5%)	115 (40.2%)	–	–
Unprotected road users	24 (12.4%)	35 (12.2%)	–	–
Low falls (<1 m)	17 (8.8%)	35 (12.2%)	–	–
High falls (>1 m)	26 (13.5%)	73 (25.5%)	–	–
Significant collision (not road related)	15 (7.8%)	25 (8.7%)	–	–
Other causes	2 (1%)	3 (1%)	–	–
Injury Severity Score				
Median	17	14	–	–
25th/75th percentile	12/25	9/22	–	–
Severe	106 (54.9%)	127 (44.4%)	1.53; 1.06–2.20	0.02
Vital signs				
Normal	74 (38.3%)	134 (46.9%)	–	–
Hypoxia	49 (25.4%)	60 (21%)	1.28; 0.83–1.97	0.26
Hypotension	35 (18.1%)	34 (11.9%)	1.64; 0.98–2.74	0.06
Hypertension	31 (16.1%)	48 (16.8%)	0.95; 0.58–1.55	0.83
Bradycardia	6 (3.1%)	8 (2.8%)	1.12; 0.38–3.27	0.84
Tachycardia	66 (34.2%)	82 (28.7%)	1.29; 0.87–1.91	0.20
Hypothermia	13 (6.7%)	16 (5.6%)	1.22; 0.57–2.60	0.61
Blood sugar level (mmol/L)				
< 8	124 (64.2%)	211 (73.8%)	–	–
≥ 8	69 (35.8%)	75 (26.2%)	1.57; 1.05–2.32	0.03
Coagulation profile				
Normal	149 (77.2%)	213 (74.5%)	1.16; 0.76–1.78	0.50
Deranged	44 (22.8%)	73 (25.5%)	–	–
Traumatic brain injury				
None	154 (79.8%)	245 (85.7%)	–	–
Mild	30 (15.5%)	29 (10.2%)	1.63; 0.94–2.81	0.08
Moderate/severe	9 (4.7%)	12 (4.1%)	1.12; 0.46–2.70	0.81
Chronic comorbidities				
None	79 (40.9%)	138 (48.3%)	–	–
1	43 (22.3%)	57 (19.9%)	1.15; 0.73–1.80	0.54
2 or more	71 (36.8%)	91 (31.8%)	1.25; 0.85–1.83	0.26

Abbreviations: CI, confidence interval; MCS, Mental Composite Score; SD, standard deviation; SF-12, Short Form 12-Questionnaire Health Survey. Note: Variables in **bold** demonstrate trend toward suboptimal SF-12 MCS scores.

Table 8 Comparison of spine injury characteristics using the SF-12 MCS and its associated univariate analysis

Spine injury characteristics	MCS < 50 (n = 193)	MCS ≥ 50 (n = 286)	Odds ratio; 95% CI	p value
Neurologic status				
Intact	179 (92.7%)	266 (93%)	–	–
NRI only	10 (5.2%)	7 (2.4%)	1.25; 0.85–1.83	0.26
SCI	4 (2.1%)	13 (4.5%)	–	–
ASIA D	3 (1.6%)	11 (3.8%)	–	–
ASIA A, B, and C	1 (0.5%)	2 (0.7%)	–	–
Injury levels per patient				
1	74 (38.3%)	110 (38.5%)	–	–
2	38 (19.7%)	76 (26.6%)	–	–
3	26 (13.5%)	43 (15%)	–	–
4	17 (8.8%)	24 (8.4%)	1.05; 0.55–2.02	0.87
5 or more	38 (19.7%)	33 (11.5%)	1.88; 1.13–3.12	0.01
Total injury levels	482	619	–	–
Spine injury by segments				
C0–C2	20 (4.1%)	52 (8.4%)	–	–
C3–C7	106 (22%)	129 (20.8%)	1.07; 0.80–1.43	0.64
T1–T12	205 (42.5%)	217 (35.1%)	1.37; 1.07–1.75	0.01
L1–L5	141 (29.3%)	205 (33.1%)	–	–
Sacrococcygeal	10 (2.1%)	16 (2.6%)	–	–

Abbreviations: ASIA, American Spinal Injury Association classification of spinal cord injury; CI, confidence interval; MCS, Mental Composite Score; NRI, nerve root injury; SCI, spinal cord injury; SF-12, Short Form 12-Questionnaire Health Survey.

