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## Surgical management of traumatic irreducible spondyloptosis of thoracolumbar junction

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**Introduction.** The thoracolumbar junction is the most common location of traumatic spinal injuries. It accounts for 50-60% of all thoracic and lumbar spine injuries. Spondyloptosis is rather rare, but one of the most severe types of traumatic injury, that is characterized by a severe damage of spinal axis in one or more planes. Traumatic spondyloptosis is classified as reducible and irreducible, depending on the possibility of intraoperative restoration of the spinal axis without resection of the damaged vertebra.

**Objective.** To determine the optimal surgical technique for traumatic irreducible spondyloptosis of thoracolumbar junction.

**Materials and methods.** A retrospective analysis of the patients' database treated at the Romodanov Neurosurgery Institute, Ukraine was performed over the past 4 years (2017 to 2020) to identify all cases with traumatic irreducible spondyloptosis of the thoracolumbar junction.

**Results.** Treatment outcomes of five patients aged 18 to 52 years (mean age 31.2 years) were analyzed. The minimum period from the moment of injury to surgery was 14 days, the maximum was 3 months and 2 days (on average 42.2 days). At the time of admission all patients had a neurological deficit that corresponds to the functional class A on the American spine injury association ASIA scale of severity of spinal cord injury. The TLICS (Thoracolumbar injury classification and severity) score was 8 points. All the patients had the injury of lateral spondyloptosis: in three cases as an isolated displacement only in the coronal plane, in two – as a combined one - in the coronal and sagittal plane. Surgical intervention in all cases was performed from the posterior approach. As a body replacement system in 2 patients, a vertical cylindrical implant (Mesh) was used, in 3 patients - a telescopic body replacing implant. The method of bicortical implantation of pedicle screws was applied. The transpedicular system was strengthened by two cross links of the rod-to-rod type. In all cases the restoration of spinal axis was achieved in both the coronal and sagittal planes. Follow-up examinations were carried out 2, 6 and 12-18 months of the postoperative period. Regression of neurological disorders was registered in two patients, in one case to ASIA B, in the other to ASIA C.

**Conclusions.** Isolated posterior approach has demonstrated high efficacy in the surgical management of traumatic irreducible spondyloptosis of the thoracolumbar junction both in restoring the axis of the spine and in ensuring the stability of fusion.

**Keywords:** thoracolumbar junction; irreducible spondyloptosis; isolated posterior approach

### Introduction

In clinical practice, the area of the thoracic and lumbar spine is usually divided into the thoracic spine (Th1 – Th10), thoracolumbar junction (Th10 – L2) and lumbar spine (L3 – L5). The thoracic spine is characterized by high mechanical rigidity, which is due to the presence of a «corset» of the chest, orientation of facet joints in the coronal plane and relatively thin intervertebral discs. A rather narrow spinal canal often leads to spinal cord

injury in traumatic osteoligamentous damage to this area [1]. The lumbar spine is characterized by greater flexibility due to the sagittal orientation of facet joints and greater height of intervertebral discs. The relatively lower incidence of neurological damage in lumbar spine fractures is due to the large size of the spinal canal and the greater resistance of the cauda equina nerve roots to trauma. The thoracolumbar junction is located between the rigid thoracic spine and the mobile lumbar



spine, which leads to a significant biomechanical load of this area [2].

When analyzing the frequency of distribution of mechanical injuries of the thoracolumbar spine, it was noted that about 50–60% of cases occur in the thoracolumbar junction zone, 25–40% - in the thoracic spine, 10–14% - in the lumbar spine and sacrum [3]. The frequency and degree of neurological disorders in thoracolumbar trauma are largely determined by the nature of the injury (22–51%). According to C. Knop et al., in type A injuries according to the AO Spine classification, neurological dysfunction was detected in 22% of cases, in type B - in 28%, in type C - in 51% [4].

One of the rather rare but most severe types of traumatic injury of the thoracolumbar junction is spondyloptosis (SP), which is accompanied by a severe damage of spinal axis in one or more planes and damage to all support columns. Depending on the possibility of intraoperative restoration of the spinal axis without resection of the body (bodies) of the damaged vertebrae, there are two types of traumatic SP: reducible and irreducible. A large number of techniques for open reduction of traumatic vertebral displacements have been proposed both in the area of the thoracolumbar junction and the entire thoracolumbar spine. However, the surgical approach of traumatic SP if it is impossible or inexpedient to open reduction due to massive damage to the vertebral bodies, remains practically unexplained.

**Objective:** to determine the optimal technique for surgical correction of traumatic irreducible spondyloptosis of thoracolumbar junction.

## Materials and methods

### Study participants

A retrospective analysis of the database of patients who underwent inpatient treatment at the Romodanov Neurosurgery Institute, Ukraine in the period from 2017 to 2020 to identify patients with traumatic SP of the thoracolumbar junction.

