Review article

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Evolution of classifications of traumatic thoracolumbar spine injuries

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According to various authors, traumatic injuries of the thoracolumbar spine account for 2/3 to 3/4 of all spinal fractures. The development, introduction into clinical practice and improvement of treatment methods for injuries of this area are associated with attempts to classify injuries into different categories based on the most significant common features, according to the author. The evolution of classifications of traumatic injuries of the spine in general and thoracolumbar spine in particular is largely due to the development of ideas about the injury biomechanics.

The review attempts to briefly chatacterize the most well-known classifications. When analyzing the literature, 28 injury ranking systems were selected, reflecting from a historical perspective the change of ideas about the principles of classification, injury biomechanics and treatment tactics. When describing certain types of injuries, we tried to accurately reflect the pathomorphological characteristics of the fracture in the author's interpretation, therefore, the same type of injury may have slightly different characteristics in different classifications given in this publication.

The information systematized in the review is mainly of historical interest, but in some cases may be useful to the practicing clinician for a number of reasons. First, given the huge amount of work carried out by the authors of the classifications on the analysis and systematization of material, a number of publications describe rare types of injuries, and the proposed methods of treatment may still be of practical value. Second, even in current publications devoted to the study of certain features of biomechanics or tactics of spinal cord injury therapy, authors often use little-known or formally outdated injury ranking systems, since a certain classification principle may be more appropriate for the research task. Third, a general analysis of the evolution of classification systems helps to identify historically formed both definitive and tactical errors, the understanding of which allows one to be more critical of actually generally accepted statements.

Key words: *evolution; classification; traumatic thoracolumbar injury*

Introduction

Traumatic injuries of the thoracolumbar spine are a fairly common result of excessive mechanical impact on the human body. The evolution of ideas about possible and optimal treatment methods is directly related both to the development and implementation of innovative techniques into clinical practice at different stages of medical development, and ideas about the biomechanics of changing injuries.

The concept of stability of traumatic spinal injuries is known to be one of the key factors in determining treatment tactics [1]. Stabilization and spinal fusion are performed to eliminate the instability due to trauma or the decompressive stage of surgical intervention. At the same time the concept of "spine instability" is widely interpreted and is constantly changing. It has been noted that the components of spinal instability are so diverse that the above concept makes little sense without taking into account the context [2].

Attempts to determine the optimal type of treatment for a certain group of such injuries have become the basis for the development of classifications of these injuries. Such binding of ranking methods to therapy is typical not only for spinal injuries, but also for the musculoskeletal system as a whole.

The most well-known classifications of traumatic injuries of the thoracolumbar spine are presented in this review. Ranking systems for non-traumatic fractures, many of which have also been developed, were not considered.

The information given is mostly of historical interest, but in some cases may be useful to the practicing clinician for a number of reasons. First, given the huge amount of work carried out by the authors of the classifications on the analysis and systematization of material, a number of publications describe rare types of injuries, and the proposed methods of treatment can still be of practical value. Second, even in current publications devoted to the study of certain features of biomechanics or tactics of spinal cord injury therapy, authors often use little-known or formally outdated injury ranking systems, since a certain classification principle may be more appropriate for the research task. Third, a general analysis of the evolution of classification systems helps to identify historically established both definitive and tactical errors, the understanding of which allows one to be more critical of actually generally accepted statements.

A.G. Devis (1929)

Artur G. Devis, who published the work "Fractures of the spine" in 1929, is considered to be one of the founders of the classification of the thoracic and lumbar spine injuries [3]. The feature of the publication is not the distribution of injuries into groups, but the author's method of treating traumatic injuries. The results of therapy of 19 cases of burst fractures of the thoracolumbar spine out of 33 cases are presented. The anatomical features of burst fractures are described in detail, allowing correction by the method of dosed hyperextension. Such signs include comminuted fractures of vertebral body, anatomical integrity of the anterior longitudinal ligament, preserved support ability of facet joints, preservation of intervertebral discs, the integrity of the vertebral arches.

A. Devis notes that the strength of the anterior longitudinal ligament is sufficient to withstand the dosed hyperextension required to restore the anatomical contour of the body of the compressed vertebra. Ligament tension contributes to axis correction and acts as a limiting membrane for hyperextension of the injured segment. Facet joints, which are the main mechanism of correction, serve as support points of the levers acting through the vertebrae adjacent to the injured one. An additional lever mechanism, which is of secondary importance, are the pedicles of the vertebral arch, which in most cases remain confluent with the inferior fragment. Rigid fixation and relative integrity of the intervertebral discs ensure the recovery of the circle and the general contour of the fragmented body.

The proposed method of treatment of traumatic spinal injuries has long been considered the most effective and preferable. The anatomical aspects of fractures described by the author were used to develop "anatomical" classifications.

L. Böhler (1929)

The first complete classification of osteo-traumatic injuries of the thoracolumbar spine is given in the book "Die Technik der Knochenbruchbehandlung" ("Technique for the treatment of bone fractures") by Austrian surgeon Lorenz Böhler, published in 1929 [4]. The author combined the mechanism of trauma and the nature of injury and classified 5 types: compression fractures, flexion-distraction fractures, extension fractures with anterior and posterior longitudinal ligament injuries, displaced fractures, rotational injuries. In subsequent publications, the 6th type was added - damage due to lateral flexion [5].

The proposed classification was purely descriptive without reference to clinical symptoms, since there were not distinguished more or less "severe" injuries, there was no prognostic component and it had little effect on general treatment tactics.

R. Watson Watson-Jones (1938)

The first classification of thoracic and lumbar spinal fractures, published in a scientific periodical, was developed by Sir Reginald Watson Watson-Jones, an English orthopedist [6]. The author distinguished vertebral body fractures, articular process fractures, avulsion fractures of the transverse processes and contusion fractures of spinous processes. Based on the results of treatment of 252 patients, R. Watson-Jones focused on vertebral body injuries as the most clinically significant and distinguished the following types: simple compression fracture, comminuted fracture and fracture-dislocation.

The author provided recommended treatment regimens for each type of injury based on postural reduction and immobilization in a plaster corset, with the exception of fracture-dislocations, where the surgical treatment is recommended before plaster cast application in some cases. R. Watson-Jones developed a classification scheme to differentiate the nature of bone fracture and determine the optimal method of closed reduction. Analysis of the effectiveness of various methods of kyphosis correction is also presented. Hyperextension immobilization according to the A. Devis method with modifications for each type of fracture is the most rational treatment.

The importance of minimizing kyphosis and achieving a perfect radiological picture as a criterion for effective therapy was noted. The author emphasized that a gross wedge deformity in any type of injury inevitably leads to a violation of the ratio in the facet joints and causes distinct pain, but did not specify clear criteria for determining the degree of deformity.

The author evaluated the importance of wedge deformity or compression of the vertebral body, decreased height of intervertebral discs and the formation of "bone spurs" – spondylosis phenomena as radiological criteria 12 months after injury. Despite the fact that according to the results of treatment, only 7% of patients had a deformity greater than 0.25 inches (0.63 cm), one third of patients were noted to have distinct pain, and 4% reported severe pain.