Note: Variables in **bold** demonstrate trend toward suboptimal SF-12 MCS scores.

injury characteristics, the majority suffered no spinal neurologic deficit (94.1%), and 5.2% suffered nerve root injuries, of which 1.6% were ASIA D and 0.5% were ASIA A, B, and C. In addition, 38.3% suffered injury at a single spinal level, and 19.7% suffered injuries to five or more levels. From a total of 482 spine injury levels suffered, the thoracic spine was the most commonly injured (42.5%).

Out of 286 patients, the MCS ≥ 50 or optimal MCS scores cohort had 74.5% males, mean age of 48.2 years (SD = 20.2 years), 25.5% elderly (≥65 years), and 31.8% with chronic medical comorbidities. The median ISS was 14 with 44.4% patients suffering severe polytrauma (ISS > 15). Motor vehicle accidents (40.2%) and falls from more than 1 m (25.5%) were the most common injury mechanisms. In addition, 46.9% had normal vital signs, 26.2% had hyperglycemia, and 25.5% were coagulopathic. Overall, 4.1% patients suffered moderate or severe TBI. In terms of spine injury characteristics, the majority suffered no spinal neurologic deficit (93%); 2.4% suffered nerve root injuries, of which 3.8% were ASIA D and 0.7% were ASIA A, B, or C. In addition, 38.5% suffered injury at a single spinal level and 11.5% suffered injury to five or more levels. From a total of 286 spine injuries, the thoracic spine was the most commonly injured (35.1%).

Mental Domain: Univariate Analysis

– **Tables 7 and 8** show the univariate associations of spine trauma predictive variables based on the SF-12 MCS. Five

univariate predictors of suboptimal physical functional outcome with statistical significance ($p < 0.05$) were identified. They were severe ISS (OR = 1.53; CI = 1.06 to 2.20), hypotension (OR = 1.64; CI = 0.98 to 2.74), hyperglycemia (OR = 1.57; CI = 1.05 to .32), injury to five or more spine levels (OR = 1.88; CI = 1.13 to 3.12), and thoracic spine injuries (OR = 1.37; CI = 1.07 to 1.75).

Mental Domain: Multivariate Regression Analysis

Model Selection and Design

The Hosmer and Lemeshow test and omnibus test of model coefficients confirmed the model fit. None of the early spine trauma predictive variables were shown to predict suboptimal mental HRQoL outcomes. The selected multivariate regression model correctly classified 61.6% of cases overall. The sensitivity and specificity of the model was 18.1 and 90.9%, respectively. The positive predictive and negative predictive values were 57.4 and 62.2%, respectively.

Discussion

This study is unique as the study population was a prospective cohort captured by clinical-quality registries consisting of polytrauma patients with spine column and spinal cord injuries.¹⁴ This study is novel as it investigates the association between spine trauma risk factors assessed within the initial

48 hours after trauma and HRQoL or health status outcomes. It is interesting that there were more patients (53.4%) with satisfactory mental well-being than patients (32.6%) with satisfactory physical well-being. Perhaps, the patients were grateful that they have survived their traumatic injuries despite their disabilities. As the study population is large, this effect is likely to be real. Furthermore, this effect is consistent with the spinal cord injury cohort in the state of Victoria where the median mental health scores were higher than the general population norm.³¹

This study identified four independent early risk factors predictive of suboptimal physical health status or HRQoL assessable within the first 48 hours after spine trauma. After adjusting for confounders, reversible risk factors identified were tachycardia and hyperglycemia. Irreversible risk factors identified were multiple medical comorbidities. Patients with thoracic spine injuries were also found to have poor physical health status outcomes.

