SURGICAL TREATMENT OF THORACIC AND LUMBAR SPINE FRACTURES USING TRANSPEDICULAR VERTEBROPLASTY AND FIXATION

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Objective. To analyze treatment results in patients with fractures of thoracic and lumbar vertebal bodies after transpedicular vertebroplasty and fixation through minimally invasive percutaneous and open approaches. **Material and Methods.** A total of 154 patients with uncomplicated type A2, A3 fractures of the thoracic and lumbar vertebral bodies were operated on. All patients were examined with X-ray densitometry, spondylography, and CT. Group 1 included 53 patients who underwent vertebroplasty with deproteinized bone graft and percutaneous transpedicular fixation. Patients of Group 2 (n = 41), Group 3 (n = 43) and Group 4 (n = 17) underwent open transpedicular fixation and vertebroplasty with deproteinized bone graft (Group 2) and titanium nikilide granules (Groups 3 and 4). **Results.** Intraoperative blood loss during open vertebroplasty combined with short-segment transpedicular fixation exceeded that during percutaneous vertebroplasty. Parameters of kyphotic deformity, the wedge index and the loss of correction did not differ significantly except for Group 4. Significant improvement in ODI and VAS scores was noted after percutaneous vertebroplasty as compared with control groups. **Conclusion.** Transpedicular verteboplasty and transpedicular fixation, both open and percutaneous, performed for the treatment of type A2 and A3 spinal fractures provide reliable stabilization of the injured spinal segments, allow vertebral body height restoration to a greater extent and correction of the kyphotic deformity.

Key Words: spinal fractures, transpedicular fixation, percutaneous vertebroplasty, open transpedicular vertebroplasty.

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Open anterior and posterior approaches are the gold standard in the surgical treatment of spinal injuries. However, despite restoring the supporting ability of the spine, these techniques have also several drawbacks: long operating room times, complicated procedure, and the potential risks of vascular and neural injury [10, 13, 30, 37]. Standard approaches to the posterior vertebral compartments are effectively used for curve correction and stabilization of injured segments [18]. The efficacy of the posterior internal fixation is a result of the long fixation length. Nevertheless, the long length arrests the function of non-injured spinal segments, impairs perfusion and innervation of paravertebral muscles, often leading to their fibrosis, thereby resulting in postoperative persistent pain syndrome and longer rehabilitation times [12, 15, 18].

Minimally invasive techniques, including transcutaneous vertebroplasty of the fractured vertebra and transpedicular fixation (TPF) have been used in the last decade for the treatment of patients with the thoracic and lumbar spine injuries [23, 38, 39]. An analysis comparing the efficacy of transcutaneous and open short-segment fixation with transpedicular vertebroplasty is not available and this circumstance motivated us to this study.

The purpose of this paper is to analyze the treatment outcomes in patients with fractures of thoracic and lumbar vertebral bodies after transpedicular vertebroplasty and fixation through minimally invasive transcutaneous and open approaches.

Material and Methods

A total of 154 patients aged 38–64 years were operated on in the Clinic of Spinal Pathology, Novosibirsk RITO and at the Department of Traumatology No. 1, RITO, Astana (Kazakhstan) in 2013–2015. The patients had uncomplicated solitary fractures of the T11–L2 vertebral bodies classified as types A2 and A3 according to Magerl et al. [28], at least 7 scores on the Load Sharing Classification (LSC) proposed by McCormack [31], and did not have osteoporosis.

The patients were divided into four groups based on the surgical approach and the type of bone grafting material (Table 1). Group I included 53 patients operated on using transcutaneous TPF and grafting of deproteinized cancellous bone (DCB) [4]. Surgical intervention was performed according to the developed method using devices for the delivery of osteoplastic material [5, 7].

Group II included 41 (26.6 %) patients who underwent open transpedicular grafting and TPF. The DCB was used for vertebroplasty.

Group III included 43 (39.0 %) patients operated on using open transpedicular vertebroplasty and TPF. Granules of titanium nickelide (NiTi) were used as grafting material.

Group IV included 17 patients with fractures estimated as greater than 8 by the LSC, who underwent open transpedicular grafting and TPF. NiTi granules were used for vertebroplasty.

