# Aspects of Traumatic Thoracolumbar Spine Fractures

Jan Siebenga

# Stellingen

1. In vergelijking met niet-operatieve methoden heeft operatieve stabilisatie de voorkeur voor traumatische thoracolumbale wervelfracturen type A3 zonder neurologische uitval.

2. Comminutieve thoracolumbale wervelfracturen met een hoge Load Sharing Classification dienen ventraal gestabiliseerd te worden.

3. De operatieve behandeling voor traumatisch type A thoracolumbale wervelfracturen is kosten-effectief.

4. De Visual Analogue Scale Spine score en de Roland-Morris Disability Questionnaire correleren met elkaar.

5. De klinische betekenis van hoogte verlies van het wervellichaam blijft onduidelijk.

6. De gevolgen van wervelletsel bij paardrijden zijn langdurig en leiden bij meer dan 10% van de patienten tot langdurige arbeidsongeschiktheid.

7. De chirurgische behandeling van een cT1(2)N0Mx Non-small cell lung carcinoma, moet plaats vinden via een Video Assisted Thoracic Surgery lobectomie.

8. De lymfklierdissectie bij open thorax dient gelijk te zijn aan die van een Video Assisted Thoracic Surgery lobectomie.

9. Ook de long heeft recht op een eigen chirurg.

10. Ventriculaire extrasystole op oudere leeftijd kan veroorzaakt worden door een pectus excavatum.

11. Tolerance of intolerance is cowardice. (Salman Rushdie, 2007)

# Traumatic
# Thoracolumbar Spine Fractures

# Traumatische Thoracolumbale Wervelfracturen

Jan Siebenga

# Traumatic
# Thoracolumbar Spine Fractures

# Traumatische thoracolumbale
# wervelfracturen

**Proefschrift**

ter verkrijging van de graad van doctor aan de
Erasmus Universiteit Rotterdam
op gezag van de
rector magnificus
prof.dr. H.A.P. Pols
en volgens besluit van het College voor Promoties.

De openbare verdediging zal plaatsvinden op
woensdag 20 november 2013 om 11.30 uur

