POST-TRAUMATIC DEFORMITIES OF THE SPINE: RELEVANCE, PROBLEMS, AND REVISION SURGERY

O.G. Prudnikova, M.V. Khomchenkov

Russian Ilizarov Scientific Center for Restorative Traumatology and Orthopaedics, Kurgan, Russia

Objective. To analyze tactical approaches and types of surgical interventions for post-traumatic deformity of the spine.

Material and Methods. Study design: retrospective monocentric cohort study. The study included 116 patients: Group 1 consisted of 50 patients with primary post-traumatic deformities, and Group 2 of 66 patients with secondary deformities after previously performed decompression and stabilization surgery who were admitted for revision interventions. The average age of patients was 42.1 ± 11.6 years, the long-term follow-up period varied from 2 to 60 months (16.6 ± 10.2). Methods used in the study were clinical (neurological status, ASIA, VAS) one, evaluation of treatment results according to MacNub scale, radiography, CT, radiometry (local kyphosis according to Cobb, Surgimap Spine), MRI, and statistical methods.

Results. The follow-up period of Group 1 patients was 31.3 ± 28.1 months, of Group 2 patients – 60.3 ± 48.1 months. Injuries were predominantly localized at the level of the thoracolumbar junction. In Group 2, more severe neurological disorders (ASIA) prevailed. All patients underwent primary or revision transpedicular fixation and Schwab vertebrotomy variants through posterior approach. The following types of primary deformities according to Rajasekaran were observed: type IIA in 16 (32 %) patients, IIIA in 30 (45 %), and IIIB in 4 (6 %). Patients with secondary deformities had failure of posterior instrumental fixation (100 %), failure (56 %) or absence (73 %) of anterior fusion, and progression of deformity (100 %). In Group 1, local kyphosis was 32.0° ± 9.9° before treatment and 12.5° ± 8.8° after treatment, pain VAS score before treatment 76.6 ± 6.9, and after treatment 47.6 ± 8.8. In Group 2, local kyphosis was 31.8° and 10.1°, and pain score 80.6 and 48.4, respectively. Complications were registered in 10 % of cases. Treatment results were assessed as good/satisfactory in 32 (64 %)/18 (36 %) Group 1 patients, and in 38 (57 %)/28 (42 %) Group 2 patients, respectively.

Conclusion. Classification options and tactical approaches for primary post-traumatic spinal deformities were defined; for secondary post-traumatic deformities there is no classification defining treatment tactics and criteria for assessing the parameters of local and global body balances. Joint multicenter studies are necessary for the adoption of consensual conclusions in the revision surgery of post-traumatic spinal deformities.

Key Words: post-traumatic spinal deformities, revision surgery for post-traumatic spinal deformities, classification of post-traumatic deformities, local kyphosis in post-traumatic deformities, sagittal balance in post-traumatic deformities.

Please cite this paper as: *Prudnikova OG, Khomchenkov MV. Post-traumatic deformities of the spine: relevance, problems, and revision surgery. Hir. Pozvonoc. 2019;16(4):36–44. In Russian.*

DOI: http://dx.doi.org/10.14531/ss2019.4.36-44.

Some operative interventions are not performed in acute spinal injury period due to certain reasons, including severity of patient's condition, insufficient technical resources or hands-on experience. Basing on the literature data, it is impossible to estimate the rate and distribution of spinal deformities that are formed in a certain post-trauma period. The most information in the literature addresses spinal and spinal cord injury rates in the acute period. Thus, from 150,000 to 170,000 spinal injuries and 17,000 spinal cord traumas are registered annually in the USA [1]. In large industrial cities of Russia (Saint-Petersburg, Nizhny Novgorod, Irkutsk), the rate of spinal and spinal cord injuries accounts for 0.58–0.6 per 10,000 population [2, 3]. Results of surgical treatment of patients with post-traumatic deformities are presented in the works of A.A. Afaunov et al. [4] who presented the analysis of treatment outcomes of 124 patients, V.V. Rerikh and K.O. Borzykh (106 patients) [5], and A.K. Dulaev et al. (76 patients) [6].

Post-traumatic spinal deformities are characterized by rigidity due to the formation of a fibrous and bone blocks at the injury level; and if they appear after performed surgeries, so a revision intervention is necessary, but such surgeries are associated with technical challenges and a high risk of complications.

The objective of the study was to analyze tactical approaches and types of surgical interventions for post-traumatic deformities of the spine.

Material and Methods

Study design: retrospective monocentric cohort study.

Inclusion criteria: the age of patients above 18 years, spinal deformity caused by traumatic injury, post-traumatic period more than 4 months.

