

Recommendations for treatment of thoracolumbar spine fractures by the Slovenian spine society

Priporočila Vertebrološkega združenja Slovenije za oskrbo zlomov prsno-ledvene hrbtenice

Marko Jug,¹ Said Al Mawed,¹ Drago Brilej,² Marko Dobravec,¹ Simon Herman,¹ Dario Kalacun,² Urška Kidrič Sivec,¹ Jošt Kokalj,¹ Jaka Košar,³ Tomi Kunej,³ Igor Movrin,³ Uroš Tominc,¹ Miloš Vesel,¹ Radko Komadina²

Abstract

Fractures of the thoracolumbar spine (TLF) represent a wide variety of injuries. Treatment depends on the severity of spinal injury, the general condition of the patient and preexisting spinal pathologies. This complex reasoning is additionally complicated by the unclear and sometimes even conflicting evidence in the literature. Nevertheless, in severe injuries only a fast and well-coordinated chain of interventions from the first care in the field to the final rehabilitation can lead to a satisfactory outcome. Therefore, the recommendations for treatment of TLF of the Slovenian Spine Society include recommendations from care in the field and emergency room, as well as diagnostic procedures and injury classification to surgical treatment, and finally, rehabilitation and post-injury follow-up strategies. A special emphasis is dedicated to the treatment of TLF with spinal cord injury and, due to the growing number of geriatric patients, to the treatment of osteoporotic fractures and fractures of the ankylosed spine. The aim of these recommendations is to set minimum standards for treatment of TLF in Slovenia, grounded in evidence-based medicine and respecting the regional specifics of the healthcare system.

Izvleček

Zlomi prsno-ledvene hrbtenice (PLH) predstavljajo širok spekter poškodb. Zdravljenje je odvisno od vrste poškodbe, splošnega stanja poškodovanca ter morebitnih pridruženih bolezni hrbtenice. Skupna ocena teh dejavnikov narekuje strategijo zdravljenja, ki je zaradi nejasnih in včasih nasprotujočih si podatkov v literaturi nemalokrat težavna. Kljub številnim odprtim vprašanjem pa v mnogih primerih lahko le hitra in usklajena veriga postopkov od začetne oskrbe na terenu do končne rehabilitacije zagotovi dober izid zdravljenja. Prispevek zato predstavi priporočila Vertebrološkega združenja Slovenije za obravnavo bolnikov z zlomom PLH. Te zajemajo celotno verigo oskrbe, od oskrbe na terenu in v urgentnem centru do diagnostičnih postopkov in klasifikacije ter kirurškega zdravljenja, končno pa do rehabilitacije in ambulantnega spremljanja zdravstvenega stanja poškodovanca. Posebna pozornost se posveča poškodbam z nevrološko prizadetostjo, osteoporotičnim zlomom in zlomom pri ankilozirajočih boleznih hrbtenice, ki so zaradi starajočega se prebivalstva v porastu. Namen priporočil je postaviti minimalne standarde oskrbe zlomov PLH v slovenskem prostoru. Zato priporočila temeljijo na empiričnih znanjih, upoštevajo pa tudi regionalne posebnosti slovenskega prostora.

¹ Department of Traumatology, Division of Surgery, University Medical Centre Ljubljana, Ljubljana, Slovenia

² Department of Traumatology, General hospital Celje, Celje, Slovenia

³ Department of Traumatology, Division of Surgery, University Medical Centre Maribor, Maribor, Slovenia

Correspondence/

Korespondenca:

Marko Jug, e: marko.jug@kclj.si

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1 Introduction

Fractures of the thoracolumbar spine are a large strain on the healthcare system as they affect all ages and can cause permanent disability. In the younger population, they are usually caused by traffic, sports or workplace injuries, and in the elderly, the cause can be an otherwise insignificant fall or excessive strain on the spine, in particular with osteoporosis or ankylosing spinal diseases. The severity of spinal injury is dependent on the direction and magnitude of the force acting on the spine, and structural integrity of the spine. Injuries most commonly affect the thoracolumbar junction (T11-L2), the anatomical transition between the relatively immobile thoracic spine and the more mobile lumbar spine (1). Treatment depends on the location, type and severity of the injury, the general condition of the patient and preexisting spinal pathology. Therefore, as population ages, the treatment becomes more and more challenging. Spinal injuries can range from mild and stable, which usually require only conservative treatment, to very unstable spinal injuries with spinal cord injury, which require rapid surgical interventions. The wide variety of injuries and a constant development of new treatment methods require a complex and specialized approach to treatment, from the first care in the field, diagnostic procedures, surgical treatment and finally to rehabilitation (2,3). Due to this complexity and the lack of robust evidence for

specific treatment options in the literature there are only few treatment recommendations for such injuries in the literature.

The working group at the Slovenian Spine Society has therefore prepared the recommendations for treatment of thoracolumbar spine fractures (TLF), based on empirical data in the literature, their own clinical experience and regional specifics of Slovenia. The aim of these recommendations is to set minimum standards and pave the way for clinical pathways for TLF treatment in Slovenia. The recommendations present comprehensive care for the injured: from the care in the field and emergency room, diagnostic procedures and injury classification to surgical treatment, and finally, rehabilitation and post-injury follow-up strategies. A special emphasis is placed on the treatment of TLF with spinal cord injury and to the treatment of osteoporotic fractures and fractures of the ankylosed spine. The recommendations are formulated in accordance with the guidelines for formulation of recommendations of the Slovenian Medical Association (4). The strength of an individual recommendation is assessed using the GRADE approach, as shown in Table 1. The recommendations were accepted by the Expert Council for Surgery at the Slovenian Medical Association on 17 August 2020, and the Main Expert Council of the Slovenian Medical Association on 9 March 2021.

Table 1: Rating the quality of evidence.

Grade of recommendation	
Grade I	The procedure or treatment is recommended.
Grade II	Opinions on procedures or treatment are not entirely reliable as the data is contradictory at times.
Grade II a	Benefit is more likely. Suggested.
Grade II b	Benefit is uncertain. No harm.
Grade III	The procedure or treatment is harmful.
Quality of evidence	
A	Numerous randomized studies or meta-analyses.
B	One randomized or several larger non-randomized studies.
C	Expert opinion or the results of smaller studies, data registries.

2 Prehospital and emergency care of patients with thoracolumbar spine injuries

2.1 What should be the prehospital and emergency care of patients with thoracolumbar spine injuries?

The initial care of patients with thoracolumbar spine (TLS) injuries is performed according to established treatment protocols (e.g. Advanced Trauma Life Support). Simultaneous diagnosis and treatment are essential. The airway is established first (A), followed by the assessment and care of breathing (B). Once ventilation is established, an assessment of circulation is made (C), followed by neurological assessment (D), basic examination, exposure and environmental control (hypothermia) (E). The cervical and thoracolumbar spine should be protected throughout this time; this holds for care in the field and the emergency room (5).

