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TRAUMATIC THORACOLUMBAR SPINE FRACTURES

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ABSTRACT

Traumatic thoracolumbar (TL) spine fractures are serious injuries that contribute substantially to morbidity and mortality. They remain relevant, particularly because the number of traffic accidents is increasing as motor vehicle use grows. Historically, we have observed that these injuries have been the subject of numerous scientific articles since the mid-1930s. Advances in technology undoubtedly affect many dynamics in the field of health. Therefore, the classification and treatment of these injuries have evolved. The purpose of this review is to present contemporary approaches to traumatic TL spine fractures and, in doing so, summarize their historical development for readers.
Keywords: Spine fractures, thoracolumbar, trauma

INTRODUCTION

Vertebral column injuries are serious injuries that occur after high-energy trauma. Approximately 75-90% of all spinal fractures occur in the thoracolumbar (TL) region, and about one-fourth of these are accompanied by neurological injury of varying severity[1,2]. The structure of the thoracic and lumbar spinal segments is more similar to each other than to the other segments, so they are classified together. The most common site for TL fractures is the TL junction. This region is vulnerable to trauma because it is the transition zone from the relatively immobile thoracic portion to the mobile lumbar portion. Although the rates vary in the literature, roughly 16% of injuries are observed between T1-T10, 52% between T11-L1, and 32% between L1-L5. The medullary canal is narrowest between T1 and T10. Therefore, fractures in the T1-T10 region are have sixfold higher risk of neurological deficits compared to fractures in other TL regions. On the other hand, the thoracic region is more stable than the lumbar region because it is located within the thoracic structure[3-5].Therefore, the thoracic region (except for the TL junction) should be considered among conservative treatment options for stable spinal fractures.

There are two important factors that make spinal injuries distinct and significant from other bone injuries. The first is undoubtedly its proximity to neural tissues. Spinal fractures and spinal cord injuries result in a decline in quality of life for 50 out of every million people each year[6]. The second factor is the difficulty in determining the extent of damage to the complex ligamentous structure after trauma. Historically, the importance of ligamentous structures in the vertebral column was first described by Nicoll[7]. Subsequently, in many classification systems, "demonstrated ligament injury" has been accepted as an important criterion.

Depending on the severity of the injury, more than 50% of spinal trauma cases are accompanied by additional injuries. Most of the accompanying injuries are intra-abdominal injuries resulting from distraction forces. Pulmonary injuries can be observed in 20% of cases, and intra-abdominal bleeding due to liver and spleen injuries can be observed in 10% of cases. In 6-15% of cases, other spinal fractures in adjacent or non-adjacent segments of the vertebral column may accompany the picture[5,8]. In TL fractures with neurological deficit, the likelihood of a second vertebral fracture, especially a cervical fracture, is 25%[9]. It should be remembered that lower extremity and pelvic fractures may accompany high-fall cases as well.

With the development of surgical techniques, imaging methods, and instrumentation techniques over time, the diagnosis, classification, and treatment of TL fractures have been revised to varying degrees but have always been a subject of debate. It would not be wrong to consider that with the developments in the last two decades, some issues related to diagnosis,

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classification, and treatment have reached a consensus. The aim of this review is to summarize the new developments in traumatic TL vertebral fractures, which are an important health problem, and to update the index review published in 2006[5].

Classification

History

The classification of TL spine fractures is an important issue in terms of organizing treatment, but it has been debated for many years. Many fracture classifications have been defined, but most now have only historical value. However, we observed significant progress in TL fracture classification over the last two decades. AOSpine has proposed a classification that actually encompasses previous classifications and can be more easily adapted for clinical use, and this has generally become established practice. We will discuss the details of this classification after a brief historical overview.

The fundamental question that classification of spinal fractures must answer is whether the fracture requires surgical treatment. Therefore, all classifications primarily question the concept of instability. According to the American Academy of Orthopaedic Surgeons definition, instability is the abnormal response of a spinal motion segment to load (a motion segment is a unit consisting of two vertebrae and an intervertebral disc). The main problem is that in a patient with a spinal injury, the concept of instability in the erect posture of the spine is usually evaluated using examinations performed in the supine position[10]. As a result, the evaluation of a spinal fracture in terms of instability cannot go beyond an estimation based on the data.

