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Predictive factors for postoperative deformity in thoracolumbar burst fractures: a statistical approach

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Objective: To assess, using statistical analysis, if and to what extent the final outcome of surgical treatment for burst fractures depends on operation type, fracture level and initial deformity severity.

Methods: A database of 287 patients with single-vertebral-level thoracic and lumbar spine fractures analysed using simple and multiple linear regression analyses models. The dependent variable was last follow-up (LFU) kyphotic angle and the predictor variables were operation type [anterior approach (AA), posterior short-segment fixation (PSSF) and posterior monosegmental fixation (PMF)], fracture level (T11–L1, L2–L3 and L4–L5) and preoperative kyphotic angle. The models were applied on either the whole sample or on the operation type subgroups.

Results: In simple linear regression analysis models, fracture level accounted for 32% and 18% of the variation in LFU kyphotic angle in the AA and PMF subgroups, respectively. In the multiple linear regression models for the same subgroups, up to 40% of the variation in LFU kyphotic angle was accounted for by fracture level. Surgical treatment, as predictor variable, indicated that patients treated by PSSF developed a post-surgical kyphotic angle 8.51° more severe than those treated by AA. However, the model accounted for only 2% of the variation in LFU kyphotic angle. Simple linear regressions performed on each subgroup with preoperative kyphotic angle as the independent variable revealed that the variable accounted for 15% (PSSF subgroup), 17% (AA subgroup) and 34% (PMF subgroup) of the variation in LFU kyphotic angle.

Conclusion: All valid regression models displayed modest explanatory power, suggesting that factors other than those taken into consideration are involved.

Keywords: Post-traumatic kyphotic deformity; thoracolumbar burst fracture.

After either surgical correction or conservative treatment of burst fractures, loss of correction with wedging of the fractured vertebral body is often observed.[1-3] Depending on the degree of eventual angulation, the loss of correction may cause minor discomfort or post-traumatic kyphosis requiring further surgical treatment. Therefore, the analysis of potential determinants of loss of correction has been the subject of many previous studies.

Frequently, the loss of correction is caused by inadequate treatment of the fracture following inaccurate initial estimation of fracture severity or insufficient instrumentation stability in surgically treated cases.[4,5]

In cases undergoing surgical correction, the surgical approach may be a potential factor responsible for the wedging of the affected vertebral body. Posterior short-segment fixation (PSSF) is the most frequently employed

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surgical treatment for burst fractures because of distinct advantages such as relatively fewer procedural demands, lower morbidity and shorter operative time.[6-8] Its main disadvantages include a relatively high incidence of loss of correction, implant failure and pseudoarthrosis.[9-11] The anterior approach (AA), an alternative to the posterior approach, offers higher stability for the anterior column but has a controversial impact on sagittal balance.[12,13] With regard to postoperative kyphotic angle, some studies have debated whether AA is preferable to the posterior approach;[14,15] however, other studies have found correlations between posterior instrumentation and higher stability.[16-18] In addition, others present relatively similar values for the 1-year follow-up kyphotic angle for all surgical methods considered.[19,20]

The amplitude of LFU kyphotic angle may also be influenced by fracture level, because biomechanical behaviour varies between spinal segments. White and Panjabi[21] showed that the compression forces vary between vertebral bodies at different levels according to their position on the vertebral column. The compression forces are concurrently dependent on the weight of the vertebral segment above and on the force arm, which is defined as the distance between the centre of the vertebral body and the plumb line. An empirical study[22] has confirmed this hypothesis for various fracture levels in conservatively treated burst fractures, showing specific best fit equations of the loss of correction.

The third factor considered in the current research is preoperative kyphotic angle, which by itself or as part of the load sharing score, is important for deciding between surgical and conservative treatment.[23,24] White and Panjabi[21] concluded that the extremely high instability of the reduced vertebral segment might favour late deformity. It is, therefore, presumable that late deformity is larger in cases requiring more significant initial reduction.

Thus, multiple predictive factors may account for late deformity. The present study, using statistical analysis and a thorough literature review, aims to assess if and to what extent fracture level, operation type, and initial deformity severity may be responsible for the variation in last follow-up (LFU) kyphotic angle developed in cases of surgically treated burst fractures.

Patients and methods

Due to data availability and representativeness, primary data were gathered from 12 articles selected after a systematic literature review of research papers published between 2000 and 2012 available in ScienceDirect, Ovid and PubMed databases, using 'burst fracture' as the search parameter. At the second stage of selection, we excluded all articles providing only metadata and not the individual patient's demographic and medical information. Thereafter, we created a database with primary data of the patients who met all of the following inclusion criteria:

(a) The patients were adults

(b) The fracture was post-traumatic or non-osteoporotic

(c) The fracture involved a single vertebral level of the thoracolumbar spine (T11–L5)

(d) The fracture had been surgically treated by one of the following methods: AA, PSSF, or posterior monosegmental fixation (PMF) and the procedure was sufficiently described

(e) The last follow-up visit was 12 months or longer

(f) The values for the pre-operative, post-operative, and LFU kyphotic angles were available for all individual patients

(g) Essential demographic data of the patient were available

The final database including data of only those patients who met the above-mentioned criteria was further divided into three subgroups according to the surgical treatment: patients treated by AA, patients treated by PSSF and patients treated by PMF. For simplification of analysis and higher relevance of results, the current study took into consideration the similarities of the biomechanical behaviour at the following vertebral levels: adjoining L4 with L5, L2 with L3 and T11 up to L1. Therefore, in the statistical analyses, fracture level (a predictive dummy variable) involved three categorical alternatives (T11–L1, L2–L3, and L4–L5).