door

**Jan Siebenga**

geboren te Leiden

ERASMUS UNIVERSITEIT ROTTERDAM

**Promotiecommissie**

**Promotor:**

Prof.dr. P. Patka

**Overige leden:**

Prof.dr. C.M.F. Dirven
Prof.dr. F.C. Öner
Prof.dr. H.J. Stam

**Copromotor:**

Dr. F.C. Bakker

To Joan

*The light of my life*

Isaak and Ezra

Lea and Anna

*The twinkles in my eyes*

**ISBN/AEN**

978-90-8590-042-9

**Lay-out**

Babs Grit / Eric Lemmens
www.dlgraphics.nl

**Coverdesign**

John Derwall

**Printed by**

Drukkerij Schrijen-Lippertz

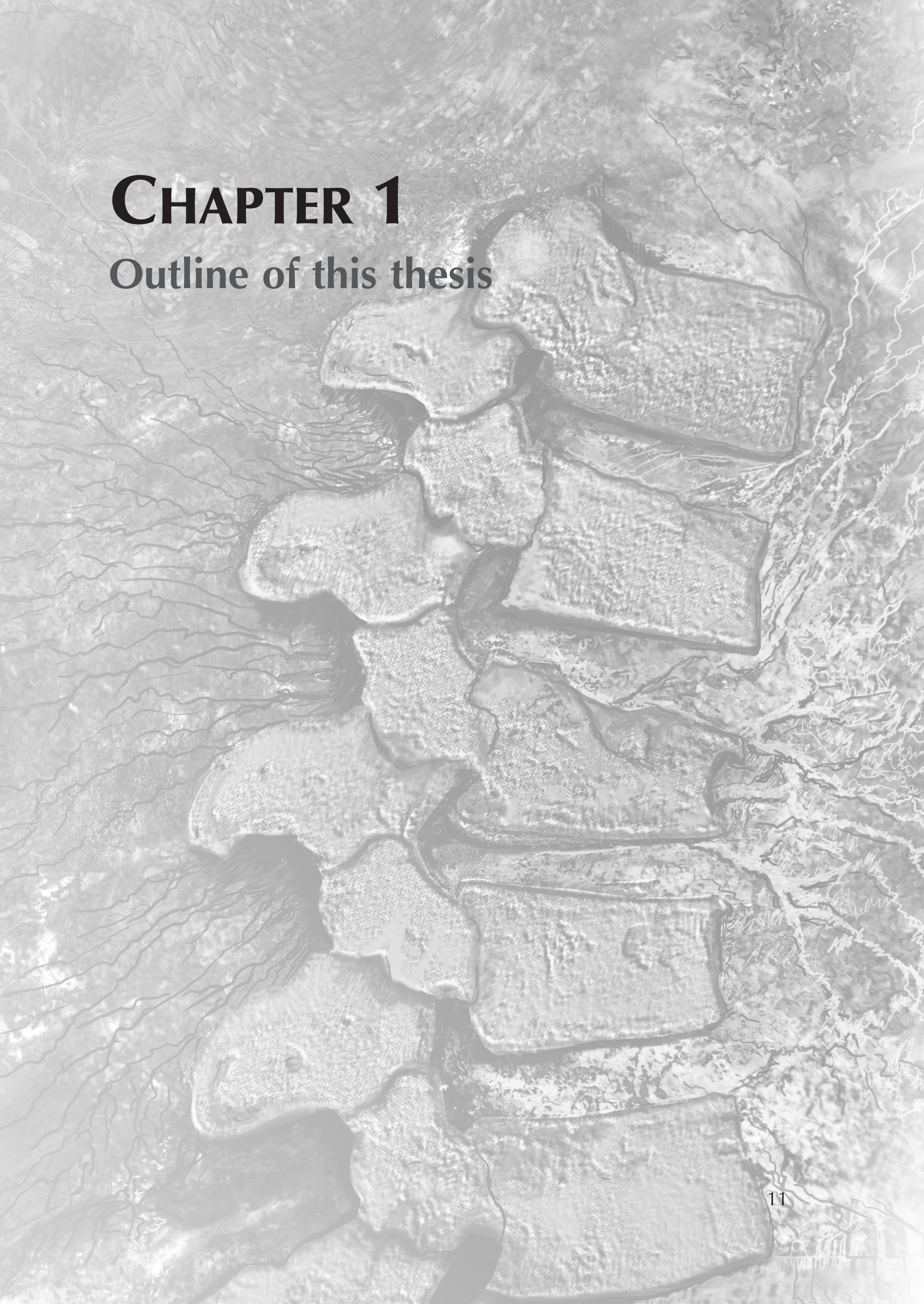
Financial support for the reproduction of this thesis was generously funded by the following institutions/companies:

## Contents

Wenn ein bedeutender Mann eine Idee in die Welt setzt, so wird sie sogleich von einem Verteilungsvorgang ergriffen, der aus Zuneigung und Abneigung besteht; zunächst reißen die bewunderer große Fetzen daraus, so wie sie ihnen passen, und verzerren ihren Meister wie die Füchse das Aas, dann vernichten die Gegner die schwachen Stellen, und über kurz bleibt von keiner Leistung mehr übrig als ein Aphorismenvorrat, aus dem sich Freund und Feind, wie es ihnen paßt, bedienen. Die Folge ist eine allgemeine Vieldeutigkeit. Es gibt kein Ja, an dem nicht ein Nein hinge. Du kannst tun, was du willst, so findest du zwanzig der schönsten Ideen, die dafür, und wenn du willst, zwanzig, die dagegen sind.
*Robert Musil. Der Mann ohne Eigenschaften. 1930*

# CHAPTER 1

## Outline of this thesis



## Outline of this thesis

**Chapter 1**

General Introduction. History of the treatment of spinal injuries. Description of the diagnostic procedures, classification and an overview of treatment options.

**Chapter 2**

Outline of thesis

**Chapter 3**

The treatment of thoracolumbar type A fractures without neurologic deficit is still controversial. This chapter presents the outcome of a multicenter, prospective study which answers the next questions:

- What are the functional results of conservative and operative treatment?
- What is the difference in return to work between these two groups?
- Which is the best treatment of type A fractures of the thoracolumbar spine?

**Chapter 4**

The Load Sharing Classification (LSC) is a classification based on CT. It seems that the LSC is a usefull addition to the AO classification. The following question is answered:

- What is the interobserver variability of the LSC?

**Chapter 5**

Loss of reduction and implant failure can occure after posterior fixation of a thoracolumbar spine fracture. It is difficult to predict which fracture type needs a complimentary anterior fixation. Therefore next questions have been formulated and answered:

- Is it possible to predict loss of reduction and implant failure using the Load Sharing Classification?

**Chapter 6**

In outcome estimation after thoracolumbar spine fractures, different methods can be used. One of these methods is measuring of functional outcome. Two scales have been developed with special attention to low back problems: the Roland-Morris Disability Questionnair (RMDQ) and the VAS Spine Score. The following questions are answered:

- What is the performance of conservative and operative treated patients measured with RMDQ and VAS Spine?
- Do the RMDQ and VAS Spine correlate?