H. Platt (1938)

Almost simultaneously with R. Watson-Jones, another English orthopedist, Sir Harry Platt, published the paper "Fractures and dislocations of the spine", in which he classified injuries depending on the mechanism of action of the traumatic factor [7]. The concept of "anterior support column of the spine" was mentioned for the first time. The author distinguished the following types of injuries:

vertical compression - this mechanism mainly causes the formation of cracks in the vertebral body due to a fall from a height on the buttocks or heels. The force is transmitted through the anterior support column of the spine and affects mainly one vertebra, usually Th12 or L1, which is damaged and becomes wedge-shaped. If the action is more intense, then in the vertebrae located immediately above and below the site of the main injury, you can see a wedge-shaped deformity of a weaker degree;

hyperflexion - in this mechanism, the spine is suddenly affected by a bending force, the point of application being the upper back, shoulders or head. The best-known examples of this type of injury are coal mine injuries caused by a collapsed roof. Fractures as a result of hyperflexion take one of the following forms:

a) collapse of one vertebral body, often with fragmentation and rupture of the intervertebral disc located below;

b) classic fracture-dislocation of the thoracolumbar transition, in which there is a fracture of the vertebral arches or more rarely a dislocation occurs in the intervertebral joints. This is followed immediately by direct displacement of the vertebral body and narrowing of the spinal canal. In some cases, spontaneous reposition is observed;

rotation - rotation, combined with flexion is force that results in subluxations or dislocations. This injury is most common in the cervical spine. In the thoracolumbar spine it is quite rare and is accompanied by a fracture of the arch or articular process;

hyperextension - flexion fractures of the spine. As noted by the author, they are quite rare. In this type of injury, the maximum compressive force affects the posterior parts of the anterior column. If the fractured vertebral body is crushed, there is a high risk of protrusion of fragments into the spinal canal, which leads to severe neurological consequences.

The basic principles of treatment of different types of injuries are presented, the main of which is immobilization of hyperextension. For the first time, the concept of the area of the thoracolumbar transition as the area that is most frequently exposed to traumatic impact is proposed.

G.Q. Chance (1948)

In 1948, George Quentin Chance's work "Note on a type of flexion fracture of the spine" was published [8]. A brief but comprehensive description of one type of injury with anatomical and biomechanical characteristics is presented. In the English language literature, such a fracture is known as "Chance fracture" or "seat belt injury".

The author notes that in case of flexion action on the spine, the load is distributed on the vertebral body, providing a compression effect, arches and interspinous ligament, resulting in distraction. Excessive force causes anatomical damage to the vertebral body with the formation of a compression fracture, or, if for some reason this does not occur, the interspinous ligament and articular processes are damaged.

Currently, the flexion-distraction mechanism of Chance fracture formation is recognized. The injury is rarely associated with a neurological deficit, in most cases it is localized in the area of the thoracolumbar transition. In more than 50% of cases it is combined with abdominal trauma.

E.A. Nicoll (1949)

Further improvement of the classification of thoracic and lumbar spine injuries is associated with the work of Ernest Alexander Nicoll, published in 1949 [9]. The author actually modified the R. Watson-Jones scheme and added the Chance fracture described a year earlier. The work is based on the analysis of 166 fractures in 152 miners injured at work.

E. Nicoll classified 5 types of injuries:

anterior wedge (compression) fracture - may have varying degrees of severity, in the case of significant anterior compression it is inevitably combined with damage to the interspinous ligament, which leads to its transformation into fracture-dislocation;

compression-comminuted fracture - occurs due to the direct impact of a traumatic factor on the spine. The author notes that this type of injury is characterized by displacement of bone fragments of the damaged vertebra in the long term;

fracture with lateral compression is registered in 14% of cases. The author suggested that the occurrence of such traumatic deformities is associated with the flexion-rotation mechanism of the injury. The fracture is characterized by lateral compression of the vertebral body, damage to the facet joint on the compression side and fracture of the transverse process on the opposite side. It is prognostically unfavorable for the restoration of functional activity of the injured. It is often accompanied by distinct pain sensations. It is poorly reducible and prone to redislocation. May be associated with spinal cord or cauda equina;

fracture-dislocation is the most severe type of injury, often associated with neurological deficits. The author refers to this type of injury any compression fracture with rupture of the interspinous ligament. As a method of differential diagnosis E. Nicoll recommends a flexion test with radiography in lateral projection. The appearance or increase of displacement makes it possible to differentiate a fracture-dislocation. Anatomical types of injury: subluxation in facet joints, superior dislocation, fracture of articular processes or arch, locked facet dislocation. According to the author, the first three types of injury are subject to postural correction and only the fourth to surgical treatment;

vertebral arch fractures, according to the author, have different biomechanical mechanisms. The first is rotational action, which usually results in symmetrical bilateral injury, the second is flexion-distraction, described by G. Chance.

The author's main contribution to the development and optimization of treatment methods is the distribution of traumatic injuries into stable and unstable ones. According to E. Nicoll, in stable fractures there is no risk of increased deformity and, as a result, spinal cord injury. Treatment of such patients does not require fixation with a plaster corset. The author classifies anterior and lateral compression fractures and fractures of the arch above the L4 vertebra as stable, and all fractures with interspinous ligament damage as well as L4 and L5 vertebral arch fractures as unstable fractures.

Unlike R. Watson-Jones, who evaluated the effectiveness of therapy based on radiographic imaging, E. Nicoll considers the functional activity of a patient who has suffered an injury as the main criterion for successful treatment. The therapy is considered to be absolutely successful, allowing to return to full-fledged work within 2 years after any traumatic injury. Examples of inconsistency of the radiological picture with the clinical condition of the injured are given.

F. Wild Holdsworth (1962)

Sir Frank Wild Holdsworth presented his own classification based on a large number of clinical, radiological and surgical observations during a lecture on spinal injuries at the Royal College of Surgeons in London in 1962.

The author was the first to mention the "posterior ligamentous complex", which included the supraspinous and interspinous ligaments, the capsule of the facet joints and the yellow ligament. It is damage to these anatomical structures leads to the formation of unstable fractures. An improved version of the classification was published in 1970 [10].

Among the stable injuries of the thoracolumbar spine F. Holdsworth included:

simple wedge fracture, resulting from a bending load, does not cause significant deformity. Requires conservative therapy: bed rest for 2-3 weeks, followed by fixation with a semi-rigid corset;

burst fracture is due to vertical compression load. It is usually accompanied by distinct pain sensations. The therapy in the form of immobilization for 8–12 weeks, followed by gradual rehabilitation is indicated;

extension fracture – is a rare type of the thoracolumbar spine fracture, which occurs during hyperextension, at the moment of injury there may be dislocation, which due to the preservation of posterior ligamentous complex is reduced spontaneously. X-ray diagnosis is difficult. Therapy depends on the injury level and is not described in detail by the author.

F. Holdsworth distinguished the following unstable fractures:

dislocation - the mechanism of formation is the bending load, which causes the rupture of the ligamentous apparatus after wedge-shaped deformity of the vertebral body or without it. The injury always requires surgical treatment with posterior implant fixation and immobilization for 12-14 weeks in a plaster corset;

rotational fracture-dislocation - is the most unstable of all possible injuries and is formed as a result of a combination of flexion and rotation. In case of uncomplicated injuries, which occur quite rarely, as the author notes, conservative therapy with immobilization in a plaster bed for 12-14 weeks is indicated. In the presence of paraplegia, surgical treatment with posterior fixation by plates on the spinous processes of the two vertebrae above and below is recommended, which facilitates the long-term care of the patient;

shear fracture occurs as a result of direct mechanical impact on the spine, is characterized by damage to the articular processes and ligamentous apparatus, occurs only in the thoracic spine. According to the author, it is always associated with spinal cord injury. The damage is conditionally stable and requires surgical correction only in case of a significant displacement.