Tachycardia was the sole vital sign abnormality that was predictive of poor physical functional outcome. This is likely to be a surrogate for patients with multiple chronic medical comorbidities such as atrial fibrillation or pain, rather than the patient being in extreme posttrauma physiologic disturbance. We believe that a decompensating critically ill polytrauma patient will present primarily with hypotension and tachycardia, and not tachycardia alone. Nonetheless, trauma assessment and intervention based on the Advanced Trauma Life Support course of the American College of Surgeons recommends the urgent investigation and treatment of any vital sign anomaly in a trauma patient. Patients with multiple chronic comorbidities in the suboptimal physical HRQoL cohort outnumbered those in the good physical HRQoL cohort by a multiple of 2.3. A significant proportion of these patients are on antiplatelet or anticoagulation medications as part of their active or prophylactic treatment of their medical conditions. At our center, spine trauma patients with chronic medical comorbidities are reviewed on a daily basis by internal medicine physicians to ensure medical optimization of their comorbidities and to prevent undertreatment of nontraumatic disorders. Patients with coagulopathy and on antiplatelet medications have their coagulopathy urgently treated, especially if there is a requirement for surgical procedures or to prevent extension of traumatic hemorrhages. Hyperglycemia has been shown to have a positive association with the degree of injury severity and age. It is also an independent predictor of increased intensive care and hospital length of stay in the trauma population.^{22,23,26}

It is interesting to note that thoracic spine injuries independently predict suboptimal physical health status. In our study, the majority of spine injuries were in the thoracic segment. It is possible that thoracic spine injuries may act as a surrogate for associated severe thoracic injury despite severe ISS not being an independent multivariate variable for suboptimal physical HRQoL. The integrity of the thoracic spine requires much more violent or greater force to disrupt than the cervicothoracic or thoracolumbar junction and is therefore more likely to be associated with chest injuries and rib

and sternal fractures. Even simple stable thoracic transverse process fractures are likely to be associated with chest and rib injuries. These patients may in the long term suffer chronic respiratory and pain issues. As it is the segment with the most vertebrae, this segment is the most at risk of suffering multilevel nonoperative spine fractures such as transverse and spinous process fractures, which again may contribute to chronic pain and disability. Unstable thoracic spine fractures are also more likely to be associated with significant neurologic injuries due to the comparatively smaller spine central canal. Comparatively, the thoracolumbar junction and lumbar spine have larger central canals and thus have more tolerance for canal compromise and perhaps, less neurologic consequence.

Multivariate analysis showed that early spine trauma independent risk factors were not predictive of suboptimal mental health status or HRQoL. It also showed that spine injury description variables were not associated with the mental HRQoL of spine trauma patients.

This study's findings reaffirm our belief that prompt treatment of the identified risk factors and optimization of medical management for chronic medical conditions may improve the physical HRQoL of these patients.

Study Strength and Limitations

This is a prospective cohort study. The patient cohort is a well-defined patient population with a collection of 10 early spine trauma predictive variables. This study had an SF-12 completion rate of 52.3%. The Short Form Health Survey is a patient-related outcome instrument. Its responses are collected directly from the patient. As such, trauma patients with dementia and those who have not recovered sufficiently from their TBI are unable to complete the SF-12. There were three main differences between the cohort with completed SF-12 and uncompleted SF-12 questionnaires: (1) the uncompleted cohort had a mean age that was 5.9 years older and 13.6% more elderly patients, (2) the uncompleted cohort had 8.8% more patients who fell from low height (<1 m), and (3) the uncompleted cohort had 1.6% more patients with severe spinal cord injuries (ASIA A, B, and C). Despite this, the study cohort (with completed SF-12) was widely represented in all collected variables, including proportion of patients with moderate or severe TBI.

The use of multiple logistic regression analysis allowed us to identify significant early spine trauma predictive variables after taking into account potential confounders. This method of statistical analysis is performed infrequently in studies investigating multiple spine trauma predictors.³²⁻³⁴ Studies performed in this manner have a potential to reduce statistical power and precision due to the multiple statistical analyses performed. The strength of this is that if an association is identified, it is likely to be strong.