**Chapter 7**

When a high Load Sharing Classification type fracture is solitary stabilised with a short-segment posterior stabilising implant, loss of the peroperative achieved reduction and substantial risk of implant failure are evident. It remains uncertain whether this increased loss of reduction and increased risk of implant failure lead to significant loss of function in these patients.

- Is the Load Sharing Classification a prognostic factor for the functional outcome of patients with a short-segmented stabilized burst fracture of the thoracolumbar spine?

**Chapter 8**

Cost-effectiveness is an important factor in choice of treatment. The following questions are answered:

- What are the direct and indirect costs of conservative and operative treatment of traumatic thoracolumbar spine fractures?
- Which of these two treatment modalities is the most cost-effective?

**Chapter 9**

Horse riding is an accident prone sport. Spinal fractures acquired in horse riding have been evaluated. The following questions are answered:

- What type of spine fractures do horse riders get?
- What is the functional outcome in patients who acquired a spine fracture by horse riding?
- What is the status of return to work?

**General Discussion and Conclusions**

**Dankwoord**

**PhD Portfolio**

**Curriculum Vitae**

We are accidents waiting to happen.
*Thom Yorke. Radiohead. 2003*

# CHAPTER 2
## General Introduction

## General Introduction

Traumatic spinal fractures have the lowest functional outcomes and the lowest rates of return to work after injury of all major organ systems.[1] This thesis will cover traumatic thoracolumbar spine fractures and not osteoporotic spine fractures because of the difference in fracture mechanism and treatment options. Fracture care has improved by incorporating scientific research in the whole continuum from basic science to the clinical application. In the following some aspects of the treatment of traumatic thoracolumbar spine fractures will be discussed with emphasis on the randomized clinical study of operative versus non-operative treatment of burst fractures of the thoracolumbar spine.

## History

Probably the first report on spinal injuries is from Imhoptep Vizer of Djoser (2686 – 2613 BC).[2] Imhoptep wrote the first treatise on surgery, which much later came into possession of Edwin Smith and are known as the Edwin Smith Papyrus. Imhoptep identified sprains, vertebral subluxations, and dislocations. He realised that paralysis resulted from severing the spinal cord.

Hippocrates (460 – 375 BC) is credited for separating medicine from mythology.[3] The material attributed to him is regarded more a compilation of many people's thoughts than the work of one man. This so called Corpus Hippocraticum was assembled in the fourth century BC at the great Library in Alexandria, where an extraordinary centre of learning had been established. The writings on surgery are clear, consistent and pragmatic. He used various methods of traction and the traction table is one of the devices described by Hippocrates. In the treatment of spinal injuries he did not differentiate between fractures and dislocations. Hippocrates described a procedure known as 'succussion on a ladder'.[4]

Galen (129 – 200 AD) was physician of the emperor Marcus Aurelius.[3] As official doctor of the gladiators he was able to observe living human anatomy, particularly of bones, joints and muscles, and to develop skill in treating fractures. He demonstrated the physiological relationship between nervous and muscular system.

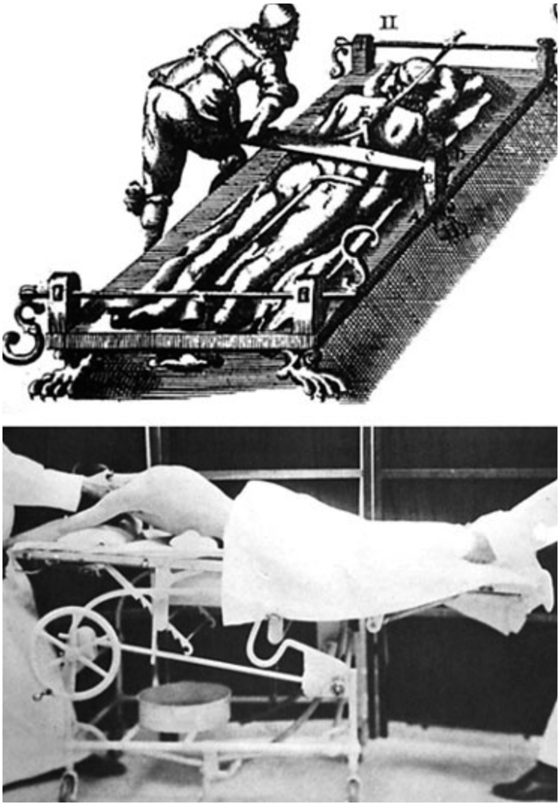



**Figure 1.**
**Above:** Extension, mechanical traction, and pressure exhibited by Joannis Scultetum in 1656. *Reprint from ArmamentariumChirurgicum*, Ulm, Tabula XXV, II, p 56.
**Below:** Extension and manual traction exhibited by Charles Elsberg in 1916. Reprinted from Elsberg CA: Diagnosis and Treatment of Surgical Diseases of the Spinal Cord and its Membranes. Philadelphia: WB Saunders, 1916, Fig. 111, p 217.