All patients with dominant injuries of other parts of the body and/or qualitative or quantitative impairment of consciousness (head injury, intoxication, confusion) and/or spinal pain and/or neurological deficits (e.g. motoric and sensory deficits, priapism, etc.) require full in-line spinal immobilization at the injury site. Such patients must not be allowed to move by themselves. Extrication devices (e.g. longboards) should be changed as soon as possible. For transport, the use of a scoop stretcher and vacuum mattress, cervical collar and head immobilization with head blocks and tape is recommended (6).

The optimal transport goal is the hospital where definitive care of a spinal injury can be achieved. For concomitant life-threatening injuries, the transport duration is a priority when choosing the transport destination. It justifies transport to the nearest institution capable of handling life-threatening injuries. Communications between the field emergency team and the emergency centre is important. Data on the age and sex

of the injured person, time and mechanism of the injury, vital signs and identified injuries (neurological impairments in particular), therapeutic measures in the field (ABCD), estimated time of arrival and method of communication are reported in a structured manner (7).

During the examination in the emergency centre, special attention needs to be paid to patients older than 65 years with complaints of back pain and/or exposure to a dangerous mechanism of injury (fall from a height >3m, high-speed vehicular collisions, rolling or falling from a vehicle or motorcycle, etc.) and to patients with previously known osteoporosis or spinal disease (e.g. ankylosing spondylitis), and in particular to patients with signs of neurological impairment (5).

Routine use of high-dose corticosteroids in the treatment of TLS injuries is not recommended in polytrauma patients, concomitant severe chest injuries, patients with diseases of the gastrointestinal tract and patients over 65 years of age. The decision to use corticosteroids is at the discretion of the attending physician and the use should be considered especially in incomplete spinal cord injuries. However, one should be aware of the possibility of respiratory and intestinal tract complications (8).

Recommendation	GR	QE
A patient with a suspected spinal injury with neurological impairment should be transported with full spinal immobilization to a hospital capable of definitive care of a spinal injury. In case the patient requires a life saving procedure the patient is transported to the nearest hospital.	I	C

Legend:

GR – grade of recommendation; QE – quality of evidence.

3 Diagnostic procedures for TLS injuries

The use of proper diagnostic procedures for TLS injuries is crucial for further management as an overlooked or delayed diagnosis of a TLS injury (an alarmingly high percentage) can have serious consequences (9,10). The diagnostic procedure for TLS injuries varies on whether the patient has an isolated spinal injury, neurological impairment and/or polytrauma, ankylosed spine or is a child.

3.1 What is the diagnostic procedure for patients with isolated TLS injuries?

Despite the advances in diagnosing and availability of sophisticated imaging techniques, such as computer tomography (CT), computer tomography angiography (CTA), magnetic resonance imaging (MRI), the golden standard and the basic diagnostic method for diagnosing TLS injuries remains the classic two-view, antero-posterior (AP) and lateral projection radiograph. Radiography of the TLS is required for any patient who complains of pain in this area. Additional risk factors for TLS injury which require the use of radiography are: impaired consciousness, signs of intoxication, abnormal neurological examination, and painful injury of other body parts. Patients without pain at palpation or percussion of the TLS and without risk factors do not need radiographic imaging (11). If a spinal injury is found or cannot be excluded, a CT of the affected segment with adjacent vertebrae should be performed. When injury of the posterior ligament complex is suspected, an MRI can be performed as it is highly sensitive for soft tissue injury.

Recommendation	GR	QE
In case of suspicion or signs of (isolated) TLS injury, a plain spinal radiograph is the first diagnostic method. CT is used to more precisely assess the fracture or to show segments poorly visible on a radiograph. An MRI is rarely required.	I	B

Legend:
GR – grade of recommendation; QE – quality of evidence.

3.2 What is the diagnostic procedure for patients with TLS injuries and neurological impairment and/or polytrauma?

Patients presenting with neurologic deficits are managed like polytrauma patients due to the usually high-energy mechanism of injury and unreliable clinical findings due to sensory deficits. In a diagnostic sense, this means that such patients require a chest and abdominal CTA with skeletal reconstruction of the spine.

MRI is time-consuming and only used with proven or suspected spinal cord injuries if it would significantly affect treatment or in cases where the level or the cause of a neurological impairment are not clear (7), for example in case of discrepancies between the vertebral and spinal cord injury levels, in the absence of injuries on CT (possible ligament injury) or with suspicion of soft tissue cord compression (e.g. haematoma, tumour, abscess), etc. In such cases, MRI helps with choosing a treatment strategy, surgical approach and extent of the procedure. As the procedure is time-consuming, continuous monitoring of vital parameters is required throughout the diagnostic procedure.

Recommendation	GR	QE
With a high-energy mechanism of injury, the method of choice is a chest and abdominal CTA with skeletal reconstruction of the spine. MRI is required only in special cases.	I	B

Legend:
GR – grade of recommendation; QE – quality of evidence.

3.3 What is the diagnostic procedure for patients with ankylosing spinal disorders?

In patients with an ankylosed spine (ankylosing spondylitis, DISH – diffuse idiopathic skeletal hyperostosis), special diagnostic sensitivity is required. Plain radiographs often point to the primary pathology – spinal ankylosis, but the signs of injury/fracture can be very subtle. If such a patient presents with history of injury, even a trivial one, and spinal pain or pain at palpation or percussion of the spine, further diagnostic imaging is required even in the absence of radiographic signs of fracture on plain radiographs. A full-length spine CT is therefore recommended and in case of a negative CT result and persistent pain MRI is suggested (the STIR sequence in the sagittal plane is usually sufficient). Great care must be taken when moving such patients until any injury is excluded.

Recommendation	GR	QE
With ankylosing spinal disorders, the threshold for further imaging should be extremely low despite a negative radiograph. In case of clinical suspicion of a fracture CT of the entire spine is recommended, followed by MRI if CT is negative.	I	B

Legend:

GR – grade of recommendation; QE – quality of evidence.

3.4 What is the diagnostic procedure for children with a TLS injury?

Diagnosing TLS injuries in children is different due to an immature skeletal structure, higher susceptibility to the harmful effects of ionizing radiation and possible neurological impairment without obvious radiographic abnormalities (spinal cord injury without radiographic abnormality, SCIWORA). Therefore, a CT is rarely the primary diagnostic method in children and is instead replaced by MRI in the case of suspicious changes on a plain radiograph or a positive clinical presentation, in particular if accompanied by neurological impairment. Additionally, a full-length spinal MRI is recommended for high-energy injuries and unclear neurological examination, even in the absence of CT findings, in particular in children under 8 years of age.

Recommendation	GR	QE
To clarify radiographic findings and/or in the case of clinical suspicion of spinal injuries in children, MRI is recommended. CT is used exceptionally and carefully.	I	B

Legend:

GR – grade of recommendation; QE – quality of evidence.