The history of classification in spinal fractures dates back to the 1930s. During these years, due to the limitations of radiological methods, classifications aimed at understanding the shape of the fracture. These classifications are termed morphological classifications (Figure 1). In Watson-Jones'[11] historical article, the definitions referred to as wedge fracture, communited fracture, and dislocation of the spine, over time, become known as compression fracture, burst fracture, and fracture-dislocations, respectively.

1980-2003

There are two fundamental characteristics that classifications should essentially cover. The first is that they should guide treatment, and the second is that they should be universally accepted. You will notice that the second is directly related to the first. As the descriptive characteristics of morphological classifications became insufficient over time, mechanistic classifications emerged alongside advances in imaging methods. These classifications introduced definitions of external load and the concept of columns to the literature, attempting to explain the mechanism of injury.

Earlier classifications defined two columns, anterior and posterior[12,13], while studies in the early 1980s defined three columns: anterior, middle, and posterior[8,14,15]. Accordingly, these classifications, which suggest surgical indications based on the affected columns regardless of the fracture mechanism, defined four fundamental injury mechanisms. The mechanisms are known according to their severity: volar flexion stress of the spine causing compression fractures, axial compression stress causing burst fractures, and vertebral tears (flexion-distraction) injuries involving flexion and distraction components. The final mechanism is multi-axial high-energy torsional forces causing fracture-dislocations. The mechanism associated with flexion-extension injuries is more common in flexion injuries occurring while wearing a seat belt, hence these fractures are referred to as seat-belt injuries. Interestingly, looking back at historical records, we see that this type of injury was described as early as 1948 by radiologist George Quentin Chance[16], predating all other classifications. Therefore, flexion-distraction injuries are also referred to as Chance fractures in textbooks. Among the classification systems of that period, the most widely accepted one was based on the three-column theory defined by Denis[8] in 1983, due to its ease of application. According to Denis[8], the TL vertebral column is divided into three columns. The anterior column includes the anterior longitudinal ligament and the anterior 2/3 of the vertebral body. The middle column includes the posterior third of the vertebral body, the posterior annulus fibrosus, and the posterior longitudinal ligament. The posterior column encompasses the posterior elements remaining posterior to the middle column. According to this definition, injuries involving all three columns should be operated on. The most recent classification of mechanistic injuries was published by Magerl et al.[17] in 1994. Known as the AO classification, it is based on the AO classification that had previously been used for orthopedic extremity injuries. The AO/Magerl classification

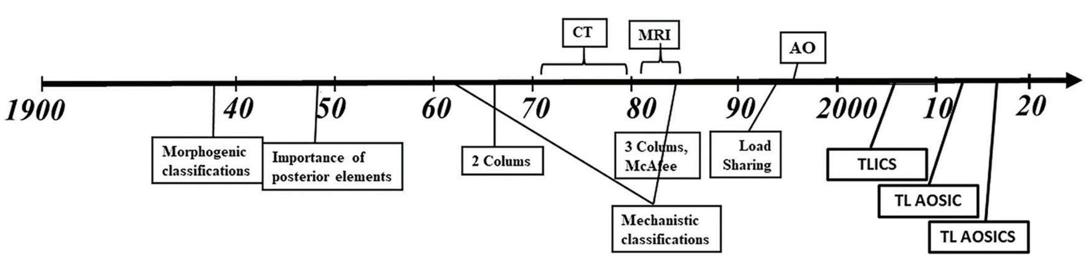

Figure 1. Historical development of the classification systems of spinal fractures (illustrative). CT: Computed tomography, MRI: Magnetic resonance imaging, TLICS: Thoracolumbar injury classification and severity score, TL AOSIC: Thoracolumbar AOSpine injury classification system

