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Analysis of the influencing factors for hospital charge of spinal fractures with a category tree model.

Yibo Tang*#, Meinan Zhang#

Department of Orthopaedics, the Hainan Branch of Chinese PLA General Hospital, Sanya City, Hainan Province, PR China

#These authors contributed equally to this work

Abstract

Objective: To determine the influencing factors for hospital cost of patients with spinal fractures using E-CHAID category tree, we performed this retrospective study.
Patients and methods: The data on 2109 patients with spinal fractures in our hospital, including the comorbidity conditions, surgical and other clinical characteristics, were collected. After Pearson correlation test was performed to explore the potential influencing factors for hospital cost, multivariate stepwise regression analyses were applied to investigate independent influencing factors. E-CHAID category tree model was used to determine the interactive relationship between these influencing factors and estimate the hospital cost of spinal fractures.
Results: The average cost of spinal fractures was RMB 26015.76 (USD 4775.35) in male patients and RMB 28652.12 (USD 3317.21) in female patients, respectively. The hospital cost was classified by ECHAID category tree into 18 groups, in which the primary driver was the treatment methods, followed by the hospital length of stay.
Conclusions: ECHAID decision tree model could be used to estimate the hospital cost of spinal fractures. The primary driver for hospital cost of spinal fractures was the treatment methods.

Keywords: Spinal fractures, ECHAID category tree, Hospital charge, Influencing factors.

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Introduction

Spinal fractures, including osteoporotic vertebral compression fractures and traumatic spine fractures, cause major morbidity and mortality in patients that is associated with a large and growing societal burden, significant health care resource utilization and direct medical costs. Approximately 700,000 spinal fractures occur annually in the United States at an estimated total cost of $746 million [1]. In the China, spinal fractures account for 4.58% of all traumas with the average cost of $18433.2 each patient in 2012 [2,3].

In fact, the medical literature and economic analysis studies have limited information and guidance regarding specific factors that significantly contribute to hospital charge of spine fracture care. Understanding hospital charge-related factors and clinical characteristics in spinal fracture population will provide a guide for health care quality-improvement and cost-saving management and helps direct health resource allocation, primary prevention and health care planning.

Although a few previous studies identify comorbidities, in-hospital complications and other potential influential factors associated with the hospital charge in patients with spinal fractures [4-7], no studies have been performed to investigate how well these risk factors correlate with the hospital charge and the interactive effect and relationship between these influential factors to date. As evidence-based medicine developed rapidly, it is important to try and determine predictive and evidence-based factors associated with specific disease.

In light of this, we performed this retrospective study that included a cohort of patients with spinal fractures and accepting either conservative or surgical treatment by a team of spine surgeons. The purpose of this study was to analyse and determine the interactive correlation of the potential influential factors for the hospital charge of spinal fractures by using the multivariate linear regression model and Exhaustive-Chi-squared Automatic Interaction Detector (ECHAID) decision tree model, and finally to model the cost of spinal fracture and measure the potential cost impact of spine fractures.

Patients and Methods

Patients selection

This was a retrospective study performed at our hospital, and approved by the hospital's Ethics and Institutional Review Committees (code: S2015-017-07). The patients' informed consent was not required due to the retrospective nature of this study. All patients with a diagnosis of spinal fracture admitted to our hospital between April 2004 and July 2014 were included in this study.

Data acquirement

Clinical characteristics on patients and diseases was retrieved from the electrical medical records, including gender, age, times of hospitalization, hospital length of stay, duration of critical illness, ICU length of stay, the number of comorbidity, the number of in-hospital complications, surgical procedures, operation site, anesthetic methods and the therapeutic outcomes.

Among these viables, surgical procedures were classified as conservative treatment (bed rest and bracing treatment), minimally invasive procedure (percutaneous balloon kyphoplasty or vertebroplasty) and open surgery. Operation sites included cervical, thoracic and lumber vertebraes. Anesthetic methods were classified as four grades, including no anesthesia, local anesthesia, spinal or epidural anesthesia and general anesthesia. Therapeutic outcomes were divided into four grades including death, invalid or untreated, improvement and cure, which meant the status of the patients when they discharged from hospital. The statuses of neurological deficits were divided into three grades, including the complete, incomplete neurological injury, and normal, according to ASIA classifications. Specifically, ASIA classification A was considered as complete neurological injury; ASIA classifications B-D were considered as incomplete neurological injury; and ASIA classification E was considered as normal.