Galen named some of the deformities of the spine, such as lordosis, kyphosis, and scoliosis.[5]

Oribasius improved Hippocrates's traction table (325 – 400 AD), and added a cross bar.[6] By means of this bar, forward pressure could be made on a gibbus to reduce the deformity, while at the same time strong traction could be maintained on the torso and the legs. (Figure 1)
Paulus of Aegina (625 – 690 AD)[7] used splints after reducing spine fractures. He performed the first laminectomies in cases where the posterior elements were fractured and pushed into the spinal cord.
In the Rolandus Parmensis Chirurgia (1210 AD), Roland of Parma[7] discarded the traction table and recommended only manual manipulation of fractures and dislocations of the spine.
Andreas Vesalius (1514 – 1564) is the founder of the science of anatomy and modern medical science as we now understand it.[8] He stated that anatomy must be learned from dissections with one's own hands, not just from books. To know the body, the doctor must know its anatomy. The relevance of this in relation to spinal disorders is clear.

The outstanding surgeon of the Renaissance was Ambrose Paré (1510 – 1590).[9] He inaugurated the idea of gentle treatment of wounds. Paré stated, ‘I dressed him and God healed him.’ He also introduced the practice of ligaturing the great vessels after amputations instead of cauterizing with boiling oil.

The logo of the crooked tree bound to a straight stake was introduced by Nicholas Andry (1658 – 1742). The curvature of the spine and the effects of bad posture and the value of postural training were described by Andry.[10]

The first report of internal fixation of the spine is that of B.F. Wilkins (1848 – 1935). A child of six days ‘with a hunch in his back’ was operated upon and the spine was fixed with a carbolized silver suture which he passed around the pedicles of Th12 and L1.[11] This procedure was successfully repeated by Hadra.[12]

Fritz Lange (1864 – 1952) tried to stabilize the spine by tying celluloid bars and later steel rods to the sides of the spinous processes, using silk and later steel wire.[13] Around the turn of the twentieth century, Wilkins[11], Hadra[12], and Lange [13] had used internal fixation in the spine. Albee used a slab of tibial bone as a form of internal fixation.[14]

Lorenz Böhler (1885 – 1973) was a great Austrian surgeon who became famous for the conservative treatment of vertebral fractures with the use of plaster casts. He introduced the adage: 'Einrichten, festhalten und üben' [Reposition, fixation and training][15] (Figure 2) In 1958 M.E. Müller was impressed by Böhler’s excellent documentation and results and decided to follow ‘this principle’ and to build up in Switzerland a school of operative treatment of fractures, resulting in the AO foundation.[16] Böhler applied his principles of reposition, fixation and training to the spine.[15] Dislocations were reduced with postural reduction and stabilized in a cast of Paris plaster. Treatment was completed with a vigorous exercising program. Magnus developed a functional treatment with disregarding the dislocation.[57] After six weeks of bed rest mobilization was performed and physical therapy given. Especially the trunk musculature was trained. The correct posture is kept by a Jewett type hyperextension orthosis.