defines three major mechanisms of spinal injury-compression (A), distraction (B), and torsion (C). Although this classification, with its 53 subgroups, aims to cover more fracture types, it is considered a difficult classification in terms of memorability and reproducibility. Many spine surgeons therefore continued to use the Denis classification, finding it more practical. The "Load-sharing classification" published by McCormack in 1994 should be evaluated separately (Figure 1)[18]. This classification covers injuries requiring surgery. Among the controversial issues in spinal fractures is whether to treat with short segment (one segment above and one segment below) or long segment (two segments above and two segments below) instrumentation. This classification was created to assess the risk of failure in patients to be treated with short segment instrumentation. This classification is the first study to aim to directly guide surgery and to use a scoring system for the first time.

2005/TL Injury Classification and Severity Score (TLICS)

Mechanistic classifications had some fundamental limitations. For example, these systems were based on inferences about the mechanism of injury rather than an objective description of the morphology of the injury. More importantly, they did not take into account the patient's neurological status, which is critical in the medical decision-making process. Furthermore, particularly in terms of the AO classification, the comprehensive structure of its descriptors led to complexity, reduced reliability, and limited its usefulness in clinical and research settings. These classifications were designed for low-tech radiological examinations of their time. With the advancement of computed tomography (CT) and magnetic resonance imaging (MRI) technology, updating these classifications became a priority, and in 2005, the "Spine Trauma Study Group" published the "TLICS"[19]. The main purpose of this classification was to approach spinal trauma as a whole, rather than perceiving the injury solely as a morphological or anatomical disruption.

Among the innovations brought by this classification were its ease of application, its inclusion of the patient's neurological status in the assessment, and the examination of the integration of the posterior ligamentous complex with MRI. More importantly, it defined a scoring system and provided treatment recommendations based on the score obtained. The TLICS system quickly gained pupularity among older classifications, was widely adopted, and became the subject of numerous studies. The main drawback of the TLICS system was its requirement for MRI examination. Obtaining MRIs in trauma patients is not a very practical procedure, and access to MRIs was not equally easy in all healthcare centers; in fact, it was limited in most. This was considered the most significant handicap in the general acceptance of TLICS as a classification system.

2013/AOSpine TLICS

In order to create a more universal classification, the same team published another study in 2013[20]. In this survey study, 40 cases were sent to members of the "Spine Trauma Study Group" to determine consensus on the classification, and the results were published. This study defined a total of nine injury patterns, including the three injury type and all its subgroups. CT examination was required for the injury patterns, but this was not a difficult imaging modality to obtain with today's emergency protocols and advanced multislice machines. Ultimately, the 53 subgroups in the old AO/Magerl classification evolved into nine subgroups in the current AO TLICS classification (Figure 2). This new classification includes six neurological modifiers, as in the 2005 TLICS. N0 is neurologically intact, N1 is a patient with transient minor neurological findings that have resolved, N2 is a patient with radiculopathy, N3 is a patient with incomplete spinal cord or cauda equina findings, N4 is a patient with complete spinal cord or cauda equina findings, and NX is recorded as unevaluable. In addition, two newly added patient-specific modifiers are denoted by the letter M. These modifiers are intended to provide information about the current status regarding whether the patient will undergo surgery or not. M1 indicates that the presence of a PLC injury cannot be confirmed by examination or imaging methods. M2 indicates that the patient has comorbidities such as ankylosing spondylitis, rheumatoid arthritis, osteoporosis, or burn scar in the surgical area. The most reliable aspect of this new classification, whose criteria are summarized in Table 1, is that it is based on Delphi

