Review article

Ukr Neurosurg J. 2021;27(2):3-15
doi: 10.25305/unj.228256

The classifications of subaxial cervical spine traumatic injuries. Part 5. Facet joint and lateral mass lesions

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Received: 31 March 2021
Accepted: 23 April 2021

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Traumatic injury to the cervical spine accompanied by a wide range of possible changes in its osteo-ligamentous apparatus. One of the basic criteria to determine the treatment strategy is the assessment of injury stability which depends on the condition of the spine supporting columns. Most of the modern and widely used classifications of subaxial cervical spine traumatic injuries quite sufficiently characterize the state of the anterior support column. At the same time, much less attention is paid to the assessment of the degree and nature of traumatic changes in lateral masses, facet joints, as well as possible dislocations.

Literature analysis reveals the absence of a generally accepted scheme that would allow one to unambiguously and comprehensively characterize the damage to the facets / lateral masses and choose the optimal surgical or conservative treatment method. This review provides well known assessment schemes: classification of traumatic changes of facet joints by Marcel F. Dvorak et al., variants of traumatic displacement of the cervical vertebrae by V.P. Selivanov, variants of lateral mass traumatic injury by Y. Kotani et al. and Posterior Ligament-Bone Injury Classification and Severity Score.

The advantages and disadvantages of anterior, posterior or combined approach for the treatment of traumatic injuries of posterior support complex are considered that is of critical importance for obtaining better clinical results. It is noted that the choice of the optimal treatment method is currently a controversial issue. Although good surgical results can be obtained using a variety of methods, there are certain situations in which one technique may be better than others. The accumulated clinical experience and current research on the injured spine biomechanics demonstrate the advantage of surgical treatment in most patients, since such injuries are usually unstable or potentially unstable.

Keywords: *traumatic injury; classification; cervical spine; subaxial level; lateral masses, facet joints*

Introduction

Traumatic impact on the human body causes 10% of mortality in the world and is the leading cause of death of young people (5–44 years) in developed countries [1]. The prevalence of traumatic spinal injuries is from 19 to 88 cases per 100 thousand population per year, spinal cord injuries - from 3,5 to 5,3 cases per 100 thousand population [2]. From 19 to 51% of cases of spinal cord injury are injuries of the cervical spine (CS) [3]. It is known that precisely the lesions of CS cause the highest rates of early mortality of patients compared to other parts and are often accompanied by neurological disorders of varying degree [4]. In addition, CS injury can complicate intubation and surgical treatment of combined injuries due to the need for neck immobilization and significantly worsens the prognosis in patients with polytrauma [5]. About 65% of fractures and more than 75% of cervical dislocations are registered at the subaxial level [6].

Facet joints and stability of damage

One of the basic criteria characterizing the severity of traumatic changes in CS and determining general strategy and nature of surgical intervention (if performed) is the level of instability [7]. It is the instability of the injury that often determines both the initial degree of traumatic damage to the structures of the spinal canal, and their further trauma in the absence of effective immobilization [8]. The occurrence of subacute instability in case of defects in diagnosis or refusal of surgical intervention significantly increases rehabilitation period and worsens the prognosis for the restoration of neurological functions and / or regression of pain [9,10].

Despite the significant improvement of imaging methods, determining stability of damage remains a clinically challenging task, and widespread use does not exclude the ambiguity of the interpretation of the concept itself. The concept of stability of injury was proposed in the classification of spinal fractures by R. Watson-Jones in 1931, and then supplemented by E.A. Nicoll in 1949 [11,12]. The formation of modern ideas about stability of injury, as well as about the biomechanics of the spine in general, was largely influenced by the work of A.A. White III and M.M. Panjabi [13–15]. The authors proposed the theory according to which the mechanical stability of the spinal column is provided by the interaction of three subsystems: 32 (or sometimes 33) vertebrae provide internal stability, back muscles attached to the spine provide dynamics, and the nervous system is a control subsystem and coordinates muscle response. The authors defined the clinical stability of the spine as the ability to limit displacement patterns under physiological loading in such a way as to exclude damage or irritation to the spinal cord and nerve roots and prevent deformities or pain caused by structural changes. Accordingly, instability is the loss of the ability of the spine to support biomechanically predicted patterns of changes in the relationships of its anatomical structures under normal physiological loadings [16].

The difficulty of perceiving the concept of spinal stability is due to a kind of dualism, since in fact the "physiological" definition proposed by A. White and M. Panjabi is based on an "orthopedic" basis. Thus, in the vast majority of schemes for determining the stability of the spine, the concept of support columns is used.

For the first time the concept of "support column" was mentioned in the works of English orthopedist H. Platt in 1938 [17]. In 1963, F. Wild Holdsworth distinguished the anterior (vertebral body) and posterior (posterior elements) support columns of the spine and the "posterior ligamentous complex", which included supraspinous and interspinous ligaments, the capsule of facet joints and ligamentum flavum suggesting that the damage to these anatomical structures leads to the formation of unstable fractures [18]. The principle of stability, which is based on support columns was directly proposed in 1968 by R.P. Kelly and T.E. Whitesides [19]. The authors suggested that the preservation of at least one of the columns ensures the stability of the damage. Later, this theory has been repeatedly modified.

The three support column model, proposed in 1983 by the French orthopedist F. Denis, is the most famous and widely used in clinical practice [20]. Based on the observations of A. White and M. Panjabi describing acute and subacute instability, the author identifies the anterior column represented by the anterior longitudinal ligament, the anterior half of the vertebral body and intervertebral disc, the middle column represented by the posterior half of the vertebral body and intervertebral disc as well as the posterior longitudinal ligament, and the posterior column, represented by pedicles, facet joints, spinous processes and interspinous ligaments [21]. Taking into account the model of F. Denis, modern principles for determining the instability of the injured spine have been developed. The proposed model provided for the assessment of only the thoracic and lumbar regions, but later in a number of works it was mistakenly extrapolated to the cervical level, which led to very illogical conclusions.

Almost simultaneously, in 1985, R. Louis proposed a three-column model of the spine, which later did not gain widespread acceptance [22]. According to the concept of articular orthogonal triangulation, the anterior column is formed by the vertebral body and the intervertebral disc, and the two posterior ones are formed by facets. Accordingly, biomechanically each spinal motion segment (SMS) is represented by a triangle, the angles of which are the intervertebral disc and facet joints. The proposed model took into account the specifics of the anatomical features of CS.