Future Directions

A formal introduction of a patient or clinical status factor comprising reversible and irreversible spine trauma patient- and physician-reported risk factors predictive of mortality and poor HRQoL may assist in existing and widely used algorithmic spine trauma management systems.^{17,18}

Conclusion

Early (initial 48 hours) independent risk factors predictive of suboptimal physical health status or HRQoL in polytrauma patients with spine injuries identified in a level 1 trauma center were tachycardia, hyperglycemia, multiple chronic medical comorbidities, and thoracic spine injuries. Early spine trauma risk factors were shown not to predict suboptimal mental health status outcomes. Further studies elucidating the association between other patient-related outcome scores and early spine trauma predictive variables are required.

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Disclosure, Competing Interests, and Ethics

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References

- Blumer CE, Quine S. Prevalence of spinal cord injury: an international comparison. *Neuroepidemiology* 1995;14(5):258–268
- Dryden DM, Saunders LD, Rowe BH, et al. The epidemiology of traumatic spinal cord injury in Alberta, Canada. *Can J Neurol Sci* 2003;30(2):113–121
- Fisher CG, Noonan VK, Dvorak MF. Changing face of spine trauma care in North America. *Spine* 2006;31(11, Suppl):S2–S8, discussion S36
- Hu R, Mustard CA, Burns C. Epidemiology of incident spinal fracture in a complete population. *Spine* 1996;21(4):492–499
- Pickett W, Simpson K, Walker J, Brisson RJ. Traumatic spinal cord injury in Ontario, Canada. *J Trauma* 2003;55(6):1070–1076
- Sekhon LH, Fehlings MG. Epidemiology, demographics, and pathophysiology of acute spinal cord injury. *Spine* 2001;26(24, Suppl):S2–S12
- Wyndaele M, Wyndaele JJ. Incidence, prevalence and epidemiology of spinal cord injury: what learns a worldwide literature survey? *Spinal Cord* 2006;44(9):523–529
- Tee JW, Chan PCH, Gruen RL, et al. Early predictors of mortality after spine trauma: a level 1 Australian trauma center study. *Spine* 2013;38(2):169–177
- Jackson G, Babbal R, Papastamopoulos D. Major Trauma Data Review: Modelling the Impact of the Trauma Triage Guidelines. Melbourne, Australia: Trauma System Co-ordination Unit, Service Development Branch, Department of Human Services; 2001
- Victorian State Trauma System (VSTS). Victorian Government Health Information. State Government of Victoria, Department of Health. October 31, 2010. Available at: www.health.vic.gov.au/trauma. Accessed October 24, 2013
- Urquhart DM, Williamson OD, Gabbe BJ, et al; Victorian Orthopaedic Trauma Outcomes Registry (VOTOR) Project Group. Outcomes of patients with orthopaedic trauma admitted to level 1 trauma centres. *ANZ J Surg* 2006;76(7):600–606
- Victorian Orthopaedic Trauma Outcomes Registry (VOTOR). Epidemiology and preventative medicine. Medicine, nursing and health sciences. Monash University. Available at: <http://www.med.monash.edu.au/epidemiology/traumaepi/orthoreg.html>. Accessed May 18, 2013
- Custer RL, Scarcella JA, Stewart BR. The modified Delphi technique: a rotational modification. *J Voc Tech Ed* 1999;15(2):1–10
- Tee JW, Chan PCH, Gruen RL, et al. The inception of an Australian spine trauma registry: the minimum dataset. *Global Spine J* 2012;2(2):71–78
- Nathens AB, Jurkovich GJ, Maier RV, et al. Relationship between trauma center volume and outcomes. *JAMA* 2001;285(9):1164–1171
