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Recovery of the Shape of Vertebral Bodies under Transpedicular Fixation in Osteoporotic Vertebral Fractures

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Abstract—The parameters of posttraumatic deformity correction in 27 patients aged from 61 to 76 (62.9 ± 1.4) years were analyzed using osteoplasty and transpedicular fixation for osteoporotic thoracolumbar fractures of vertebral bodies. Indicators of posttraumatic deformity, the wedging index (WI) and segmental kyphosis (SK), decreased in all patients. At the same time, minimally invasive (transcutaneous) surgery made it possible to restore the lost anatomy without being inferior to the results of open intervention. In patients with compression fractures both the WI and SK decreased significantly; in patients with a burst nature of injury only WI became lower. In patients with the *T*-test > –3 SD both the deformation indicators decreased, and with a more pronounced decrease in mineral density (*T*-test < –3) only WI decreased significantly. The results indicate recovery of lost anatomy, but the degree of correction depends on the nature of the fracture and the amount of bone mass.

Keywords: osteoporosis, transpedicular fixation, osteoplasty, spine, vertebral fractures, vertebroplasty, minimal invasive intervention

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INTRODUCTION

The problem of treating osteoporotic fractures of thoracolumbar vertebral bodies is a topical issue in modern traumatology and orthopedics. These spinal injuries are one of the leading causes of reduced quality of life in the elderly [19, 24], and in some cases they can be life threatening: the mortality rate reaches 23–34% [25]. The principal moment of treatment of osteoporotic fractures of vertebral bodies is the reconstruction of the lost anatomy at the injured level, creation of stability and recovery of the anatomical axis of the spine [37]. Due to reduced bone strength in osteoporosis, the use of traditional methods of surgical treatment of vertebral fractures with normal bone mineral density is limited, which significantly reduces the possibility of correcting posttraumatic deformity and worsens the outcome of treatment [38]. In addition, the tolerance to such interventions in this category of patients is very low due to age and concomitant somatic diseases [1, 3, 44].

The purpose of the study was to evaluate the recovery of the vertebral body shape and the posttraumatic deformity correction when using osteoplasty under transpedicular fixation in patients with osteoporotic thoracolumbar fractures.

MATERIALS AND METHODS

Retrospective analysis of surgical treatment was carried out for 27 patients aged 61–76 years (mean age 62.9 ± 1.4 years; 11 (40.7%) men and 16 (59.3%) women) with uncomplicated osteoporotic thoracolumbar fractures. By the circumstance of the injury, 59.3% of the patients had fractures of the vertebral bodies due to a low-energy trauma (falling from their own height), which is characteristic of osteoporotic vertebral fractures.

A comprehensive examination of the patients included X-ray-spondylography (before, during, and after surgery), densitometry, and multilayer spiral CT. In many patients (33.4%), injuries were located at the L_1 vertebra; at the Th_{XII}, L_{II}, and L_{III} vertebrae in 29.6, 25.9, and 11.1% of patients, respectively. The universal classification of spine injuries proposed by F. Magerl et al. (1994) was used to verify fractures. Fractures of type *A*3 were diagnosed in 13 (48.1%) cases, type *A*1 in 11 (40.7%), type *A*2 in 2 (7.5%), and type *B*1 in 1 (3.7%) case.

The severity of deformations of the damaged segment of the spine was determined by kyphosis and the wedging index of the vertebral body on routine X-ray pictures. Kyphosis was measured from the cranial occlusal plate of the overlying intact vertebrae and caudal occlusal plate of the underlying intact vertebrae

[36]. The wedging index was calculated by the formula of the ratio of the anterior height of the injured vertebra and the height of the anterior parts of adjacent vertebral bodies [29]. Osteoporosis of the spine was diagnosed by X-ray densitometry (HOLOGIC Discovery-A) using accepted X-ray traits. Taking into account these data, all patients were divided into three groups based on the *T*-test: 1st (*T*-test from −2.5 to −2.9), 7 people; 2nd (*T*-test from −3.0 to −3.5), 13 people; and 3rd (*T*-test −3.6 and below), 7 patients.

