STAGED SURGICAL TREATMENT OF POSTTRAUMATIC DEFORMITIES IN THE THORACIC AND LUMBAR SPINE

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Objective. To analyze corrective opportunities of staged combined surgical treatment of posttraumatic deformities in the thoracic and lumbar spine.
Material and Methods. A total of 106 patients (58 men and 48 women) were operated on for posttraumatic kyphosis of the thoracic and lumbar spine using staged operations at the same session. The study included the assessment of radiological parameters, the analysis of clinical outcomes using Oswestry Disability Index (ODI) and Visual Analogue Scale (VAS), and the estimation of intraoperative blood loss and complications.
Results. Segmental kyphotic deformity was on average corrected from 24.0° ± 8.7° to 10.5° ± 1.3° (P = 0.17), the mean deformity correction was 23.1°. The ODI and VAS scores changed significantly. The duration of multi-stage interventions was 227.5 ± 623 minutes, with blood loss of 407.5 ± 258.2 ml. There was no appearance of neurological symptoms or their worsening in the postoperative period. Complications were noted in 6 (5.6 %) patients.
Conclusion. Staged surgical treatment of posttraumatic deformities ensures high correction capability combined with the safety of interventions and low complication rates.
Key Words: posttraumatic spinal deformities, anterior spine fusion, staged spinal surgery.

Please cite this paper as: *Rerikh VV, Borzykh KO. Staged surgical treatment of posttraumatic deformities in the thoracic and lumbar spine. Hir. Pozvonoc. 2016;13(4):21–27. In Russian.*
DOI: http://dx.doi.org/10.14531/ss2016.4.21-27.

Despite the progress in surgery of traumatic injuries of the thoracic and lumbar spine, late effects of traumatic injuries of the thoracic and lumbar vertebrae are a pressing issue. Inadequate conservative treatment methods, late detection of vertebral fractures due to severe polytrauma, concomitant injuries, undiagnosed and untreated vertebral fractures are considered to be the cause of post-traumatic deformities [17, 24].

Posttraumatic deformities lead to sagittal imbalance, development of painful syndromes, functional impairment of the thoracic and lumbar spine, and cosmetically undesirable deformities [18].

Rehabilitation and full adaptation of patients with posttraumatic deformities to everyday and stress loads is impossible without restoring spinal segment anatomy and normal biomechanical relationships in the spine by correcting and stabilizing surgical interventions. Recovery of the anterior column anatomy is of key importance in the treatment of posttraumatic kyphosis [3, 11, 25]. Development of reliable ventral implants and retainers enabled correction and stable fixation of the spinal segment as early as on the operating table [4, 14]. However, the use of isolated ventral fixation is associated with the risk of correction loss and development of kyphosis relapse and false joint, especially in the presence of osteoporotic changes of the spine [20]. Excellent capabilities of ventral correction and limited capabilities of ventral fixation led to the development of a combined two-stage surgical approach. Some authors [2, 4, 7, 21, 23, 25] mention insufficient capability of kyphotic deformity correction through the ventral approach, limiting its value to about 20°. In the case of more severe deformity, they suggest using the posterior three-column vertebrotomy characterized by rigid deformity correction by shortening of the posterior spinal column. However, these techniques are associated with high blood loss, time-consuming surgery, and high incidence of complications [5, 9, 10, 12].

This study was aimed at analyzing the correction capabilities of multistage combined interventions in the treatment of posttraumatic deformities in the thoracic and lumbar spine.

Material and methods

The study included medical histories of 106 patients (58 males and 48 females) aged 16–70 years (mean age 43,1 ± 14,7 years), who were operated on at the Novosibirsk Research Institute of Traumatology and Orthopaedics in 2013–2014 for posttraumatic kyphosis of the thoracic and lumbar spine using ventral correction of spinal deformity. Inclusion criteria were as follows: no preexisting deformity of the thoracic and lumbar spine, no spinal osteoporosis as shown by T-test (not less than -3.0) and

motor neurological disorders impeding patient's ability to take orthostatic position without additional support.