Informed consent was obtained from all patients for the processing of treatment outcomes under the conditions of confidentiality and publication of generalized results. The study was approved by Ethics and Bioethics Committee of the Romodanov Neurosurgery Institute, Ukraine (Meeting Minutes No. 4 of September 05, 2018). The work is a fragment of research work (state registration number 0119U000110).

### Inclusion criteria

The study involved patients with traumatic injury to Th11 – L2, which was characterized by complete displacement of the vertebra relative to the lower one, complete disruption of the congruence of the endplates, dislocation of the displaced vertebra caudally by more than 50% of body height and the presence of «double vertebra» on axial sections of spiral CT [5]. Prerequisite for the study involvement was the presence of preoperative and postoperative magnetic resonance imaging (MRI) and / or spiral computed tomography (CT) and at least two follow-up examinations in the postoperative period.

## Study design

Retrospective observational study.

The assessment of the level of neurological disorders was performed in accordance with the criteria of the American Spinal Injury Association (ASIA) [6]. The severity of injury was characterized using the Thoracolumbar injury classification and severity scale (TLICS) [7]. The nature of vertebral bodies damage was assessed using the AOSpine Thoracolumbar Spine Injury Classification System (TLSICS) [8]. Onis 2.5 Free Edition (DigitalCore, Co. Ltd) software was used to analyze spondylography, MRI and CT data.

## Statistical analysis

Statistical processing of the obtained digital indicators was not performed due to a small clinical group. The main task was to identify general patterns to determine the direction of further detailed research.

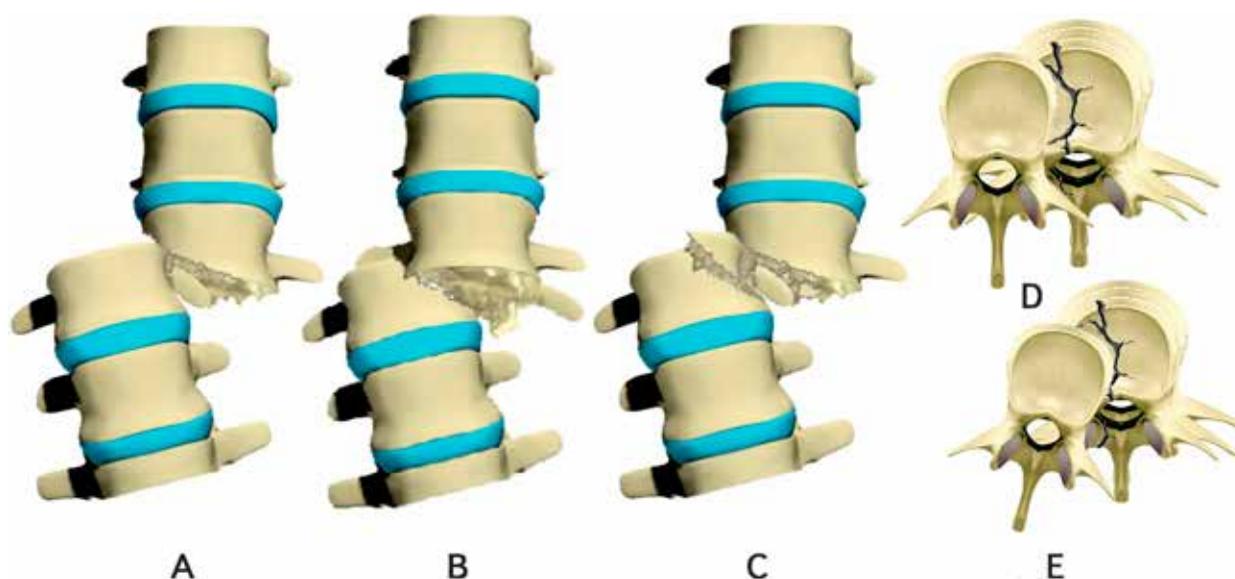
## Results and discussion

During the analyzed period, 5 patients aged 18 to 52 years (average age - 31.2 years) were identified who met the criteria for inclusion in the study. The cause of injury in 3 cases was a road traffic accident, in 2 cases - fall from height. Two patients were diagnosed with thoracic trauma, which was accompanied by rib fractures and hemothorax, in 2 - abdominal trauma, in 3 - fractured limbs, in 2 - craniocerebral trauma.

Due to the severity of polytrauma in all cases, the patients were transferred to the Romodanov Neurosurgery Institute, Ukraine after stabilization of vital functions. The minimum period from the time of injury to surgery was 14 days, the maximum - 3 months 2 days (on average - 42.2 days). At the time of hospitalization, all patients had neurological disorders of ASIA A. In the preoperative period, all patients underwent MRI to assess the degree of damage to neural structures and exclude of intradural hematomas and spiral CT - to adequately assess the extent and nature of the damage, as well as to choose surgical technique.