The author, like E. Nicoll, did not consider the restoration of radiologically correct spinal axis as the fundamental criterion for the effectiveness of therapy.

The term "Holdsworth fracture", a flexion-rotation injury described by the author and characterized by a fracture of the vertebral body, rupture of the ligamentous apparatus and fracture of the facet joints, is found in modern English-language literature [11].

H. Kaufer and J.T. Hayes (1966)

In 1966, two American researchers Herbert Kaufer and John T. Hayes presented their own classification of dislocations and fracture-dislocations of the lumbar spine and thoracolumbar transition zone [12]. The authors considered the spinal motion segment as a complex of three anatomically separate but functionally unified joints (two facet joints and disco-ligamentous complex). Various combinations of damage to these structures form 5 types of injuries identified by the authors:

Type 1 - dislocation in both facet joints with displacement of the body - damage to synchondrosis. The injury is purely a dislocation without damage to the bony structures;

Type 2 - dislocation in facet joints with vertebral dislocation and compression damage of one or two vertebral bodies;

Type 3 - dislocation in facet joints without vertebral dislocation. Compression or horizontal damage to the anterior parts of the vertebral body is characteristic;

Type 4 - unilateral dislocation with a fracture line passing through the opposite pedicle of the arch or the base of the articular process and extending either to the vertebral body or to the intervertebral disc;

Type 5 - dislocation of the vertebral body without dislocation of facet joints. The fracture line passes bilaterally through the pedicle of the arch or articular process, extends anteriorly to the intervertebral disc and affects the underlying vertebral body.

The biomechanical model of the spinal motion segment proposed by the authors, characterized by orthogonal triangulation, was described in detail only in 1985 by the French orthopedist Rene Louis [13].

R.P. Kelly and T.E. Whitesides Jr. (1968)

One of the works that influenced the study of the biomechanical aspects of traumatic spinal injuries was the publication of Robert P. Kelly and Thomas E. Whitesides Jr. [14]. The authors proposed the concept of two support columns, which allows you to determine the stability of the injury and choose the most optimal treatment method. The anterior support column includes the anterior and posterior longitudinal ligaments, vertebral body and intervertebral disc, and the posterior support column includes the arch with articular processes and posterior capsular ligament. According to the authors, unstable injuries are caused by the simultaneous damage of two support columns, whereas in case of injury to one support column, the fracture is stable and is subject to conservative therapy.

The authors proposed a classification of injuries into stable and unstable ones. Anterior and lateral wedge fractures, as well as stable burst fractures were classified as stable fractures; unstable fractures included both dislocation fractures both reduced and existing. This group included new injuries (flexion dislocations, flexion-rotation fracture dislocations, unstable burst fractures and other injuries not specified by the authors) and old injuries with restored stability or persisting instability.

Both the stability concept and classification were developed for injuries of thoracolumbar transition. Subsequently, they were spread to other parts of the spine.

The authors first suggested the use of anterolateral approach according to the method of A.R. Hodgson and F.E. Stock for the treatment of traumatic injuries of the thoracolumbar transition. Previously, this technique was used only for the surgical treatment of spinal tuberculosis [15]. Researchers suggested that, since it is often impossible to restore the posterior support column after laminectomy with existing stabilization systems, anterior traumatic approach is optimal. This concept was further developed, although with the introduction of transpedicular fixation systems into clinical practice, the actual arguments in its favor were lost.

J.B. Roberts and P.H. Curtiss Jr. (1970)

One of the simplest classifications of traumatic injuries of the thoracolumbar spine was proposed in 1970 by John B. Roberts and Paul H. Curtiss Jr. [16]. The authors analyzed the results of examination of 25 patients with traumatic paraplegia as a result of fracture or fracture dislocation of the thoracic and lumbar spine. The main objective of classification was to determine the stability of injury and predict the probability of deformity progression with conservative therapy.

Three types of injury are distinguished:

wedge compression fracture (type I) - conditionally stable. Surgical stabilization is the optimal method of treatment;

compression burst fracture (type II) - stable. Spontaneous interbody fusion is characteristic. Surgical stabilization is not indicated;

rotational fracture dislocation (type III) - unstable, often accompanied by progressive deformity. The fusion of vertebral bodies occurred only occasionally. Surgical correction is indicated.

The authors identified the following signs of unstable injuries: fracture with subluxation and damage to the interspinous ligament, fracture-dislocation, fracture of the arch at the level of the vertebrae L4 and L5.

A.A. White III and M.M. Panjabi (1978)

In 1978, Augustus A. White and Manohar M. Panjabi published "Clinical Biomechanics of the Spine", organizing all the ideas about spinal biomechanics known at the time. In addition to the popular concept of spinal stability, the authors studied the features of kinematics of the spinal motion segment, having assumed that any movement due to excessive load causes pathomorphological changes in a specific pattern. The spinal motion segment was analyzed in a three-dimensional coordinate system, and the authors suggested that along each axis there are only two possible variants of movement - dislocation and rotation, which determines 6 degrees of freedom, respectively, any fracture or dislocation can be described within forces acting on compressed vertebrae relative to the x, y and z axes. Compression-distraction and rotation injuries are formed when acting along the y-axis, flexion-extension and lateral dislocations - when acting along the x-axis, lateral tilts and anteroposterior dislocations - when acting along the z-axis. The proposed classification was important for understanding the relationship between the mechanics and pathomorphology of injuries, but was not useful for practice.

In 1990, the authors identified 8 types of injuries, the most characteristic for the thoracolumbar spine [18]:

endplate fractures: damage to the central part of the plate, the peripheral layer and the entire endplate [19]. Injuries occur when exposed to vertical loads;

ejection seat fractures occur due to a significant load that affects a person who is in a sitting position. Endplate fracture and compression fracture are usually without wedge deformity;

compression fractures: characterized by reduced vertebral height with varying degrees of wedge-shaped deformity and often with damage to the endplates;

burst fractures resulting from the impact of significant force on a vertical or close to a vertical vector. In contrast to compression fractures, the posterior wall of the vertebral body is necessarily damaged;

comminuted fractures are also known as tear drop fractures. They occur as a result of high-intensity vertical action with a pronounced flexion moment. Fragmentation of the upper part of the vertebral body and sagittal fracture of the lower part are characteristic. They were described for the first time by S. Lindahl et al. [20];

severe fracture dislocations are accompanied by various combinations of osteo-ligamentous changes in combination with dislocations of facet joints;

solitary fractures of the posterior support complex occur mainly under the influence of flexion or rotation load. The authors also consider extension loads as a possible cause of vertebral arch fractures;

"seat belt" fractures are described by G. Chance [8]. The authors distinguish ligamentous, bony and osteo-ligamentous variants.