The patient sought medical advice at the clinic for the following reasons: functional impairment of the spine, severe pain in the adjacent segments, and cosmetic defect. Time elapsed after injury ranged from 3 to 240 months (on the average, 20.6 ± 45.3 months).

The causes of posttraumatic deformity were determined (Table 1). We selected separate group of patients who previously underwent spinal surgery in the posterior portions of the spine for acute injury. In these patients, the presence of metal structures, fibrous and bone blocks resulted in high rigidity of the deformity.

Neurological status of all patients did not impede their ability to move independently. There were no neurological symptoms in 101 patients, 5 patients had spinal neurological deficit in the form of lower distal paraparesis with preserved ability to walk and take orthostatic position.

All the patients were subjected to a complex of diagnostic measures, including clinical, X-ray, and CT examination.

X-ray study consisted of radiographic examination of the cervical, thoracic, lumbar, and sacral spine including also femoral heads in two projections in patient's upright position. We took into account the following parameters: the magnitude of the thoracic kyphosis (T4–T12) and lumbar lordosis (L1–L5), local segmental kyphosis as assessed by Cobb's angle, and sagittal index [15, 22].

We studied global sagittal balance calculated based on the deflection of the plumb line drawn from the center of C7 vertebral body to the neutral point of the sacrum (cranial segment of S1 vertebra); forwards or backward deviation of the axis from the said point by more than 2.5 cm was considered as sagittal imbalance; by more than 4 cm – severe sagittal imbalance [13].

We assessed the relative anterior and posterior height of the interbody space at the apex of the posttraumatic deformity (ratio of the height of interbody space at the apex of the posttraumatic deformation to the normal value defined as a half-sum of the height of adjacent segments) before and after surgery.

Posttraumatic deformities were classified with allowance for the initial injury based on the Comprehensive Classification of Thoracic and Lumbar Injuries [16]: Type A – 88 (83.5 %), type B – 10 (9.4 %), type C – 8 (7.1 %).

The vast majority of posttraumatic deformities was caused by type A injuries.

Posttraumatic deformities were treated using multi-stage surgical procedures. When treating the consequences of type A injuries, anterior spinal fusion was carried out as the first stage, and posterior internal short-segmental fixation was carried out as the second stage (in the same surgical session). When treating the consequences of type B and C injuries accompanied by formation of osseous and osteofibrous block at the level of previous injuries of the posterior structures, ventral correction step was preceded by mobilization of the posterior structures using facetectomy at the level of damaged segment of the central angle of the deformity. Furthermore, in the surgical treatment of the consequences of type C injury, derotation is required during deformity correction, and for this reason, release stage was combined with decompressive laminectomy in order to control the state of the spinal cord and its roots during repositioning. Further, correcting stage was carried out followed by final instrumental stabilization of the ventral or dorsal spine during the same surgical session. Postoperatively, patients received conventional therapy, including adequate anesthesia, preventive antithrombotic and antiulcer therapy. Upright position was allowed on day 3–4 after the operation. In all cases, immobilization with removable orthopedic corset was used and orthopedic regimen up to 4 months after the operation was advised.

Intraoperative blood loss and duration of the surgery were evaluated; postoperative complications were documented. Functional treatment outcome was assessed based on the *Oswestry Disability Index* (ODI) and VAS scale [1]. Postoperatively, stage-by-stage clinical and radiographic examinations was performed 4, 8, and 12 months after the surgery to assess the formation of bone and bone-metal blocks. Patients answered ODI and VAS questionnaires at all follow-up stages.

Statistical analysis was carried out using Excel 2003 software and t-test. The value was considered as significant with $P < 0.05$.

Results

A total of 246 operations (18 three-stage and 96 two-stage) were required to achieve post-traumatic deformity correction in 106 patients. The average duration of multistage operations was 227.5 ± 62.3 min (135 to 395 min), the average blood loss was 407.5 ± 258.2 ml (250 to 1600 ml), and the average length of stay in the intensive care and resuscitation unit was 1.1 ± 0.7 days.

On the average, segmental kyphotic deformity was corrected from preoperative value of 24,0° ± 8,7° (20 to 57°) to 1,3° ± 10,5° (P = 0.17), the average deformity correction value was 23.1° ± 2.6°.