4 Thoracolumbar spine fractures classification

4.1 Which TLF classification is the most useful and how are TLF injuries assessed?

Gradual upgrading of TLS injury classification systems aims to develop a classification system that would serve in the assessment of injury and have a predictive value in terms of treatment and outcome of injury. Although numerous internationally recognized classification systems are in use, the AOSpine Thoracolumbar Classification System, which is a synthesis of clinical and imaging investigations, is the currently most sophisticated. It uses a morphological description of the injury, taking into account the force at the time of injury (Figure 1), neurological impairment and comorbidities or clinical modifiers (Tables 1 in 2), which can significantly affect treatment (12). The AOSpine classification divides TLS injuries into 3 main groups and subgroups, depending on morphology and stability of the fracture, with gradually rising instability (Figure 1) (12).

To assess the injury, we follow the proposed algorithm (Figure 2). At first, we assess the fracture with a radiograph and CT (and if needed, MRI) and check whether it is a translation injury (group C). If we find displacement or dislocation, the injury is classified as very unstable and belongs in group C. In the absence of displacement or dislocation, we check for distraction of the posterior tension band elements (laminae, spinous processes, ligaments) and classify the injury as B1 or B2 (depending on the involvement of ligaments or bone structures).

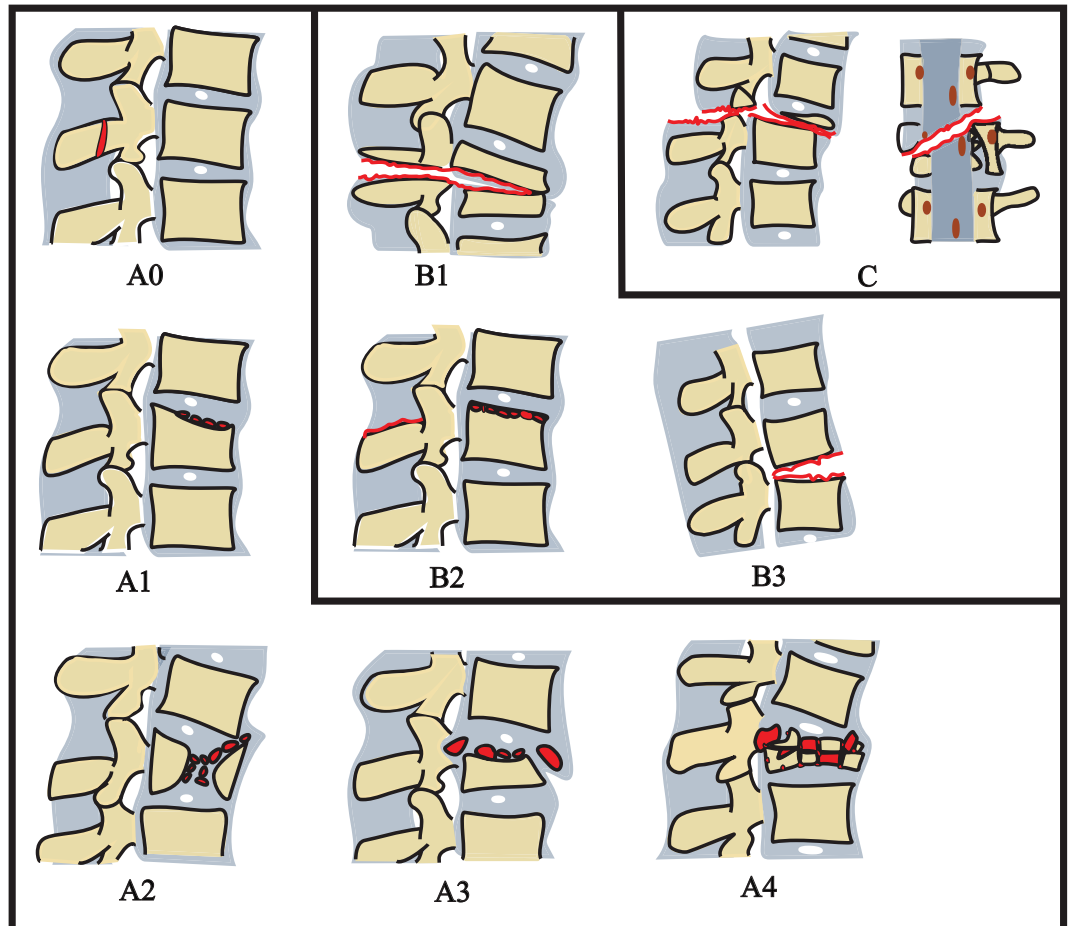


Figure 1: Morphological representation of the AOSpine Thoracolumbar Classification System. *Type A: compression fractures of vertebral bodies:* A0 – insignificant injury (e.g. transverse process fracture); A1– wedge compression injury; A2 – split or pincer type injury (in sagittal or coronary planes); A3 – incomplete burst injury (involves a single endplate along with the posterior vertebral wall, reaching into the spinal canal, but one endplate remains intact); A4 – complete burst injury. *Type B: distraction injuries (greater instability):* B1 – pure transosseous tension band disruption; B2 – pure transosseous tension band disruption; B3 – hyperextension. *Type C: translation injuries (greatest instability) – injuries which involve displacement in any direction – translation or dissociation between vertebrae.* Type A or B injuries can also be present.

In case of a wedge-shaped hyperextension of the anterior tension band elements, the injury is classified as B3. In the absence of injury of the posterior elements, the injury is classified as A and adequately assessed, depending on the involvement of the posterior wall and both endplates of the vertebral body.

After the morphological assessment of the fracture, the neurological deficits are assessed (Table 2), along with the presence of modifiers, with which we can assess ligament injury and the presence of comorbidities (Table 3). The overall assessment gives us a comparable and comprehensive overview of the injury and directs us to treatment.