The difference between open transpedicular vertebroplasty with TPF and transcutaneous vertebroplasty with TPF was as follows: the first procedure involved the postural correction of kyphosis through positioning of the patient on an operating table in an extension position followed by screw insertion, vertebroplasty, and an extra local extension created after construct implantation. The transcutaneous procedure incorporated an extension positioning of the patient on an operating table for postural correction and unilateral screw insertion; local extension using instrumentation and vertebroplasty using DCB were then performed [4].

The bone mineral density (BMD) was assessed using the Duo Diagnost Sonost–2000 dual energy roentgen densitometer. All patients underwent multislice helical CT, frontal and lateral standard spondylography of the fractured spinal segments as well as lateral spondylography when the patient lied in the maximum extension position. The intensity of the deformity of the injured spinal segment was graded from kyphosis measures and the vertebral wedge indexon routine radiographs. Kyphosis was assessed from the cranial endplate of the overlying vertebra to the caudal endplate of the underlying intact vertebra [32]. The wedge index was estimated using the ratio of the anterior height of the injured vertebrae to the height of anterior portions of adjacent vertebrae [19]. The amount of kyphosis correction and the height restoration of the fractured vertebra were estimated from lateral radiograms recorded in the supine extension position on a cushion. Intraoperative blood loss was assessed by intraoperative material weighing (napkins, balls) on electronic scales and the volume of blood during vacuum aspiration. The amount of administered grafting material necessary for the complete correction of the fractured vertebral body was estimated using the formula: $Vpl = \varpi R2 (h1 – h2)$, where Vpl – the volume of osteoplastic material, mm3; R –the vertebral body radius in the frontal plane, mm; h1 –vertebral body height prior to compression (the mean height of adjacent vertebrae, mm), h2 –vertebral body height after compression, mm [1]. The weight of administered DCB was 5.76 ± 1.09 g and the weight of NiTi granules was greater by 1.35 g than that of DCB based on the specific weight of NiTi granules. The Oswestry index [9] was used to evaluate the long-term function after vertebroplasty and VAS scale [27] – to assess pain intensity. ODI scoring: 0 to 20 %– minimal disability, 20 to 40 % – moderate disability, 40 to 60 % – severe disability, 60 to 80 %–incapacitating pain, and 80 to 100 % – these patients are either bedbound or have an exaggeration of their symptoms.

Statistical measures: the mean and standard deviation were used for quantitative data. Magnitude frequencies and percentages are given for qualitative data. The quantitative data were tested for normality using the Shapiro–Wilk test. Since almost all data had non-normal distribution, nonparametric Mann–Whitney test was used for the comparisons of independent samples. A p-value of < 0.05 was considered statistically significant. Statistical estimations were performed using the IBM SPSS 19 software [2, 3].

Results

The treatment outcomes were traced immediately after surgery, in the shortterm period up to 4 months, and in the long-term period – 6 to 24 months. The average intraoperative blood loss was 145.80 ± 90.35 ml in group I, 193.70 ± 110.60 ml – in II, 162.80 ± 57.20 ml – in III, i.e., the volume of blood loss was statistically equal in groups I and III, while in group II it significantly exceeded that of the main group.

The LSC indices were 7.0 ± 0.8 in group I, 7.0 ± 0.9– in II, and 7.0 ± 0.9– in III, which were statistically comparable ($p < 0.05$). However, it is emphasized that LSC scores reached 8–9 in 17 patients in group IV.

Preoperative kyphotic deformity was 10.30° ± 2.86° in group I, 10.40° ± 3.89°– in II, and 10.70° ± 4.04° – in III, which means that preoperative data were comparable equal between the groups and did not differ significantly ($p < 0.05$).

Table 1

Characterization of study groups

Group	Age, years	Fracture type, n (%)		T-score, SD
		A2	A3	
I (n = 53)	55.6 ± 9.2	30 (56.6)	23 (43.4)	1.91 ± 0.50
II (n = 41)	60.0 ± 8.8	23 (56.0)	18 (43.9)	2.28 ± 0.60
III (n = 43)	46.6 ± 13.6*	30 (50.0)	30 (50.0)	1.84 ± 0.70
IV (n = 17)	48.1 ± 9.4	7 (41.0)	10 (59.0)	1.83 ± 0.80

*significant differences compared to group I ($p > 0.05$).