In-hospital complications included decubitus ulcer, hospital-acquired pneumonia, urinary tract infection, lower extremity venous thromboembolism and wound infection. Comorbidity included cardiovascular diseases (hypertension, coronary heart disease, atrial fibrillation, myocardial infarction, etc.), central nervous system diseases (cerebral infarction or hemorrhage, dementia, Parkinson's disease, epilepsy, etc.), bone and joint diseases (osteoarthritis or osteoporosis), respiratory system diseases (pneumonia or chronic obstructive pulmonary disease), diabetes, etc.

Statistical analysis

The continuous data was expressed by Mean Standard Deviation (M ± SD). The normal distribution of the continuous data was verified using the Kolmogorov-Smimov test. Homogeneity of variance of the continuous data between different gender groups were tested using Levene test. The data with normal distribution and homogeneity of variance were compared using independent samples Student's t-test between different gender groups. The categorical data was expressed by constituent ratio. The continuous data without normal distribution were compared using Mann-Whitney test. Pearson's Chi square test was used for analyzing the multiple categorical variables between two groups. One-way ANOVA was used for analyzing continuous data between multiple groups.

Correlations between continuous or categorical data were determined using Pearson or Spearman's correlation analysis, respectively. After univariate analyses were used to explore the potential risk factors for the hospital charge of spinal fractures, the multivariate linear regression models were applied for determining the independent risk factors for the hospital charge. The validity of the regression model was tested by Hosmer-Lemeshow statistic for goodness of fit. The hazard ratio of the risk factor was expressed as regression coefficients (β).

A P value less than 0.05 was considered statistically significant. All the independent risk factors for the hospital charge were imported into the ECHAID category tree to present the interactive relationship between these factors. In order to avoid over fitting, the growing depth of the E-CHAID tree was specified as 3 with the parent node and a child node at least 100 and 50 subjects, respectively.

The merging and splitting of the nodes were based on the significant level of 0.05. All statistical tests were performed using SPSS 20 software (SPSS Inc., Chicago, IL, USA).

Results

General characteristics and univariate analyses

A total of 2109 patients were included in this retrospective study, with 1123 males (69.34 ± 21.02 years) and 986 females (67.68 ± 23.15 years). The average costs of spinal fractures were RMB 26015.76 (USD 4775.35) in male patients and RMB 28652.12 (USD 3317.21) in female patients, respectively. The highest incidence of spinal fractures was at lumbar vertebra (60.1% male *vs.* 62.8% female) followed by thoracic vertebra (31.2% male *vs.* 31.4% female) and cervical vertebra (8.7% male *vs.* 5.8% female), respectively.

The general and clinical characteristics are summarized in Table 1. It can be shown that the hospital charge, the number of minimally invasive surgery, the rate of local anesthesia and the rate of lumbar fracture were significantly higher in female group than male group, and the hospital length of stay, the rate of conservative treatment and the rate of cervical fracture were significantly higher in male group than female group. Comparisons of hospital charges between different treatment methods, anatomical sites of the fracture, fracture types and neurological status of the patients were shown in Table 2.

Correlation analysis showed that the variables having significant correlation with hospital charge included: the number of comorbidity (r=0.425, p<0.001), neurological deficits (r=0.671, p<0.001), treatment methods (r=0.573, p<0.001), fracture types (r=0.342, p<0.001), anatomical sites (r=-0.219, p<0.001), anesthesia types (r=0.473, p<0.001), therapeutic outcomes (r=0.495, p<0.001), hospital length of stay (r=0.735, p<0.001), duration of critical illness (r=0.425, p<0.001), duration of terminal illness (r=0.612, p<0.001), ICU length of stay (r=0.512, p<0.001), days of special nursing(r=-0.721, p<0.001).

Multivariate analyses

In order to find out the most influential factors for the hospital charge, multivariate linear regression analyses were used with the hospital charge as dependant variable and the factors having significant correlation with hospital charge as independent variables, respectively. The analysis results were shown in Table 3. Hosmer-Lemeshow statistic showed that the R^2 of the regression model was 0.735 with F value of 875.35 and p value less than 0.001, respectively.

It can be shown that the independent risk factors for the hospital charge of spinal fractures include conservative treatment, open surgery, hospital length of stay, the number of comorbidity, general anesthesia, duration of critical or terminal illness, fracture type, and days of special nursing.

ECHAID category tree analysis

For further analysis to determine the interactive correlation between these risk factors, all the independent risk factors were imported into the ECHAID category tree model, and the analysis results were shown in Table 4.