The middle segment theory was also proposed by R. Roy-Camille (1979), the theory of W.H. Kirkaldy-Willis (1982), the centroid theory of S.D. Gertzbein (1985), the theory of the central spine S.M. Iencean (2003) and a number of others who explain the stability of the spine based on the state of certain anatomical structures of the SMS both in traumatic injuries and in degenerative changes [23-27]. The development of biomechanics and the use of modern methods of analysis contributed to the development of new models of support columns, since none of the above is able to unambiguously characterize the degree of stability of SMS in each case. Thus, in 2020 a group of Chinese scientists led by Qihang Su proposed an updated three-column theory [28].

An important role in the formation of stability of SMS in all the above models is assigned to the facet joints, and it is in the CS that their significance is most pronounced. However, currently there is no classification that would allow characterizing the complex of morphological changes of facet joints and lateral masses in traumatic injuries of the CS, and attention continues to be paid mainly to the condition of the vertebral body. This can be explained by the fact that detailed morphological classifications were proposed based on the analysis of radiographic data, and the X-ray technique itself did not allow to detail complex facet changes in the interpretation. At the stage of active use of spiral computed tomography, and later also magnetic resonance imaging (MRI), the general trend was to minimize the classification characteristics and combine similar, according to the authors types of damage, is observed in modern classifications [29]. Moreover, when analyzing the literature it is noted that the tactical aspects of treatment of isolated injuries of facet joints is the most controversial issue in the surgery of traumatic injuries of the CS. Therefore, the purpose of the review is to summarize the different data on the types of damage to the intervertebral joints, both fractures and dislocations, as well as a brief description of methods of therapy proposed for each of them.

This article contains some figures that are displayed in color online but in black and white in the print edition

Morphology of facet joints injury

The most ordered, albeit brief, the most common classification of facet joint injuries was published by M.F. Dvorak et al. in 2007 [30]. This scheme became a generalization of the data available in literature and was used as a tool to assess therapy effectiveness for various types of injuries [31]. A significant disadvantage that limited the further use of the classification was the almost complete absence of the morphology description, as well as the definition of only those types that the authors observed in a small group of patients (unilateral lesions).

The classification identifies three main types of injury: facet fracture (type A), dislocation (type B) and dislocation fracture (type C) ***(Fig. 1)***.

Type A includes fractures of the superior facet of the vertebra located below (subtype A1), the inferior facet of the upper vertebra (subtype A2) and the floating lateral mass - fracture of the pedicle / or vertical fracture of the lamina (subtype A3). All these subtypes are not accompanied by a significant dislocation of the vertebrae of the damaged SMS. Considering the damage to the facet joints, especially subtypes A1 and A2, which makes it difficult, and under certain conditions makes it impossible to assess the ratio of articular surfaces of facets, the presence of displocation of one vertebra relative to the other is determined according to the standardized Spine Trauma Study Group method [32] as the distance between lines drawn in parallel to the posterior surfaces of the bodies of the displaced and subsequent caudally located vertebra, measured at the level of the lower endplate of the displaced vertebra, and in case of significant deformity- as the length of the perpendicular drawn from the posterior-inferior angle of the displaced vertebra to the line running parallel to the posterior surface of the body of the vertebra located below [33]. However, there is no consensus on what the minimum displacement should be considered as a criterion for the presence of dislocation. It is believed that unilateral dislocation can cause the displacement of up to 25% of the anterior-posterior diameter of adjacent vertebral bodies [34]. And, accordingly, when the displacement of the vertebral body is ≥50% relative to the lower vertebra, it often indicates bilateral damage to the facets, although this sign, according to some authors, is quite conditional [30].

Type B includes all injuries without verified fractures of arches and facet joints. Subtype B1 (subluxation) - is characterized by solution of contiguity of the articular surfaces of the facets located above and