Exclusion criteria: the age up to 18 years, infection in the injury area or in the area of previous surgery, post-traumatic period less than 4 months.

The following study methods were applied: clinical methods (neurological status, ASIA, VAS [7]), evaluation of treatment outcomes according to modified MacNub scale [8], radiological method (radiography, CT), radiometry (local kyphosis according to Cobb, Surgimap Spine software), MRI, and statistical methods (calculation of arithmetic mean (M) and its errors (±m), *r*-Pearson correlation coefficient with the Chaddock score, the Student's *t*-test was used to determine the indicator of statistical significance of the difference in mean, $p < 0.05$).

Evaluation criteria: post-traumatic period, type of a primary surgery, option of reoperation, vertebrotomy variant, deformity type and correction degree, and structure of complications.

The studies were carried out in accordance with the requirements of the Helsinki Declaration of 1964. All the patients included in the study gave written informed consent for conducting diagnostic tests, medical intervention, and using of the data obtained for scientific purpose.

The patients were enrolled from January, 2014 to June, 2019.

The study included 116 patients, who were admitted for operative treatment. Group 1 consisted of 50 patients with primary deformities, and no operative treatment had been carried out in the acute period. Group 2 consisted of 66 patients with secondary deformities after previously performed decompression and stabilization surgery who were admitted for revision interventions. The mean age of patients at the moment of the surgery was 42.1 ± 11.6 years (range 18–71 years), the male/female ratio was 66 (56.8 %)/50 (42.1%). The long-term follow-up period varied from 2 to 60 months (16.6 ± 10.2).

The operative treatment was performed in the Department of Traumatology and Orthopedics No 10 of the Russian Ilizarov Scientific Center for Restorative Traumatology and Orthopaedics (Kurgan).

Results

The patients with catamnesis for more than 4 months were included in the study due to the fact that spinal deformities had been formed because of a fibrous and/or bone block formation at the injury level within this very period. Moreover, this very period corresponds to an interim period of a traumatic disease of the spinal cord according to the classification proposed by O.A. Amelina [9]. Patients with secondary deformities were admitted for treatment with longer post-traumatic periods. For Group 1 patients, this period was 31.3 ± 28.1 (4–240) months, for Group 2 patients, 60.3 ± 48.1 (4–300) months.

Spinal injuries were predominantly localized at the level of the thoracolumbar junction of the spine (Fig. 1).

In Group 2, more severe neurological disorders (ASIA) prevailed, that is why a neurogenic component was supposed to contribute for deformity progression (significance of differences according to t-criterion was 0.09; Fig. 2).

All the patients underwent operative treatment through posterior approach and primary or revision transpedicular fixation (TPF) and vertebrotomy variants [10, 11]. In some cases, an additional, supporting, anterior spinal fusion with a cage was performed at the level of the consolidated vertebral body. The scope of an operative intervention was determined depending on the condition of the anterior support column, dural sac compression, and intensity of the deformity at the injury level.

Primary deformities were assessed according to the kyphosis classification by Rajasekaran et al. [12]. The following types of primary deformities were observed: Type IIA in 16 (32 %) patients, IIIA in 30 (45 %), and IIIB in 4 (6 %). Patients with Type IIA deformities underwent TPF with Shwab 1 or Shwab 2 vertebrotomy variants. Patients with Type IIIA kyphosis, without spinal canal deformity, underwent TPF with Shwab 3 vertebrotomy or TPF with anterior spinal fusion with a cage (in the absence of signs of a spontaneous anterior fusion). In case of dural sac compression, TPF was combined with Shwab 5 vertebrotomy. Spinal deformity of Type IIIB caused dural sac compression in all cases and required a reconstructive intervention, involving TPF with Shwab 5/Shwab 6 vertebrotomy.

In order to choose an adequate scope of the operative intervention in Group 2, the condition of the fixation system and of the anterior bone block was additionally assessed.

So, in case of primary deformities, the combinations of TPF with Type 5 vertebrotomy (resection of a vertebral body with adjacent discs), and TPF with Type 2 vertebrotomy were more often performed. The following methods prevailed in revision interventions: TPF with Type 5 vertebrotomy and TPF variants (reinsertion of screws and reinstallation of spinal instrumentation) (Table 1).

It was impossible to group secondary deformities according to the classification of Rajasekaran because of postoperative changes and implanted instrumentation. That is why the spinal condition, variants of previously performed manipulations, and the condition of the instrumentation were analyzed (Table 2).

In Group 1 patients, local kyphosis was 32.0° ± 9.9° before treatment and 12.5° ± 8.8° after treatment, pain VAS score was 76.6 ± 6.9 before treatment, and 47.6 ± 8.8 after treatment. In Group 2 patients, local kyphosis was 31.8° and 10.1°, pain syndrome was 80.6 and 48.4, respectively.