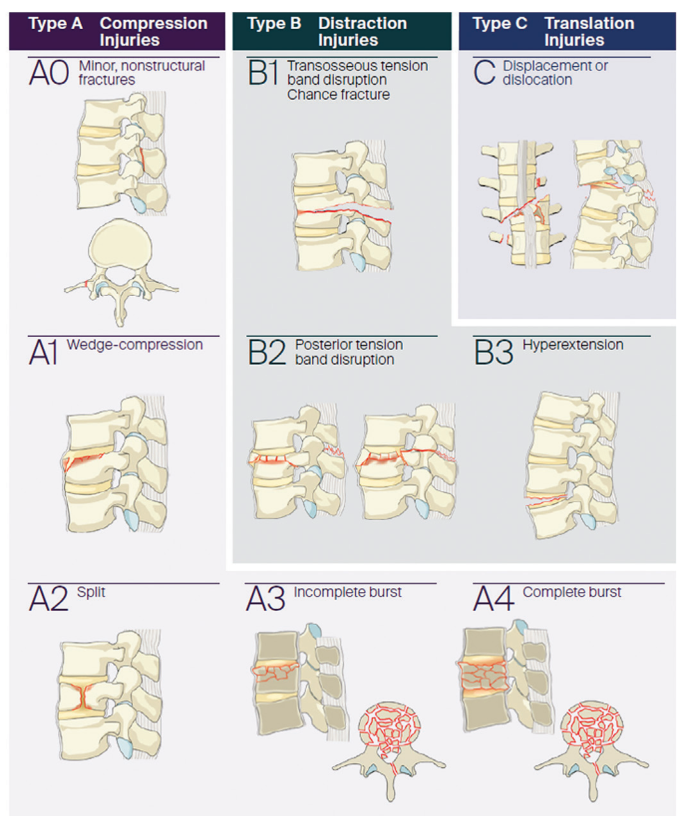

Figure 2. Nine different fracture types, along with their subgroups in the current classification (https://www.aofoundation.org/spine/clinical-library-and-tools/aospine-classification-systems)

analyses using data obtained from a pool of spine surgeons worldwide. When the classification was first published, it did not include scoring.

TL AOSpine Spinal Injury Score (TL AOSIS)

The TL AOSIS and TL AOSIS surgical algorithm were published in 2015 and 2016[21,22]. This scoring system was developed based on the evaluation of spine surgeons in a large survey. The TL AOSIS surgical algorithm uses an integer scoring system similar to that used in the AO TLICS (Table 1). According to the algorithm, conservative treatment is recommended for injuries with TL AOSIS <4. Early surgical treatment is recommended for injuries with TL AOSIS >5. Injuries with TL AOSIS 4 or 5 can be treated surgically or nonoperatively, depending on patient variables and the surgeon's preference (Table 2).

Treatment

The main goals in treating spinal column injuries are to protect the integrity of the spinal column, decompress neural tissues, and achieve a stable column with the appropriate contour when the spine is in an upright posture. Spinal fracture treatment has evolved around certain controversial issues in the history of spinal surgery. The primary point of debate has been whether fractures should be treated conservatively or surgically. The fundamental goal in all classifications is to make this distinction. Conservative treatment includes bed rest (for minor fractures), hyperextension splints, three-point contact hyperextension braces, or TL-sacral orthosis style full-contact orthoses. However, over time, these treatment methods have become less commonly used by spine surgeons. This is primarily due to the improvement in imaging techniques, which allow for better assessment of fracture morphology, and the advancement of implantation technology. The increase in surgical practice and the associated surgical experience has also made the surgical treatment of these types of injuries less of a feared prospect.

Another much-debated topic in historical development concerns surgical technique. Anterior surgery performed via thoracotomy and lumbotomy was a popular approach for a time. It was fundamentally believed that adequate decompression and optimal restoration of compromised anterior support could only be achieved through this method. Although this is a valid concept, the additional morbidity associated with anterior surgery has led to the greater popularity of posterior approaches today. Of course, the technical advancement of anterior cord decompression performed via the posterior approach has also contributed to this. Anterior surgery still has a place in patients with apparent cord compression and neurological deficit.