The score on the TLICS scale in all cases was 8 points (3 points - the morphology of injury, 3 points - characteristics of the posterior ligamentous complex, 2 points - the level of neurological disorders).

The morphology of the injured spinal motion segment (SMS) was characterized in 3 cases by a fracture of the body of cranially located (displaced vertebra) (**Fig. 1A**), in 1 - caudally located vertebra (**Fig. 1B**), and in 1 - a fracture of the bodies of both vertebrae simultaneously (**Fig. 1C**). In 2 out of 3 cases of fractures of the displaced vertebra, damage to the body of the adjacent cranial vertebra was detected. In all analyzed cases, the dislocation was classified as the lateral SP: in three patients - as an isolated displacement only in the coronal plane (**Fig. 1D**), in two - as a combined one (in the coronal and sagittal plane), but with a predominance of lateral displacement (**Fig. 1E**). The rotational component of the dislocation was 10, 18 and 25°, in 2 cases it was absent. The largest rotation was observed when displaced simultaneously in two planes (**Table 1**).



**Fig. 1.** Morphological variants of spondyloptosis (schematically): laterospondyloptosis with damage to the cranial vertebra (A), caudal (B), both vertebrae of the injured spinal motion segment (C). Rotational deformity variants: lateral spondyloptosis without rotational component (D), latero-retrospondyloptosis with rotation (E)

**Table 1.** Morphological injury pattern

Number of the patient	SP	Type of SP	Cranial vertebra	Caudal vertebra	Additional trauma	RD,°	SD,°	FD,°
1	Th12-L1	Lateral	A4	N	Th11: A1	0	14	10
2	L1-L2	Lateral	A3	N	Th12: A1	0	26	8
3	L1-L2	Latero-ante-spondyloptosis	N	A3	-	25	15	22
4	Th11-Th12	Latero-retro-spondyloptosis	A2	N	-	18	43	16
5	Th12-L1	Lateral	A3	A4	-	10	34	11

Note: RD – rotational deformity; SD – deformity in the sagittal plane; FD – deformity in the frontal plane; N – no verified vertebral body injuries.

Surgery in all cases was performed from the posterior approach in prone position of the patient on Wilson frame with the possibility of intraoperative correction of the support height. The extent of laminectomy was determined by the degree of damage to the posterior support complex, compression of the spinal canal and the estimated extent of vertebrectomy. In 3 cases laminectomy of two vertebrae was performed, in 2 - three vertebrae. Intraoperatively, damage to the dura mater (DM) with symptoms of cerebrospinal fluid in 2 cases, root detachment - in 2, damage to the root cuff with partial preservation of fibers - in 1 was found. In one patient no damage to the membranes of the spinal cord and roots was found. DM dissection and subdural space revision were performed in two patients (provided at the planning stage based on MRI data). In all cases, DM defects were sutured with additional sealing with fibrin glue. The extent of vertebrectomy was determined by the number of damaged vertebral bodies. The damaged bodies and all bone fragments were completely removed, which was a prerequisite for a full and adequate restoration of the axis of the damaged spine and the correct installation of

the interbody support. As a body replacement system in 2 patients a vertical cylindrical mesh implant was used, in 3 - a telescopic body replacing implant (in one case with endplates). Insertion of pedicle screws in 2 cases using Mesh was performed before implantation of the body replacement support for additional segment distraction. In all cases, the method of bicortical implantation of pedicle screws was used. Due to the complete destabilization of the segment, the correction of the sagittal profile was performed dosed to prevent the formation of a significant mismatch between the plane of vertebral endplates and the end elements of the interbody support (in 4 cases). One patient was able to achieve a complete restoration of the sagittal profile due to the presence of endplates on the body replacement implant. In all cases, the transpedicular system was strengthened with two cross links of type rod-to-rod. Two patients were installed with epidural electrodes and a receiving stimulation system antenna. In the case of laminectomy of two vertebrae at the final stage of surgery, bone chips were placed with preliminary decortication of the areas of the arches of adjacent vertebrae to form bone fusion. In all cases,

the wounds were sutured tightly without drainage. The total volume of blood loss in none of the analyzed cases exceeded 800 ml.