Table 1. *The clinical characteristics of spinal diseases.*

Factors		Male (N=1123)	Female (N=986)	T/$\chi^{2\#}$	P
Age in years: M (SD)		69.34 (21.02)	67.68 (23.15)	1.73	0.0846
Hospital LOS in days: M (SD)		20.29 (22.68)	19.31 (22.77)	1	0.3181
Average duration of terminal illness in days: M (SD)		0.13 (1.98)	0.05 (0.6)	1.22	0.22
Average duration of critical illness in days: M (SD)		0.10 (1.56)	0.14 (1.3)	-0.64	0.53
ICU LOS in days: M (SD)		0.15 (2.30)	0.13 (1.32)	0.24	0.81
Average days of special nursing: M (SD)		0.14 (2.29)	0.1 (1.18)	0.49	0.62
Hospital charge in RMB: M (SD)		26015.76 (10454.15)	28652.12 (19903.24)	-3.87	<0.001
The number of comorbidity/N (%)	0	834 (74.3)	705 (71.5)	24.62	<0.001
	1	185 (16.5)	138 (14)		
	2	79 (7)	81 (8.2)		
	≥ 3	25 (2.2)	62 (6.3)		
Neurological deficits	Complete	113 (5.36)	91 (4.31)	1.16	0.56
	Incomplete	102 (4.84)	80 (3.79)		
	Normal	908 (43.05)	815 (38.64)		
The treatment outcome/N (%)	Death	2 (0.2)	2 (0.2)	1.31	0.73
	Invalid/untreated	41 (3.7)	28 (2.8)		
	Improvement	500 (44.5)	433 (43.9)		
	Cure	580 (51.6)	523 (53)		
Treatment methods/N (%)	Conservative treatment/N (%)	660 (58.8)	501 (50.8)	38	<0.001
	Minimally invasive surgery/N (%)	50 (4.5)	111 (11.3)		
	Open surgery	413 (36.8)	374 (37.9)		
Fracture type/N (%)	Osteoporosis	451 (40.2)	520 (52.7)	33.79	<0.001
	Trauma	525 (46.7)	371 (37.6)		
	Others*	147 (13.1)	95 (9.6)		
Anesthesia type/N (%)	No anesthesia	643 (57.3)	489 (49.6)	34.7	<0.001
	Local anesthesia	85 (7.6)	151 (15.3)		

	Spinal or epidural anesthesia/N (%)	160 (14.2)	129 (13.1)		
	General anesthesia	235 (20.9)	217 (22)		
Anatomical site/N (%)	Cervical fracture	98 (8.7)	57 (5.8)	6.82	0.033
	Thoracic fracture	350 (31.2)	310 (31.4)		
	Lumbar fracture	675 (60.1)	619 (62.8)		

N: Number; M: Mean; SD: Standard Deviation; T and χ^2 value were for the continuous and categorical data, respectively. *Spinal metastases, haemangioma, etc. #Pearson's Chi square test was used for analyzing the multiple categorical variables between two groups.

Table 2. *Comparison of hospital charges between different groups.*

Groups/subgroups		Number	Hospital charge in RMB: M (SD)	F#	P
Anatomical site	Cervical fracture	155	35473.45 (13111.3)	132.67	<0.001
	Thoracic fracture	660	25547.41 (11908.1)		
	Lumbar fracture	1294	20985.34 (10529.1)		
Fracture type	Osteoporosis	1008	20892.36 (7510.84)	697.26	<0.001
	Trauma	971	39837.04 (16008.57)		
	Others*	130	15150.5 (5790.5)		
Neurological deficits	Complete injury	204	60598.11 (25203.17)	1371.55	<0.001
	Incomplete injury	182	45184.14 (16263.95)		
	Normal	1723	21511.8 (7060.34)		
Treatment method	Conservative treatment	1161	9712.21 (4781.84)	1685.85	<0.001
	Minimally invasive surgery	161	22557.93 (4429.73)		
	Open surgery	787	40149.5 (17538.85)		

*Spinal metastases, haemangioma, etc. #One-way ANOVA was used for this analysis.

Table 3. *Regression analysis results of risk factors for hospital charges of spinal fractures.*

Risk factors	Coefficient	T	P
Hospital LOS	6711.15	39.91	<0.001
Anesthesia type	8015.22	12.61	<0.001
Duration of critical illness	4421.21	13.95	<0.001
Duration of terminal illness	2773.42	5.95	<0.001
The number of comorbidity	3241.72	11.17	<0.001
Neurological deficits	7605.65	5.75	<0.001
Treatment method	5871.17	36.6	<0.001
Fracture type	2054.15	5.31	<0.001
Days of special nursing	-1375.11	-3.97	<0.001

LOS: length of stay. The model: R^2=0.735, F=875.35, P<0.001.