G. Gumley et al. (1982)

Detailed variants of distraction injuries of the spine were reviewed by a group of Australian orthopedists headed by Graham Gumley [21]. The data of 20 patients were used as clinical material. According to the authors, the area from Th12 to L3 is the most susceptible to such injuries. Researchers distinguished three types of damage:

type 1 - described by G. Chance. The fracture line extends transversely from the spinous process through the arch, facet joints, arch pedicle with transverse processes on the vertebral body;

type 2 - the fracture line begins above the base of the spinous process and, extends to the arch, repeats that of type 1;

type 3 – is the result of distraction in combination with rotation. The injury is asymmetric and can be type 1 and 2 on different sides, resulting in an oblique fracture line.

The proposed classification is the first attempt to organize the types of distraction injuries of the thoracolumbar spine. The authors were among the first to emphasize the high incidence of abdominal trauma in distraction spinal injuries.

F. Denis (1982)

One of the known classifications of traumatic injuries of the thoracolumbar spine is a scheme proposed in

1982 and described in detail in 1983 by Francis Denis, an American orthopedist of French origin [22, 23].

The author divided all injuries into mild and severe ones. Mild injuries included fractures of the transverse and articular process, intra-articular part and solitary fracture of the spinous process. Severe injuries are classified into four categories: compression fracture, burst fracture, "seat belt" fracture, and fracture dislocation.

The proposed classification is actually based on the original concept of spine stability. F. Denis suggested that solitary damage to the posterior capsular ligament did not lead to instability. A model of three support columns was proposed. The posterior column actually corresponds to the described R.P. Kelly and T.E. Whitesides Jr. The anterior column includes the anterior longitudinal ligament, the anterior part of the vertebral body and the intervertebral disc. The posterior wall of the vertebral body and the fibrous ring of the intervertebral disc with the posterior longitudinal ligament form the middle column. The schematic representation of the support columns in the original publication does not correspond to the description in the text, so it is assumed that the author considered the middle of the vertebral body as the border of the anterior and middle columns, although this is not clearly stated. This incorrectness subsequently led to inaccuracies in the interpretation and generally to the rejection of the proposed model.

Combinations of injuries of these support columns define different types of injuries:

compression fracture: destruction of the anterior column under the influence of compression. The middle column, completely intact, acts as a hinge, leading to tension in the posterior column, which can be damaged by severe compression injuries. Two types of compression injuries are proposed: anterior and lateral;

burst fracture: a characteristic feature is damage to the anterior and middle columns during axial compression, which leads to loss of height of the posterior wall of the vertebral body, retropulsion of the vertebral body fragment into the spinal canal with or without corresponding neurological disorders. The author identified 5 types of burst fractures, which were characterized by damage to both endplates (type A), upper endplate (type B), lower endplate (type C), one or two endplates in combination with vertical laminar fracture - burst rotational fracture (type D) or a combination of lateral compression fracture with damage to the posterior wall of the vertebral body - burst lateral-flexion fracture (type E);

"seat belt" injury is a flexion-distraction injury of the posterior and middle columns and is characterized by an increase in the height of the posterior vertebral body and / or expansion of the interdiscal space. The author distinguished 4 variants of injury: solitary one-level bone injury - Chance fracture (type A), one-level disco-ligamentous injury (type B), two-level with damage to the bone structures of the middle column (type C) and two-level with damage to the disco-ligamentous structures of the middle column (type D);

fracture-dislocation is characterized by the destruction of all supports by compression, tension, rotation or shear, resulting in subluxation or dislocation. The author distinguished 3 types and corresponding subtypes:

• flexion-rotation (type A): the posterior and middle support columns are completely damaged under the influence of distraction and rotation, whereas the anterior column – is damaged due to compression and rotation forces. This results in wedge-shaped deformity of the vertebral body anteriorly, partial rupture of the periosteum of the anterolateral surface and avulsion of the anterior longitudinal ligament. Flexion-rotational injuries may pass through the disc or vertebral body (shear fracture);

• fracture-dislocation of displaced type (type B): all three columns are most often injured due to the posterior-anterior shear force, dislocation can also be caused by anteroposterior force. Under the action of posteroanterior shear force, the upper segment is displaced forward relative to the lower segment, breaking the posterior arch of the upper vertebral body (posterior-anterior subtype). Due to the anteroposterior displacement, the upper segment is displaced without fracture of the lamina (anteroposterior subtype);

• flexion-distraction type: resembles a seat belt injury, with disruption of both the posterior and middle columns, but with complete damage to the entire fibrous ring. As a result, subluxation or dislocation is formed in the corresponding segment.

The F. Denis classification is the first system of ranking traumatic injuries of the thoracolumbar spine, based on the analysis of computer thermograms of the spine.

P.C. McAfee et al. (1983)

One year after F. Denis published a three-column concept of spinal stability, a group of researchers led by American orthopedist Paul C. McAfee proposed their own classification of traumatic injuries of the thoracolumbar spine [24], which was a combination of F. Denis scheme and biomechanical aspects of stability of A.A. White and M.M. Panjabi. The authors considered that the classification of F. Denis was overly detailed. For example, distinguishing 5 types of burst fractures is inappropriate since it has no practical value when choosing a treatment straregy. In addition, the classification of A.A. White and M.M. Panjabi has a biomechanical basis, but determining the types of damage is rather complicated, and clinical use is very limited.

The authors distinguished 6 types of injuries:

wedge-compression fracture is an injury caused by isolated anterior column injury as a result of flexion. The vertebral body (bodies) are usually wedge-shaped;

stable burst fracture is a fracture in which the anterior and middle columns are destroyed due to the impact of compression load without losing the integrity of the posterior elements;

unstable burst fracture in contrast to the stable burst is characterized by additional damage to the posterior support column due to compression, lateral flexion or rotation. Post-traumatic kyphosis tends to develop due to instability;

Chance fracture - horizontal avulsion injury of the vertebral body as a result of flexion along the axis located forward from the anterior longitudinal ligament;

flexion-distraction injury - the axis of flexion passes behind the anterior longitudinal ligament. Compression of the anterior support column is characteristic, whereas the middle and posterior columns are injured distractively. When the capsules of the facet joint are ruptured, subluxation or dislocation may occur. Most types of this injury are potentially unstable because the ligamentum flavum, interspinous, and supraspinous ligaments tend to rupture;

dislocated injuries are injuries in which the axis of the spinal canal is disrupted. At the level of the lesion, one part of the spine is displaced in the transverse plane. At the same time all support columns are usually damaged. This category of injuries includes the so-called comminuted fractures of Holdsworth, as well as rotation fractures, fracture-dislocations and pure dislocations [10].

A specific feature of the classification of R.S. McAfee et al. is a clearly defined tactics of surgical treatment of unstable injuries, determined by the mechanism of damage to the middle support column. Since, according to researchers, the main mechanisms of damage to this column may be compression, distraction and displacement, it is advisable to use distraction and compression rod systems or sublaminar fixation, respectively.

The proposed classification proved to be convenient and simple for practical application, but was not widely used. It is noteworthy that the most modern AOSpine thoracolumbar spine injury classification system, proposed in 2013, completely repeats most of the classification categories of the system by P.C. McAfee et al., although it is based on other biomechanical principles [25].

R.L. Ferguson and B.L. Allen Jr. (1984)

In 1984, Ron L. Ferguson and Ben L. Allen proposed their own classification of traumatic injuries of the thoracolumbar spine, which was actually based on the same principles as the classification of injuries of the cervical spine at the subaxial level that they proposed two years earlier, although much less detailed [26]. Data of 54 patients were used as clinical material [27]. The authors analyzed spondylograms performed in standard projections.