- World Health Organization (WHO). Proposed Working Definition of an Older Person in Africa for the MDS Project: Definition of an older or elderly person. Available at: <http://www.who.int/health-info/survey/ageingdefolder/en/>. Accessed May 18, 2013
- Vaccaro AR, Lehman RA Jr, Hurlbert RJ, et al. A new classification of thoracolumbar injuries: the importance of injury morphology, the integrity of the posterior ligamentous complex, and neurologic status. *Spine* 2005;30(20):2325–2333
- Vaccaro AR, Hulbert RJ, Patel AA, et al; Spine Trauma Study Group. The subaxial cervical spine injury classification system: a novel approach to recognize the importance of morphology, neurology, and integrity of the disco-ligamentous complex. *Spine* 2007;32(21):2365–2374
- Baker SP, O'Neill B. The injury severity score: an update. *J Trauma* 1976;16(11):882–885
- Thurman D, Guerrero J. Trends in hospitalization associated with traumatic brain injury. *JAMA* 1999;282(10):954–957
- Susman M, DiRusso SM, Sullivan T, et al. Traumatic brain injury in the elderly: increased mortality and worse functional outcome at discharge despite lower injury severity. *J Trauma* 2002;53(2):219–223, discussion 223–224
- Bochicchio GV, Sung J, Joshi M, et al. Persistent hyperglycemia is predictive of outcome in critically ill trauma patients. *J Trauma* 2005;58(5):921–924
- Desai D, March R, Watters JM. Hyperglycemia after trauma increases with age. *J Trauma* 1989;29(6):719–723
- Laird AM, Miller PR, Kilgo PD, Meredith JW, Chang MC. Relationship of early hyperglycemia to mortality in trauma patients. *J Trauma* 2004;56(5):1058–1062
- Sung J, Bochicchio GV, Joshi M, Bochicchio K, Tracy K, Scalea TM. Admission hyperglycemia is predictive of outcome in critically ill trauma patients. *J Trauma* 2005;59(1):80–83
- Yendamuri S, Fulda GJ, Tinkoff GH. Admission hyperglycemia as a prognostic indicator in trauma. *J Trauma* 2003;55(1):33–38
- Gabbe BJ, Williamson OD, Cameron PA, Dowrick AS. Choosing outcome assessment instruments for trauma registries. *Acad Emerg Med* 2005;12(8):751–758
- Andrews G, Henderson S, Hall W. Prevalence, comorbidity, disability and service utilisation. Overview of the Australian National Mental Health Survey. *Br J Psychiatry* 2001;178:145–153
- Gandek B, Ware JE, Aaronson NK, et al. Cross-validation of item selection and scoring for the SF-12 Health Survey in nine countries: results from the IQOLA Project. International Quality of Life Assessment. *J Clin Epidemiol* 1998;51(11):1171–1178
- Ware JE Jr, Kosinski M, Keller SD. SF-12: How to Score the SF-12 Physical and Mental Health Summary Scales. 3rd ed. Lincoln, RI: QualityMetric Incorporated; 1998
- Victorian State Trauma Outcome Registry and Monitoring Group (VSTORM). Special Focus Report on Spinal Cord Injury (SCI) 2001–2008. Department of Health, State Government of Victoria,

- Australia. Available at: <http://docs.health.vic.gov.au/docs/doc/The-Victorian-State-Trauma-System--The-First-Five-Years:-July-2001-to-June-2006>. Accessed October 24, 2013
- 32 Akmal M, Trivedi R, Sutcliffe J. Functional outcome in trauma patients with spinal injury. *Spine* 2003;28(2):180–185
- 33 Kraemer WJ, Schemitsch EH, Lever J, McBroom RJ, McKee MD, Waddell JP. Functional outcome of thoracolumbar burst fractures without neurological deficit. *J Orthop Trauma* 1996;10(8):541–544
- 34 van Middendorp JJ, Albert TJ, Veth RP, Hosman AJF. Methodological systematic review: mortality in elderly patients with cervical spine injury: a critical appraisal of the reporting of baseline characteristics, follow-up, cause of death, and analysis of risk factors. *Spine* 2010;35(10):1079–1087