With regard to the severity of initial deformity, one of the most commonly used parameters is the Load-Sharing Classification Score. Due to the unavailability of data, the current study chose the pre-operative kyphotic angle as a proxy variable.

"SPSS 20 for Windows" statistical software was used in the current study. The statistical analysis involved a series of simple and multiple linear regressions performed on the whole sample of patients as well as at the subgroup level. The present study considered the last follow-up (LFU) kyphotic angle as the dependent variable. Operation type, fracture level, and preoperative kyphotic angle were considered, either alone or simultaneously, as independent variables. The level of significance was set at 0.05.

The statistical analysis was performed in three steps. The first step consisted of a series of regressions performed on the whole sample of patients with LFU kyphotic angle as the dependent variable, with fracture level, operation type and preoperative kyphotic angle as predictors. In the following steps, we considered regression models for the subgroups formed according to operation type. At the subgroup level, multiple linear regression models in which both preoperative kyphotic angle and fracture levels were considered as independent variables.

Results

The database consisted of 287 patients. Seventy-six patients were treated by AA,[19,25-27] 175 were treated by PSSF[28-32] and 36 were treated by PMF.[33,34]

The regression analysis for the whole database revealed that the model with LFU kyphotic angle regressed on fracture level (dummy variable) had no explanatory power. The simple linear regression of LFU kyphotic angle on surgical treatment, a dummy variable, indicated that the patients treated by PSSF developed a post-surgical kyphotic angle 8.51° more severe than those treated by AA. Compared with the other two methods, PMF did not seem to have explanatory or predictive significance regarding LFU kyphotic angle variation. Moreover, despite model validity, the treatment itself accounted for only approximately 2% of the variation in LFU kyphotic angle.

The simple linear regression of LFU kyphotic angle on preoperative kyphotic angle for the whole sample suggested that approximately 17% of the variation in LFU kyphotic angle was because of variation in preoperative kyphotic angle. The regression coefficient indicated that LFU kyphotic angle increased by 0.25° for each 1° increase in preoperative kyphotic angle and the correlation was statistically highly significant.

The multiple linear regression analysis performed on the whole sample after entering simultaneously all three predictive variables proved to be invalid. The main results of the regression models for each subgroup of patients (after operation type) can be seen in Table 1.

Discussion

In general, LFU kyphotic angle is inherently the result of the combination between postoperative kyphotic angle and degree of loss of correction. Both of them, to a certain extent, are related to the type of treatment. Post-

Table 1. Results of the regression models at the subgroup level.

Analysis	Subgroup	Independent variables	Regression coefficient	Adjusted R-squared value
1	Operation type PSSF	Fracture level	Invalid model	
		Preoperative angle	0.28	0.15
		Fracture level and preoperative angle	Preoperative angle: 0.24	
			Fracture level: non-significant	0.18
2	Operation type AA	Fracture level	L4–L5 vs L2–L3: −19***	
			T11–L1 vs L4–L5: +25***	0.32
			T11–L1 vs L2–L3: +6*	
		Preoperative angle	0.34	0.17
		Fracture level and preoperative angle	Preoperative angle: non-significant	
			Fracture level:	
			L4–L5 vs L2–L3: −18.3***	0.33
			T11–L1 vs L4–L5: +21.7***	
			T11–L1 vs L2–L3: non-significant	
3	Operation type PMF	Fracture level	L4–L5 vs L2–L3: −8.3 ($p = 0.06$)	
			T11–L1 vs L4–L5: +11.7**	0.18
			T11–L1 vs L2–L3: non-significant	
		Preoperative angle	0.45	0.34
		Fracture level and preoperative angle	Preoperative Angle: 0.40***	
			Fracture Level:	0.41
			L4–L5 vs L2–L3 and	
			T11–L1 vs L4–L5: non-significant	
			T11–L1 vs L2–L3: +3.62	

*0.05 level of significance; **0.01 level of significance; ***0.001 level of significance.

operative kyphotic angle depends on the reduction accuracy, and correction loss is partially attributed to the capacity of the specific device to support the anterior column. For example, PSSF allows for good fracture reduction, but the construct provides less stable support.[20,35] In contrast, AA confers high column stability through the construct and a lower correction loss, but it offers less accurate fracture reduction,[36-38] which possibly accounts for the similar values for LFU kyphotic angle for each operation type.