Table 4. *ECHAID analysis results of risk factors for hospital charges of spinal fractures.*

Groups	Conditions	Hospital charge in RMB: M (SD)	N	P	F	df1	df2
1	Minimally invasive surgery, Hospital LOS ≤ 7	22557.93 (4429.73)	161	0.002	207.78	5	1100
2	Open surgery, Hospital LOS (>7, ≤ 12), general anesthesia, Compression fracture, ICU LOS=0	15363.16 (5115.49)	85	0.016	105.255	1	181
3	Open surgery, Hospital LOS (>7, ≤ 12), general anesthesia, Compression fracture, ICU LOS>0	22014.91 (8515.29)	80	0.003	14.685	1	76

4	Open surgery, Hospital LOS (>7, ≤ 12), general anesthesia, Traumatic fracture, No neurological deficits	18662.74 (5631.38)	86	<0.001	229.541	1	386
5	Open surgery, Hospital LOS (>7, ≤ 12), general anesthesia, Traumatic fracture, Neurological deficits	25613.03 (7853.60)	90	0.009	229.541	1	386
6	Open surgery, Hospital LOS (>12, ≤ 28), general anesthesia, Compression fracture, Duration of critical illness=0	23789.68 (10816.72)	56	0.029	10.53	1	88
7	Open surgery, Hospital LOS (>12, ≤ 28), general anesthesia, Compression fracture, Duration of critical illness>0	41316.77 (15344.23)	94	<0.001	14.4	1	130
8	Open surgery, Hospital LOS (>12, ≤ 28), general anesthesia, Traumatic fracture, No neurological deficits	39452.55 (13250.31)	89	0.002	8.913	1	128
9	Open surgery, Hospital LOS (>12, ≤ 28), general anesthesia, Traumatic fracture, Neurological deficits	54085.95 (18455.13)	76	<0.001	8.913	1	128
10	Open surgery, Hospital LOS>28, Duration of terminal illness=0	45250.90 (39980.61)	76	<0.001	90.165	1	121
11	Open surgery, Hospital LOS>28, Duration of terminal illness>0	115945.32 (50425.73)	55	0.002	90.165	1	121
12	Conservative treatment, Hospital LOS ≤ 10	2426.57 (2089.49)	231	0.012	175.515	6	1255
13	Conservative treatment, Hospital LOS (>10, ≤ 20), The number of comorbidity=0, Compression fracture	5301.65 (4928.40)	241	0.002	13.755	1	528
14	Conservative treatment, Hospital LOS (>10, ≤ 20), The number of comorbidity>0, Compression fracture	11400.73 (1966.05)	160	0.016	13.755	1	528
15	Conservative treatment, Hospital LOS (>20, ≤ 28), Traumatic fracture, No neurological deficits	7540.06 (4922.55)	204	0.011	7.217	1	156
16	Conservative treatment, Hospital LOS (>20, ≤ 28), Traumatic fracture, Neurological deficits	12145.78 (964.89)	80	0.001	7.217	1	156
17	Conservative treatment, Hospital LOS>28, No neurological deficits	10397.74 (7714.49)	155	<0.001	9.78	1	110
18	Conservative treatment, Hospital LOS>28, Neurological deficits	18772.95 (10886.99)	90	<0.001	9.78	1	110

LOS: Length of Stay; M: Mean; SD: Standard Deviation.

Discussion

Estimates of the hospital charges of spinal fracture are required by governmental health agencies to determine the optimal allocation of health care resources and to assess the cost-benefit and cost-effectiveness outcome of the used therapeutic interventions. To the best of our knowledge, there was limited literature about the economic analysis of the risk factors for the hospital charge of patients with spinal fractures.

With increasing prevalence of osteoporosis in China with an estimated of 13 % in 2009 [8], Qu et al.'s study showed that the average cost of osteoporosis vertebral fracture was about RMB 21,474 or USD 3,409 [9]. An epidemiological study on Chinese spinal trauma by Liu et al. indicated that spinal traumas occurred most frequently in the lumbar spine with an incidence of 56.09%, followed by the thoracic and cervical spine with incidences of 23.77% and 17.75%, respectively [10]. In the current study, the average cost of spinal fractures was RMB 26015.76 (USD 7163.03) in male patients and RMB 28652.12 (USD 4975.81) in female patients, respectively. Although the incidence of lumbar fractures was higher than those of the two previous Chinese studies, the frequency trend of spinal fractures regions was similar to them, with the highest incidence at lumbar vertebra followed by thoracic and cervical vertebras.