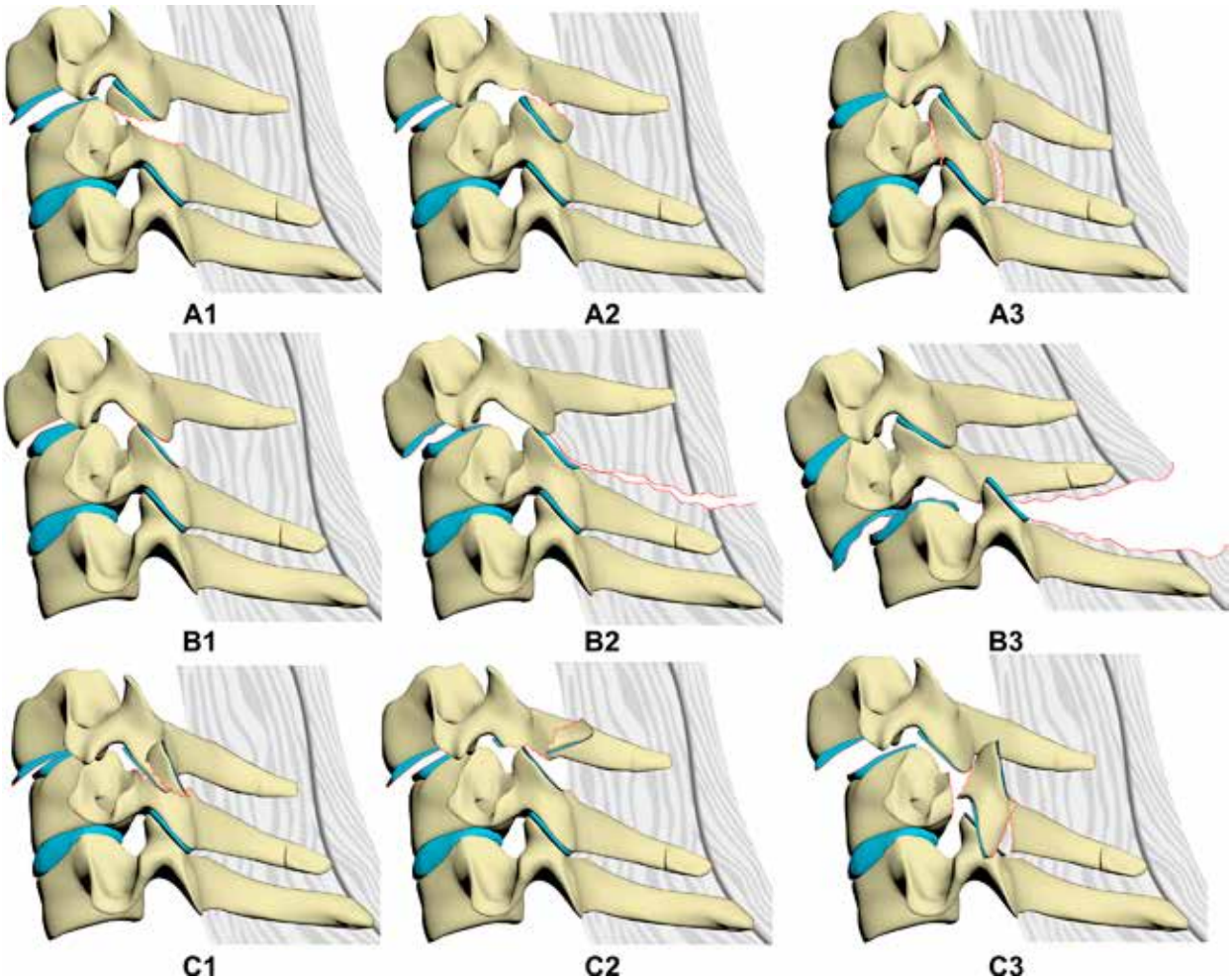

Fig. 1. Classification of traumatic changes of facet joints according to M.F. Dvorak et al. [30] (schematically). Explanation in the text

below the vertebrae of the injured SMS. The presence of subluxation is indicated by a value <0.5 of the coefficient, calculated as the ratio of the length of contacting surfaces to the length of the inferior articular surface of rostrally located vertebra [32]. Subtype B2 (upper subluxation) is the highest degree of subluxation, when the posterior edge of the inferior facet of the cranial vertebra is located on the anterior edge of the facet of the caudal vertebra [35]. Subtype B3 (locked facet) is a type of complete dislocation in which the inferior articular process of the vertebra located above is displaced into the superior intervertebral notch of the vertebra, which is adjacent.

Type C (combined injury) – is a facet fracture of with dislocation / subluxation, although it is impossible to clearly distinguish these types of displacement for such injuries. Thus, subtypes C1, C2 and C3 duplicate similar subtypes of type A, but are accompanied by displacement of one vertebra relative to another.

It is natural that the high mobility of CS, a wide range of possible effects of traumatic force both in vector and in intensity, significant individual differences between the patients (bone density, rigidity and elasticity of the disc ligamentous apparatus, muscle tone) lead to various types of injuries. Accordingly, the classification of M.F. Dvorak et al. subtypes can be unilateral, bilateral, and combinations thereof.

Considering that SMS is a single combined joint, it is natural that the presence of unilateral subluxation / dislocation leads to a certain deformity in the opposite joint, but such changes, according to some authors, have no practical value, since the elimination of the main displacement restores the congruence in the opposite joint [36].

In the case of bone-traumatic changes of the contralateral facet, even without displacement, such damage is considered as bilateral dislocation / subluxation.

As indicated above, the complexity of the classification of traumatic injuries, as well as the interpretation of results of clinical trials is due to the lack of unified definitions of basic concepts. A significant contribution to the standardization of the principles of diagnostics, description of morphology and determination of optimal treatment methods was made by V.P. Selivanov. He defines dislocation as a condition characterized by complete loss of contact between articulated facets [37]. The author distinguishes the following types of *anterior complete dislocation*: *dislocation with high-riding of articular processes* (***Fig. 2A***), when inferior articular processes are not displaced into superior vertebral notches, *locked dislocation*, which corresponds to subtype B3 according to the classification of M.F. Dvorak et al. (***see Fig. 1***). In addition, a *total dislocation* is distinguished as an extreme degree of ventral displacement with complete bilateral dislocation in the lateral and interbody joints (***Fig. 2B***).

In most cases, the term "dislocation" is understood as the ventral displacement of the cranially located vertebra, that is the anterior dislocation, which is actually determined by the angulation of the facet plane. *Posterior dislocations* are rarely registered (***Fig. 2C***). V.P. Selivanov notes that backward displacement in the facet joints without bone-traumatic changes is not possible, however J.T. Hueston describes a single case of posterior dislocation with only ligamentous injury [38]. According to clinical observations, posterior