Clinical example 1. Female patient L., 35 years old, with a catatrauma, and catamnesis for 23 months. Diagnosis on admission: traumatic disease of the spinal cord, late period, type A (ASIA). Results of the T7, T8 vertebrae fracture. Kyphotic deformity of the thoracic spine was of type 3B according to Rajasekaran. Reconstruction and stabilization surgery was performed, including: Shwab 6 vertebrotomy of the T7, T8 vertebrae, resection of the T9 vertebral body. The spinal cavity was restored. Plasty of the dural sac was performed. TPF of the T2–T5, T10–L1 vertebrae, spinal fusion of T6–T9 with a mesh implant were performed (Fig. 3).

Clinical example 2. Female patient U., 22 years old, with catatrauma, and catamnesis for 11 months. Diagnosis on admission: traumatic disease of the spinal cord, interim period, type C (ASIA), results of the L1 vertebra burst fracture, the condition after operative treatment (laminectomy, 4-screw TPF), and failure of the instrumentation. Reconstruction and stabilization surgery was performed, including dismantling of the metal system, Schwab 5 vertebrotomy of the L1 vertebra, reposition and stabilization spondilosynthesis of T12–L2 with a mesh implant, spondilosynthesis of T11–L3 with a TPF system, restoration of the spinal canal (Fig. 4).

Complications were registered in 10 % of cases. They were mostly observed after types 5 and 6 vertebrotomies (technically challenging operative interventions) (Table 3).

Treatment outcomes were assessed according to MacNab classification within the period of 16.6 ± 10.2 (from 2 to 60) months as good/satisfactory in 32 (64 %)/18 (36 %) Group 1 patients; and in 38 (57 %)/28 (42 %) Group 2 patients, respectively.

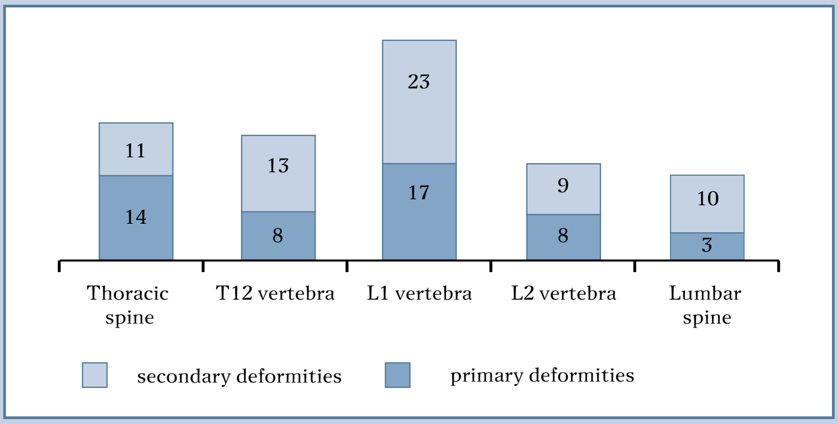

Fig. 1
Distribution of patients by levels of spinal injury, n

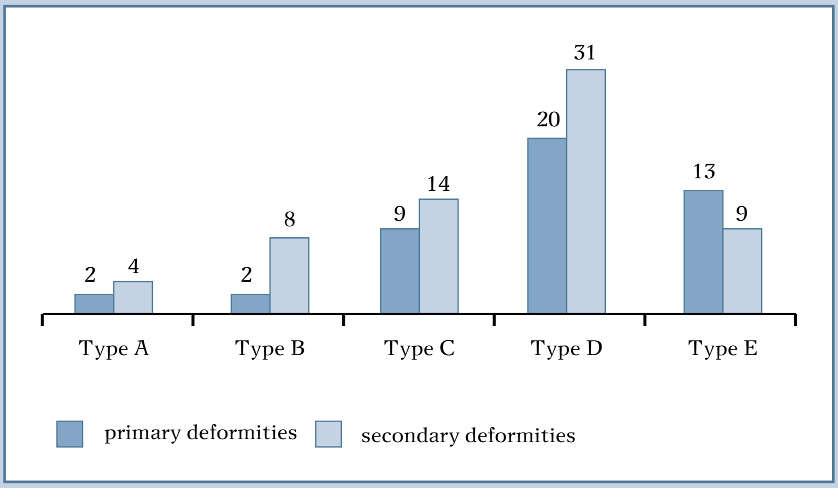

Fig. 2
Distribution of patients by types of neurological disorders according to the ASIA scale, n

Discussion

The main issues addressed to patients of this category are as follows: a lack of classification defining treatment tactics, criteria to assess deformities and their correction, as well as a choice of an operative intervention with regard to a high risk of neurological complications.