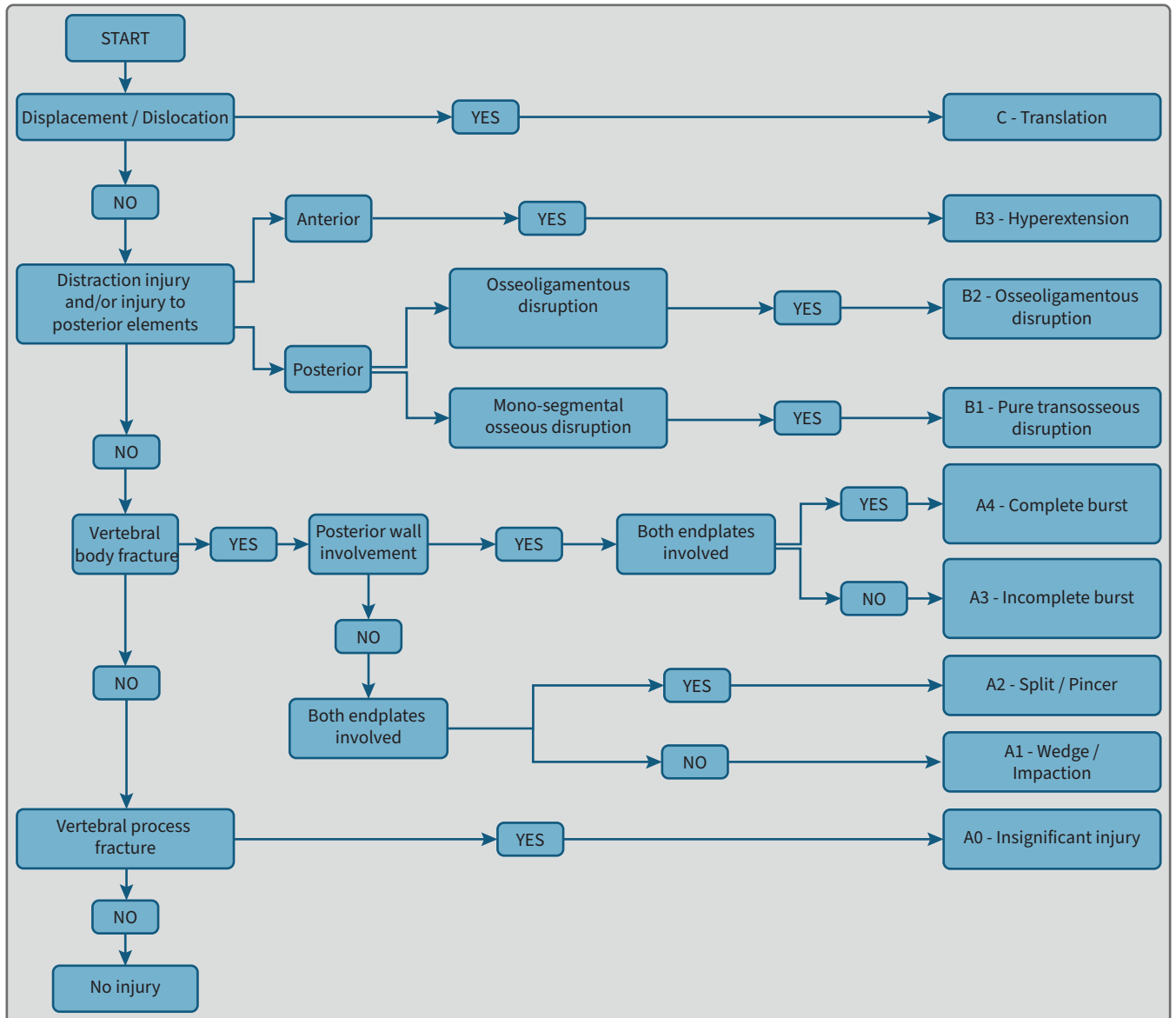


Figure 2: Algorithm for AOSpine morphological classification.

Recommendation	GR	QE
A TLS injury is classified according to a morphological assessment with radiography and CT imaging and possibly MRI with suspicion of soft tissue injury, along with neurological impairment and comorbidities. The use of the AOSpine algorithm is recommended	I	B

Legend:
GR – grade of recommendation; QE – quality of evidence.

5 Management of thoracolumbar fractures according to the AOSpine classification

5.1 Treatment of type A TLF

Type A fractures involve the anterior portion of the vertebral column with an intact posterior tension band, including clinically insignificant fractures of the

Table 2: Neurological deficits.

Type	Description
N0	Neurology intact
N1	Transient neurological deficit
N2	Radicular symptoms
N3	Incomplete spinal cord injury or any degree of cauda equina injury
N4	Complete spinal cord injury
Nx	Cannot be examined
+	Continued spinal cord compression

Table 3: Clinical modifiers.

Type	Description
M1	This modifier is used to designate fractures with an indeterminate injury to the tension band based on spinal imaging with or without MRI. This modifier is important for designating those injuries with stable injuries from a bony standpoint for which ligamentous insufficiency may help determine whether operative stabilization is a consideration.
M2	Is used to designate a patient-specific comorbidity, which might argue either for or against surgery for patients with relative surgical indications. Examples of an M2 modifier include ankylosing spondylitis or burns affecting the skin overlying the injured spine.

spinous or transverse processes (13).

Decisions on the treatment plan are made after a precise fracture assessment. The level of spinal angulation after injury, vertebral body comminution, possible narrowing of the spinal canal and injury of the intervertebral disc need to be assessed with a radiograph and CT. MRI is also recommended in individual cases for a more precise fracture assessment and to exclude potential type B or C injuries or spinal cord compression (6).

In many cases, stable type A fractures can be treated conservatively with functional treatment and adequate pain relief. Treatment with orthoses is not

required, unless the orthosis is used as a pain relief in individual cases. Regular radiographic follow-ups in a standing position for the first 3 months after the injury are required (14).

With type A0 fractures, conservative treatment with immediate mobilization and adequate pain relief is adequate.

With type A1 fractures, a single endplate is injured in the absence of injury of the posterior wall of the vertebral body. Conservative treatment is usually adequate. An indication for surgery is a kyphotic angulation $> 20^\circ$. In such cases a short-segment (even monosegmental) posterior stabilization can be performed (15).

A type A2 fracture, also known as a split fracture, involves both endplates without the involvement of the posterior wall. Treatment is usually conservative. In case of concomitant intervertebral disc destruction, reconstruction with an anterior approach with or without posterior stabilization can be performed. Only posterior indirect reduction and stabilization can also be performed and the implants removed after the fracture has healed.

Type A3 fractures involve a single endplate along with the posterior vertebral wall; a vertical laminar fracture is usually also present (insufficient to qualify as a tension band failure). Fractures with less extensive deformations (kyphosis $< 20^\circ$ and scoliosis $< 10^\circ$) can be treated conservatively. Surgery is indicated in cases of more extensive deformations with the involvement of the intervertebral disc or severe spinal stenosis with imminent cord compression. A monosegmental posterior stabilization can be performed but with more extensive involvement of the vertebral body a bisegmental posterior stabilization is

preferred. In the thoracic spine above the level T10 a long-segment stabilization may be necessary, however, an anterior reconstruction without posterior fixation is possible if the posterior structures are intact.

Type A4 fractures involve both endplates along with the posterior vertebral wall and are also often associated with the involvement of adjacent intervertebral discs. In cases with less extensive deformations (kyphosis $< 20^\circ$ and scoliosis $< 10^\circ$), a conservative approach can be tried, but follow-up radiographs in a standing position after 2 and 4 weeks should be performed. As the possibility of nerve injury is greater, surgery is usually recommended. At least a bisegmental posterior stabilization of the lumbar spine and a long-segment procedure of the thoracic spine are recommended. We decide on the need for anterior reconstruction according to the degree of involvement of the vertebral body and the intervertebral discs. The anterior reconstruction is usually performed after posterior instrumentation, but an exclusively anterior approach is possible in select cases.