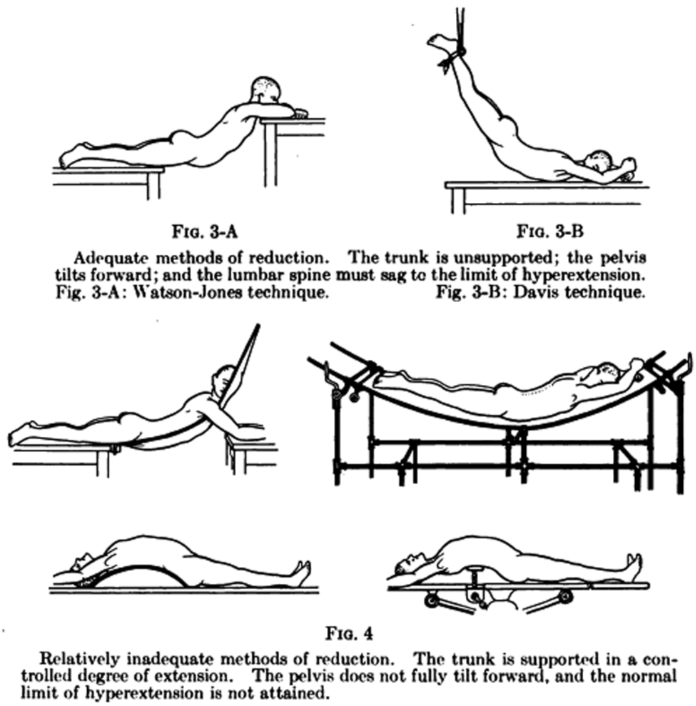



**Figure 2.** Different reduction techniques according to Watson-Jones which were also applied by Böhler.[49]

Philip Wilson Sr. used a plate that he bolted to the processus spinosus, usually with a graft on one side and the plate on the other.[17] The next step in the use of internal fixation was made by Don King. He recommended using screws through the facets.[18] Boucher improved the procedure by aiming the screws more medially so they went down into the pedicles.[19] This was the first use of pedicle screws.

The next great advance in spinal internal fixation was made by Harrington.[20-22] Although his rods were used predominantly in scoliosis of the young, later on they were also used in thoracolumbar spine fractures. During the 1970s and 1980s this became the standard procedure for the stabilization of vertebral fractures of the thoracic and lumbar spine. Greatest drawback was the need for multiple segment fixations and dislocation of the hooks. The Luque system, which consists of sublaminar wires and posterior rods, was developed during the 1970's.[23,24] Roy-Camille, Judet[25] and

Louis[26] pursued the use of pedicle screws with connecting plates between the screws. Fritz Magerl developed a system in which he inserted Schanz screws into the pedicles either percutaneously or by open surgery.[27] These were held in place by an external fixator. Dick and others have modified this system so that the fixator is internalised.[28,29] The last decade short segment pedicle screw fixation has become the gold standard for the posterior stabilization of thoracolumbar fractures and is used by surgeons all over the world.

## Diagnostics

The mechanism and the impact of the trauma, in combination with the complaints of the patient generally give rise to the suspicion of a spinal fracture. Mechanisms include fall from a height, deceleration trauma in traffic accidents but also in sports and especially horse riding.[30,31] If vital functions are impaired, treatment of spinal fractures can be delayed if the patient is immobilized.[90] Treatment of spinal fractures in trauma patients is always with respect of the general Advanced Trauma Life Support principles.[90] For the diagnosis of neurologic impairment in patients with thoracolumbar spine fractures an complete neurologic examination with respect to sensibility and motoric function is mandatory.[90]

Acute back pain, neurologic complaints, deformity of the spine, abrasions and ecchymosis, and a step-off or interspinous widening by palpation of the back add to the suspicion.[32]

Plain radiographs of the thoracic and lumbar spine in two directions are the initial forms of imagining for the vast majority of patients. (Figure 3 and 4) Special attention should be paid to the thoracolumbar junction. The patient must be in supine position..

About 5% of the thoracolumbar spine injuries are not recognised in the first diagnostic approach.[33] The main reason for delay is failure to take radiographs, not discovering a fracture on the radiograph, and, less common, patient delay. Other factors associated with delayed diagnosis include intoxication, polytrauma, decreased level of unconsciousness, and multi-level spine injuries. Four percent of patients with a spinal fracture have a fracture at a non-contiguous level.[34]