The existing classifications of spinal injuries (Denis, Magerl, AO Spine: Thoracolumbar Classification System) are elaborated to classify acute-period traumas and do not suit for assessing already formed post-traumatic changes that are distinguished by bone (fibrous) block and accompanied degenerative changes [13–17].

Vaccaro et al. [18] distinguish post-traumatic deformities depending on the level, etiology, degrees of kyphosis, and presence of pain syndrome.

In many publications, patients are grouped depending on a vertebrotomy variant [19–26] or other surgical techniques [4, 5, 27–31]. At the same time, the majority of publications assess primary post-traumatic deformities. Problems of secondary deformities are not discussed.

Rajasekaran et al. [12] proposed a universal classification of kyphosis, independent of the etiological factor. This classification makes it possible to assess the condition of support structures of the spine and angular deformity for further determination of a vertebrotomy variant. We used this classification to assess deformities in patients with primary post-traumatic deformities. This classification is not suitable for assessing secondary deformities in revision interventions, because a question arises how to assess deformity taking into account iatrogenic factors (resection of support bone structures, presence of metal systems). All the problems connected with the fixation instability and deformity progression should be reflected in a classification of revision interventions.

A.A. Afaunov et al. [32] proposed a classification based on spondylometric parameters, rigidity, spinal stenosis, and surgical risk, depending on the initial neurological status of the patient. The classification takes into account the main parameters of post-traumatic deformities, but it does not define such tactic approaches as reinsertion of screws, additional fixation of vertebrae, choice of vertebrotomy, indications to anterior spinal fusion.

Assessment of deformities is still disputable. The parameter of local kyphosis is unclear in case of injuries in the thoracic spine associated with physiological kyphosis. But even in these cases, the authors propose to measure the deformity value as a difference between the local and mean physiological kyphosis [29]. The measurement of lumbar kyphosis, especially at the L3–L5 level associated with lordosis is problematic. Typically, a decrease of lordosis is observed at this level, but not a kyphotic deformity.

The measurement of sagittal balance in patients with post-traumatic deformities [19–21, 25] is also disputable. A part of patients, who have neurological disorders of various intensities, are unable to keep a vertical position without assistance, and some patients use auxiliary walking aids. Consequently, the assessment of the sagittal balance parameters in a selected group of patients without neurological changes is of limited significance. There is another problem of spinal deformities correction. What values of sagittal balance should be the surgeon's aim – standardized (it might require more complicated reconstructive interventions) or individual, preoperative (but where to take these parameters)? After all, patients could have initial pre-traumatic imbalance accompanied with pathology of the spine, pelvis, or extremities.

Pain syndrome must be taken into consideration, when indications for an operative treatment are determined. It is diagnosed in 60–84 % of patients [6, 27].

Post-traumatic myelopathy with/without initial neurological deficit is a risk factor of neurological complications in postoperative period. It is necessary to consider the condition of the spinal cord, when choosing a variant of osteotomy, taking into account decompression, deformity correction, and prosthetic repair of the anterior support structures of the spine [32].

During the study of the primary treatment tactics for revision interventions, the following mistakes were identified: failure of the posterior bone block (100 % of cases), failure (56 %) or absence (73 %) of the anterior bone block; they resulted in instability of the systems and deformity progression. Tactic mistakes at treatment stages are the most common reasons for unsatisfactory treatment outcomes in the acute period of injury [6].

For primary deformities, tactical approaches to operative intervention are defined by the choice of a vertebrotomy variant, decompression, fixation, and correction of kyphosis. Posterior instrumented fixation combined with variants of posterior vertebrotomies (Shwab 1, Shwab 2, and Shwab 3) is recommended in the absence of the dural sac compression and local kyphosis up to 30°. An additional, anterior interbody spinal fusion is performed in the absence of the anterior block at the injury lev-

Table 1

Distribution of patients by types of operative interventions, n (%)

Surgery type	Group 1 (n = 50)	Group 2 (n = 66)
TPF/Shwab 1	6 (12)	21 (32)
TPF + Shwab 2	11(22)	10 (15)
TPF + anterior spinal fusion	6 (12)	6 (9)
TPF + Shwab 3	7 (14)	6 (9)
TPF + Shwab 5	20 (40)	23 (35)
TPF + Shwab 6	1 (2)	–

TPF — transpedicular fixation.