Recommendation	GR	QE
Conservative and functional treatment with adequate pain relief is recommended for stable type A fractures. Orthoses are not required, but they can be prescribed for pain relief.	IIa	B
Surgery is an option for unstable fractures; depending on the type of fracture, we can decide for posterior stabilization, anterior stabilization or a combination of both. Minimally invasive techniques are preferable.	IIa	B

Legend:

GR – grade of recommendation; QE – quality of evidence.

We always strive to use minimally invasive techniques that still allow sufficient reduction and stabilization. Greater stability can be achieved with monoaxial screws. Additional stability can also be achieved by using short screws in the injured vertebra and with cross-links. With poor bone quality, augmentation of the vertebral body and screws with bone cement (polymethylmethacrylate, PMMA) combined with long posterior instrumentation is recommended.

5.2 Treatment of type B TLF

Nondislocated type B1 fractures with minimal involvement of the anterior column can heal with conservative treatment (16), but secondary dislocation or kyphotic angulation can occur and regular radiographic follow-ups are required until the fracture has healed. On the other hand, most type B fractures require surgical stabilisation (17). In type B1 fractures, where only the bone of the posterior elements is involved, fracture reduction and posterior stabilization is required on the immobile thoracic spine (from T1 to T10), which can be short (bisegmental) or long (multisegmental), depending on bone quality. With short-segment stabilizations, the probability of implant failure is higher, but otherwise, there are no significant differences in clinical or radiological results (18). In the mobile TLS (T11 to S1), a short-segment bisegmental posterior stabilization is preferred to avoid long constructs in the mobile lumbar spine. Spondylodesis (spondyloplasty) is not required with pure bone involvement and the procedure can be performed with a minimally invasive technique (19).

Type B2 fractures with disruption of the posterior tension band ligaments with or without involvement of the posterior bones, require posterior reduction and instrumentation. In case of good screw purchase instrumentation can be monosegmental. Spongionoplasty at the site of ligamentous injury is indicated in particular if removal of the implant is planned after healing, as the effectiveness of the posterior ligament complex after an injury remains questionable (20) and injured posterior ligaments are prone to insufficiency without spondylodesis (15). If possible, hybrid minimally invasive techniques, such as percutaneous stabilization with local spongionoplasty, are recommended.

Type B3 fractures, also known as hyperextension injuries with disruption of the anterior tension band and extension through the intervertebral disk or vertebral body, usually require a posterior instrumentation. A short-segment monosegmental or bisegmental posterior stabilization usually suffices in type B3 fractures. However, as most of these injuries occur in ankylosing spinal disorders, long-segment posterior stabilization, usually with a percutaneous method, is required due to altered spinal biomechanics (21). Posterior spondylodesis is not required.

The need for anterior column reconstruction depends on the level of anterior body disruption, similar to type A injury, except that in type B injuries anterior reconstruction always follows posterior instrumentation. In case of osteoporosis, the anterior column can be reinforced with bone cement during the posterior stabilization.

Conservative treatment may be also indicated in patients in poor general condition in whom surgery should be avoided.

Recommendation	GR	QE
Type B TLS injuries require surgical stabilization.	I	B
In the thoracic spine a long-segment instrumentation is preferred as it provides greater stability.	IIa	B
In the mobile lumbar spine, a short-segment stabilization is preferred to preserve mobile segments.	IIa	B
For pure osseous injuries, spongionoplasty is not required.	IIa	B

Legend:

GR – grade of recommendation; QE – quality of evidence.

5.3 Treatment of type C TLF

Operative reduction and posterior stabilization is always indicated in type C fractures, except in patients who are not fit for surgery. Such injuries are often accompanied by neurological impairment. Pure monosegmental injuries can be stabilized with a short-segment posterior stabilization, but multisegmental injuries require long-segment stabilization. Short-segment stabilization can be reinforced with the addition of short pedicular screws in the injured vertebra (22), and/or cross-links. Although increased stability with the use of cross-links has not been confirmed in clinical studies (23), cross-links do add to the rotational stability of a construct in biomechanical studies (24). Biomechanically, the X-shaped cross-link is the strongest (24) and can be used in short-segment stabilizations for rotationally unstable injuries. In injuries of posterior elements, open spongionoplasty can be used even with percutaneous stabilization as a so-called hybrid technique. A hybrid technique, ie. the combination of

minimally invasive instrumentation with local open decompression and spondyloplasty, can be of value even if decompression is needed due to spinal canal compression as it reduces blood loss, shortens the procedure and reduces the infection rate (19). If a reconstruction of the anterior column is needed, the same principles apply as per type B injuries.

Recommendation	GR	QE
In type C TLS injuries, long-segment instrumentation increases stability and is recommended.	IIa	B
In type C injuries, cross-links add to construct stability.	IIa	C
Minimally invasive techniques can be performed in combination with partially open techniques to reduce operative time, blood loss and post-surgical complications.	I	B

Legend:

GR – grade of recommendation; QE – quality of evidence.

6 TLS injury with neurological deficit

Unstable TLS injuries are often accompanied by neurological impairment. At the T1-T11 level, the spinal cord (upper motor neuron) is usually affected, and from T12 to L1, combined injuries of the upper and lower motor neurons and/or the »conus medularis« syndrome can be found with only the sphincters being affected. Below that level we find different levels of injury to the lumbar and sacral roots (lower motor neuron). Proper

assessment of the level and degree of neural damage is crucial for appropriate management (diagnostics and treatment) and anticipation of possible complications such as respiratory or cardiovascular insufficiency, due to neurogenic shock, which may occur in complete thoracic spinal cord injuries. The ASIA (American Spinal Cord Injury Association) Impairment Scale is therefore used for neurological assessment of the level and severity of spinal cord injury as soon as the patient is capable of cooperation. In addition, spinal cord injury in TLS is often a result of high-energy injuries or part of a polytrauma, which further complicates management. Therefore, a patient with spinal cord injury, independent of other concomitant injuries, needs to be managed by a resuscitation team and treated as a polytraumatized patient. Invasive blood pressure and ventilation monitoring and management must be started immediately, with the focus on providing adequate perfusion and oxygenation of the injured spinal cord to alleviate secondary injury and improve the neurological outcome (25).