All patients underwent surgical treatment in the form of transpedicular fixation in combination with plastics by deproteinized bone (DPB) [2]. Transcutaneous (TTPF) surgical intervention was performed in 18 and open (TPF) in 9 cases. The main stage was identical in both the surgical treatment variants. In accordance with anatomical landmarks, channels were formed and transpedicular screws were installed in the roots of the vertebral arches adjacent to the injured ones. On one side, the rod was fixed in the screws, followed by extension and distraction. The control X-ray examination was carried out with the aid of an electron-optical transducer in direct and lateral projections. The kyphotic deformation at the corrected level of the damaged spine region and the wedging index of the fractured vertebral body were measured. On the opposite side, a channel was formed in the pedicle of the fractured vertebra. Into the body of the fractured vertebra in patients of the 1st group, we administered, in total, up to 5.76 ± 1.09 g DPB. The volume of the introduced plastic material needed to completely correct the deformation of the vertebral body was calculated by the formula: $V_{pl} = \pi R^2(h_1 - h_2)$, where V_{pl} is the volume of the plastic material, mm^3; R is the radius of the vertebral body found in the frontal plane, mm; h_1 is the height of the vertebral body before compression (average height of adjacent vertebral bodies), mm; h_2 is the height of the vertebral body after compression, mm [1]. For dense introduction of DPB into the body of the fractured vertebra, a funnel with a pusher was used. The funnel was removed, a screw was inserted through the channel in a transpedicular manner, the pin was fixed in the screw heads, and preliminary extension and distraction were provided for uniform redistribution of load on the structure. On the opposite side, the structure was dismantled and the manipulations described above were performed. The final installation of the transpedicular structure was carried out sequentially, depending on its type.

RESULTS AND DISCUSSION

The results of treatment were traced during the surgery and in the early postoperative period. Recovery of deformations of the damaged spine region was evaluated using an X-ray study. In the entire sample, the segmental kyphosis before surgery was on average 10.2° ± 1.2° and the wedging index (WI) was 40.5 ± 7.2%. It should be noted that during the surgery phase, after correction was performed only under TPF conditions without osteoplasty, kyphotic deformation was convincingly and significantly reduced more than twice, but no significant decrease in the wedging shape of the body was achieved, including for various types of vertebral fractures (table).

After the surgery, both the indicators decreased and amounted to 3.2° ± 0.6° and 10.4 ± 2.4%, respectively ($p < 0.003$). In patients who underwent TTPF, kyphosis was 10.5° ± 1.3° before and 4.7° ± 0.6° after the surgery ($p < 0.003$), and WI decreased from 41.1 ± 4.8 to 11.5 ± 2.6% ($p < 0.003$). In patients who were operated openly, the WI decreased from 49.5 ± 5.4 to 8.3 ± 5.1% ($p < 0.003$), and no significant differences were found in the changes in the kyphotic deformation, although there was a tendency towards its reduction. In patients with type *A*1 fractures, kyphosis decreased from 10.8° ± 1.7 to 4.8° ± 0.8° ($p < 0.003$), WI from 54.2 ± 4.8 to 11.0 ± 3.4% ($p < 0.003$). In patients with type *A*3 fracture, WI decreased from 38.8 ± 6.6 to 6.8 ± 3.3% ($p < 0.003$), and a tendency towards lower segmental kyphosis was noted from 9.4° ± 1.2° to 3.6° ± 1.0° ($p > 0.005$). Values of the wedging index in patients of the three groups significantly decreased. In patients of the 1st group, the kyphosis index decreased from 9.1° ± 1.4° to 4.7° ± 0.7° ($p < 0.003$), and with a more pronounced decrease in the mineral density in patients of the 2nd and 3rd groups no significant changes were detected ($p > 0.005$).