Table 2

Characteristics of primary decompression and stabilization interventions

Parameters	Patients, n (%)	Notes
Instrumented fixation of the spine		
Without posterior instrumented fixation	20 (32)	It was deleted in 6 cases
Anterior plate	2 (3)	–
Transpedicular fixation	42 (63)	Twenty six (62 %) patients had a 4-screw system, and four (9 %) patients had a 6-screw system
Anterior spinal fusion		
Without anterior spinal fusion	50 (75)	–
NiTi	6 (9)	–
Expandable implant	4 (6)	–
Homobone	2 (3)	–
Mesh implant	3 (4)	–
Cement	1 (2)	–
Condition of fixation systems		
Screws instability	42 (100)	–
Fractures of screws/rods	18(43)/2 (5)	–
Migration of implants	7 (43)	Expandable implant – 4; mesh implant – 2; NiTi – 1
Spinal condition		
Without laminectomy	13 (20)	–
Spinal canal deformity	21 (32)	Intracanal malposition of screws – 3
Spinal deformity progression	61 (92)	–

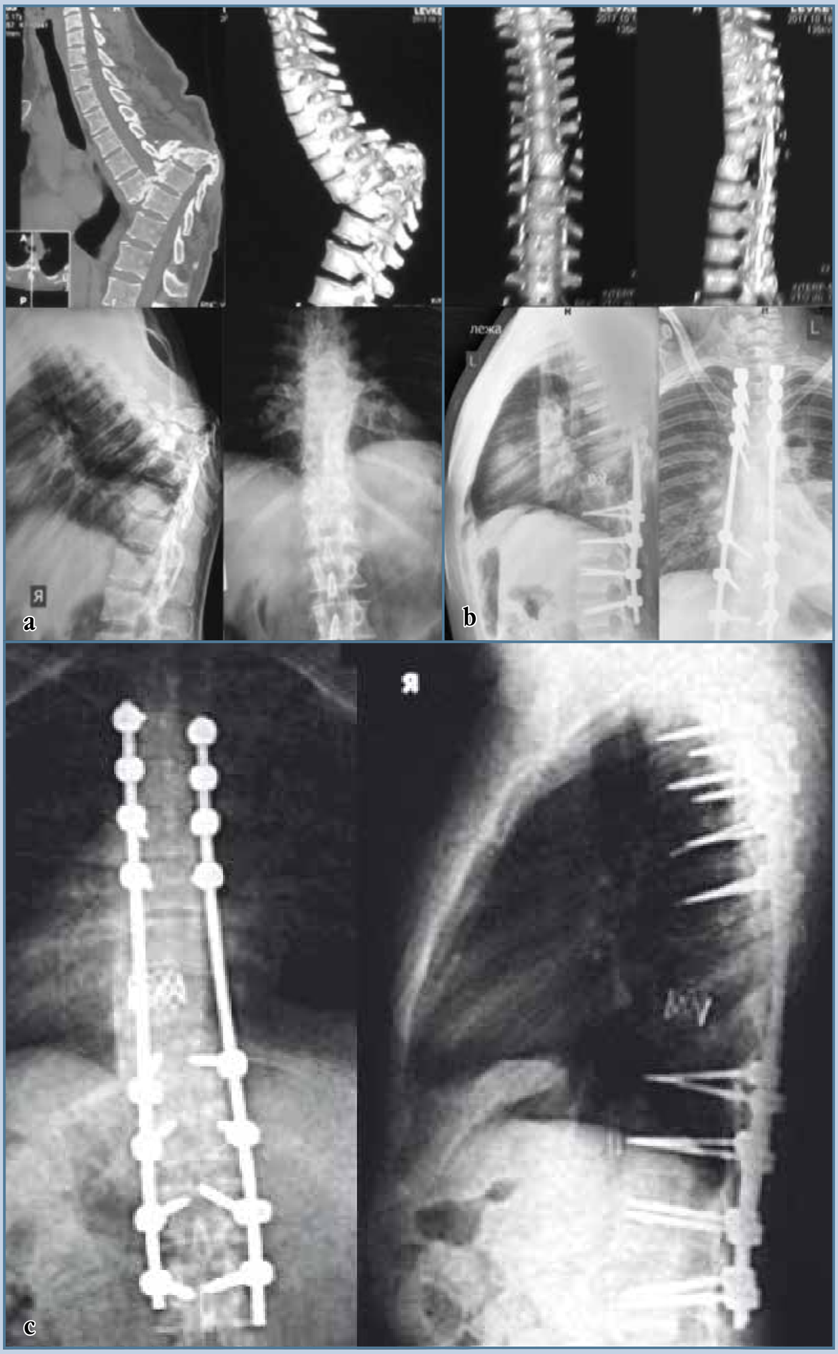

Fig. 3
Spondylograms and CT images of patient L., 35 years old, at the following treatment stages: **a** – on admission; **b** – after treatment; **c** – in 12 months after the surgery

el. The dural sac compression requires a reconstructive intervention with Shwab 5/Shwab 6 vertebrotomy variants.