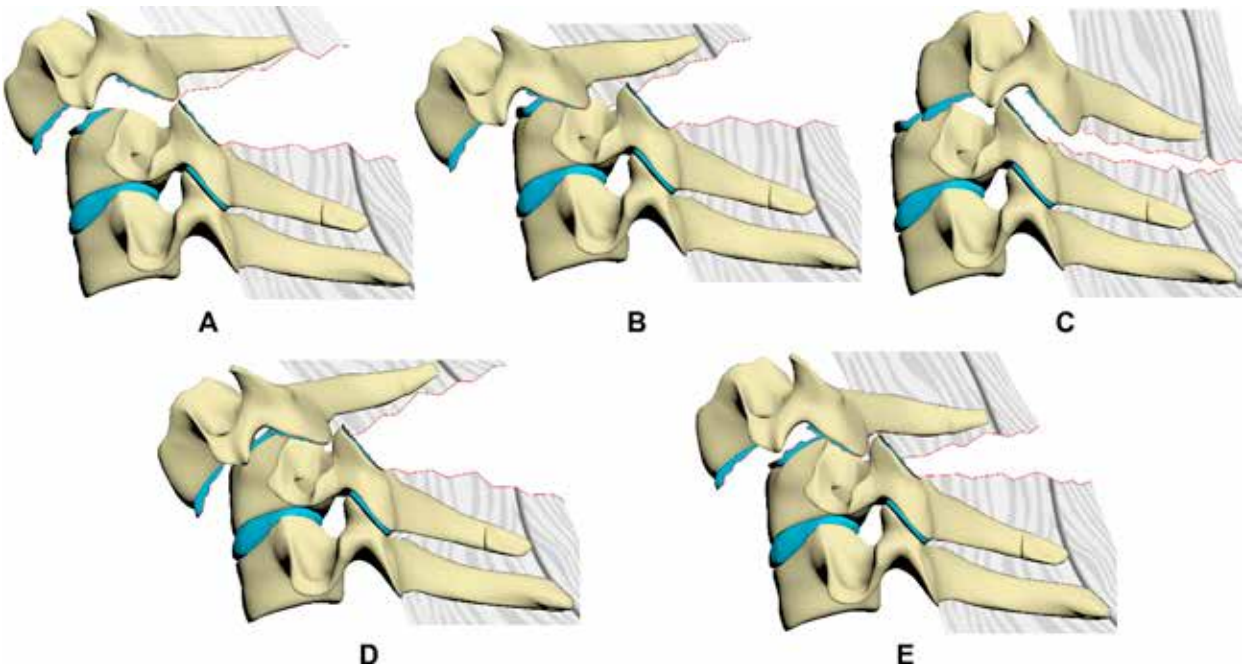

Fig. 2. Some variants of traumatic dislocation of the cervical vertebrae (according to V.P. Selivanov [36] schematically): A - complete anterior dislocation with high-riding of the articular processes; B - total dislocation; C- posterior dislocation; D - bending dislocation; E – slide dislocation

dislocations are almost always accompanied by severe neurological symptoms.

In fact, posterior dislocation is a special case of DE2 injury according to B.L. Allen and R.L. Ferguson [39]. Primary damage to the anterior longitudinal ligament with ongoing extensionally distraction effect is considered as a possible mechanism of formation of posterior dislocation of the CS at the subaxial level. Accordingly, the presence or absence of bone-traumatic changes in posterior dislocations is determined by the predominance of extension or distraction. Minor dislocations tend to be spontaneously reduced. In contrast to anterior dislocations, in which the severity of dislocation is determined by the ratio of the articular surfaces of the facets, in posterior dislocations the degree of displacement of the vertebral body is taken into account [36].

One of the basic criteria that determines the degree of damage to neural structures in dislocations is the shear (anterior-posterior) displacement in the damaged SMS, but the displacement in other planes is also of great clinical significance. Thus, with a complete anterior dislocation the degree of angular deformity is assessed. Therefore, dislocations with an inclination of the displaced vertebra forward are called those that are bending (***Fig. 2D***), and without an inclination- they are called *slide* ones (***Fig. 2E***). The latter are much more often accompanied by damage to facet joints, that are actually fracture dislocations. It is noted that all other things being equal, the greater the anterior (inclination) tilt, the less pronounced the narrowing of the spinal canal and, accordingly, the lower likelihood of severe spinal cord (SC) injury [36].

According to the concept of articular orthogonal triangulation of R. Louis, the dislocation in one of the support points inevitably leads to a violation of contiguity in others. In unilateral subluxations / dislocations, a certain rotation of the upper vertebra relative to the lower one is always observed (***Fig. 3A***), while the forward displacement is much more pronounced than the lateral one, since the intact facet serves as a kind of fixation point (***Fig. 3B***). The main deformity is observed in the intervertebral disc system - longitudinal ligaments, which is due to the greater initial elasticity of these structures (compared to the capsule of the facet joint) and the absence of bone support (present in the facet joint). In some cases, the fixation point is the intervertebral disc and the *antero-posterior dislocation* is observed, when one facet joint is dislocated forward, and the opposite - backward (***Fig. 3C***). This situation is more typical for the superior cervical region, but is rarely recorded at the subaxial level [40]. Adequate assessment of the nature and degree of rotation is critical for a number of closed single-step reduction techniques.

According to C.A. Beyer et al. [34,41], about 5% of traumatic injuries of the CS are accompanied by isolated non-displaced or minimally displaced facet joints fractures. Traditionally, conservative therapy is used in patients with these types of injuries, which to some extent minimizes the need to detail the injuries. In contrast to dislocations and fracture dislocations which require active therapy (closed reduction followed by immobilization or open reduction with stabilization), all isolated facet fractures without displacement were considered for a long time to be stable injuries and, accordingly, those that do not require surgical intervention. However, recent publications demonstrate the need in some cases for surgical treatment of isolated unilateral facet fractures [41,42]. It is noted that the mechanism of this type of injury is due to the simultaneous effect of hyperextension, lateral compression and rotation and is often accompanied by damage to the anterior of the nucleus pulposus of the intervertebral disc and the anterior longitudinal ligament, which can not always be verified even with the use of modern neuroimaging methods. Therefore, all isolated facet fractures should be considered as conditionally rotationally unstable [44].

The development and improvement of surgical techniques in recent decades, the use of minimally invasive technologies, as well as the general trend towards minimizing the period of disability and the fastest possible rehabilitation of patients in developed countries necessitate a review of tactical approaches to the treatment of patients with isolated facet fractures. According to the problem of verification

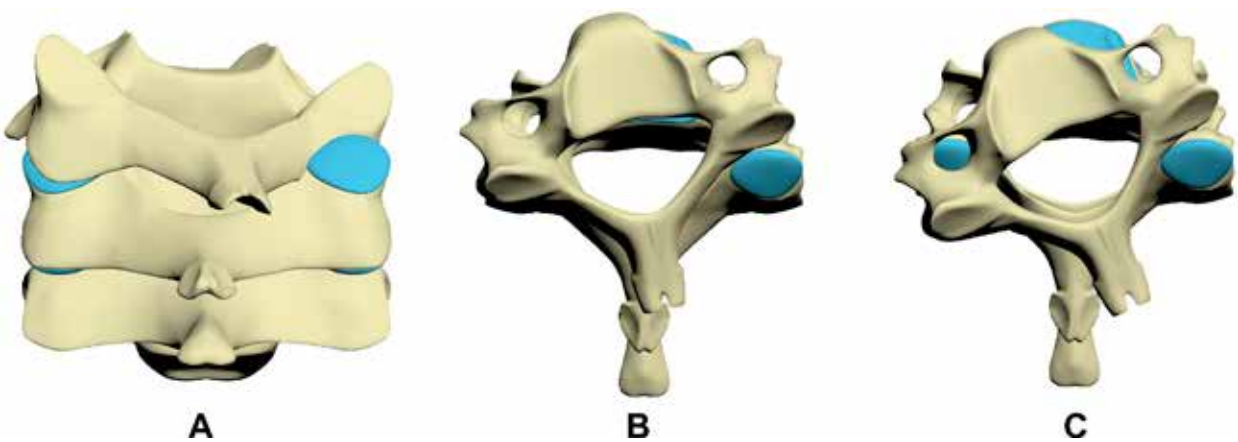

Fig. 3. Rotation for unilateral dislocations (schematically): A - rotational dislocation (rear view); B - rotational dislocation (top view); C - antero-posterior dislocation (top view)

and standardization of the nature of the damage it is relevant.