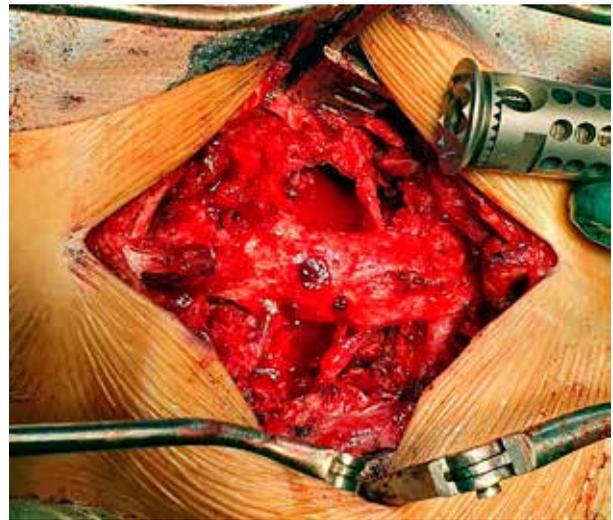
On the 3rd-7th day of the postoperative period, patients underwent spiral CT. The applied surgical intervention technique made it possible to achieve complete restoration of the spinal axis in all cases in both the coronal and sagittal planes. The maximum angular deformity of the operated SMS in the coronal plane did not exceed  $3^\circ$ . It is noted that when using the Mesh-type body replacement support, the maximum deviation of the implant axis from the spinal axis in the coronal plane was  $6^\circ$ , in the sagittal plane -  $7^\circ$ , when using telescopic implants - 2 and  $4^\circ$ , respectively.

The average length of postoperative hospital stay was 11,6 days. The length mainly depended on the initial stage of neurorehabilitation. No pyoinflammatory complications were registered either in the early or long-term postoperative period.

Subsequent control of fusion was carried out on the basis of X-ray data in two standard projections 1,5–2,5 months after surgery in 5 patients, 5,5–7,5 months - in 3 patients, 12-18 months - in 4 patients. The minimum follow-up period after surgery was 6 months, the maximum - 2,5 years. Regression of neurological disorders was registered in two patients: in one - to ASIA B, in the other - to ASIA C.

#### Clinical case

Patient B., 21 years old, was admitted to the Romodanov Neurosurgery Institute, Ukraine due to severe traumatic injury of the thoracolumbar junction. She was injured in a traffic accident as a pedestrian. For 3 months she was treated in a multidisciplinary hospital, after stabilization of vital functions she was transferred to perform reconstructive and stabilizing surgery. At the time of transfer, the neurological deficit corresponded to ASIA A. According to CT, TLSICS type C damage was detected in the Th12-L1 segment with a fracture of the Th12 vertebra of the A3 type and the L1 vertebra of the A4 type (**Fig. 2**). Considering the absence of support function of L1 body remnants and the impossibility of installing the

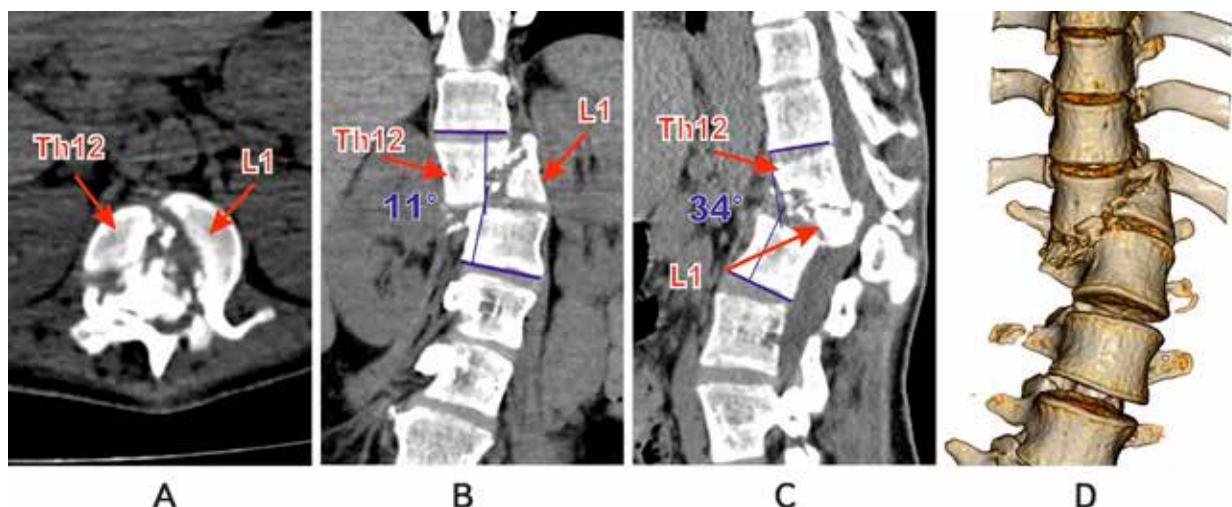


**Fig. 3.** The stage of surgical intervention after performing laminectomy of the Th12 and L1 vertebrae, coprectomy of the Th12 and L1 vertebrae and correction of the spinal axis before installing the body replacement implant