An operative intervention in the revision surgery includes additional stages, involving dismantling of the unstable spinal instrumentation or its elements, reinsertion of screws with the change of the screw insertion trajectory, additional fixation of the vertebrae, creation or replacement of the anterior bone block, restoration of the spinal canal, and spinal deformity correction.

Technical peculiarities of the revision interventions are the state of soft tissues, fibrous/bone block, high risk of infectious and neurological complications, and availability of revision instruments.

Conclusion

Classification options and tactical approaches for treatment of primary post-traumatic spinal deformities are defined. Spinal fixation, decompression and correction of deformity depend on a vertebrotomy variant.

For secondary post-traumatic spinal deformities, there is no classification defining treatment tactics. Revision surgery requires assessment of the condition of the spine, spinal cord, and instrumentation, and it entails high risks of complications.

Criteria for assessing the parameters of local and global body balances are a common problem for post-traumatic spinal deformities.

Joint multicenter studies are necessary for the adoption of consensual conclusions in the revision surgery of post-traumatic spinal deformities.

The study had no sponsorship. The authors declare no conflict of interest.

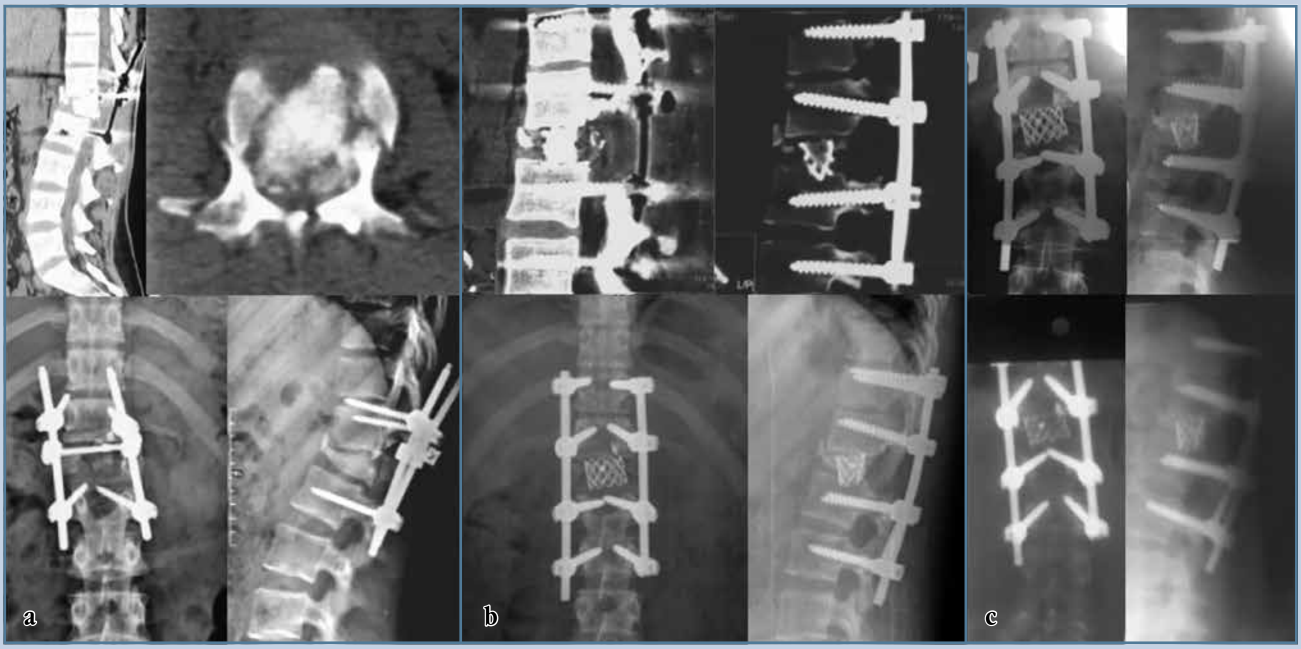

Fig. 4
Spondylograms and CT images of patient U., 22 years old, at the following treatment stages: **a** – on admission; **b** – after treatment, **c** – in 12 and 32 months

Table 3
Complications observed after vertebrotomies

Types of vertebrotomy according to Schwab	Ratio of complications	Types of complications
Type 1	–	–
Type 2 (SPO), multi-level	–	–
Type 2 (SPO), 2 levels + anterior spinal fusion	1.5	Durotomy – 1
Type 3 (PSO)	1.5	Durotomy – 1
Types 5 and 6 (VCR)	7.0	Durotomy – 2, failure of fixation – 1, bleeding – 1, neurological – 1