The concept of support columns, which the authors called elements was modernized because the mentioned structures are neither anatomically nor biomechanically columns. Thus, the posterior elements corresponded to the posterior support column of R.P. Kelly and T.E. Whitesides Jr., the middle elements corresponded to posterior third of the vertebral body and fibrous ring with posterior longitudinal ligament, and the anterior elements corresponded to the anterior 2/3 of the body and fibrous ring and anterior longitudinal ligament. The authors defined instability as acute or chronic progression of spinal deformity, prolonged pain affecting the lifestyle of injured person, acute or chronic increase in neurological disorders, life features due to trauma, as well as decompressive and destabilizing surgeries.

The proposed classification was a logical continuation of the biomechanical concept of A.A. White and M.M. Panjabi, but the distinguished types of injuries had a clear pathomorphological description. In fact, it was assumed that the complex of morphological changes was clearly determined by the sum of the loads that define the direction of traumatic force. Thus, a decrease in the height of any vertebral structural element is always determined by compression load, an increase in height or rupture by distraction, torsional forces result in rotational injuries, and forces applied anteriorly, posteriorly or laterally result in shear deformations.

The authors identified 7 types of injuries:

compression-flexion: caused by compression effect on the spinal motion segment in a flexion position. The pathomorphological picture can be represented by: 1) wedge-shaped deformity of the body with intact middle and posterior elements, 2) distraction damage to the posterior elements in combination with compression of the anterior ones; 3) destruction of the middle element in addition to the described damage to the anterior and posterior elements. In this case, the posterior upper fragment of the vertebral body is displaced into the spinal canal;

distraction-flexion: characterized by damage to all support elements during distraction effect on the bent spinal motion segment. Examples of such injuries are Chance fracture - a bone injury and true dislocation - a discoligamentous injury. Combined variants are possible;

lateral flexion: an injury caused by unilateral compression due to lateral flexion. There are two pathomorphological variants. In the first case, there is unilateral compression damage of the anterior and middle elements with intact posterior element, in the second case, the posterior support elements are damaged, and on the flexion side there is a compression, and on the contralateral one - distraction;

torsion-flexion: characteristic compression injury to the anterior support elements and rotation injury to the posterior support elements, accompanied by a fracture and dislocation of the articular processes. The middle support structures are damaged variably. The anterior longitudinal ligament is usually intact, but is often detached from the surface of the vertebral body;

shear: visualized by a direct displacement of the vertebra in the direction that determines the traumatic force: anteriorly, posteriorly or laterally. The ligaments and articular processes are damaged by a displacement of> 25%. This type of injury rarely occurs in isolation, it is often combined with other injuries;

vertical compression: damage of the anterior and middle support elements is typical from minor fractures of the endplates to a significant uniform decrease in the height of the vertebral body. In the latter case, single or multiple fractures of the posterior elements are possible, but with the preservation of the ligaments;

distraction-extensions are rare injuries for the thoracolumbar spine. They are characterized by distraction injury to the anterior support elements and compression injury to the posterior element.

For all these injuries, the authors suggested a surgical treatment method. In their opinion, posterior approach is better.

S.D. Gertzbein and C.M. Court-Brown (1988)

In 1988, Canadian researchers Stanley D. Gertzbein and Charles M. Court-Brown streamlined both pathomorphological and biomechanical ideas about flexion-distraction injuries of the lumbar spine [28]. Clinical material consisted of survey data of 20 patients. The authors proposed to characterize the injuries taking into account three main criteria: the nature of the posterior elements damage, the location of the vertebral body fracture line and the type of vertebral body damage. Fracture of the posterior support column elements was supposed to be classified according to G. Gumley et al. without significant changes [21]. Depending on the location of the fracture line of the body, three groups were distinguished:

A - the damage passes through the intervertebral disc;

B - the fracture line passes through the center of the vertebral body [29];

C - damage to the endplate:

subgroup 1 - damage to the superior endplate;

subgroup 2 - damage to the inferior endplate.

Depending on the nature of the body damage, fractures were divided into wedge compression (group D) and burst fractures (group E). In case of intact vertebral body, group F was indicated. Each injury was characterized according to these features.

The authors provided a detailed pathomorphological description of each category, indicating the best treatment. In addition, aspects of biomechanics were considered in detail. It was noted that group A injuries occurs at relatively low accelerations, whereas group B and C injuries require more intense exposure. The occurrence of compression and burst injuries of the body has fundamentally different mechanisms. According to the authors, compression body injuries are formed before the distraction changes of the posterior support complex, comminuted fractures are formed at the final stage of exposure to a traumatic force, when the posterior support complex is already damaged and there is a certain degree of instability.

The classification proposed by the authors had limited clinical application, but a number of clinical and biomechanical aspects were used to develop more modern grading schemes.

T. McCormack et al. (1994)

The first widely known digital scale for assessing the nature of traumatic injuries of the thoracic spine and thoracolumbar transition was the load sharing classification, proposed by T. McCormack et al. (Load sharing classification of spine fractures, 1994) [30]. Injuries characterized by damage to three support columns were studied. The main goal of the authors in developing the grading system was to differentiate the degree of pathomorphological traumatic changes, in which "short" transpedicular fixation is possible (one vertebra, located above and below the compressed), from one for which this fixation is impossible and the injury requires long "stabilization".

Three parameters were used as basic criteria, each of which, depending on the severity of the sign, could have a value from 1 to 3:

• required level of kyphotic deformity correction: <3 ° - 1 point, 4–9 ° - 2 points, ≥10° - 3 points;

• degree of vertebral body damage - the percentage of bony tissue of the vertebral body fragmented as a result of traumatic action: <30% of vertebral body - 1 point, 30–60% - 2 points, > 60% - 3 points. Evaluated by sagittal reconstruction of spiral computed tomography data;

• fragments ratio - characterizes the diastasis between bone fragments: minimum difference - 1 point, displacement of at least 2 mm of bone fragments, which comprise <50% of the cross-sectional area of the body - 2 points, diastasis of at least 2 mm of bone fragments, which is > 50% of the body cross-sectional area - 3 points.

The first two criteria are evaluated on the basis of spondylograms and sagittal reconstruction of spiral computed tomograhies, the third criterion is determined using axial spiral computed slices.

When analyzing the treatment outcomes of 28 patients, the authors found that in the case of a total score of ≤6 "short" fixation demonstrates satisfactory results, whereas in the case of a total score of > 6 the frequency of fragmentation of metal structures is high.

The system proposed by the authors has no analogues and is widely used today, since the question of the feasibility of "short" / "long fixation" for certain injuries has not lost the relevance. In addition, the proposed criteria are used as additional modifiers in determining the principal treatment strategy [31].

F.P. Magerl et al. (1994)

The most detailed classification of traumatic injuries of the thoracolumbar spine was proposed in 1994 by Friedrich P. Magerl et al. (AO / Magerl) [32].

The classification is based on pathomorphological criteria. Categories are formed according to the main predicted mechanism of injury, pathomorphological homogeneity and prognostic aspects. The three main types of injuries are formed according to the concept of TE Whitesides Jr., who argued that the stability of the spine is determined by the ability to withstand the influence of three main types of traumatic forces: compression, extension and rotation [33]. The alphanumeric code and general scheme 3-3-3 used by the authors correspond to the unified principles constructing classifications of traumatic injuries, adopted by the Arbeitsgemeinschaft für Osteosynthesefragen [34]. The biomechanical classification concept is based on the principle of two support columns R.P. Kelly and T.E. Whitesides Jr., since, according to some scientists, the middle support column has no clear anatomical landmarks, it is rather conditional and can not be used for ranking injury types.