Kyphotic deformity was approximately 13.20° ± 3.04° in group IV, which indicates that this parameter exceeds that of other groups and is related to sample selection criteria. The postoperative magnitudes of kyphotic deformity significantly decreased in all groups: in I – to 0.50° ± 0.91°, in II – to 1.40° ± 2.12°, in III – to 1.60° ± 2.0°, and in IV – to 1.90° ± 2.25°. Pairwise comparison of magnitudes from all groups with group I revealed significantly exceeded postoperative correction of kyphotic deformity in group I compared to other groups ($p < 0.05$; Table 2).

Preoperatively, the wedge index was 133.0 ±19.0 % in group I, 136.6 ± 22.2 % – in II, 146.7 ± 23.2 % – in III, and 151.6 ± 6.1 % – in IV, indicating that the data of groups I and II were equal and the data of group I were significantly lower compared to groups III and IV ($p < 0.05$). The postoperative wedge index significantly decreased in all groups: I – to 105.5 ± 5.5 %, II – to 105.5 ± 8.2%, III – to 110.8 ± 9.9%, and IV – to 109.6 ± 7.2 %. Pairwise comparison of the wedge indices revealed that the vertebral body height was equal in groups I and II, but the wedge indices were higher in groups III and IV than in group I ($p < 0.05$).

Therefore, it was revealed that along with the postoperative decline in the deformity magnitudes of the fractured spinal segment in all groups, significant improvements in the correction of kyphosis in group I compared to other groups ($p < 0.05$) and in the wedge index in group I compared to groups III and IV ($p < 0.05$) were achieved.

In the short-term postoperative period, the slight aggravation of kyphotic deformity in groups II, III, IV was not reliable. However, pairwise comparison of this indicator in group I with that in other groups detected that kyphotic deformity reliably worsened in all other groups. In the long-term period, kyphosis increased in all groups, but there were no significant differences in the curve progression in pairwise comparison ($p > 0.05$; Table 2).

In the short-term postoperative period, the wedge indices tended to grow in all groups. Pairwise comparison did not reveal any significant differences between groups I and II. However,when wedge indices of groups I, III, and IV were compared, the wedge indices of group I were significantly lower than those in groups III and IV ($p < 0.05$). In the long-term postoperative period,vertebral wedging increased in all groups; there were no significant differences in the progression of the wedge index in pairwise comparison ($p > 0.05$). It is noted that the major loss of kyphosis correction in the short-term and long-term periods was observed in group IV ($p < 0.05$; Table 3).

Preoperative BMD indices in the groups were within the range of osteopenia due to that this range was an inclusion criterion in study groups (T-score up to -2.4 SD). The mean preoperative value of BMD in group I was -1.9 SD and in the long-term period -2.2 SD; in group II preoperative T-score was -2.2 SD, and in the long-term period -2.3 SD; in groups III and IV preoperative T-score was -1.8 SD and in the long-term period -2.4 SD (Table 4). Thus, despite a significant exceeding of BMD indices in group II compared with group I, T-scores in all groups were the same and did not decrease below the threshold of osteopenia in the long term period.

There were no significant differences between group I and other groups when VAS scores were compared in the short-term postoperative period ($p > 0.05$). Similar results were obtained when the Oswestry index was compared ($p > 0.05$; Table 5).

A comparison of VAS scores in the long-term periods revealed a significant alleviation of pain syndrome: to 1.90 ± 1.58 scores – in group I, to 2.80 ± 1.27 scores – in II, to 3.00 ± 1.07 scores – in III and IV ($p < 0.05$). Based on the Oswestry index,the worst outcomes were observed in group IV ($p < 0.001$). Thus, in addition to the alleviation of pain syndrome in the short-term period in all groups, the alleviation of pain syndrome remained in the long-term postoperative period only when using minimally invasive techniques indicating the efficacy of the method.