The number of vertebrae to be included in the fixation has also been a topic of debate, with short segment and long segment approaches. A short segment refers to the vertebrae one level above and below the fractured vertebra (3 vertebrae), while a long segment refers to the vertebrae two levels above and below (5 vertebrae). We may say, theoretically, the concept that a short segment is sufficient in patients accompanied anterior surgery, while fixation of two segments above and two segments below is required in those undergoing posterior surgery alone, remains valid today. Therefore "posterior-only" surgeries, which involve applying a long segment from the back, have become the standard for surgeons. If decompression is necessary, anterior cord decompression from the posterior can also be added to the procedure. The current development regarding whether the segment should be long or short concerns the application of screws to fractured vertebrae. This technique, known as intermediate screw application, was actually defined by Dick et al.[23]. It has gained popularity over the past 15 years and is now increasingly applied. The intermediate pedicle

Table 1. AOSpine thoracolumbar spine injury classification system[20]

Fracture morphology	**A: Compression injury**	A0: No fracture, insignificant spinous or transverse process fractures	
		A1: Single endplate, no posterior wall involvement	
		A2: Both endplates, no posterior wall involvement	
		A3: Single endplate and no posterior wall involvement	
		A4: Both endplates and no posterior wall involvement	
	B: Tension band injury	B1: Monosegmental osseous failure of posterior tendon band, extending into vertebral body	
		B2: Disruption of posterior tension band w/ or w/o osseous involvement	
		B3: Disruption of anterior tension band, intact post	
	C: Displacement/translational injury		
Neurological status	N0: Neurologically intact	Case-specific modifiers	M1: Fractures with indeterminate injury to tension band (based on MRI or clinical examination)
	N1: Transient neurological deficit, resolved		
	N2: Symptoms or signs of radiculopathy		
	N3: Incomplete spinal cord injury or cauda equina injury		M2: Patient-specific comorbidity affecting surgical decision
	N4: Complete spinal cord injury		
	N5: Patient cannot provide reliable examination		

MRI: Magnetic resonance imaging

Table 2. Thoracolumbar AOSpine injury score

A0	0
A1	1
A2	2
A3	3
A4	5
B1	5
B2	6
B3	7
C	8
Neurological status	
N0	0
N1	1
N2	2
N3	4
N4	4
NX	3
Case-specific modifiers	
M1	1
M2	0

Conservative treatment is recommended for injuries with TL AOSIS <4. Early surgical treatment is recommended for injuries with TL AOSIS >5. TL AOSIS 4 or 5 can be treated surgically or non-operatively. TL AOSIS: The AOSpine spinal injury score

screw significantly increases the stability of the construct[24-26] and therefore allows for short segment (3 vertebrae) fixation in posterior approaches[25]. Some authors have also noted its positive effect on kyphosis correction and endplate restoration. Bleeding may increase slightly when placing screws in an fractured level, but no other complications, including surgery time, have been observed that would be detrimental to the technique[27,28].

Another fixation technique that has entered practice in the last two decades is percutaneous transpedicular instrumentation. Placement of transpedicular screws with small incisions on the skin by reducing soft tissue damage is a technique that has a long history. In the external fixation concept, a percutaneous vertebral pedicle fixation was first reported by Magerl[29]. Since the beginning of the 2000s, percutaneous pedicle screw fixation (PPSF) has come into common use as an internal fixation method in spinal surgery in the direction of increased usage of pedicle screws in surgical procedures and the developments in implant technology[30]. The indications for this application have expanded over time due to the advantages of less invasiveness[31]. All type A fractures without neurological deficit and not suitable for conservative treatment are candidates for PPSF. In addition, depending on the surgeon's experience, it can also be applied in type B and C fractures, provided there is no neurological deficit[32]. There are numerous studies on PPSF, both biomechanical and clinical. Their positive outcomes have supported the widespread adoption of the procedure.

In conclusion, we have observed significant changes in the diagnosis and treatment of TL injuries in recent decades. These developments have also significantly influenced our practical applications. Looking ahead, it seems inevitable that new innovations, along with advances in navigation, imaging, and implant technology, will change our practice and routines.

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Footnotes

Authorship Contributions

Surgical and Medical Practises: E.A., Concept: E.K., Design: E.K., Data Collection or Processing: E.K., A.Ç., Literature Search: E.K., A.Ç., Writing: E.K.

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