Post-traumatic deformation of the fractured vertebral body disrupts the load distribution in the spine, which is due to the additional flexion moment at the injured level. This eccentric load increases the pressure on the vertebrae adjacent to the injury and increases the risk of new fractures of their bodies against the background of reduced bone strength in osteoporosis [14]. Such a phenomenon is described in the literature as a "domino effect" [37]. Multiple osteoporotic fractures cause a coarse kyphotic deformation of the thoracic and lumbar spine segments. This leads to a decrease in the volume of the chest and abdominal cavity, which is clinically manifested in a decrease in pulmonary function and early saturation syndrome, respectively [32, 41]. Patients experience reduced quality of life, difficulties in daily activities and self-care, depression and decreased self-esteem, imbalance and gait disturbance, and higher mortality rates [17, 19, 24–26]. Recovery of the lost height of the fractured vertebral body and recovery of the segmental kyphosis will result in a decrease in the additional flexion moment, and, consequently, in reducing the risk of damage to adjacent levels [37].

Currently, the main methods of surgical treatment of osteoporotic compression fractures of vertebral bodies (type *A*1 according to the classification of F. Magerl) are vertebroplasty, kyphoplasty, and stentoplasty. Vertebroplasty was first described in 1987 as a

Results of deformation elimination for a fractured vertebral body and kyphosis under TPF before osteoplasty

Type of fracture	Wedging, %		Kyphosis	
	before surgery	under TPF without osteoplasty	before surgery	under TPF without osteoplasty
In the general group	40.5 ± 7.2	33.5 ± 4.2 ($p < 0.05$)	10.2° ± 1.2°	4.0° ± 0.3° ($p < 0.05$)
*A*1	54.2 ± 4.8	43.0 ± 9.7	10.8° ± 1.7°	4.3° ± 0.8° ($p < 0.05$)
*A*3	38.8 ± 6.6	29.8 ± 4.3	9.4° ± 1.2°	3.6° ± 0.9° ($p < 0.05$)

method of treating vertebral hemangiomas. After that, percutaneous vertebroplasty is widely used to treat pain associated with osteoporotic vertebral fractures [18]. Nevertheless, percutaneous vertebroplasty cannot restore the lost height of the vertebral body and has a high degree of bone cement leakage, up to 40.3% [23, 35]. Cement may migrate into the intervertebral disc, paravertebral tissues, epidural space, intervertebral foramens, or venous system. Most of these leakages are asymptomatic, but significant migration of bone cement into the spinal canal and/or the intervertebral foramen can lead to pain, radiculopathy, or compression of the spinal cord, which would require additional conservative or surgical treatment [40, 45]. Migration of the bone cement through the epidural or paravertebral venous system into the bloodstream can lead to pulmonary embolism [5, 9]. Embolization, as a rule, is asymptomatic, but the literature describes cases of fatal outcomes [4, 11]. There is also evidence of other lethal effects of bone cement migration, such as paradoxical embolism of cerebral vessels [39], embolism of the renal artery [10], etc.

With the development of minimally invasive surgery, the method of balloon kyphoplasty was developed, the distinctive feature of which is the introduction of bone cement into the preformed cavity, which makes it possible to partially restore the lost height of the vertebral body and reduce the risks of bone cement leakage to 8.6% [6]. Thus, according to a number of authors, percutaneous balloon kyphoplasty is the preferred method for treatment of osteoporotic compression fractures of vertebral bodies [7, 16, 33, 45]. But the clinical results indicate that the height of the vertebral body is then restored by an average of only 2.9 mm, which is about 1/3 of the lost height, and the Cobb angle is corrected on average by only 3.4° [42, 43].

To improve these indices, the method of percutaneous stentoplasty has been developed and is currently widely used in the treatment of osteoporotic compression fractures of vertebral bodies. The use of a mechanical, vertically (craniocaudally) directed force of a stretched stent in the body of a fractured vertebra, similar to a jack, makes it possible to restore the lost height of the affected vertebra, as shown in several biomechanical studies [8, 30]. According to J. Fan et al. (2016), when using the *Jack* vertebra dilator in 218 patients for osteoporotic compression fractures of vertebral bodies, the height of the anterior part of the vertebral body reaches up to 84.7% of normal height. Segmental kyphosis at the level of injury was corrected on average by 7.7° ± 3.4° ($p < 0.01$). The incidence of bone cement leakage was 5.1% [12].