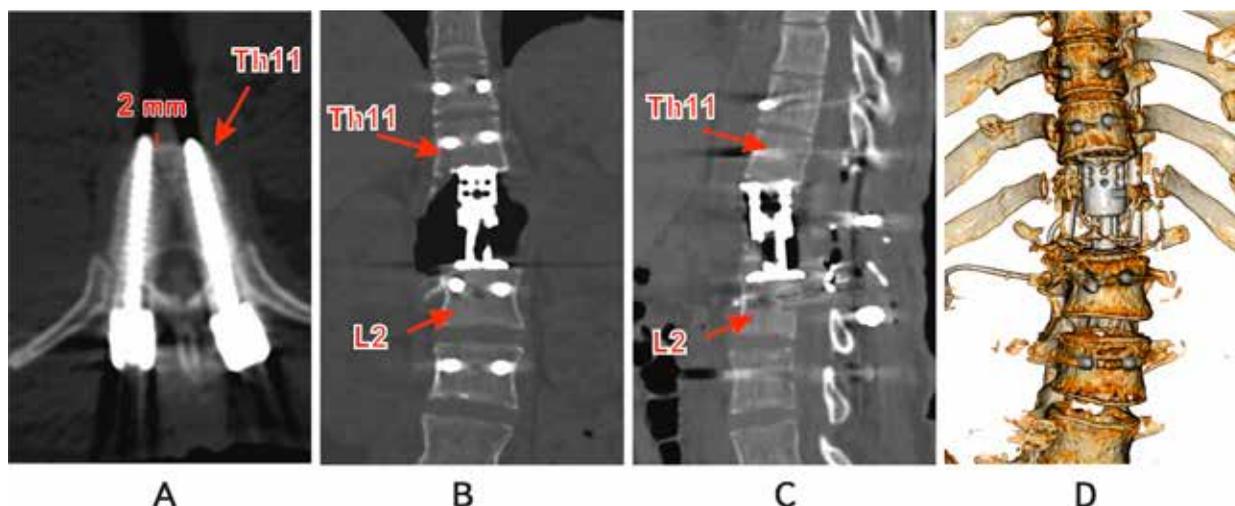
prosthesis of vertebral body with support based on the damaged Th12, it was decided to perform vertebrectomy of Th12 and L1 vertebrae with the replacement of bodies with a telescopic body replacing implant.

From the posterior approach, laminectomy of Th12 and L1 was performed with total Th12 and L1 vertebrectomy and removal of all bone fragments (**Fig. 3**). After restoration of the spinal axis by changing the height of Wilson frame support, a telescopic body replacing implant was installed.

Posterior transpedicular spondylodesis with bicortical installation of screws into the vertebral bodies Th10, Th11, L2 and L3 was performed. The system is strengthened with two transverse connectors. Epidural electrodes and receiving antenna of the system of electroneurostimulation was installed. The results of postoperative CT are shown in **Fig. 4**. On the 5th day



**Fig. 2.** Results of spiral CT of the thoracolumbar transition of patient B. in the preoperative period: A - axial section; B - frontal reconstruction; C - sagittal reconstruction; D - 3D reconstruction



**Fig. 4.** Results of postoperative spiral CT of the thoracolumbar transition of patient B: A - axial section at the Th11 level; B - frontal reconstruction; C - sagittal reconstruction; D - 3D reconstruction

of the postoperative period, the appearance of elements of position sense was observed.

Spondyloptosis as the most severe form of traumatic spinal cord injury was first described in 1882 by Franz Neugebauer as grade V spondylolisthesis with L5 vertebral displacement relative to the sacrum [9]. Currently, this term is used to describe injuries that are accompanied by more than 100% vertebral dislocation in the sagittal or coronal plane.

According to the literature, in more than 80% of cases SP is accompanied by a clinic of neurological disorders ASIA A [8,10,11]. Significant improvement of neurological functions in the postoperative period occurs quite rarely, so the initial level in most cases is a predictor of lifelong dysfunction [12]. It is natural that, given the predominantly unfavorable functional prognosis for a long period of time there was a trend towards a limited amount of surgical correction of this pathology. As practice shows, this trend is observed in some clinics today.

Improvement of methods of surgical interventions and accumulation of clinical material contributed to the fact that at present the only acceptable result of surgery is the restoration of the spinal axis and decompression of spinal canal structures, regardless of the degree of initial deformity, the level of neurological disorders and the duration of injury [13]. M.P. Bellew et al. observed a regression of neurological deficit from ASIA A to ASIA D in a patient who underwent surgery for traumatic SP of L2 vertebra 3 weeks after injury [14]. Clinical cases of positive neurological dynamics and later decompression are also described. Thus, B. Landau and J. Ransohoff presented the results of decompression laminectomy of 7 patients within 1 month to 17 years after injury. Some improvement in neurological functions has been reported in patients [15].