The developers suggested that the classification reflects a progressive scale of morphological injuries that determine the degree of instability. The severity of injury in terms of instability is expressed by its rank in the classification system. *Type A* (vertebral body compression) is defined by the nature of the vertebral injury. *Type B* injuries (anterior and posterior element injuries with distraction) are characterized by a transverse tear of the anterior or posterior support column. *Type C* injuries (injuries to the anterior and / or posterior structures with rotation) result from the axial torque. The latter are most often superimposed on type A or B lesions. Morphological criteria are mainly used for the subsequent classification of lesions. The severity progresses from type A to type C, as well as within types, groups, and other units.

The classification has four levels of detail: each of the three types (A, B, C - 1st level of detail) is divided into three groups (2nd level), and each group is divided into three subgroups of 1st level (3rd level) except for group C3 (two 1st level subgroups). Some 1st level subgroups are divided into 2nd level subgroups (4th level). Thus, the overall rather large structure of the grading system proposed by the authors can be represented as 3–9–26–55, which corresponds to the number of lesion variants at different levels of detail.

T. Aihara et al. (1998)

Takato Aihara et al. [35] developed the grading system for traumatic fracture-dislocations of the 5th lumbar vertebra:

type 1 - unilateral lumbosacral dislocation with / without facet fracture. In this type, the contralateral facet is intact;

type 2 - bilateral lumbosacral facet dislocation with / without facet fracture;

type 3 - unilateral dislocation with contralateral facet fracture;

type 4 - dislocation of the L5 vertebral body with bilateral fracture of the interarticular part (traumatic spondylolysis);

type 5 - dislocation of the L5 vertebral body with a fracture of the body and / or pedicle with / without lamina injury and / or facet.

The authors note that all traumatic fracture-dislocations are subject to surgical treatment: in type 1 transpedicular stabilization is preferred, in type 2 and 3 - transpedicular stabilization with interbody fusion, in type 4 - anteroposterior stabilization, in type 5 - "long" posterior transpedicular stabilization in combination with interbody fusion of L4-L5 and L5-S1.

F. Cumhur Öner et al. (1999)

A group of researchers led by F. Cumhur Öner proposed a magnetic resonance scale of injury severity based on the analysis of examination results of 100 patients with traumatic injuries of the thoracolumbar spine [36]. The authors evaluated all anatomical structures that are well visualized on magnetic resonance imaging, and are probably important for determining mechanical stability.

Grading from 1 to 3 points was applied, for some structures - 4 points:

anterior longitudinal ligament: 1 point - no damage, 2 points - the ligament is weakened, but its integrity is intact, characterized either by detachment of the ligament from the anterior surface of the vertebral body, or stretching it due to protrusion of the intervertebral disc, 3 points – ligament rupture;

posterior longitudinal ligament: 1 point - no damage, 2 points - the ligament is fixed to the displaced bone fragment, but its integrity is intact, 3 points – ligament rupture;

posterior ligamentous complex: 1 point - intact, 2 points - edema in the area of the interspinous space without signs of stretching or disruption of integrity, 3 points - stretching of the ligamentous complex, 4 points - convincing rupture;

cranial and caudal endplates (evaluated separately): 1 point - deformity without signs of integrity, 2 points - damage to the anterior half of the endplate, 3 points - damage to the posterior half of the endplate; 4 points - total damage to the endplate;

intervertebral disc (discs located cranially and caudally from damage are evaluated): 1 point - intact, 2 points – tear or fragmentation of the anterior half of the disc, 3 points - tear or fragmentation of the posterior half of the disc, 4 - intervertebral disc is completely damaged;

vertebral body: 1 point - less than a third of the vertebral body is damaged, 2 points - 1/3–2/3 of the vertebral body is damaged, 3 points - more than 2/3 of the total vertebral body volume is damaged.

The authors initially used the scale to compare the degree of damage to anatomical structures with AO / Magerl classification level 1st subgroup, but no convincing correlation was found. It is assumed that the higher the total score, the higher the severity level, but the clinical significance of the total value is not given.

A.R. Vaccaro et al. (TLISS, 2005)

In 2005, a large group of researchers led by Alexander R. Vaccaro proposed the first clinical scale for assessing the degree of thoracolumbar spine traumatic injuries (The Thoracolumbar Injury Severity Score (TLISS)). This system differs from other classifications and scales taking into account not only pathomorphological but also clinical factors. The main objective was to develop a practical but simple classification that would allow differentiating the necessity of surgical and conservative treatment methods for a certain injury, and in case of unstable injury - to determine the optimal surgical tactics [37].

The authors suggested that the morphology of the injury determines immediate mechanical instability, the condition of the posterior capsular ligament characterizes long-term stability, while the neurological status assessed immediately after injury determines the final functional prognosis [38]. The complex of these three independent variables objectively reflects the picture of spinal stability. Each variable is scored in points depending on the severity of the symptom and its impact on the overall treatment strategy.

The morphology of damage is determined using spondylograms, spiral computed tomography and magnetic resonance imaging. Classically represented by the categories of compression, distraction and rotation. Compression injury is scored by 1 point (burst fracture - add 1point, lateral angulation> 15 ° - add 1 point), displacement or rotation - 3 points, distraction - 4 points.

The integrity of the posterior capsular ligament is determined by indirect signs on spondylograms and spiral computed tomography. Damage may be indicated by the expansion of the interspinous space, diastasis of the facet joints or their dislocation / subluxation. Direct signs of damage, assessed by magnetic resonance imaging, are discontinuity of the signal from the supraspinous ligament, represented by a dark line on T1-weighted images, as well as high signal intensity of the interspinous space corresponding to the interspinous ligament on T2-weighted images. According to the proposed grading, the absence of signs posterior capsular ligament damage is scored by

1 point, convincing signs of damage - 3 points, doubtful signs - 2 points.

Neurological status is assessed clinically. Absence of neurological symptoms corresponds to 0 points, nerve root damage or complete spinal cord injury (ASIA A) - 2 points, incomplete spinal cord injury (ASIA B-D) or signs of cauda equina damage - 3 points [39].

The general therapy strategy is determined by the sum of points obtained in the assessment of damage: <4 points - conservative therapy is indicated, > 4 points - surgical intervention. If the total score is 4, the decision on the optimal method of treatment is made individually.

A.R. Vaccaro et al. (TLICS, 2005)

In 2005, A. Vaccaro et al. slightly modified TLISS (Thoracolumbar Injury Classification and Severity Score (TLICS)) [40]. In fact, TLICS is the same scale as TLISS, except for a slight simplification of the pathomorphological rubric. Thus, compression fracture is scored by 1 point, burst fracture - 2 points, displacement or rotation - 3 points, distraction - 4 points. The therapy strategy determined by the total score is identical for TLISS and TLICS.