We studied radiographic correction results depending on the type of injury, preceding the deformity. In the group of patients with consequences of type A injury (n = 88), mean value of kyphotic deformity was 17.4° ± 8.4°. In the postoperative period, decrease to an average value of -3.0° ± 4.1° was achieved followed

Table 1
Distribution of patients according to the causes of posttraumatic deformity, n (%)

Causes	Patients
Ineffectiveness of conservative treatment	72 (67.9)
Deformity relapse after surgical treatment	20 (18.8)
Concomitant and multiple traumatic injury	14 (13.3)

by the loss of correction by the time of the final postoperative examination to 0.8° ± 5.3°. Type B and C injuries (n = 18) were characterized by an average kyphotic deformity of 28,3° ± 11,3°, the presence of axial and shearing deformations, and multilevel damage to the posterior osteoligamentous complex. Multistage surgical treatment (release stage was carried out in all cases) resulted in average kyphotic deformity value of 8.1° ± 3.3° followed by the loss of correction by the time of follow-up examination in 1 year to 9.7° ± 5.4°.

Patients were divided into two groups depending on the severity of kyphotic deformity: group 1 patients (82) had kyphotic angle of 20–30° (an average of 24.6° ± 5.8°); group 2 patients (24), more than 30° (an average of 35.4° ± 6.9°). Surgical correction resulted in the angle of -0.6° ± 9.2° in group 1 patients, and – 6.9° ± 5.8° in group 2 patients; no significant differences were observed (P = 0.018).

The dynamics of lumbar lordosis change from preoperative 41.1° ± 9.6° to postoperative -38.6° ± 17.6° was statistically significant (P < 0.05). Opposite situation was observed when analyzing the dynamics of thoracic kyphosis change from 39.5 ° ± 17.3° to 34.2° ± 10.4° (P > 0.05).

The study of the global sagittal balance demonstrated that preoperative deflection of the plumb line with respect to the neutral point of the sacrum was ±2.5 cm in 82 (77.3 %) patients, sagittal imbalance of +4 cm was observed in 18 patients, and severe sagittal imbalance above +4 cm was observed in 6 patients. There was no significant correlation between the severity of pain and imbalance value.

The dynamics of changes in the anterior and posterior height of the vertebral segment was characterized by complete correction through the ventral approach. In the preoperative period, the anterior and posterior height of the interbody space at the apex of the deformity was 57.7 ± 12.8 % and 82.1 ± 8.5 %, respectively.

Treatment resulted in good and satisfactory results: functional capacity (ODI) changed on the average from 55.2 ± 6.5 (48 to 60) to 21.5 ± 4.8. VAS indexes also changed from an average of 7.4 ± 1.1 to 2.3 ± 0.4 points after surgery.

The best dynamics of functional capacity values was observed in the case of surgical treatment of the consequences of type A injury, less pronounced dynamics – with type B and C injuries (Table 2).

At the same time, the dynamics of changes in VAS and ODI values in the group of patients with kyphosis greater than 30° was not significantly different from that in patients with less severe kyphosis (Table 3).

Fig. shows a typical clinical example.

Complications. None of the patients demonstrated development or worsening of neurological symptoms in the postoperative period. Complications were reported in 6 (5.6 %) patients: postoperative pleurisy on the side of the thoracotomy in 2 patients, urinary infection in 2 patients, positional brachial plexus injury in 1 patient, and hematoma of the postoperative wounds in 1 patient. Complications were resolved during hospital stay as a result of conservative treatment.

Discussion

Here we report the results of successful correction of posttraumatic deformity in the thoracic and lumbar spine, whose severity ranged from moderate (30°) in 82 patients to severe (more than 30°) in 24 patients. In the reported series, the severity of blood loss and duration of the operation were moderate, and postoperative complications were nonspecific and could not influence the choice of surgical approach. At the same time, improvement in functional capacity and pain relief were achieved over time.

Posttraumatic kyphotic deformities result in persistent pain syndromes, functional disorders, and possible worsening of neurological symptoms. Therefore, the need for surgical treatment of posttraumatic deformities is of no doubt [4, 7, 17, 23, 24].