It is known that the current trend is the earliest decompression of the structures of the spinal canal and stabilization of the damaged SMS, which contributes to the greatest recovery of neurological functions [16]. However, the analysis of the literature suggests that in

most cases delayed or late surgery is used for SP. M. Garg et al., who analyzed a series of 5 patients with lateral SP of the thoracic and thoracolumbar junction and found that the mean duration of the period between trauma and surgery was 13.2 days (from 4 to 30 days) [11]. An even longer interval was recorded by A. Mishra et al. Thus, out of 20 patients, 13 underwent surgical correction 2-3 weeks after injury, and 1 - in 4 weeks [17]. F. Wang et al. according to the results of treatment of 11 patients with traumatic SP of the thoracolumbar junction found that the duration of the interval should not exceed 3 weeks [18]. However, such approach is mainly aimed at preserving the possibility of reduction of SP and decreasing the likelihood of complications associated with trauma, rather than preserving the neurological functions of the patients.

The formation of SP as one of the most severe injuries of the spinal column is associated with the influence of the high-intensity traumatic factor. Therefore, polytrauma is recorded in most patients. The general sequence of treatment in such patients includes resuscitation in accordance with the ATLS protocol, surgery for life-threatening injuries of internal organs, reconstructive and stabilizing surgery of the spine and rehabilitation. The duration of the first two points of the algorithm determines the preoperative period. In addition, the specificity of the injury excludes the use of «spine damage-control» protocol, which provides for the division of surgery into two stages: decompression and stabilization primarily as less traumatic surgery and reconstruction and additional stabilization secondary, with normalization of vital functions, since adequate decompression in SP is impossible without restoration of the spinal axis, that is without the reconstructive stage [19].

Some authors recommend the use of halo-pelvic traction or cranio-bifemoral traction in the preoperative period to facilitate intraoperative reduction of SP [18,20,21]. We do not use these methods and consider them impractical for a number of reasons.

Firstly, the installation of devices for performing these methods of traction is a rather traumatic and

painful procedure for the patient, and the presence of trophic disorders in patients with neurological disorders significantly increases the risk of purulent-infectious complications.

Secondly, as noted above, the vast majority of patients with SP have polytrauma. Modern approaches to the treatment of both thoracic and abdominal trauma provide for the mandatory implementation of elements of rehabilitation measures immediately after the restoration of vital functions. Complete immobilization of the patient significantly limits the possibilities of rehabilitation therapy and complicates care, increasing the risk of neurotrophic manifestations.

Thirdly, skeletal traction of the SP does not fully predict the nature of the displacement of all bone fragments and, accordingly, prevent further trauma to the neural structures. It is known that initially the methods of external traction were developed for the correction of dislocations and fracture-dislocations of the cervical spine. The types of injuries and the angulation of effort were clearly regulated. For the thoracolumbar spine, due to the significant rigidity of ligamentous apparatus and a more pronounced muscular corset, the actual axis of traction always corresponds to the axis of the spine, excluding the adaptation of the method to the type of displacement.

Analysis of literature data indicates the limited use of these methods of traction mainly in the treatment of scoliosis. In addition, electroneuromonitoring is a prerequisite for choosing the intensity of traction, followed by continuous clinical assessment of the neurological status [22,23]. In patients with ASIA A, which is observed in most cases, these methods are not informative, therefore it is mostly impossible to detect the negative impact of skeletal traction on the structures of the spinal canal in traumatic SP. It is clear that ASIA A in no way indicates a complete anatomical damage to the structures of the spinal canal and the impossibility of positive dynamics. In our opinion, any iatrogenic additional mechanical effect on the structures of the spinal canal, regardless of the level of neurological disorders is unacceptable. Accordingly, the orthopedic feasibility of SP reduction without body resection is always less important compared to even a minimal increase in the likelihood of regression of neurological disorders.

The optimal surgical approach for the most effective correction of the SP has not been determined yet. Literature data indicate the successful use of anterior, posterior and combined approaches [8,14,24,25,17]. At the same time, it is noted that for the SP the classical five AOSpine methods of reduction type C damage according to TLSICS are practically not used [13]. As for the SP without the possibility of reduction, in most cases an isolated posterior or posteroanterior-posterior approach is used. In a specific clinical situation, the choice is determined by a combination of factors (specificity of the injury, the qualification of the surgeon, material and technical basis, etc.). However, other things being equal, the advantages and disadvantages of these options for surgery can be highlighted.