In addition to determining the overall strategy, the proposed scheme allows choosing the optimal surgical approach [41]. According to the authors, the most important parameters influencing the choice of surgical tactics are the level of neurological disorders and the condition of the posterior capsular ligament. Thus, in case of an intact ligamentous complex, posterior approach should be preferred in patients without neurological disorders, with clinical manifestations of nerve root damage or complete spinal cord injury. In this case the anterior approach is indicated for ASIA B-D. In patients with detected posterior capsular ligament damage, posterior approach is considered optimal in all cases except for incomplete spinal cord or cauda equina damage. Combined anteroposterior surgery is recommended for such patients. The proposed scheme is quite formal, since many aspects of surgical treatment tactics of injuries of the thoracolumbar spine and especially the thoracolumbar transition zone are the subject of discussion.

P.M. Tsou et al. (2006)

One of the most non-standard concepts of spinal motion segment stability was proposed in 2006 by Paul M. Tsou et al. [42]. Using the three support column model of F. Denis, the researchers suggested that stability is determined by the ability of resistance to distraction and compression, with distraction affecting all support columns, and compression - only the anterior and middle. Consequently, any injury to the thoracolumbar spine can be described by a combination of five possible types of damage to the supporting structures. For example, anterior column compression and posterior distraction. The authors considered the sixth type of injury to be acute traumatic deformity of the spinal motion segment, which is characterized by angulation ≥5 ° in any plane, rotational deformity ≥5 °, dislocation, any two variants of intrasegmental injury. If any 3 of the 6 signs are present, the damage is unstable.

The authors singled out intersegmental and intrasegmental lesions, the latter included:

type 1 - damage to both endplates to the vertical fracture of the vertebral body in the coronal plane;

type 2 - fracture of the pedicle of the arch or interarticular zone;

type 3 - vertical fracture of the vertebral body in the sagittal plane;

type 4 - fracture of the lamina.

A severity grading was developed, taking into account three criteria:

• neurological status, which is determined by a modified Frankel scale (8 grading levels) [43];

• deformity of the spinal canal. Two criteria was proposed: displacement due to imbalance between the vertebrae and extrusion, which is formed by prolapse into the canal of bone fragments. These symptoms can occur either in isolation or in combination. The calculation is proposed to be carried out by the method of E. Carlisle et al. [44];

• mechanical stability. Separately distraction damaged support columns, traction-damaged support columns and signs of deformity are taken into account.

The lack of quantitative interpretation of the proposed rubrics has significantly limited the clinical use of the scale.

J.R. Chapman et al. (2008)

Flexion-distraction injuries of the spine have been one of the topical issues during almost the entire period of studying the specifics of thoracolumbar spine injuries. This is due to the high frequency of abdominal injuries compared to other types of traumatic injuries, the lack of correlation between the radiological picture and the level of neurological disorders, certain diagnosic difficulties and, accordingly, a variety of tactical approaches to therapy of these injuries. One of the largest studies of flexion-distraction injuries was carried out by Jens R. Chapman et al. [45]. A retrospective data analysis of 151 patients treated at Harborview Medical Center allowed four injury grades (Harborview Thoracolumbar Flexion-Distraction injury classification) to be identified:

grade 1 - Chance fracture, which is characterized by distraction of the posterior support complex without compression of the anterior one;

grade 2 - distraction of the posterior support complex with compression of the vertebral body without a burst component. Accompanied by subluxation of facet joints, but without complete loss of contact of the articular surfaces;

grade 3 - burst fracture of the vertebral body with distraction of the posterior complex, subluxation, but the contact of the articular surfaces of the facet joints is preserved;

grade 4 - complete loss of contact of the articular surfaces of facet joints, compression or burst fracture of the vertebral body, displacement or rotation are absent.

According to the authors, the overall incidence of abdominal injury was 30.0%, neurological disorders - 25.0%. Abdominal injuries were most often (53.0%) registered in the 1st grade of injury, the least (24.5%) - in the 2nd grade, while neurological disorders were characteristic mainly for the 4th grade (85.7%), rarely - for the 1st grade (15.6%).

A.L. Sander et al. (2013)

In 2013, a group of researchers led by Anna L. Sander proposed a classification of traumatic intervertebral disc injuries [46]:

grade 0 - indicates no differences between the damaged disk and the corresponding undamaged disk;

grade 1 - characterized by a hyperintensive signal on T2-weighted / T2 TIRM (Turbo inversion recovery magnitude)-images, indicating edema. The criteria for denial are disc vascularization due to chronic spondyloarthropathy and fibrovascular changes of the endplate;

grade 2 - defined as decreased signal intensity with the appearance of perifocal hyperintensity on T2-weighted/T2 TIRM-images, as well as with isointense/ hyperintense manifestations on T1-weighted images, indicating a disc rupture with intradiscal hemorrhage;

grade 3 - characterized by ruptures of the fibrous ring or prolapse of the disc into the vertebral body.

The classification itself has no clinical significance, but, according to the authors, it can be used as part of comprehensive scales to assess the injury severity level.

M. Reinhold (2013)

As mentioned above, for a long period of time the classification proposed by F. Magerl was the *de facto* standard for describing traumatic injuries of the thoracolumbar spine. Thus, Max Aebi in a detailed review of this classification demonstrated that its use within the levels of detail type – group is quite convenient, and the grading of severity from A to C within the type of injury and from 1 to 3 within the group correlates with the level of neurological disorders [47]. However, the author notes that "some authors and groups come up with surprising results when trying to assess the validity of the classification." Therefore, AO Spine Classification Group has long been developing a more reproducible and clinically adapted injury grading system.

One of the most famous attempts to modify the F. Magerl classification is the grading system proposed in 2013 by a group of researchers led by Maximilian Reinhold [48]. The authors traditionally use the principle of M.E. Müller, a method of injury classification based on therapy and prognosis of anatomical and functional consequences in the patient. There are three main classes of injuries:

A: characterized by damage to the anterior support complex as a result of axial compression with intact posterior support complex;

B: characterized by damage to the posterior support complex;

C: characterized by damage to the anterior and posterior support structures, resulting in displacement.

The developers noted two important differences from the F. Magerl system. First, type B injuries are not defined as distraction injuries, but rather as injuries with damage to the posterior support structures. According to the authors, this makes it much easier to differentiate between type A and B injuries and apply them to injuries of other regions of the spine. Secondly, the redefinition of type C as "explicit dislocation", since in the original AO / Magerl classification this type is referred to as "rotational injuries", which makes it difficult to identify some compression fractures with small rotational deformities of the spine.

The following subtypes are proposed:

A1 - wedge-shaped or depressed body fracture;

A2 - split or pincer fracture;

A3 - incomplete burst fracture;

A4 - complete burst fracture;

B1 - perosseous fracture of the posterior support complex (classic Chance fracture);

B2 - transligamentous damage of the posterior support complex isolated or in combination with damage to bone structures. In addition, there may be different variants of compression fractures of the vertebral body;

C1 - extension injury of the anterior support complex persosseous or in combination with lesions of the intervertebral disc;

C2 - bony or disco-ligamentous damage to the support columns with displacement in any plane;

C3 - total damage with diastasis and displacement in any plane.

The authors noted high reproduction rates of the proposed classification. Thus, the consistency coefficient for the entire grading system was 0.77, for types A, B and C - 0.81, 0.71 and 0.81 respectively. However, the classification was only a prototype and had limited practical application.