It is natural that when considering different variants of dislocations, the main characteristic of pathomorphological changes is the contiguity of the articular surfaces of the facet joints, and in some cases - the contiguity of the vertebral bodies. At the same time SMS is always considered. Osteo-traumatic changes of the facet joint, lateral mass, pedicle and lamina of the vertebral arch are assessed. The presence of a certain type of facet fracture does not exclude different variants of displacement in the SMS. No type of facet joint injury has been described that is never accompanied by dislocation, since, as indicated above, all such injuries are conditionally unstable. When describing fracture dislocations, the characteristics and degree of displacement and the nature of bone damage are given.

Damage to the lateral masses

The article of Yoshihisa Kotani et al. [47] led to further study and improvement of the nomenclature of traumatic changes of the posterior support complex. Thus, Japanese researchers, in addition to fractures of the articular processes (types A1 and A2 according to the classification of M.F. Dvorak et al.), distinguish 4 types of lateral mass injuries: separation, comminution, split fractures and traumatic spondylolysis (***Fig. 4***).

Separation fracture is characterized by fracture lines that pass through the lamina and pedicle of the vertebral arch, isolating and separating the articular mass (floating lateral mass). In fact, it corresponds to type A3 according to the classification of M.F. Dvorak et al. and F3 by AOSpine Subaxial Classification System.

Comminution fracture is characterized by the presence of multiple fracture lines of the lateral mass with significant fragmentation, often accompanied by lateral wedging in coronal plane.

Split fracture is characterized by a vertical fracture line in the coronal plane of one of the lateral masses with the formation of anterior and posterior fragments and wedging between them of the superior articular process of the caudally adjacent vertebra.

Traumatic spondylolysis is formed by bilateral horizontal fracture lines of pars interarticularis, resulting in separation of the anterior and posterior structures of the vertebra.

Y. Kotani et al. give a comparison of the degree of instability in fractures of facets and lateral masses of the vertebrae. Thus, in a fracture of the lateral mass the anterior displacement of the injured vertebra was observed in 77% of cases, the displacement of the cranial vertebra - in 24%. In 10% of cases, the authors registered a ventral dislocation of the vertebra located below the injured one, which is probably due to the damage to the ligamentous apparatus in the SMS adjacent to the injured one. In 33% of cases of lateral mass damage, a displacement in the coronal plane was noted. In case of injury to facet joints ventral displacement of the damaged vertebra is registered in 33% of cases (due to a fracture of the inferior articular process) and in 50% of cases the displacement of the vertebra located above the damaged one (in a fracture of the superior articular process). Dislocations of the vertebrae located below, as well as displacements in the coronal plane were not observed in these injuries. When analyzing the subtypes of damage to the lateral masses, the authors noted a high frequency of ventral displacement: 80, 91 and 100% for split and separation fractures and traumatic spondylolysis, respectively. Anterior displacement of the vertebra located above the injured one was observed in 50% of cases in comminution fractures and spondylolysis, in 20% of cases in a floating lateral mass, and in no case in a split

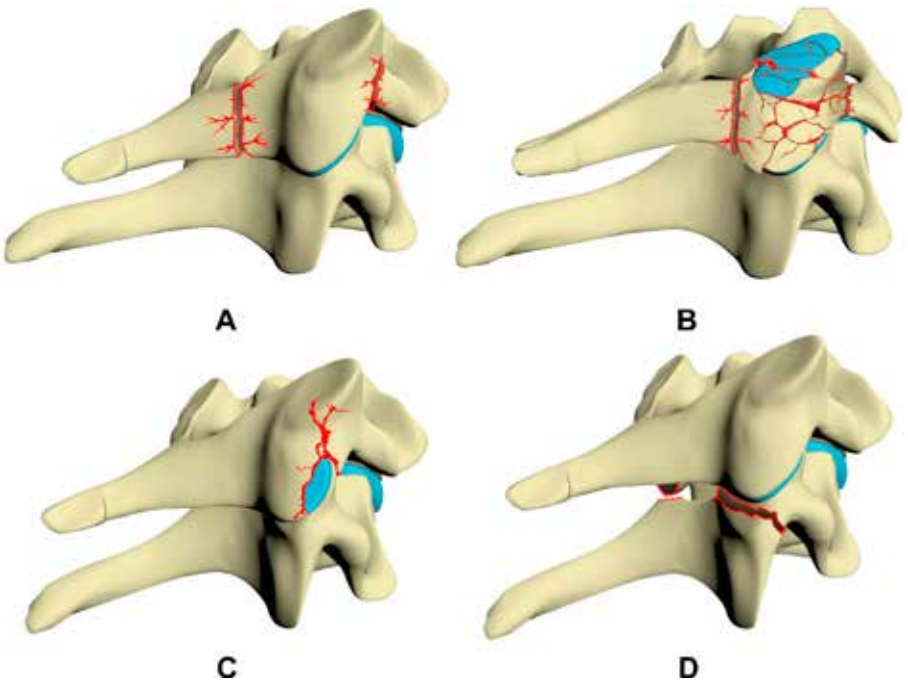

Fig. 4. Variants of traumatic injury of lateral masses (according to Y. Kotani et al. [47] schematically): A – separation fracture; B - comminution fracture; C - split fracture, D - traumatic spondylolysis

injury. In addition, coronal displacement was observed in comminution and split fractures.

All of the described types of the lateral mass injuries require surgical treatment. Y. Kotani et al. prefer short posterior stabilization: for facet fractures, separation fractures and non-gross comminution fractures, monosegmental transpedicular stabilization is recommended, while for split and comminution fractures with coronal displacement - bisegmental. In some cases, with a floating lateral mass, it is suggested to fix the fragment with a cannulated screw with non-locking segment.

Classification proposed by Y. Kotani et al. was used in further studies. Thus, Sun-Ho Lee et al. [44] when analyzing unilateral injuries to the lateral masses of the subaxial part of the CS adhere to this system. In this case unilateral spondylolysis is naturally distinguished. The authors provide a comparative assessment of conservative and surgical methods of treatment, preferring ventral spondylodesis. A positive result in primary surgical approach was registered in 83.3% of patients, while rigid fixation of CS in 80% of cases is ineffective and requires further stabilization. Delayed surgery is effective in 66.7% of cases. Thus, even in unilateral damage to the lateral mass, surgical intervention is practically no alternative method of treatment. As an exception, the authors consider unilateral spondylolysis with minimal displacement, in which it is sometimes possible to achieve a positive result by prolonged external fixation.