References

1. **Rerikh VV, Borzykh KO, Shelyakina OV.** Posttraumatic Deformities of the Thoracic and Lumbar Spine. Clinical recommendations. 2016. In Russian.
2. **Morozov IN, Mlyavykh SG.** The epidemiology of vertebral-cerebrospinal trauma: review. Meditsinskyi Almanakh. 2011;(4):157–159. In Russian.
3. **Krivenko SN, Shpachenko NN, Popov SV.** Emergency medical care at the prehospital stage and outcome prediction for concomitant injuries with spine-and-spinal cord trauma as their component. Genij Ortopedii. 2015;(3):22–25. In Russian.
4. **Afaunov AA, Polyukhovich EM, Afaunov AI, Mishagin AV, Vasilchenko PP.** Surgical treatment of posttraumatic deformities in the thoracic and lumbar spine. Hir. Pozvonoc. 2007;(3):8–15. In Russian. DOI: 10.14531/ss2007.3.8-15.
5. **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: 10.14531/ss2016.4.21-27.
6. **Dulaev AK, Khan IS, Dulaeva NM.** Causes of anatomical and functional failure of treatment in patients with thoracic and lumbar spine fractures. Hir. Pozvonoc. 2009;(2):17–24. In Russian. DOI: 10.14531/ss2009.2.17-24.
7. **Belova AN, Shchepetova ON.** Scales, Tests and Questionnaires in Medical Rehabilitation. Moscow, 2002. In Russian.
8. **MacNab I.** Negative disc exploration. An analysis of the cause of nerve root involvement in sixty-eight patients. J Bone Joint Surg Am. 1971;53:891–903.
9. **Amelina OA.** Spinal Cord Injury. Clinical Neurology with the Basics of Sociomedical Assessment. Ed. by AYu Makarov. St. Petersburg, 1998:232–248. In Russian.
10. **Schwab F, Blondel B, Chay E, Demakakos J, Lenke L, Tropiano P, Ames C, Smith JS, Shaffrey CI, Glassman S, Farcy JP, Lafage V.** The comprehensive anatomical spinal osteotomy classification. Neurosurgery. 2014;74:112–120. DOI: 10.1227/NEU.0000000000000182o.
11. **Diebo B, Liu S, Lafage V, Schwab F.** Osteotomies in the treatment of spinal deformities: indications, classification, and surgical planning. Eur J Orthop Surg Traumatol. 2014;24 Suppl 1:S11-S20. DOI: 10.1007/s00590-014-1471-7.
12. **Rajasekaran S, Rajoli SR, Aiyer SN, Kanna R, Shetty AP.** A classification for kyphosis based on column deficiency, curve magnitude, and osteotomy requirement. J Bone Joint Surg Am. 2018;100:1147–1156. DOI: 10.2106/JBJS.17.01127.
13. **Denis F.** The three-column spine and its significance in the classification of acute thoracolumbar spinal injuries. Spine. 1983;8:817–831.
14. **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.
15. **Vaccaro AR, Baron EM, Sanfilippo J, Jacoby S, Steuve J, Grossman E, DiPaola M, Ranier P, Austin L, Ropiak R, Ciminello M, Okafor C, Eichenbaum M, Rapuri V, Smith E, Orozco F, Ugolini P, Fletcher M, Minnich J, Goldberg G, Wilsey J, Lee JY, Lim MR, Burns A, Marino R, DiPaola C, Zeiller L, Zeiller SC, Harrop J, Anderson DG, Albert TJ, Hilibrand AS.** Reliability of a novel classification system for thoracolumbar injuries: the Thoracolumbar Injury Severity Score. Spine. 2006;31(11 Suppl):S62–S69. DOI: 10.1097/01.brs.0000218072.25964.a9.
16. **Joaquim AF, de Almeida Bastos DC, Jorge Torres HH, Patel AA.** Thoracolumbar Injury Classi cation and Injury Severity Score System: a literature Review of its safety. Global Spine J. 2016;6:80–85. DOI: 10.1055/s-0035-1554775.
17. **Vaccaro AR, Baron IM, eds.** Operative Techniques: Spine Surgery. Transl. under edition of Yu. A. Shcherbuk. Moscow, 2015. In Russian.
18. **Vaccaro AR, Silber JS.** Post-traumatic spinal deformity. Spine. 2001;26(24 Suppl):S111–S118. DOI: 10.1097/00007632-200112151-00019.