According to most researchers, the advantages of the anterior stage in combined surgery are in more

convenient and controlled vertebrectomy with removal of all fragments and the possibility of using a wider range of body replacement devices with additional plate fixation, if the implant design does not provide independent fixation to vertebral bodies adjacent to resected. The disadvantages of the combined approach include the fact that the availability of additional surgical approach increases the risk of postoperative infectious complications [26]. A meta-analysis conducted by En-Hui Ren et al. found that anterior decompression compared with posterior one is accompanied by a longer duration of surgery, a large volume of blood loss and, accordingly, a longer length of hospital stay without any advantages in regression of neurological disorders [27]. Yong-Ming Jin et al. note that in comparison with isolated posterior approach, the combined approach is accompanied by more severe pain syndrome in the early postoperative period [28].

When planning 360° stabilization, it should be taken into account that the installation of ventral or ventrolateral plate with screw fixation to the vertebral bodies adjacent to the removed one makes it difficult or impossible to insert the pedicle screws of the posterior stabilizing system into the bodies of these vertebrae [29]. This leads to the use of longer fixation, which is biomechanically impractical, significantly increases the load on the stabilizing structure and in some cases leads to its failure [30].

In our opinion, the main disadvantage of using the combined approach is the need to rotate the patient twice when performing a surgery. Unlike most other traumatic injuries of the thoracolumbar spine, in which the anteroposterior approach is successfully used, the SP requires a posterior-anteroposterior approach. This is due to the fact that the effective installation of the interbody support requires a restored axis of the spine, which is impossible to form without removing the damaged posterior support complex. After a posterior laminectomy of the required length, the absolute instability of the operated SMS is formed, since removed remnants of arches and articular processes discontinue to perform even a minimal stabilizing function. Attempting to rotate a patient in this state is always associated with a very high risk of increased mixing and iatrogenic trauma to neural structures. Although several intraoperative fixation options have been proposed for the safe rotation of patients, all of them are of limited use and their clinical efficacy has not been proven [29].

One of the most controversial and least highlighted in the literature aspects of surgery for severe traumatic injuries of the thoracolumbar spine is the approach of processing the dural sac in visually verified complete anatomical damage to the spinal cord. It is known that in contrast to the fractures of Chance SP even with a rupture of the spinal cord is rarely characterized by a complete horizontal section of the dural sac, which creates more opportunities for its plastic repair, sealing and restoration of cerebrospinal fluid dynamics. However, few publications indicate that in most cases ligation of proximal or proximal and distal segments is performed [11]. This approach has advantages in preventing cerebrospinal fluid and decreasing the duration of surgery. Some authors recommend

preserving cerebrospinal fluid regardless of the degree of spinal cord injury to prevent the development of hydromyelia [7]. We are guided by the principle of the maximum possible restoration of anatomical integrity of damaged structures. As the analysis of the course of the postoperative period revealed, the use of modern sealing agents intraoperatively allows completely preventing the development of cerebrospinal fluid.

A general trend in spinal surgery in recent decades is the use of «short segment fixation», which in its simplest version involves fixation of one vertebra, cranially and caudally located relative to the injured one. According to the literature, the main indications for the use of short segment fixation are comminuted fractures of the thoracolumbar spine (TSLICS type A3, A4) and flexion-distraction injuries (TSLICS type B) [31, 32]. The advantages of short segment fixation are preservation of the mobility of more SMS, a decrease in the load on rods of transpedicular stabilization system, risk reduction of developing gross degenerative changes in segments adjacent to the stabilized ones, a decrease in the duration of surgery and size of surgical approach, economic feasibility [33]. Disadvantages include less reconstructive capabilities and a significant increase in the load on the screws of the system. R.F. McLain et al., who were among the first to describe the failure of the stabilization system when using the method of short segment fixation, recorded the frequency of screw fragmentation in 45% of cases during the first 6 months after surgery [34]. In the following publications, the authors noted that the long fixation is appropriate for the thoracic spine and thoracolumbar junction, while the short segment fixation is for the lumbar spine. It is noted that the risk of failure to fix is largely determined by the nature of the damage to the anterior support complex [35]. An algorithm for predicting the ability of short segment fixation was proposed by T. McCormack et al. [36]. The authors developed a load sharing classification, which takes into account three main parameters: the degree of compression of the vertebral body according to sagittal CT-reconstruction, the separation of fragments in the axial sections of the CT, the degree of correction of kyphotic deformity. Each of the parameters has 3 degrees of severity and is assessed by points from 1 to 3. The high risk of damage to the stabilization system is indicated by the sum of points  $\geq 7$ . J.J. Chokshi et al. provide data on the successful use of short segment fixation in patients with fracture-dislocations even at the level of the thoracolumbar junction [37]. Regarding SP as an injury that is accompanied by damage to all support columns and the posterior ligamentous complex, most researchers recommend the use of long fixation (2 or 3 vertebrae cranially and caudally according to the level of damage). In most cases, we restrict ourselves to fixing the two vertebrae above and below, using the system installation technique which provides the most rigid fixation. It is noted that, in addition to the number of fixation points, when using posterior transpedicular stabilization, the technique of screw installation is important, which is determined by both the depth and the projection of the insertion.