Injury severity score

One of the attempts to quantify the degree of damage to the posterior support complex of CS and to some extent to standardize the surgical approach is the publication in 2021 by a group of Chinese scientists of *Posterior Ligament-Bone Injury Classification and Severity Score* (PLICS)) [48]. The authors propose to divide the posterior support complex into three functional structures: lateral (lateral masses with facet joints and joint capsules) and posterior (lamina, spinous processes, supraspinous and interspinous ligaments). PLICS is based on a comprehensive assessment of traumatic changes in the osteo-ligamentous apparatus. Each functional structure is assessed with a score from 1 to 3 depending on the severity of the injury and its contribution to the stability of the posterior support complex of CS.

The nature of injury to the posterior structure according to the proposed classification is determined by clinical examination, 3D computed tomography reconstruction and MRI. The only criterion for identifying a ligamentous apparatus injury is the presence of a hyperintensive MR signal in T2VI mode and / or in fat-suppressed MRI mode, such as T2FFE-SPIR [49,50].

There are three types of injuries depending on the severity (***Table 1***). Minor include injuries with partial rupture of the ligamentous apparatus (***Fig. 5A***) without dislocation of the facet joint. In these patients physical examination reveals tenderness on palpation of the spinous processes of the injury site. X-ray signs of expansion of the interspinous space or fracture of the spinous process are not determined. *Moderate injuries* are characterized by complete rupture of the ligamentous complex (***Fig. 5B***), anteroposterior displacement of the vertebra and dislocation of the facet joint. On computed tomography scans an increase in the distance between the spinous processes without fractures of the latter is recorded, and the expansion of the interspinous space can be determined by palpation. Moderate injury, that is accompanied by a fracture of the spinous process and / or lamina, is classified as severe (***Fig. 5C***).

Table 1. Injury severity score of the posterior structure

Characteristic	Score
Intact	0
Minor injury	1
Moderate injury	2
Severe injury	3

When assessing the stability of lateral structures it is recommended to consider both ligaments and bone formations. Preservation of ligaments determines the integrity of the facet joint capsule. Since the capsular ligaments are too small for convincing visualization, the degree of displacement of the affected facet joint is considered as an indirect sign that reflects the severity of the capsular injury. Subluxation refers to a partial rupture of the joint capsule, score - 1 point (***Fig. 5A***), dislocation - refers to a complete rupture of the capsular ligament, score - 2 points (***Fig. 5B, C***). The severity of damage to bone elements is determined by the stability of the injured joint and lateral mass. If the fracture line passes through only one articular surface, as in case of partial separation (***Fig. 5G***) or partial split fracture (***Fig. 5D***), then the damage is considered to be stable, the score is 1 point. If the linear fracture simultaneously affects the superior and inferior articular surfaces, as in a complete split fracture (***Fig. 5E***) or complete separation of one articular surface from the lateral mass (***Fig. 5H***), then the facet joint is relatively unstable, the score is 2 points. A comminuted fracture of the facet joint at the affected level (***Fig. 5F***) or separation of the pedicle and / or lamina which leads to the separation of the entire lateral mass (floating lateral mass) (***Fig. 5I***), score - 3 points is considered extremely unstable. Bone elements and ligaments of lateral structures are evaluated separately, the greatest value is taken into account in the calculations (***Table 2***).

The assessment scheme proposed by the authors was used in patients with scores of > 4 points on the SLIC scale, that is, surgical inntervention is recommended in all cases, [51]. In contrast to the previous works of Y. Kotani the absolute preference is given to ACDF. In case of a total PLICS score of ≤7 points and the absence of extremely unstable lateral mass fracture, ventral corporadesis is recommended, in case of ≥7 points and / or the presence of extremely unstable injury - 360° stabilization.

Due to the fact that damage to the posterior support complex is the main thing in determining the approach