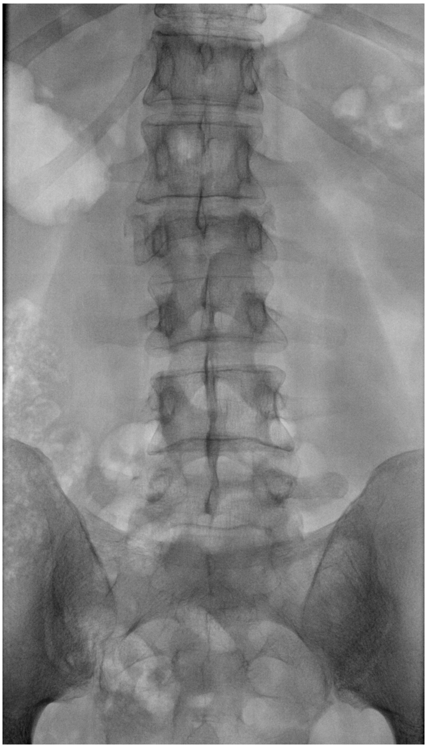


**Figure 3.** Plain posteroanterior X-ray of thoracolumbar spine

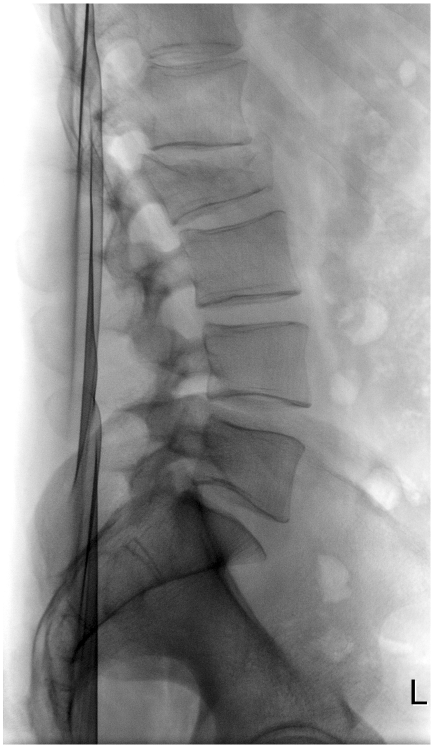



**Figure 4.** Plain lateral X-ray of thoracolumbar spine

Computer tomography (CT), including digital coronal and sagital reconstructions, is used to trace fractures that are not demonstrable on plain x-rays, to classify the fracture(s) and to assess stability. (Figure 5) Imaging of the vertebral bodies above and below the fracture level is necessary to assess concomitant fractures and the integrity of the pedicles which are to be used for pedicel screw fixation.[35]

Magnetic Resonance Imaging (MRI) is useful to diagnose injury to the soft tissues.[36] (Figure 6) Injury to the discoligamentous elements has influence on the stability of spine fractures and has implications in the use of ligamentotaxis for indirect canal decompression.[37] To differentiate AO type A or type B fractures[38], MRI can be used. In the majority of cases the intervertebral disc above the fracture shows evidence of injury, manifested either as increased signal intensity of T2-


**Figure 5.** CT image of vertebral fracture

weighted sequences or as a rupture of the disc into the vertebral body.[35] In the treatment of thoracolumbar spine fractures MRI will have more influence.[35,36,39,40]

**Figure 6.** MRI image of a rupture of the posterior ligament complex.

## Classification

Traumatic injuries of the thoracolumbar spine present with considerable heterogeneity in terms of causative mechanism, clinical presentation, and patterns of bone and soft-tissue injury. Recognition of various patterns of injury and grouping of these into a coherent classification is critical for the development of a rational plan of management.
Although the concept of spinal stability is intuitive to most clinicians, the issue of defining instability in the clinical setting continues to present problems in the context of acute trauma.

White and Panjabi defined clinical instability as the ability of the spine under

physiologic loads to maintain relationships between the vertebrae such that there is neither acute nor subsequent neurologic injury, deformity, or pain.[42]
Numerous schemes for the classification of injuries of the thoracolumbar spine have been developed.[32,43-49]

Watson-Jones subdivided thoracolumbar fractures in three basic morphologic types; simple wedge fracture, the comminuted fracture, and the fracture dislocation.[49] (Figure 7)

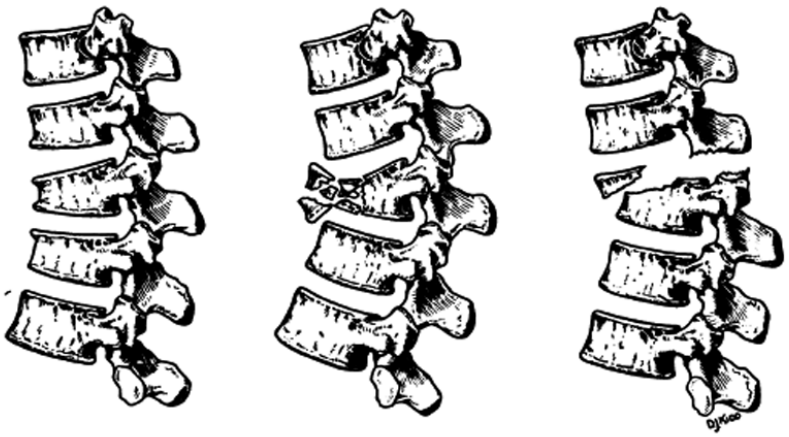


FIG. 1-A FIG. 1-B FIG. 1-C

**Three types of flexion compression fractures of vertebral bodies.**
**Fig. 1-A: Simple wedge fracture by diffuse bending or vertical compression; several bodies are involved; the discs are normal; ankylosis is rare. (151 cases.)**
**Fig. 1-B: Comminuted fracture by acute angulation; one body only is involved; the disc is ruptured; ankylosis is common. (33 cases.)**
**Fig. 1-C: Dislocation of the intervertebral joint with fracture of the neural arch; the cord is compressed or severed; there is a secondary fracture of the body below. (68 cases.)**