19. **Avila JM, Garcia OS, Vergara PA, Cisneros AC.** Surgical correction of post-traumatic kyphosis with osteotomies in the spine. Coluna/Columna. 2019;18:60-63. DOI: 10.1590/S1808-185120191801215074.
20. **Cecchinato R, Berjano P, Damilano M, Lamartina C.** Spinal osteotomies to treat post-traumatic thoracolumbar deformity. Eur J Orthop Surg Traumatol. 2014;24 Suppl 1:S31–S37. DOI: 10.1007/s00590-014-1464-6.
21. **Heary RF, Bono CM.** Pedicle subtraction osteotomy in the treatment of chronic, posttraumatic kyphotic deformity. J Neurosurg Spine. 2006;5:1–8. DOI: 10.3171/spi.2006.5.1.1.
22. **Hu W, Wang B, Run H, Zhang X, Wang Y.** Pedicle subtraction osteotomy and disc resection with cage placement in post-traumatic thoracolumbar kyphosis, a retrospective study. J Orthop Surg Res. 2016;11:112. DOI: 10.1186/s13018-016-0447-1.
23. **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.
24. **Shigematsu H, Koizumi M, Iida J, Iwata E, Tanaka Y.** Floating spine after pedicle subtraction osteotomy for post-traumatic kyphosis. Eur Spine J. 2014;23 Suppl 2:278–284. DOI: 10.1007/s00586-014-3298-7.
25. **Xi YM, Pan M, Wang ZJ, Zhang GQ, Shan R, Liu YJ, Chen BH, Hu YG.** Correction of post-traumatic thoracolumbar kyphosis using pedicle subtraction osteotomy. Eur J Orthop Surg Traumatol. 2013;23 Suppl 1:S59–S66. DOI: 10.1007/s00590-013-1168-3.
26. **Buchowski JM, Kuhns CA, Bridwell KH, Lenke LG.** Surgical management of posttraumatic thoracolumbar kyphosis. Spine J. 2008;8:666-677. DOI: 10.1016/j.spinee.2007.03.006.
27. **Munting E.** Surgical treatment of post-traumatic kyphosis in the thoracolumbar spine: indications and technical aspects. Eur Spine J. 2010;19(Suppl 1):69–73. DOI: 10.1007/s00586-009-1117-3.
28. **Rerikh VV, Borzykh KO, Rakhmatillaev ShN.** Atypical segmental corrective vertebrectomy in the treatment of post-traumatic thoracic kyphosis. Hir. Pozvonoc. 2014;4:20–24. In Russian. DOI: 10.14531/ss2014.4.20-24.
29. **Dulaev AK, Nadulich KA, Vasilevich SV, Teremshonok AV.** Surgical approach to posttraumatic thoracic kyphotic deformity. Hir. Pozvonoc. 2005;2:20–29. In Russian. DOI: 10.14531/ss2005.2.20-29.
30. **Tomilov AB, Kuznetsova NL.** Orthopedic correction of posttraumatic spinal deformities. Genij Ortopedii. 2012;1:60–63. In Russian.
31. **Li S, Li Z, Hua W, Wang K, Li S, Zhang Y, Ye Z, Shao Z, Wu X, Yang C.** Clinical outcome and surgical strategies for late post-traumatic kyphosis after failed thoracolumbar fracture operation: Case report and literature review. Medicine (Baltimore). 2017;96:e8770. DOI: 10.1097/MD.0000000000008770.
32. **Afaunov AA, Kuzmenko AV, Basankin IV, Ageev MYu.** Classification of post-traumatic deformities of the thoracic and lumbar spine. Hir. Pozvonoc. 2018;2:23–32. In Russian. DOI: 10.14531/ss2018.2.23-32.

Address correspondence to:
Prudnikova Oksana Germanovna
Russian Ilizarov Scientific Center for Restorative Traumatology and Orthopaedics,
6 M. Ulyanovoy str., Kurgan, 640014, Russia,
pog6070@gmail.com

Received 21.06.2019
Review completed 05.07.2019
Passed for printing 12.07.2019

Oksana Germanovna Prudnikova, DMSc, senior researcher at Scientific-Clinical Laboratory of axial skeleton pathology and neurosurgery, Head of Trauma-Orthopaedic Department No. 10, Russian Ilizarov Scientific Center for Restorative Traumatology and Orthopaedics, 6 M. Ulyanovoy str., Kurgan, 640014, Russia, ORCID: 0000-0003-1432-1377, pog6070@gmail.com;

Maxim Viktorovich Khomchenkov, trauma orthopaedist, surgeon of Trauma-Orthopaedic Department No. 10, Russian Ilizarov Scientific Center for Restorative Traumatology and Orthopaedics, 6 M. Ulyanovoy str., Kurgan, 640014, Russia, ORCID: 0000-0001-5996-8444, m.khomchenkov@yandex.ru.