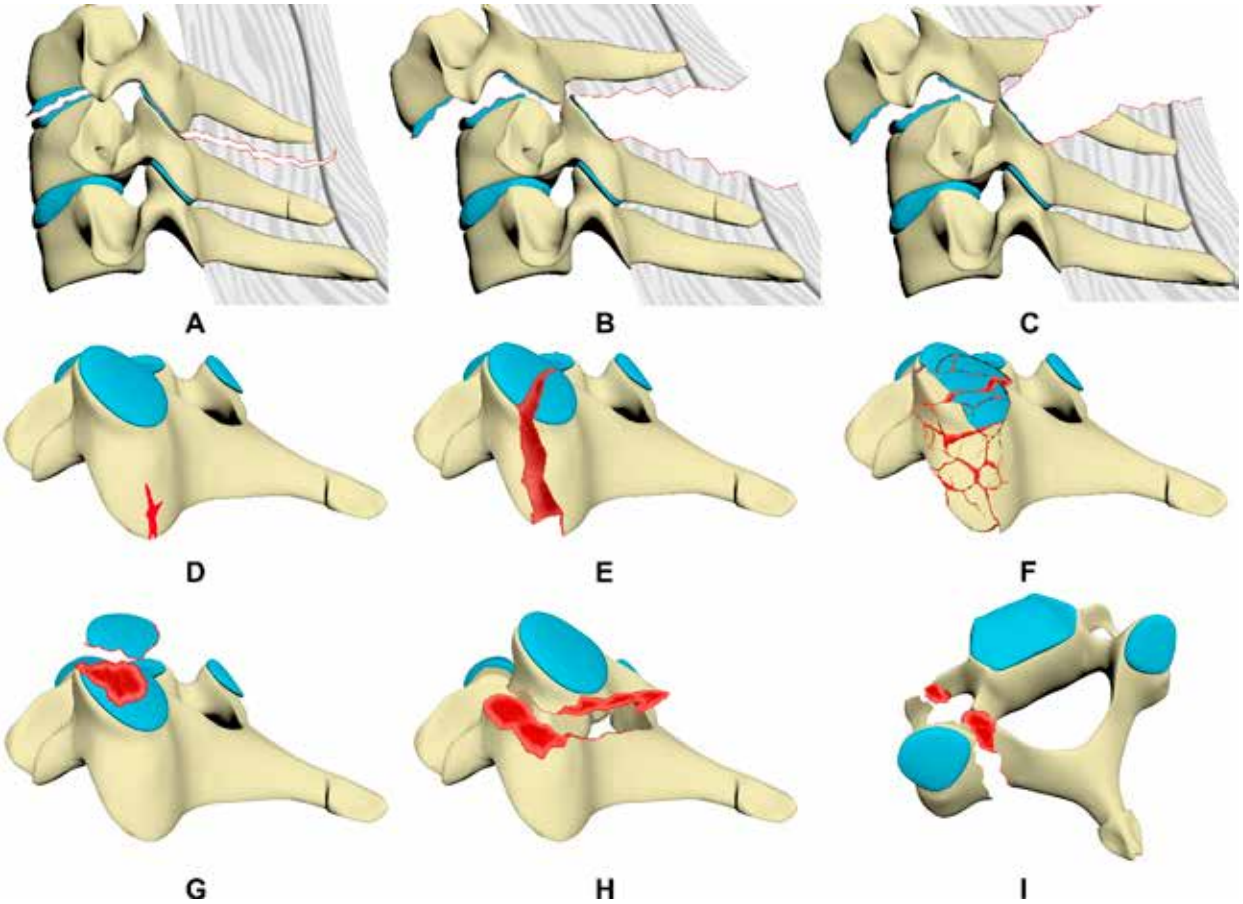

Fig. 5. Types of damage to the lateral and posterior structure according to PLICS [48] (schematically). Posterior structure injuries: A - minor; B - moderate; C - severe. Lateral mass lesions: D - partial split fracture; E - complete split fracture; F - comminution fracture; G- partial separation of the articular surface; H- complete separation of the articular surface; I - floating lateral mass

of surgical intervention using PLICS, the use of this scale is not recommended in patients with comminution or compression of > 30% of vertebral body fractures. A separate category includes patients with ankylosing spondylitis, in whom isolated ventral stabilization is often unsuccessful [52].

Table 2. Injury severity score of the lateral structures of the posterior tension band

Characteristic	Score
Ligamentous apparatus:	
• normal facet ratio	0
• subluxation	1
• dislocation	2
Bone structures:	
• intact lateral masses	0
• stable lateral mass fracture	1
• unstable lateral mass fracture	2
• extremely unstable lateral mass fracture	3

General principles of therapy

Both unilateral and bilateral injuries of facet joints and lateral masses with or without obvious dislocation are often accompanied by neurological disorders in patients with subaxial CS trauma. Thus, in unilateral facet dislocations, about 25% of patients are neurologically intact, in 37% there are signs of irritation or compression of the roots of SC, 22% show a clinical picture of incomplete damage to the SC, and tetraplegia is observed in 15% [31]. Bilateral injuries are more often accompanied by severe soft tissue injuries and a higher incidence of neurological disorders compared to unilateral facet dislocation. Considering the significant instability, early immobilization is recommended, if necessary - closed reduction, SC decompression and stabilization, which in general allows to improve the neurological status of patients [53]. The results of the multicenter prospective study of Surgical Timing in Acute Spinal Cord Injury Study (STASCIS) published in 2012, demonstrate that early reduction and / or early surgical decompression and stabilization performed within the first 24 hours after injury provide better regression of neurological disorders than later decompression [54].

Despite the high practical significance, the question of optimal methods of surgical correction

of these injuries has not been resolved. In 2014, D. Del Curto et al. published a systematic review of the assessment of surgical approach in traumatic facet injuries, which was included in the Cochrane database [55]. However, even this work did not reveal the most optimal surgical approach. This publication is the only one that summarizes the results of randomized studies on this issue.

Analysis of the literature revealed three main surgical approaches in treatment of traumatic facet injuries and lateral masses: ACDF, posterior transpedicular / transarticular stabilization, and 360° surgery [56]. The following are the main advantages and disadvantages of these techniques.

Anterior cervical approaches

In patients with traumatic injury of the posterior support complex at the subaxial level of CS, the advantages of ventral approaches are: no need to rotate the patient and, accordingly, a lower risk of trauma to neural structures in unstable injury, since surgical intervention is performed in a supine position; minor surgical trauma; the possibility of direct decompression of the structures of the spinal canal in the presence of traumatic hernia of the intervertebral disc or bone fragment [57].

It is noted that ACDF when performed for unilateral facet fracture dislocation results in a lower frequency of infectious postoperative complications and is characterized by lower pain intensity compared to posterior approach. According to some authors, ventral surgical approach provides more opportunities for restoring the sagittal contour of the operated segment and promotes better consolidation [58].

For a long time, ACDF was preferred in patients with traumatic intervertebral disc herniation and incomplete neurological deficit, since ventral direct decompression is always better than posterior indirect [59]. However, a number of publications have demonstrated the possibility of effective removal of posterior hernias by the posterior approach without significant risks of increasing neurological disorders [57].

One of the main tasks when performing surgical intervention for traumatic injuries of facets or lateral masses is the restoration of the axis of the spine. A large number of techniques of open indirect anterior reduction have been developed, which are quite effective and safe for both unilateral and bilateral injuries [60].

The most common methods include open reduction using a cervical distractor, in which after discectomy by means of compressing pins, a local kyphotic deformation is formed, providing unlocking the facet joints. Aside from anteroposterior compression on the body of cranially located vertebra a dosed distraction of pins, restoration of congruence of facets and the formation of lordosis with subsequent installation of the interbody support are performed.

An alternative method is continuous intraoperative external skull traction, aside from this, after intervertebral discectomy, by dosed pressure on the body of the cranial vertebra of the damaged SMS and the additional use of Cobb elevator or other instrument, facet repositioning is performed. In most cases, surgical approach after ventral discectomy is sufficient to remove disc fragments present in the canal, even in case of some caudal or cranial migration.

In cases where the dislocation cannot be reduced by anterior approach, the patient is rotated on the abdomen, and a direct partial facetectomy, reposition and posterior fixation are performed. In this case further anterior fixation is possible which allows to restore the height of disk space and promotes maintenance of a lordotic curvature of the injured SMS. However, the issue of re-anterior approach is decided by the surgeon, since it is not actually mandatory.