Only one patient from group I experienced a complication in form of infectious infiltration of hematoma in postoperative wound, which was relieved by vacuum drainage up to complete healing. In group II, six patients required secondary surgical wound cleaning via resection of the necrotic margins with placement of secondary sutures.

Discussion

The foreign literature includes numerous references on the use of transcutaneous vertebroplasty and TPF in the treatment

Table 2

Deformity magnitudes of the fractured spinal segment in the short-term and the long-term postoperative periods in the study groups

Group	Kyphosis, degree		The wedge index, %	
	the short-term postoperative period	the long-term postoperative period	the short-term postoperative period	the long-term postoperative period
I (n = 53)	0.5 ± 0.9	2.1 ± 2.3	107.3 ± 7.6	110.8 ± 12.9
II (n = 41)	1.4 ± 2.1*	3.8 ±4.3**	109.1 ± 11.8**	112.2 ± 15.6**
III (n = 43)	2.0 ± 2.6*	3.4 ± 4.2**	110.3 ± 10.3*	111.7 ± 10.7**
IV (n = 17)	3.0 ± 2.7*	3.6 ± 3.2**	111.6 ± 11.6*	112.6 ± 12.8**

*significant differences ($p< 0.05$), **insignificant differences ($p> 0.05$).

Table 3
The mean magnitudes of correction loss in groups studied

Group	Loss of correction, degrees	
	the short-term period	the long-term period
I (n = 53)	1.0 ± 1.6	2.0 ± 2.2
II (n = 41)	2.0 ± 3.3*	2.0 ± 3.5**
III (n = 43)	1.0 ± 1.1**	1.0 ± 2.0**
IV (n = 17)	3.2 ± 1.5*	3.5 ± 1.7*

*significant differences ($p < 0.05$), **insignificant differences ($p > 0.05$).

Table 4
Densitometry indices of the spine according to T-score in study groups

Group	T-score, SD	
	preoperative	the long-term period
I	-1.91 ± 0.50	-2.22 ± 0.40
II	-2.28 ± 0.60*	-2.33 ± 0.40**
III	-1.84 ± 0.70**	-2.48 ± 1.20**
IV	-1.83 ± 0.60**	-2.30 ± 0.40**

*significant differences ($p < 0.05$), **insignificant differences ($p > 0.05$).

of the thoracic and lumbar spinal fractures [23, 38, 40].

Minimally invasive technique, an alternative to traditional approaches, can substantially reduce the traumatization degree of a surgical intervention, intraoperative blood loss, operating times, and the risk of infectious complications, permits stabilization and elimination of kyphotic deformity [6, 8, 11, 33, 34, 36]. In addition, cost minimization in the treatment of patients with spinal fractures is also an important issue [29].

Thoracic and lumbar vertebral fractures with at least 6 scores on the LSC require surgical correction of deformity and stabilization. Meanwhile, a high risk of failure is present when using only short-segment fixation. For this reason, it is recommended to restore the supporting ability of the spine using anterior fusion [31]. It is possible to raise the strength of the fractured vertebral body and enhance its resistance to compression loads by administering granular implants or bone grafts into the fractured segment. Moreover, the higher implant strength is associated with the higher resistance to compression and better preservation of the restored shape and vertical size of the fractured vertebral body [1]. Fractures of the cortical bone plate, including of the posterior vertebral elements, always appear in Magerl type A3 vertebral body lesions and are associated with weaker resistance to compression [1].

Our study included patients with vertebral body fractures scoring 6 to 8 points on McCormack classification in groups I–III and more than 8 points – in group IV.

Surgical treatment for vertebral fractures with anterior fusion and different cages has been always associated with the loss of correction in the long-term radiographic findings; Pesenti et al. [35] therefore used a combination of anterior and posterior fixation. The authors evaluated the clinical and radiologic outcomes for patients operated by percutaneous (transcutaneous) TPF and anterior fusion using telescopic vertebral body prosthesis for fractures at the thoracic and lumbar spine without neurological deficit and observed the loss of correction up to 1° in the long-term follow-up. Jo et al. [16] used anterior spinal fusion with cage and TPF for unstable fractures with LSC score more than 7; no loss of correction was noted in the long-term follow-up. During posterior short-segment fixation after vertebroplasty, transpedicular screw was inserted in the fractured vertebra as a required step allowing equal load redistribution over the fixation system. Lin et al.[26] and Liao et al. [24] also implanted additional screws in the fractured vertebra during transpedicular fixation after vertebroplasty resulting in a low percent of deformity progression at the injured vertebral segment. Along with successful outcome of such operations, short-segment instrumentation can potentially prevent degeneration of adjacent segments [42]. The outcomes of our proposed minimally invasive method for the treatment of types A2 and A3