Correction of posttraumatic kyphosis can be achieved either by increase in the anterior height of the spinal segment using operation on the ventral spine or formation of wedge-shaped defect in the posterior structures followed by correction and stable posterior internal fixation of the segment of interest, using osteotomy of their modifications [7]. However, in our view, the attitude to these types of surgical treatment including three-column vertebrotomy should be cautious, especially in patients without neurological deficit, due to the large number of complications, which is up to 42 % [5]. Of these complications, more than 2.6 % account for severe neurological disorders, such as severe paresis and plegia, resulting from persistent spinal cord dysfunction, which is the reason for reoperations in the early period. Heavy intraoperative blood loss greater than 4000 ml belong among the factors complicating the surgery and postoperative period [5, 26].

In our study, the correcting ventral spinal fusion is a primary surgical technique that enables correction of the rigid segmental deformation. Anterior decompression of neural structures can be performed during the ventral approach, when necessary. Anterior spinal fusion is performed using mesh, crown-shaped hollow fixators developed at the Novosibirsk Research Institute of Traumatology and Orthopedics (registration number RK-IMN-5 No CP-000095), and implants made of porous titanium nickelide. Spinal fixator enables both monosegmental anterior fusion after resection of the damaged portion of the vertebral body and degenerated disc and bisegmental fusion after vertebral body resection over the entire vertical dimension. Autologous osteoplastic material, which was placed into the hollow ventral structures prior to implantation and around the implant, provides formation of the ventral bone-metal block within 4–6 months after the injury. Methodology of monosegmental and bisegmental anterior spinal fusion with these implants does not require extensive mobilization of ventral spinal segments, it is less traumatic, technically simple, and not associated with significant blood loss. The use of anterior spinal fusion and fixators is especially effective and less traumatic, when using minimally-invasive and endoscopic approaches.

Table 2
The study of the functional capacity depending on the type of injury preceding the deformity

Injury type	ODI		VAS, points	
	Preoperative	Postoperative	Preoperative	Postoperative
A	56.1 ± 7.2	19.1 ± 5.2*	5.6 ± 1.2	1.8 ± 0.2*
B	65.4 ± 10.1	25.3 ± 4.8*	6.4 ± 1.4	2.4 ± 0.7*
C	67.0 ± 11.1	29.8 ± 4.3*	7.8 ± 0.7	2.8 ± 0.2*

*P < 0.05.

Table 3
The study of the functional capacity depending on the severity of kyphosis

Group of patients	ODI		VAS, points	
	Preoperative	Postoperative	Preoperative	Postoperative
1 (n = 82)	58.1 ± 7.1	21.4 ± 5.4	5.6 ± 1.2	2.2 ± 0.2
2 (n = 24)	63.4 ± 8.4	24.0 ± 4.9	6.4 ± 1.4	2.6 ± 0.3

On our view, when treating rigid posttraumatic deformities accompanied by not only decrease in the anterior height of the vertebral segment, but also adnation of the posterior structures characteristic of type B and C injury, mobilizing steps, such as facetectomy, and, in some cases, especially when there is rotational deformation component, laminectomy and foraminotomy are appropriate.

In this case, ventral correcting manipulations are safer than dorsal three-column remedial vertebrotomy. In our series of patients, there were no cases of the development or worsening of neurological symptoms. At the same time, the literature reports the cases of neurological complications during simultaneous dorsal correction after spinal osteotomy [5, 6, 19]. Intraoperative blood loss is believed to be one of the criteria of traumatic operation. Blood loss exceeding 55 % of the circulating blood volume results in increased incidence of postoperative complications [5]. In the remedial vertebrotomy, it averages 1570–1600 ml [5, 8, 26]. In our cases, blood loss was 2 times lower.