**Figure 7.** Three type of compression fracture of the vertebral body according to Watson-Jones.[49]

Nicoll subdivided fractures into stable and unstable categories, depending on disruption of the posterior ligament.[50]

Holdsworth introduced the much used two-column theory of spinal stability.[32] He divided the spine into two columns, anterior and posterior. (Figure 8)

In addition to this morphologic difference he introduced four mechanisms of injury: flexion, flexion-rotation, extension, and compression. Later, translation was

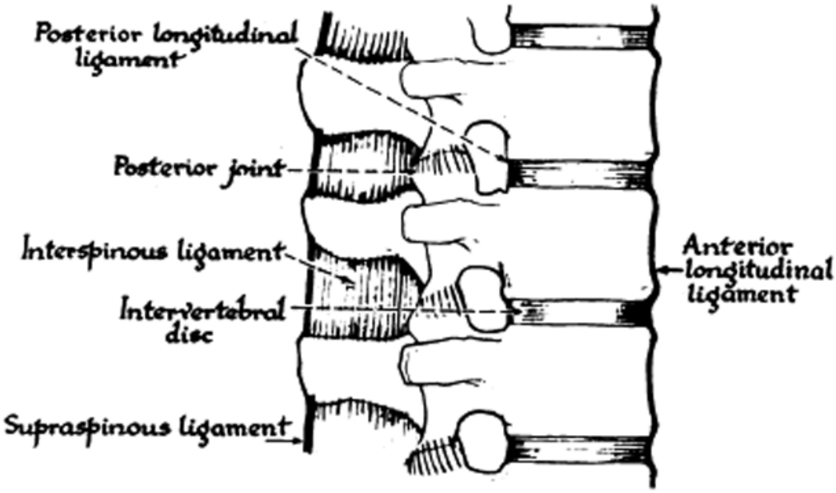



FIG. 1

**Diagram of the vertebral articulations with the principal ligaments. The intraspinous and supraspinous ligaments, the capsules of the lateral joints and the ligamentum flavum constitute the " posterior ligament complex."**

**Figure 8.** Posterior ligament complex as described by Holdsworth.[32]

added.[51] Stability was primarily determined by the state of the posterior column. The concept of Holdsworth has been modified by different authors but the two-column formulation was retained.[52,53]

After a review of 400 thoracolumbar fractures, Denis refined Holdsworth his classification and defined a third column, the middle.[43] The anterior column of the spine is defined by the anterior vertebral body, the adjacent annulus and disc, and the anterior longitudinal ligament. The middle column is comprised of the posterior aspect of the vertebral body, disc, and annulus and the posterior longitudinal ligament. The posterior column is the neural arch and facets and the posterior ligamentous complex. (Figure 9) His system consists of four major types of spinal injury: compression fractures, burst fractures, seat-belt type injury and fracture dislocations; each fracture is then further classified into one of sixteen subtypes.

Stability in Denis his scheme is based on the integrity of two of the three columns. McAfee combined the CT findings of 100 patients with some of the individual merits of the classification of Denis and the biomechanical evaluation of White and

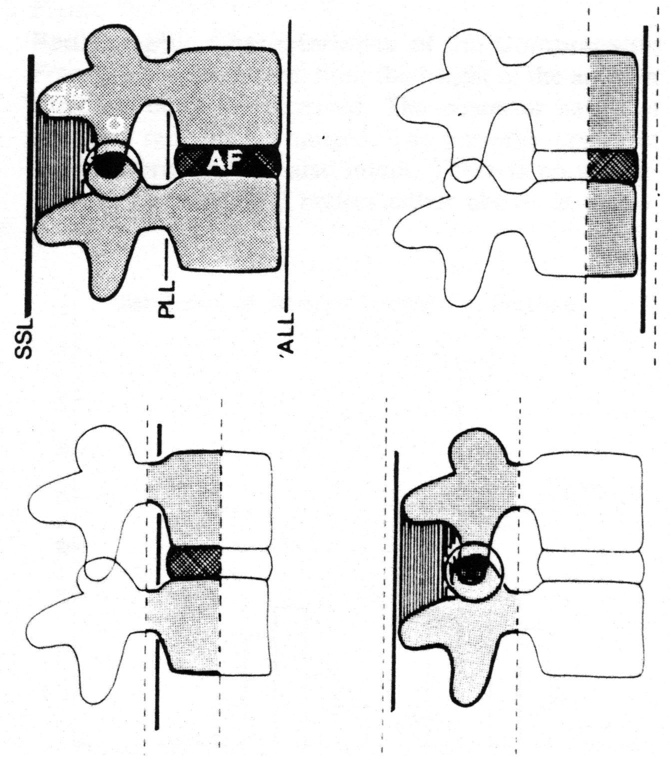



**Figure 9.** Three columns as defined by Denis.[48]

Panjabi.[47] The system is based on three forces as they act on the middle column: axial compression, axial distraction, and translation within the transverse plane. McAfee distinguished between stable and unstable fractures based on the integrity of the posterior ligamentous complex.[47,54]