Currently, there are three main techniques of insertion the pedicle screw depending on the depth

of its immersion in the vertebral body: mid-body, pericortical and bicortical [38]. At the initial stages of clinical application of transpedicular fixation, it was believed that the optimal depth of screw insertion into the vertebral body is 50-70% of its anteroposterior size, since spongiosis is not of fundamental importance in determining the rigidity of fixation [39]. Accumulated clinical practice and exploring of complications revealed the correlation between screw length and mechanical reliability. Thus, K.J. Karami et al., who, based on *ex vivo* models of the lumbar spine showed that cyclic loading reduces the angular rigidity of fixation by (25,6  $\pm$  17,9)% (mid-body method), (20,8  $\pm$  14,4)% (pericortical) and (14,0  $\pm$  13,0)% (bicortical), while the extraction force is (583  $\pm$  306), (713  $\pm$  321) and (797  $\pm$  285) H, respectively [40]. These results have been confirmed in a number of studies [41,42]. Despite its biomechanical feasibility, bicortical transpedicular fixation is of limited use due to a number of reasons. First, the protrusion of the screw beyond the ventral surface of the vertebral body is associated with the risk of damage to large vessels [43]. According to some authors, this risk is somewhat exaggerated. Thus, K.C. Foxx et al. based on the results of the analysis of 115 operations, it was found that out of 680 installed screws, 33 had direct contact with the main vessels, but in no case this led to complications. The follow-up period was 44 months [44]. The second reason is the increased requirements for the installation technique and the need for the size chart of screws. However, taking into account the need to achieve maximum rigidity of stabilization in SP in all analyzed clinical cases, the bicortical method was used.

The second criterion that determines the rigidity of transpedicular fixation is the angle of screw insertion in the sagittal plane. For the thoracic spine, two design options are used: anatomic and straight-forward. In the anatomic trajectory, the screw is inserted parallelly to the anatomical axis of the pedicle, that is in the cranio-caudal direction. The technique requires the use of only polyaxial screws, which complicates direct derotation in case of its implementation. The point of screw insertion in the anatomic trajectory is practically unchanged for the entire thoracic region, this greatly facilitates the installation, but leads to trauma of the superior articular process [45]. In the straight-forward trajectory, the screw runs parallelly to the superior endplate, which allows using monoaxial screws, but their installation is technically more difficult, since the insertion point is chosen depending on the level. The technique requires more frequent use of intraoperative X-ray control, but provides an increase in extraction force by 27% compared to the anatomic trajectory [46].

In contrast to the thoracic spine in the lumbar the inclination angle of pedicle is almost parallel to the endplate, so the rectilinear projection is anatomical. However, according to a number of studies, in the lumbar spine for bicortical stabilization, the maximum rigidity of fixation is provided by the cranio-caudal inclination of the screw [47]. It is noted that in both the thoracic and lumbar spine, the possibility of achieving an optimal projection in terms of reliability is largely determined by individual anatomical features, mainly - the diameter of the pedicle. In the analyzed clinical group, we were

able to use the optimal angulation in 55% of cases (22 out of 40 installed screws).

Installation of cross links on rods of the transpedicular system is an additional method of stabilizing the structure. Thus, studies of the mechanical stability of thoracolumbar transpedicular fixation conducted by G. Lynn et al. showed that the rotational stability and rigidity at lateral flexion in a structure with two cross links are much greater than in a system without connectors [48].

Thus, the use of the described methods of increasing the rigidity of transpedicular stabilization allows limiting the use of 4 pairs of transpedicular screws and ensures the stability of the interbody support, which when placed from the posterior approach can not be directly fixed to the vertebral bodies.

### Conclusions

These data indicate the high efficiency of isolated posterior approach in the surgical treatment of traumatic irreducible thoracolumbar spondyloptosis, both in restoring the spinal axis and in ensuring the stability of spondylodesis. Telescopic body replacement implants have been shown to have advantages. A prerequisite is the resection of all damaged bodies and bone fragments to ensure both restoration of the spinal axis and maximum reliability of the interbody support. The methods we use to increase the stability of transpedicular fixation are important to ensure the overall capacity of spondylodesis.

### Disclosure

#### *Conflict of interest*

The authors declare no conflict of interest.

#### *Ethical approval*

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

#### *Informed consent*

Informed consent was obtained from each of the patients.

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