6.1 What is the effect of timing of decompression of the spinal cord on neurological outcome?

Current guidelines recommend surgical decompression of the spinal cord in TLS injuries in the first 24 hours after the injury, regardless of the neurological level of injury (26). However, recent studies on the effect of timing of decompression in cervical spinal cord injury suggest that the time from injury to decompression is inversely related to the neurological outcome with the authors strongly favouring

very rapid decompression in the first hours after injury (27). The beneficial effect of urgent decompression within 8 hours after injury on the functional outcome is suggested also by recent studies on thoracic and thoracolumbar spinal cord injury (28,29). Although injuries of the cervical and thoracolumbar spinal cord cannot be directly compared as the prognosis after cervical spinal cord injury is usually more favourable than after thoracolumbar injury, timing of decompression seems to be very important. The cause for a worse prognosis in TLS injuries can be found in the higher energy needed for TLS injury and the narrower spinal canal and poorer spinal cord perfusion, in particular at the level of the upper thoracic spine. Moreover, patients with thoracic spine injury may also be polytraumatized and surgery can pose an additional life-threatening risk. Therefore, due to the poorer prognosis in complete injuries at the level of the upper thoracic spine, which usually also require longer and more demanding surgical procedures in the prone position, surgery is indicated only after patient stabilisation. On the other hand, in incomplete spinal cord injuries or even neurological worsening the risk of surgery seems more acceptable and the potential risks and benefits must be discussed between surgeon, anaesthesiologist and the patient, if applicable. During surgery, the mean arterial blood pressure should be targeted above 85 mm Hg (25), which can result in additional bleeding. Therefore, it is essential to rule out and manage life-threatening conditions such as abdominal bleeding, aortic injury, pneumothorax, etc., and whole-body CTA is mandatory before surgery. MRI is only performed if the neurological

level does not match the level of spinal injury on CT. However, surgical decompression should never be delayed due to non-medical reasons. To achieve a rapid decompression, the patient must be brought directly from the field to a hospital capable of offering definitive surgical care (Celje General Hospital, University Clinical Centre Ljubljana and University Clinical Centre Maribor).

Recommendation	GR	QE
Surgical spinal cord decompression should be performed as soon as possible, preferably within 8 hours of injury or as soon as the surgery is safe and the mean arterial blood pressure can be kept above 85 mmHg.	Ila	B

Legend:

GR – grade of recommendation; QE – quality of evidence.

6.2 Is there any pharmacologic treatment of spinal cord injury?

A patient with spinal cord injury must be treated in the intensive care unit, where it is possible to accurately monitor and maintain adequate arterial blood oxygenation and mean arterial blood pressure above 85 mm Hg for at least seven days (25). Prevention of deep venous thrombosis is started as soon as possible. If there are no contraindications and in agreement with the attending intensive care specialist, methylprednisolone succinate can be given for 24 hours if therapy was started within 8 hours after injury as a treatment option according to the NASCIS II protocol. (25). However, the use of methylprednisolone is considered mainly in cases of incomplete spinal cord injuries or deterioration of the neurological

condition. According to the author, 100 mg of vitamin B1 and 400 mg of magnesium can be prescribed daily as a supportive treatment in the first month after the injury, along with a diet with a high content of omega-3 and omega-6 fatty acids. A combination of opioid analgesics, antidepressants and pregabalin is used for the treatment of acute neuropathic pain in the absence of contraindications (25). Respiratory and physical therapy is started immediately and special care is dedicated to possible complications such as pressure ulcers, urinary tract infections, pneumonia, defecation disorders and the very dangerous neurovegetative disorders, deep vein thrombosis and pulmonary embolism. Immediately after surgical and cardio-respiratory stabilization, the patient continues rehabilitation in a specialized rehabilitation institution (25).

Recommendation	GR	QE
Mean arterial blood pressure should be maintained between 85 and 90 mmHg for 5 to 7 days after the injury.	I	B
Methylprednisolone succinate can be given for 24 hours if the patient has received the first dose within 8 hours of the injury.	IIb	B
Vitamin B1 100 mg and magnesium 400 mg daily are suggested.	IIb	C

Legend:

GR – grade of recommendation; QE – quality of evidence.

7 Ankylosing spinal disorders of the TLS

Ankylosing spinal disorders (ankylosing spondylitis, DISH and other

spondyloarthropathies) are a group of inflammatory diseases in which the vertebrae gradually fuse together. Erosions first appear in the corners of the vertebrae, becoming square in shape, followed by the development of syndesmophytes, ossification of the posterior interspinous ligaments, and gradual fusion of the spine and facet joints, intervertebral discs and costovertebral joints, causing the spine to become rigid with the characteristic radiographic feature of a bamboo spine. All these changes lead to deformations, in particular thoracic kyphosis. In the later phase, fractures are common; patients with ankylosing spondylitis are up to 4 times more likely to suffer a fracture than people with a normal mobile spine (30). Due to loss of spinal flexibility most fractures result from low-energy injuries, such as a falls from standing height.

Osteoporosis and susceptibility to falls due to gait and balance disorders, limited mobility of the cervical spine and advanced kyphosis also contribute to the increased rate of fractures.

In the majority of cases, a hyperextension fracture affecting all spinal columns is observed. These fractures are very unstable and have a high risk of a secondary displacement. Neurological impairment is up to 11 times more common than in a healthy spine (31). Spinal cord injury can usually be the result of spinal cord compression by bone fragments, ossified ligaments, intervertebral discs and/or epidural haematoma. As missed fractures are common, secondary neurological worsening is observed in 15% of injuries and the fracture may even be discovered only after neurological deterioration.

7.1 What are the specifics of diagnosing injuries of the ankylosed spine?

Radiological diagnosing of spinal injuries in patients with ankylosing spinal disorders is challenging. When an injury is suspected, we quickly decide on a CT or MRI. Namely, in patients with ankylosing spondylitis and painful palpation of the spine, a fracture must be suspected until the fracture is excluded by CT and/or MRI.

Recommendation	GR	QE
Patients with ankylosing spinal disorders, should be imaged, preferably with CT or MRI in every instance of TLS pain.	I	A

Legend:
GR – grade of recommendation; QE – quality of evidence.

7.2 Treatment of fractures in ankylosing spinal disorders

Surgical stabilization is usually needed. Surgical stabilization reduces pain and can prevent secondary dislocation and spinal cord injury and facilitates verticalization, thereby reducing the possibility of complications associated with prolonged bed rest (thrombosis, urinary tract infections, pneumonia). A posterior minimally invasive technique is preferred. In case of spinal cord compression, decompression, laminectomy and removal of fragments and/or haematoma is performed. Due to poor bone quality, long-segment fixation with pedicle screws two levels above and below the fractured level with additional bone cement screw augmentation is recommended. Anterior stabilization is rarely required (30).

Recommendation	GR	QE
In ankylosing spinal disorders, long-segment fixation with pedicle screws two levels above and below the fractured level is recommended.	I	A
Fractures of the ankylosed spine involving all 3 columns require surgical stabilization.	I	A
Posterior instrumentation is preferred, the anterior approach is only very rarely needed.	IIa	B
Minimally invasive techniques are recommended.	IIa	C

Legend:
GR – grade of recommendation; QE – quality of evidence.