In some cases, transcutaneous transpedicular fixation was applies at one stage, which contributed to decrease in the duration of surgery and blood loss. In the present group of patients, who were operated on for posttraumatic deformity,

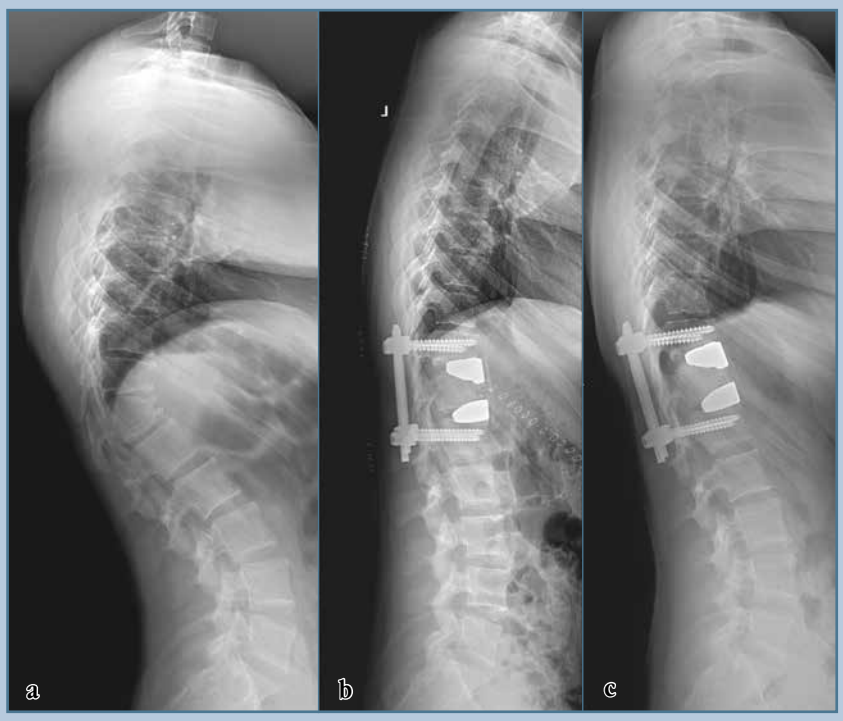

Fig.
Radiographs of a female patient M., 17 years old, with an injury (a fall from a horse), which occurred 36 months before applying to the clinic; conservative treatment was conducted. Diagnosis: "posttraumatic kyphosis of 34° with the apex at T11–L1 level, functional impairment of the spine"; ODI = 60, VAS = 6 points: **a** – preoperative; **b** – two-stage surgical treatment resulted in complete correction of the deformity; **c** –11.8 months after surgery, kyphotic deformity correction loss by 4°, ODI = 19, VAS = 1 point

it was shown that radiographic results of correction depend on the type of injury preceding the deformity and the severity of the deformity. The most complete correction of deformity was achieved in treatment of type A injuries. Moderate deformity 17.4° ± 8.4° was fully corrected using the anteroposterior surgery and had no tendency to correction loss during further follow-up.

When treating the consequences of type B and C injury, correction of kyphotic deformity after three-stage surgery (posterior, anterior, and posterior stages) averaged only 71.5%. Residual deformity averaged 8.1° ± 3.3° (5 to 12°) and had a tendency to increase during follow-up period.

We analysed correction results in the group 1 (less severe deformity of up to 30°) and group 2 (severe, over 30°). The analysis showed that the most complete correction (on the average 95.3 %) was achieved, when using the discussed method in the group 1 regardless of the type of preceding injury. In the group 2, ventral correction of the deformity was less effective and correction value averaged 81.5 %.

There was no statistically significant difference in the postoperative dynamics of thoracic kyphosis and lumbar lordosis between the groups. This is apparently due to the high compensatory tension of postural muscles.

The postoperative period was characterized by high patient's satisfaction according to ODI score and decrease in VAS scores, which was the most pronounced in the case of multistage treatment of the consequences of type A injury.

Lower correction effectiveness and patient's satisfaction with the procedure, when using multistage surgery, were obtained in patients with rigid deformities due to type B and C injuries. Spontaneous posterior bone blocks and high rigidity of the deformity, even with adequate mobilization of the posterior structures, often hinder full-scale correction of the deformity of the injured spinal segment: simultaneous intraoperative correction through the ventral approach results in reproduction of distraction elements rather than extension elements of the segment, which is the cause of insufficient correction. In the literature, corrective dorsal vertebrotomy is the method of choice in the treatment of these deformities [4].