Possible complications of ventral surgical approach, according to T.J. Yee et al. [61], are listed in ***Table. 3***. The main disadvantage in some cases is the difficulty of facet reposition, which is especially typical for chronic dislocations [62].

Postoperative dysphagia in ventral approaches is associated with compression and traction of the esophagus during surgery [63]. Operations accompanied by extended dissection, significant duration, multilevel spondylodesis and thus postoperative edema, increase the risk of postoperative dysphagia. In some cases, ischemia of the esophageal mucosa is recorded. In addition, dysphagia can be caused by the stabilization system protrusion above the anterior surface of vertebral bodies, which is determined by the thickness of the ventral plate. Other factors that can lead to dysphagia after CS surgery include pain, muscle spasm, and immobilization in the cervical collar.

Esophageal injuries are a rare complication and can be diagnosed both intraoperatively and within 20 years after surgery [64]. The main clinical manifestations are dysphagia or odynophagia, hyperthermia, swelling of the neck, drainage through the postoperative wound. According to S.H. Halani [65], iatrogenic intraoperative injury is the cause of perforation only in 19% of cases.

Table 3. Frequency (%) of the most common complications after performing surgery at the subaxial level by the ventral approach (according to T.J. Yee et al. [61])

Complications	Average frequency	Range
Dysphagia	5,3	0,2–87,5
C5 root palsy	3,0	0,1–7,7
Displacement/implant breakage	2,1	0–50,0
Pseudoarthrosis	2,0	0–55,0
Recurrent laryngeal nerve paralysis	1,3	0,1–60,9
Infection	1,2	0–16,7
Hematoma	1,0	0–12,5
Liquorrhea	0,5	0,03–7,70
Increasing neurological deficit	0,5	0–25,7
Horner syndrom	0,4	0,1–2,5
Vertebral artery injury	0,4	0,2–2,2
Esophageal perforation	0,2	0–0,46

In general, ventral approaches in surgery for injuries of the posterior support complex are characterized by a relatively low frequency of complications. The main disadvantages are the difficulties with repositioning and providing rigid fixation. A potential problem after ACDF is the postoperative kyphosis. Thus, in 13% of patients who underwent ACDF due to facet damage, kyphotic deformity of the operated SMS was registered [66]. However, the incidence is not associated with age, gender of patients, intervention technique, unilateral or bilateral injury, plate type, degree of displacement, level of injury, or the degree of intraoperative correction of the sagittal contour. The use of longer screws and fixation with a rigid cervical collar is proposed as a means of preventing these complications.

Posterior cervical approaches

A definitive advantage of posterior approach in the surgical correction of dislocations and fracture dislocations of the subaxial section of CS is the ability to perform the direct open reduction. Posterior stabilization using rigid fixation methods with lateral mass screws or pedicle screws is relevant for patients with ankylosing spondylitis or osteoporosis [67]. Experimental studies have shown that in case of unilateral damage to the facet joint, the stabilization of the lateral masses provides a more effective restriction of range of motion than ACDF [68].

Posterior surgical approaches are characterized by a significantly lower incidence of dysphagia in the postoperative period, but this complication is not completely excluded [69]. The incidence of C5 root palsy is higher in posterior approach, although the volume and technique of surgery are important [70].

Despite advances in surgery, posterior approaches are characterized by a high risk of increasing of neurological deficit in patients with ventral compression, but are more effective when the compression factor is a facet / lateral mass fragment that compresses the root or spinal canal structure (principle of decompression efficiency from the side of compression).

Posterior approach surgery makes it less likely to restore cervical lordosis compared with ACDF, and the absence of a normal sagittal profile of CS may adversely affect the long-term treatment outcomes [71]. On the other hand, it is noted that in the treatment of distraction and rotational injuries, which often require complex reduction manipulations, the posterior approach has a significant advantage over the anterior one [72,73].

Posterior direct open reduction is conventionally contraindicated in patients with anterior spinal cord compression due to the risk of increased compression during reduction [68]. Due to the need to lie on the stomach, performing posterior approach intervention may be associated with certain difficulties in patients with polytrauma and / or unstable vital functions. In addition, posterior approaches are characterized by a statistically significantly higher incidence of infectious complications [74-76].

Combined approaches

Combined surgical approaches are presented by anteroposterior, posterior-anterior, in some cases posterior-anterior-posterior or anteroposterior-anterior. The main advantage of the combined 360° stabilization is reliable fixation of the operated SMS, which significantly limits the residual range of motion [77,78]. It is noted that combined stabilization in case of dislocations / fracture dislocations of the CS at the subaxial level increases the rate of consolidation, but has no significant advantages in regression of neurological disorders [79]. The combined approach is expedient when correcting long-term dislocation, pseudoarthrosis and in all situations when a large osteotomy is planned. Significant damage to all support columns is often an indication for 360° fixation. In patients with reduced bone density in the presence of ankylosing spondylitis or some other systemic diseases, combined stabilization is the method of choice. The disadvantages of this method are a priori the higher level of costs for stabilization, the long duration of surgery and, accordingly, the increased risk of infectious complications. Therefore, when planning sizable and long-term surgery, despite all the benefits, the risk-benefit balance of 360° stabilization should be assessed.

Conclusions

The data presented indicate the complexity of both the assessment and classification of traumatic injuries of the posterior support complex of the CS. Analysis of the literature did not reveal a single generally accepted scheme that would allow to unambiguously and comprehensively characterize the damage of facets / lateral masses and choose the optimal surgical or conservative method of treatment. Accumulated clinical experience and current studies of biomechanics of the injured spine demonstrate the advantage of surgical techniques in majority of patients, since these injuries are almost always unstable or potentially unstable.

The choice of anterior, posterior or combined approach is important for the treatment of traumatic injuries of the posterior support complex. Although good surgical results can be obtained with all methods, there are certain situations in which one method may be better than another. Most often, the main principle is the principle of decompression from side of compression. Considering that the level of evidence for choosing the optimal method of treatment is currently unconvincing, neurosurgeons who provide specialized care to this category of patients should have methods of both closed single-step repositioning and direct and indirect reduction followed by ventral or dorsal fixation / stabilization.

Disclosure

Conflict of interest

The authors declare no conflict of interest.

Ethical norms

This article is a literature review, therefore no ethics committee approval was required.

Financing

The study was performed without sponsorship.

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