7.3 Is conservative treatment of fractures of an ankylosed spine possible?

Conservative treatment may be tried in elderly patients with multiple comorbidities who are not fit for surgery. In such cases, stability is carefully assessed and if the diagnostic procedures show no injury to the posterior elements and pain is only moderate and no secondary displacement occurs during verticalization, surgery can be avoided (30).

Recommendation	GR	QE
Certain fractures without evident posterior elements injury can be treated without surgery with rapid mobilization and careful and regular clinical and radiological follow-ups.	IIa	C

Legend:
GR – grade of recommendation; QE – quality of evidence.

8 Treatment of osteoporotic vertebral fractures

8.1 What are the specific features of a diagnostic work-up of a suspected osteoporotic vertebral fracture?

In case of suspected osteoporotic vertebral fracture (OVF), the first diagnostic method of choice, along with a thorough history and physical examination, is a two-view spinal radiograph. A CT is performed when the radiograph is unclear or a more accurate assessment of the fracture is required. With neurological involvement, additional imaging with an MRI is recommended (32), which is also used to determine whether the OVF is acute or chronic and in identifying other pathologic causes of vertebral body compression (metastasis, plasmacytoma, infection, etc.). In 60% of patients, low-energy vertebral fractures occur without known injury. In such cases, the diagnosis of OFV cannot be made only on the basis of history of an irrelevant injury, spinal pain and plain radiograph. With an unclear cause, a referral to a physician who can identify a possible primary disease (serum protein electrophoresis, laboratory confirmation of primary osteoporosis, FRAX) is indicated (33). The OVF classification of the German Society for Orthopaedics and Trauma is recommended for OVF classification (34). The Genant classification of OVF divides them into mild, moderate and severe and is used to monitor the linear vertebral body compression in advanced osteoporosis, which can

also be monitored with densitometric vertebral fractures assessment (VFA), but it has not established itself in surgery (35).

Recommendation	GR	QE
In osteoporotic vertebral fractures without neurological involvement, the first diagnostic method is spinal radiography.	I	C

Legend:

GR – grade of recommendation; QE – quality of evidence.

8.2 Treatment of osteoporotic vertebral fractures

The majority of OVF can be treated conservatively with adequate pain relief, activity modification, physical therapy and optional orthosis use (36). Regular clinical and radiographic follow-up is needed due to possible deterioration. In cases of uncontrollable acute pain, persistence of severe pain for more than 6 to 12 weeks or with the progression of local kyphosis, OVF can be successfully treated by injecting bone cement into the vertebral body by vertebroplasty or balloon kyphoplasty (37,38). In case of major local kyphosis, severe spinal stenosis or neurological deficits, OVF is treated with operative reduction, internal fixation and, if necessary, decompression of neurological structures. Due to the poor screw purchase in osteoporotic vertebrae, pedicle screw and vertebral body augmentation with bone cement and/or multilevel fixation are recommended (36,37,39,40).

Recommendation	GR	QE
In OVF without neurological involvement conservative treatment is recommended.	IIa	C
Vertebroplasty or balloon kyphoplasty are recommended for refractory pain.	IIb	B

Legend:

GR – grade of recommendation; QE – quality of evidence.

9 What is the optimal rehabilitation of patients with a thoracolumbar spinal fractures?

Rehabilitation is best started at the same time as surgical treatment and is individually adjusted according to the patient, surgical treatment and neurological deficits. The rehabilitation goal is the best possible functionality of the patient.

Before preparing a rehabilitation plan, age, cognitive and pre-injury function and social history of the patient are assessed and a detailed neurological examination is performed according to the ASIA Impairment Scale. Surgical treatment and its limits, risk of complications and the limits of intensive care must be respected. Potential concomitant injuries, such as limb fractures which slow verticalization, chest and lung injuries, which, in particular with thoracic spinal injuries, additionally worsen ventilation, are also taken into account. In case of pathologic fractures due to malignancy, the rehabilitation plan is adapted to the treatment of the underlying disease.

In patients without neurological deficits, the rehabilitation goal is rapid mobilization and verticalization with

adequate pain relief (41) and independence in basic daily activities and self-care. During hospitalization, the patient is taught core-strengthening exercises and the correct use of orthoses if prescribed. After discharge, the patient can be referred to a physiatrist or physical therapist to continue with physiotherapy.

In patients with neurological deficits, the rehabilitation goal is focused on strengthening the intact functions, learning alternative strategies for lost functions, pain management, preventing secondary complications resulting from neurological impairment, and preparing for the return to the home environment or institutional care (14). The mobility of the lower limbs is maintained and training of postural mechanisms, sitting and transfer to a wheelchair and its use is required. When walking becomes possible, we use training aids, practice daily activities and exercise the upper limbs, which are under distal load. Respiratory therapy is particularly important in thoracic spinal injuries. If a tracheostomy tube is required, options for communication are sought (speaking valve, communication boards, augmentative communication devices, etc.). In patients with sphincter disorders, regular voiding and defecation must be achieved at first, followed by sphincter training. Pressure sores, thrombosis and hospital-acquired infections must be prevented. Team-based care is required, encompassing physicians, care staff, physical therapists and occupational therapist. Loss of function is often associated with personal distress; therefore, a clinical psychologist is also involved to assist the patient in the learning to cope with this loss. The social worker arranges

for more permanent accommodation or help at home.

After the completion of acute hospital treatment, depending on the assessment, neurological deficits and functional status, the patient may be referred for further rehabilitation. In patients with neurological deficits who are capable of cooperation, rehabilitation continues at the University Rehabilitation Institute Soča (URI Soča). When functionality is improved during acute treatment and only mild neurological deficits persist, the patient may be referred for thermal spa treatment. In patients with cognitive decline or who are unable to cooperate in rehabilitation programmes, a temporary hospitalization at a dedicated care hospital may be followed by definitive care at home or in a care facility. In malignancy-associated pathologic fractures, rehabilitation continues depending on the functional status after oncological treatment is completed.

Patient may be also referred to an outpatient clinic at URI Soča for tertiary aids prescription or special adjustments.

10 Follow-up with patients after their discharge from the hospital

Follow-up of patients with TLS injuries is patient specific and depends on the primary injury and treatment. First outpatient appointments depend on potential wound complications. The wound is assessed when sutures are removed, usually 2 weeks after surgery, depending on the fixation method and expected complications (osteoporosis, tumour, ankylosing disorder). At the same time, a control plain spinal radiograph in a standing position is recommended. A radiographic follow-up in a standing position should always be performed after 2 weeks especially in conservatively treated patients (7). Further radiographic follow-up depends on fracture characteristics. The next radiographic control is planned in four weeks and further controls in three and then in six months or until the fracture has healed. In case of complications or implant insufficiency, the intervals between controls are usually shorter to allow for a more rapid response or change of the treatment plan. We advise patients to avoid long periods of sitting, lifting heavy loads and forced posture, and we recommend walking with walking sticks as much as possible, as well as appropriate pain relief and antithrombotic prophylaxis until complete mobility has been achieved or at least 4 weeks after the injury.