Conclusion

Our experience of surgical treatment of posttraumatic deformities suggests high correcting capabilities along with low incidence of neurological complications, when using combined surgery. Multistage combined surgery is currently the method of choice for surgical treatment of the majority of post-traumatic deformities, combining high correcting capabilities, safety, and low incidence of complications.

References

1. **Byval'tsev VA, Belykh EG, Sorokovikov VA, Arsent'eva NI.** The use of scales and questionnaires in vertebrology. Zh Nevrol Psikhiat Im SS Korsakova. 2011;(9 Pt 2):51–56. In Russian.
2. **Dulaev AK, Usikov VD, Ptashnikov DA, Fadeev EM, Dadykin AV, Alikov ZYu, Dulaeva NM.** Surgical treatment of patients with unfavorable consequences of vertebral-spinal injuries. Traumatology and Orthopedics of Russia. 2010;(2):51–54. In Russian.
3. **Been HD, Poolman RW, Ubags LH.** Clinical outcome and radiographic results after surgical treatment of post-traumatic thoracolumbar kyphosis following simple type A fractures. Eur Spine J. 2004;13:101–107. DOI:10.1007/s00586-003-0576-1.
4. **Benli IT, Kaya A, Uruc V, Akalin S.** Minimum 5-year follow-up surgical results of post-traumatic thoracic and lumbar kyphosis treated with anterior instrumentation: comparison of anterior plate and dual rod systems. Spine. 2007;32:986–994. DOI: 10.1097/01.brs.0000260796.77990.f7.
5. **Bianco K, Norton R, Schwab F, Smith JS, Klineberg E, Obeid I, Mundis G Jr, Shaffrey CI, Kebaish K, Hostin R, Hart R, Gupta MC, Burton D, Ames C, Boachie-Adjei O, Protopsaltis TS, Lafage V.** Complications and intercenter variability of three-column osteotomies for spinal deformity surgery: retrospective review of 423 patients. Neurosurg Focus. 2014;36:E18. DOI: 10.3171/2014.2.FOCUS1422.
6. **Buchowski JM, Bridwell KH, Lenke LG, Kuhns CA, Lehman RA Jr, Kim YJ, Stewart D, Baldus C.** Neurologic complications of lumbar pedicle subtraction osteotomy: a 10-year assessment. Spine. 2007;32:2245–2252. DOI: 10.1097/BRS.0b013e31814b2d52.
7. **Buchowski JM, Kuhns CA, Bridwell KH, Lenke LG.** Surgical management of posttraumatic thoracolumbar kyphosis. Spine J. 2008;8:666–667. DOI: 10.1016/j.spinee.2007.03.006.
8. **Bourghli A, Boissiere L, Vital JM, Bourghli MA, Almusrea K, Khoury G, Obeid I.** Modified closing-opening wedge osteotomy for the treatment of sagittal malalignment in thoracolumbar fractures malunion. Spine J. 2015;15:2574-82. DOI: 10.1016/j.spinee.2015.08.062.
9. **Chiffolot X, Lemaire JP, Bogorin I, Steib JP.** [Pedicle closing-wedge osteotomy for the treatment of fixed sagittal imbalance]. Rev Chir Orthop Reparatrice Appar Mot. 2006;92:257–265. In French.
10. **Cho KJ, Bridwell KH, Lenke LG, Berra A, Baldus C.** Comparison of Smith-Petersen versus pedicle subtraction osteotomy for the correction of fixed sagittal imbalance. Spine. 2005;30:2030–2037. DOI: 10.1097/01.brs.0000179085.92998.ee.
11. **Jo DJ, Kim YS, Kim SM, Kim KT, Seo EM.** Clinical and radiological outcomes of modified posterior closing wedge osteotomy for the treatment of posttraumatic thoracolumbar kyphosis. J Neurosurg Spine. 2015;23:510–517. DOI: 10.3171/2015.1.SPINE131011.
12. **Kawahara N, Tomita K, Baba H, Kobayashi T, Fujita T, Murakami H.** Closing-opening wedge osteotomy to correct angular kyphotic deformity by a single posterior approach. Spine. 2001;26:391–402. DOI: 10.1097/00007632-200102150-00016.