A.R. Vaccaro et al. (AOSpineThoracolumbar Spine Injury Classification System, 2013)

Six months after the publication of the above-mentioned prototype, a group of researchers led by A.R. Vaccaro proposed the final version of the updated AO classification, which is still relevant [25]. The grading system is of practical importance and, like TLICS, takes into account not only pathomorphological but also clinical aspects. The classification has three rubrics: damage morphology, neurological status and additional specifying modifiers.

The morphological component is close to the classification of M. Reinhold, but has some differences. Thus, type A includes compression injuries of the vertebral body and other biomechanically insignificant traumatic injuries:

A0 - no traumatic changes, as well as fractures of the transverse or spinous process;

A1 - compression injuries of one endplate without damage to the posterior wall of the vertebral body;

A2 - damage to two endplates without damage to the posterior wall of the vertebral body;

A3 - incomplete burst fracture, as well as other injuries involving one endplate and the posterior wall of the vertebral body;

A4 - complete burst fracture and other injuries involving the posterior wall of the vertebral body and both endplates, such as a vertical fracture of the splitting vertebral body in the sagittal plane.

Type B authors refer to damage to the anterior or posterior ligamentous complex with / without bone-traumatic changes. In some publications, this group is called flexion-extension injuries, which is not quite correct, since pure flexion at the initial stage is more likely to cause compression changes rather than damage to the posterior capsular ligament:

B1 - perosseous damage to the posterior support complex - a classic Chance fracture or its modifications that do not extend beyond the bone structures of one vertebra;

B2 - ligamentous or osteoligamentous injury of the posterior support complex with any types of vertebral body damage or excessive damage to the posterior support complex, but with the the fracture line extending beyond the body - on the intervertebral disc with damage to the endplate or the adjacent vertebral body;

B3 - disc-ligamentous, osteoligamentous or disc-osteo-ligamentous damage to the anterior support column. It is characteristic for extension injuries. The obligatory criterion is the rupture of the anterior longitudinal ligament.

Type C includes any injury related to displacement or shear, as well as severe damage to the anterior and posterior support complex, even without disturbance of the spinal axis.

Grading of neurological disorders:

N0 – no neurological symptoms;

N1 - transient neurological deficit in past medical history, not detected during examination;

N2 - phenomena of radiculopathy;

N3 - signs of incomplete spinal cord or cauda equina injury;

N4 - clinical picture of complete spinal cord or cauda equina injury (ASIA A).

In addition, the NX modifier is provided for the inability to adequately assess the neurological status.

According to the authors, specific modifiers allow the clinician to clarify the optimal treatment tactics:

M1 - in case of impossibility to clarify the status of the posterior ligamentous complex or in case of doubtful results;

M2 - any comorbidity that hypothetically influencing treatment tactics, both vertebral and extravertebral (rheumatoid arthritis, ankylosing spondyloarthritis, severe soft tissue damage in the area of the planned surgery, etc.).

High reproducibility of classification results by different experts or by one expert during repeated assessment is one of the basic conditions for using the ranking system in clinical practice. According to the developers, the indicator of the overall reproducibility of the classification was 0.72, for types A, B and C - 0.72, 0.58 and 0.7, respectively.

C.K. Kepler et al. (2016)

Active introduction of the AO Spine Thoracolumbar Spine Injury Classification System into clinical practice, as well as the successful experience of using TLICS became prerequisites for the creation of a digital severity assessment scale, based on modifiers of the new AO classification. In 2016, Christopher K. Kepler et al. proposed a new scale, based on the results of the subjective assessment by 74 surgeons of the impact of each of the modifiers on the overall severity of traumatic injury - Thoracolumbar AO Spine Injury Score [49]. Verification of the obtained data was conducted in 2016 with the participation of 483 experts [50].

The authors proposed the following grading system:

morphological changes:

A0 - 0 points;

A1 - 1 point;

A2 - 2 points;

A3 - 3 points;

A4 - 5 points;

B1 - 5 points;

B2 - 6 points;

B3 - 7 points;

C - 8 points;

neurological status:

N0 - 0 points;

N1 - 1 point;

N2 - 2 points;

N3 - 4 points;

N4 - 4 points;

NH - 3 points;

additional modifiers:

M1 - 1 point,

M2 - 0 points.

The final score is the sum of the scores of three rubrics. It is assumed that injuries with a total score of <4 points are subject to conservative therapy, injuries with a score of > 5 points require surgery. In the case of 4 and 5 points, different treatment options are possible.

The authors' analysis revealed that injuries of type A3N1M1, A3N2M1, A4N0M1, A4N1M1, A4N2M0, A4N2M1, B1N0, B1N1, B1N2, B2N0, B2N1 and B2N2 are always subject to surgical treatment, whereas A2N0 and A3N0 injuries are better treated conservatively.

There is no consensus on the advantage of a particular severity assessment scale. The data presented in the review demonstrate that TLICS and Thoracolumbar AOSpine Injury Score actually use the same data. However, according to some authors, TLICS is the best tool for determining optimal treatment tactics [51]. It is likely that further revision of score distribution in the category of "damage morphology" will change the attitude to a promising tool for determining the overall therapy strategy.

Conclusions

The data on the evolution of the principles of classification of traumatic injuries of the thoracolumbar spine make it possible to identify a pattern. Thus, the first attempts to differentiate the types of injuries were only descriptive. The authors actually identified a group or groups of injuries with similar pathomorphological features without systematization according to any anatomical criterion. However, already at this stage there are attempts to distinguish the optimal method of therapy for each type of injury identified by the authors.

The development of ideas about the biomechanics of the intact spine, as well as the mechanisms of its damage became the basis for the development of mechanical classifications, the top of which is definitely the grading system proposed by F. Magerl et al. A distinctive feature of this group of classifications is that they are based on individual concepts of spine stability. The authors tried to identify the relationship between the mechanism of injury, the complex of pathomorphological changes and the recommended method of treatment. An example is the technique proposed by P.C. McAfee et al., according to which compression injuries of the middle support column require distraction, distraction injuries require compression, and so on.

Further accumulation of clinical material and implementation of the principles of evidence-based medicine have demonstrated the low effectiveness of a mechanical approach alone. Many studies have found that the pathomorphology of the resulting injury is determined not only by the mechanism, i.e., the summerized direction of the vector of applied traumatic forces, but also by a large number of other factors, both directly related to the injury and due to individual characteristics of the patient. Consequently, verification of the initial mechanism does not play a leading role in determining treatment tactics. The adoption of this concept, as well as the development of statistical analysis methods has contributed to the development of the most modern classifications that have only clinical significance on the one hand, and high reproducibility of results - on the other. The most modern AOSpineThoracolumbar Spine Injury Classification System almost does not take into account the mechanism of injury, that is, it is descriptive. At the same time, the features that allow verifying the type of injury are clearly determined, and the number of types is insignificant, which leads to simplicity and reproducibility.

In addition, the current trend is to use not only pathomorphological, but also clinical signs as ranking criteria, which definitely improves the choice of treatment methods. None of the most widely used classifications today (mechanical F. Denis (1982) or AO / Magerl (1994), clinical A.R. Vaccaro et al. (2013)) has a clearly established and clinically proven algorithm for providing care to patients. According to some authors, the criteria used in these systems are insufficient to unambiguously determine therapeutic efforts [31].

These disadvantages are the reason for improving the ranking system of traumatic injuries of the thoracolumbar spine.

Information disclosure

Conflict of interest

The authors declare no conflict of interest.

Ethical approval

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