Table 5
The mean VAS scores and the Oswestry indices in study groups

Group	VAS, scores		Oswestry index, %	
	the short-term period	the long-term period	the short-term period	the long-term period
I	2.70 ± 1.49	1.90 ± 1.58	22.00 ± 6.32	19.90 ± 3.89
II	2.90 ± 1.28**	2.80 ± 1.27*	22.70 ± 6.22**	23.80 ± 5.04*
III	2.80 ± 1.36**	3.00 ± 1.07*	23.60 ± 6.41**	24.20 ± 4.81*
IV	3.10 ±1.07*	3.10 ± 1.10*	32.60 ± 6.41*	30.60 ± 7.41*

*significant differences ($p < 0.05$), **insignificant differences ($p > 0.05$).

vertebral fractures with LSC score up to 8 were not inferior to vertebroplasty and fixation through an open approach. Along with the significant postoperative improvement of the kyphotic deformity magnitudes in all groups, kyphotic curve correction, when compared, was improved significantly better in group I. In the long-term period, kyphotic deformity magnitudes increased in all groups; however, there were no significant differences between the groups in pairwise comparison.

The reduced wedge indices after operation went up slightly in the short-term period, but the increase was significantly less in group I compared to groups III and IV. In the long-term postoperative period, these indicators continued to decline in all groups, and pairwise comparison did not reveal significant differences that also agrees with the data by Liao et al. [25] and Li et al. [22].

The magnitude of the loss of achieved deformity correction at the level of fracture in the short-term follow-up in group I in pairwise comparison was significantly lower than in groups II and IV. The loss of correction increased in the long-term period in all groups and the magnitudes were significantly lower only in the group IV compared to group I in a pairwise comparison.

The comparison of the outcomes with the results after TPF alone in the long-term period has revealed that TPF alone resulted in screw breakage, progression of the initial kyphotic deformity, loss of correction, absence of consolidation, neurological signs, and worsening of pain syndrome which required repeated surgical intervention on the anterior spine [14, 17, 30, 41].

Despite the significant exceeding of BMD indices in group II compared with group I, the magnitudes of all groups were similar in the long-term period and did not fall below the osteopenia threshold. Similar results were obtained by Li et al. [21] in the long-term period who also noted correction loss of up to 2–5°.

This study demonstrates that along with the alleviation of pain syndrome in the short-term period in all groups, only minimally invasive techniques are associated with milder pain syndrome in the long-term postoperative period that indicates the efficacy of this method.

When the Oswestry index scores were compared, the magnitudes of only group I were significantly lower versus the rest groups in the long-term period ($p < 0.001$), which also supports the efficacy of minimally invasive method in the improvement of functional adaptation of a patient. The outcomes match to the results by Li et al. [23] and Lee et al. [20] who compared the efficacy of conventional and transcutaneous short-segment TPF with vertebroplasty.

We observed that the intraoperative blood loss averaged 145.80 ± 90.35 ml in group I, which did not differ significantly from that of group III – 162.80 ± 57.20 ml, while this indicator in group II significantly exceeded that of the main group – up to 193.70 ± 110.60 ml thereby evidencing to the low traumatization of our proposed method. This agrees with data by Wang et al. [39].

Conclusion

Transcutaneous vertebroplasty and TPF in the treatment of types A2 and A3 fractures with LDS score up to 8 provides solid stabilization of fractured spinal segments over the entire period of vertebral body consolidation, vertebral body height restoration to a greater extent, and correction of kyphotic deformity. Our developed method reduces the traumatization degree of surgery, alleviates pain syndrome, and facilitates the functional adaptation of patients in the long-term postoperative periods.

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