13. **Koller H, Acosta F, Hempfing A, Rohrmuller D, Tauber M, Lederer S, Resch H, Zenner J, Klampfer H, Schwaiger R, Bogner R, Hitzl W.** Long-term investigation of nonsurgical treatment for thoracolumbar and lumbar burst fractures: an outcome analysis in sight of spinopelvic balance. Eur Spine J. 2008;17:1073–1095. DOI: 10.1007/s00586-008-0700-3.
14. **Kostuik JP, Matsusaki H.** Anterior stabilization, instrumentation, and decompression for post-traumatic kyphosis. Spine. 1989;14:379–386.
15. **Kuklo TR, Polly DW, Owens BD, Zeidman SM, Chang AS, Klemme WR.** Measurement of thoracic and lumbar fracture kyphosis: evaluation of intraobserver, interobserver, and technique variability. Spine. 2001;26:61-66.
16. **Magerl F, Aebi M, Gertzbein SD, Harms J, Nazarian S.** A comprehensive classification of thoracic and lumbar injuries. Eur Spine J. 1994;3:184–201. DOI: 10.1007/BF02221591.
17. **Malcolm BW, Bradford DS, Winter RB, Chou SN.** Post-traumatic kyphosis. A review of forty-eight surgically treated patients. J Bone Joint Surg Am. 1981;63:891–899.
18. **Morrison R, Schnake KJ.** Correction of a mobile posttraumatic kyphosis in the thoracolumbar spine with a combined posterior-anterior approach. Eur Spine J. 2015;24 Suppl 8:S955–S956. DOI: 10.1007/s00586-015-4330-2.
19. **Murrey DB, Brigham CD, Kiebzak GM, Finger F, Chewning SJ.** Transpedicular decompression and pedicle subtraction osteotomy (eggshell procedure): a retrospective review of 59 patients. Spine. 2002;27:2338–2345. DOI: 10.1097/01.BRS.0000030853.62990.BC.
20. **Suk SI, Kim JH, Lee SM, Chung ER, Lee JH.** Anterior-posterior surgery versus posterior closing wedge osteotomy in posttraumatic kyphosis with neurologic compromised osteoporotic fracture. Spine. 2003;28:2170-2175. DOI: 10.1097/01.BRS.0000090889.45158.5A.
21. **Schnake KJ, Kandziora F.** Correction of posttraumatic kyphosis of the thoracolumbar spine with modified pedicle subtraction osteotomy. Eur Spine J. 2010;19:2231–2232. DOI: 10.1007/s00586-010-1622-4.
22. **Stagnara P, De Mauroy JC, Dran G, Gonon GP, Costanzo G, Dimnet J, Pasquet A.** Reciprocal angulation of vertebral bodies in a sagittal plane: approach to references for the evaluation of kyphosis and lordosis. Spine. 1982;7:335–342. DOI: 10.1097/00007632-198207000-00003.
23. **Vaccaro AR, Silber JS.** Post-traumatic spinal deformity. Spine. 2001;26(24 Suppl):S111–S118.
24. **Verlaan JJ, Diekerhof CH, Buskens E, van der Tweel I, Verbout AJ, Dhert WJ, Oner FC.** Surgical treatment of traumatic fractures of the thoracic and lumbar spine. A systematic review of the literature on techniques, complications, and outcome. Spine. 2004;29:803–814.
25. **Wu SS, Hwa SY, Lin LC, Pai WM, Chen PQ, Au MK.** Management of rigid posttraumatic kyphosis. Spine. 1996;21:2260–2267.
26. **Zeng Y, Chen Z, Sun C, Li W, Qi Q, Guo Z, Zhao Y, Yang Y.** Posterior surgical correction of posttraumatic kyphosis of the thoracolumbar segment. J Spinal Disord Tech. 2013;26:37–41. DOI: 10.1097/BSD.0b013e318231d6a3.

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Received 21.06.2016
Review completed 17.08.16
Passed for printing 28.08.2016

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