Some researchers have attempted to screen and identify a set of potential risk factors for the hospital charge by means of multiple linear or logistic regression analyses models [4-7,11,12]. Parker et al. studied the risk factors for 2 year health care costs in patients undergoing revision lumbar fusion procedures and found that congestive heart failure, severe leg or back pain, bad mental health, surgical site infection, secondary operation and spine-related hospital readmission could significantly increase the 2 year cost of care [4]. Walid et al. reported that postoperative fever could lead to a delay in patient discharge and increases in hospital charge of spine surgery patients [5]. With regard to the traumatic spinal cord injuries, Selvarajah et al. concluded that older patients experienced longer hospital length of stay with more hospital charges than younger patients [6]. Besides, it has been proven that the concomitant injury and status of neurological deficits can significantly increase the length of hospitalization and cost of hospitalization, according to Wang et al.'s study [2].

Du studied cost of spinal fractures and concluded that "lodging costs accounted for the majority of the social security expense of which the length of patient stay was the primary driver" [11]. The same results of the close association of decreased hospitalization costs with shorter length of stay were also concluded in the studies by van der Roer et al. [12] on traumatic thoracolumbar spine fractures and Maillard et al. on the traumatic or degenerative spine fractures [7]. Maillard et al. revealed the difference of hospital charge mainly caused by minimally invasive surgery [7]. In the present study, as was shown in the ECHAID analysis, the primary driver for the hospital charge was the treatment methods, followed by the hospital LOS closely.

To determine the most influential factors for the hospital charge, 12 potential risk factors found out by univariate analyses were imported into the multivariate linear regression model. The R^2 of the regression model was 0.735, with F value of 875.35 and p value less than 0.001 indicated that this model could fully explain the degree of the influential factors impacting on the hospital charge. Among these risk factors, only length of special nursing was a protective factor, which can significantly reduce the hospital charge; however, hospital length of stay, ICU length of stay, duration of critical or terminal illness, anesthesia types, the number of comorbidity, treatment method and fracture type were all independent risk factors for the hospital charge. Meanwhile, our results indicated that age cannot significantly increase the hospital charge, however, the number of comorbidity can significantly increase the hospital charge for spinal fractures.

Although the traditional regression models have the ability to determine the independent risk factors in terms of the selected potential risk factors which are still statistically significant after adjusting other variables, it is impossible to reveal the interactions of these multiple factors which results in difficulties in interpretation of the outcomes. On the contrary, classification or decision tree model, as a nonparametric statistic approach for data mining, has its own capacity to classify data with uncovering previously unknown correlations and complicated interactions among the determined independent risk factors which are undetectable by traditional regression models [13,14].

Thus, ECHAID category tree were conducted to reveal the relation between the risk factors and the impacting methods of these factors on the hospital charge in the present study. ECHAID category tree model is a commonly used algorithm of classification tree analysis that was improved based on the CHAID tree model and employed multi-contingency tables of Chi-squared significant test to identify optimal splits [15,16]. Until now, ECHAID category tree model has been used in the predicting the risk factors for some internal and psychiatry diseases, such as stroke, coronary artery disease, delirium, dementia, diabetes control, etc. and other public health and clinical epidemiology issues [14,15,17-23]. Spratt et al. performed the ECHAID category tree model on predicting the outcome after conservative decompression surgery for lumbar spinal stenosis based on patients' information available prior to surgery [24]. In the present study, ECHAID category tree was developed to classify the hospital charge as 18 groups, which might be used as the reference for governmental health agencies to estimate the hospital charge of spinal cost in China.

We didn't compare the actual cost between our results and those in other countries, as the economic and societal factors were different from each other. The first limitation of this study was that we couldn't perform a cost-effectiveness analysis for different types of the treatments. Some studies indicated that surgery with similar effectiveness incurs higher expense, thus, the conservative treatment could be more cost-effective for the spinal fractures [25]. Furthermore, Wood and colleagues concluded that patients with a stable spinal burst fracture treated conservatively presented less pain and better function than those treated surgically at a long-term follow-up [26]. Another limitation of the present study was that the sample size was small, which should be strengthened in future clinical studies to determine specific comorbidities that can increase the cost. Meanwhile, the severity of concomitant injury was not included as a risk factor for the costs of spinal fractures; however, the duration of critical illness and terminal illness, and ICU length of stay could indirectly reflect the severity of the spinal and concomitant injures of patients.

Conclusions

ECHAID category tree model could be used to estimate the hospital charge of spinal fractures. The primary driver for hospital charge of spinal fractures was the treatment methods, followed by the hospital length of stay.

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*Correspondence to

Yibo Tang

Department of Orthopaedics

The Hainan Branch of Chinese PLA General Hospital

PR China