Recommendation	GR	QE
Rehabilitation is best started immediately and is individually adjusted according to the patient.	IIa	B

Legend:

GR – grade of recommendation; QE – quality of evidence.

Recommendation	GR	QE
Outpatient monitoring should be individually tailored.	Ila	C
The first radiographic control is recommended 2-4 weeks after surgery with a spinal radiograph in the standing position.	Ila	C

Legend:

GR – grade of recommendation; QE – quality of evidence.

11 Is removal of osteosynthetic material necessary and when should it be performed?

There is no unified opinion in the literature on when or in which cases osteosynthetic material should be removed. Also, there are no clear data on the potential complications of long-term implants. On one side, studies favour removal, as one year after implantation, loss of intervertebral space and facet joint arthrosis due to degenerative changes of the intervertebral disc and impaired mobility of the fixated segment occur, and after approximately 8 years, fracture occurs in a third of retained implants (7). Follow-up radiographs after removal often show a clinically insignificant increase in kyphosis (42). Residual instability of the “healed fracture” and other complications of surgical implant removal are extremely rare (43). Despite numerous advantages of implant removal, deterioration after implant removal was found in 11% of patients (43). The general principles dictate that greater benefit in implant removal is to be expected in younger patients and longer fixations involving more flexible segments. The optimal time for removal is 12 months after implantation or when there is

radiographic proof of a healed fracture. In ankylosing disorders and the elderly, implant removal without a valid clinical reason is not recommended (30). Objective reasons for implant removal are infection, migration and/or implant pressure on neural structures and motion restriction, directly associated with long-segment fixation, and finally, the patient’s personal preference (44). Therefore, implant removal requires an in-depth conversation with the patient, and the decision is always individual.

Recommendation	GR	QE
Implants removal is recommended in the case of infection, migration and/or implant pressure on neural structures and motion restriction associated with long-segment fixation, in particular in younger patients.	Ila	C
In ankylosing disorders and the elderly, implant removal without a valid clinical reason is not recommended.	Ila	C

Legend:

GR – grade of recommendation; QE – quality of evidence.

12 Discussion

Despite advanced treatment methods, TLS injuries remain a diagnostic and therapeutic challenge due to a wide range of injuries. Opinions on the ideal treatment method are not uniform and can even be contradictory in the literature.

On one side of the spectrum, we see patients with severe high-energy TLS injuries with spinal cord injury which

require treatment according to polytrauma protocols and urgent surgical decompression and instrumentation, and on the other side, we have patients low-energy injuries which occur mainly in elderly patients or due to preexistent spinal pathology without neurologic involvement. In the first case, an immediate transport to a centre capable of providing definitive care of patients with TLS injuries is needed, whereas in the second, the patient can receive primary and sometimes also definitive treatment in a regional hospital. The key factor is neurological impairment. Therefore, the first clinical examination is crucial and needs to be thorough and comprehensive. It is followed by an assessment of stability and potential compression of neural structures, based on CT and sometimes MRI of the affected segment (45). In the case of a stable injury without neurological involvement, treatment can be continued in a regional hospital and the patient can be transferred to a specialized centre after consultation, if needed. For the final decision on treatment, in addition to potential neurologic injury and fracture pattern, we take into account the intensity of pain, comorbidity, preexisting spinal disorders and the patient's general state and expectations. Modern classification methods, such as the AOSpine TLICS, can be of help in this regard (13), but the decision is always patient specific and discussed with the patient. Generally, unstable injuries and injuries with neurologic involvement require surgery, while in other cases, the demarcation between surgical and conservative treatment is less clear. In unclear cases, conservative treatment with careful verticalization and radiographic control in the standing position, which enables the

assessment of the effect of physiological load on the affected segment, can be tried (7).

In patients with spinal cord injury, the literature recommends urgent decompression of the spinal cord and instrumented stabilization, best summarized by the syntagma "spine is time". In addition to urgent decompression, a mean arterial blood pressure above 85 mmHg is suggested for 5-7 days. Methylprednisolone succinate for 24 hours represents a treatment option at the discretion of the attending surgeon, especially in the case of incomplete spinal cord injury or progressive neurologic deterioration (25). Although decompression of the spinal cord is recommended as soon as possible, it should be emphasized that clear evidence on the effectiveness of the so-called ultra-early spinal cord decompression in the first few hours after a TLS injury is lacking. Historically the prognosis of thoracolumbar spinal cord injury is worse than that of cervical spinal cord injury, in particular with injuries of the upper thoracic spine from T1 to T5 (46). The reasons for the poorer prognosis of spinal cord injury at the level of the upper thoracic spine are to be found in the higher energy required for TLS injury and the narrower spinal canal and poorer perfusion, in particular at the level of the upper thoracic vertebrae. Therefore, complete spinal cord injuries, potentially with concomitant severe chest injuries, are more common at this spinal level and the neurological prognosis is usually poorer than with injuries at other spinal levels (46). Surgical stabilization of the severely injured upper thoracic spine, therefore, serves more to stabilize the chest and improve patient survival than improve the neurological prognosis. Namely, it is

known that surgical stabilization of an unstable spinal fracture in the 72-hours after the injury improves the prognosis and reduces the need for intensive care treatment of a polytrauma patient (47). In patients with low-energy TLS injuries, special attention is dedicated to ankylosing spinal disorders as they represent a high risk for severely unstable injuries despite no clear radiographic signs of instability and minor trauma and can be easily missed (48). Although in most cases elderly patients are usually affected, the probability of complications of conservative treatment seems larger than the expected intraoperative or perioperative complications and surgery is recommended (48). However, regardless of surgical or conservative treatment, each patient requires close clinical and radiographic monitoring in the standing position at intervals of several weeks to months until the fracture has healed. Additionally, regardless of the type of injury, every patient with a TLF requires guided physical rehabilitation. In the case of neurological impairment, this is performed at a tertiary institution, and otherwise, as part of rehabilitation at a thermal spa and/or physical therapy at the local medical institution. After the fracture has healed, the decision on osteosynthetic

material removal is patient specific and based on symptoms, patient's age and expectations.

13 Conclusion

Due to the possibility of severe complications, every patient with a TLS injury requires urgent care at all levels of the healthcare system, from the scene to the emergency centres and regional hospitals to the tertiary spinal centres. Only a coordinated and rapid patient management in this pyramid of care, can provide a good outcome of these severe injuries. Prompt recognition of neurological impairment and assessment of spinal injury stability are therefore crucial, as in the case of spinal cord injury, a direct transfer from the scene to a specialized centre is recommended. On the other hand, most stable injuries can be treated conservatively at a regional hospital. However, the treatment strategy must always represent a synthesis of the morphological and clinical characteristics of the spinal injury, pre-existing spinal comorbidities and general patient's state and expectations and it should be always developed with cooperation between the patient and attending physician.

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