Despite a significant decrease in the frequency of bone cement migration, compared with percutaneous vertebroplasty, the risk of complications remains high. In order to better restore the lost shape of the vertebral body and reduce the risk of complications associated with bone cement migration, the plastic of the fractured vertebral body was carried out using DPB [2], which was injected into the fractured vertebral body under pressure. This made it possible to restore the height of the anterior vertebral part up to 89 ± 3.4% of normal height, and the segmental kyphosis on average decreased by 6° ± 0.9° ($p < 0.003$).

Thus, comparing the results obtained in our study with the data of modern methods for treatment of osteoporotic compression fractures of vertebral bodies (vertebroplasty, kyphoplasty, and stentoplasty), which were considered in the course of the literature review, we can confidently conclude that the use of osteoplasty in transpedicular fixation in osteoporotic compression fractures of the vertebral bodies of the thoracic and lumbar spine regions makes it possible to achieve the best indices of posttraumatic correction with minimal risk of complications.

Surgical treatment of burst vertebral fractures (type *A*3 according to the classification of F. Magerl) in patients with osteoporosis is even more difficult. The use of traditional methods of surgical treatment of vertebral fractures with normal bone mineral density is limited due to reduced bone strength in osteoporosis [38]. Posterior fixation of vertebrae by transpedicular

or laminar structures in case of osteoporotic injuries was considered the most successful surgical method for treating these injuries. But in the available literature, we did not find any data on the recovery of the shape of the vertebral body with the use of TPF. It should also be noted that its effective use requires an increase in the contact points of metal structures with bone tissue and extension of the fixation length [22]. This, in turn, leads to restriction of movement, aggravation of the degree of severity of osteoporosis and degenerative processes in the spine [22].

At the same time, in osteoporotic fractures of vertebral bodies, surgical interventions on the ventral spine regions were in many cases considered a method of choice [27]. However, ventral spondylodesis in the treatment of vertebral fractures is not reliable. Reduced mechanical resistance of bone tissue in vertebral osteoporosis significantly reduces the possibility of correction of posttraumatic deformity with the use of ventral fixation and spondylodesis and worsens the outcome of treatment [28]. From our point of view, intervention in the ventral spine regions should be considered as an operation aimed mainly at restoring the anatomical relations in the injured segment of the spine at osteoporosis, which should be supplemented by effective posterior internal fixation. One of such methods in the treatment of osteoporotic burst vertebral fractures, widely covered in the modern literature, is the combination of percutaneous kyphoplasty and short segmental transpedicular fixation [13, 15, 20]. In this combination, the main primary stability is achieved through posterior short segmental fixation, and partial reconstruction of the lost height of the vertebral body and the introduction of bone cement make it possible to restore the stiffness of the fractured level and reduce the load on the dorsal structure [13]. R. Hartensuer et al. (2013) in their biomechanical study did not find any signs of additive functional supplementation to the primary stability of TPF, which may be due to the limitation of the correction of the vertebral body height by balloon kyphoplasty.

Thus, some of the conclusions from the literature on the treatment results achieved by an increase in the primary stability cannot be explained by their biomechanical study [34]. The frequency of bone cement leakage with the use of kyphoplasty with respect to the burst nature of injuries exceeds the frequency of its migration in osteoporotic compression fractures [21]; when combined with short segmental TPF, the leakage rate may reach 40.7% [46]. It follows that the risk of complications when using this method in patients with burst vertebral body fractures is unjustifiably high, and the combination of osteoplasty and posterior transpedicular fixation that we suggested for this category of patients makes it possible to achieve the recovery of the lost shape of the fractured vertebral body without exposing patients to the risk of developing severe complications.

CONCLUSIONS

The use of open or transcutaneous transpedicular fixation in combination with osteoplasty in the treatment of patients with osteoporotic fractures of the thoracic and lumbar spine regions in most cases makes it possible to recover the height of the broken vertebra and eliminate kyphosis, but when planning the surgery, one should take into account the fact that the result is affected by the nature of the fracture and the degree of decrease in bone mineral density.

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