Verlaan et al.[1] conducted a literature review of articles on surgically treated thoracic and lumbar burst fractures published over 10 years. The results showed that despite considerably different values for the loss of correction associated with the four surgical treatments under consideration in the study—long posterior procedures, short posterior procedures, isolated anterior procedures and anterior combined with posterior procedures—the mean value of LFU kyphotic angle varied only between 8.7° and 10.8°. The difference between the mean values calculated for the PSSF and AA subgroups was only 1.3°, but the study did not specify whether this different was statistically significant.

The results of the current regression analysis statistically confirmed that PSSF is more likely to favour the development of late deformity than PMF and AA. However, the adjusted R-squared value suggests that only 2% of the variation in LFU kyphotic angle is accounted for by the operation type factor.

With regard to the level of the fractured vertebrae, it is apparent that the compression forces act differently on the vertebral body depending on their specific location along the spine. According to previous studies,[21,22] compression force is directly proportional to the force arm, which is the distance between the centre of the vertebral body and the plumb line.

In the current study, the simple linear regression analysis performed on the whole database with fracture level as the independent dummy variable rendered a invalid model. This may be accounted for by the considerably larger size of the PSSF subgroup than the AA and PMS subgroups. Further research is need to investigate this hypothesis.

As shown in Table 1, regression models were valid for the AA and PMF subgroups where the L4–L5 fracture level presented significantly higher long-term stability than the T11–L1 level. Patients with lower lumbar fractures were more likely to develop LFU kyphotic angle that is smaller by 19° (in the AA treated subgroup) and by 11.7° (in the PMF subgroup) than those with thoracolumbar fractures. In AA-treated patients, L4–L5 fractures showed even higher stability than L2–L3 fractures; according to the regression coefficient, LFU kyphotic angle in the former type were 25° smaller than that of the latter type. The L2–L3 level displayed higher stability than the T11–L1 level, resulting in LFU kyphotic angle being approximately 6° lower. With regard to the PMF procedure, both lower lumbar fractures and thoracolumbar fractures did not induce significantly different LFU kyphotic angles compared with the upper lumbar fractures.

However, for both the AA and PMF subgroups, the simple linear regression models with fracture level as the independent variable displayed relatively low explanatory power. Fracture level accounted for only 18% and 32% of the variation in LFU kyphotic angle in the PMF and AA subgroups. Moreover, with regard to AA-treated fractures, some of the variation may be due to the particular difficulty in achieving accurate reduction.

With regard to burst fractures, the deformation process of the affected vertebral body would persist until the traumatic force either dissipates in the surrounding bone or fibrous tissues, or is compensated by the resistance of the affected vertebral body. Biomechanical studies showed that the reduction of a fractured vertebral body would alter acquired balance, causing the spinal segment to be extremely unstable, and rendering it vulnerable to underlying compression forces.[39-41] Considering that preoperative kyphotic angle is the equilibrium point where the traumatic force is offset by the affected vertebral body's resistance, it is presumable that postoperative kyphotic angle may not exceed the initial preoperative kyphotic angle.

The simple linear regression equation built for the whole sample, with preoperative kyphotic angle as the independent variable, indicates that 1° of preoperative kyphotic angle corresponds approximately to 0.25° increase in LFU kyphotic angle. However, this factorial variable accounted for only 20% of the total variation in LFU kyphotic angle.

Preoperative kyphotic angle was a predictive factor for LFU kyphotic angle in all simple regression models run at the subgroup level. The model with the highest explanatory power, which was considerably higher than both models for the other two subgroups, was the one associated with the subgroup treated by PMF where 34% of the variation in LFU kyphotic angle was accounted for by preoperative kyphotic angle. In addition, the model displayed the highest impact of preoperative kyphotic angle on the dependent variable because 1° of preoperative kyphotic angle may be responsible for a

0.45° increase in LFU kyphotic angle.

Adding preoperative angle to fracture level as a predictive factor in a multiple linear regression analysis at the subgroup level did not significantly increase the explanatory power of the model for both the AA and PSSF subgroups. With regard to the AA procedure, this conclusion may be accounted for by the replacement of the vertebral body with a metallic device.

Alternatively, for the PMF subgroup, the explanatory power of the model significantly increased, accounting for 41% of the variation of the dependent variable. Preoperative kyphotic angle was, in this case, a statistically significant predictive factor. In this multiple linear regression model, when keeping preoperative kyphotic angle constant, there are statistically significant differences only for the T11–L1 level compared with the L2–L3 level; however between L4–L5 and L2–L3, there seemed to be no significant difference regarding the variation in LFU kyphotic angle.

Therefore, it is assumed that compared with AA or PSSF, preoperative kyphotic angle of a thoracolumbar burst fracture may prove more determinative to the development of LFU kyphosis in PMF.

In conclusion, all regression models proved to result in modest explanatory power for the variation in LFU kyphotic angle. Therefore, further research is needed to identify and confirm other relevant factors than the three potentially predictive variables under consideration in the present study.

Conflics of Interest: No conflicts declared.

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