Based on injury morphology, Magerl proposed a classification based on a scale of progressive morphological damage.[46] Three primary injuring forces were described: compression (A), distraction (B), and rotation (C). (Figure 10)

According to AO-principles these fractures are further classified into 3 groups (1, 2 and 3), which themselves each contain 3 sub-groups (1, 2 and 3), and further specification. Each type represents a principal injury mechanism, while the groups and sub-groups are based upon morphological characteristics, with ranking (1, 2 or 3) of the lesions according to progressive severity. The system can by explained in

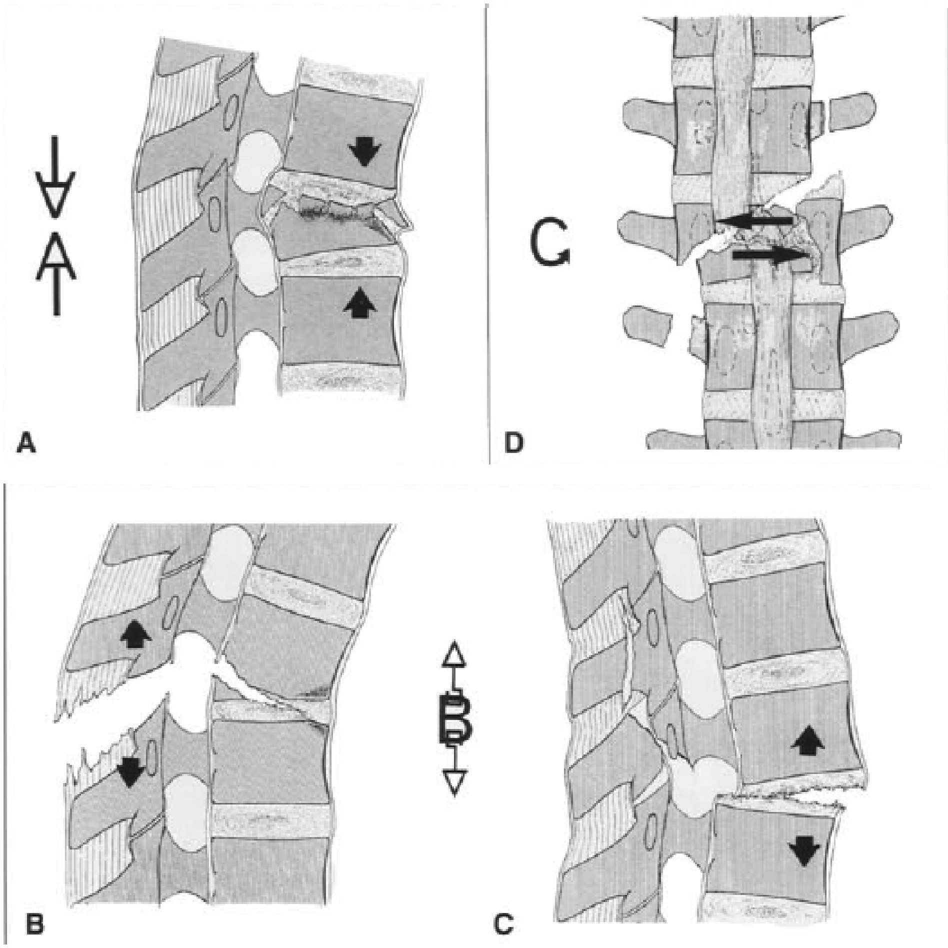



**Figure 10.** Classification of Magerl according to AO-principles.[46]

simple terms by saying that type A represents a compression mechanism (lesions located mainly in the vertebral body), with group A1 representing wedge impaction fractures; group A2, split fractures, and group A3, comminute or burst fractures. The mechanism in type B is distraction of the posterior or anterior structures (distinguishing in each case whether there is a lesion of the vertebral body and/or of the disc), with group B1 representing predominantly ligamentous posterior flexion-distraction injuries; group B2, predominantly osseous posterior flexion-distraction injuries; and group B3, hyperextension-shear injuries with disruption through the disc. Type C represents lesions caused by a rotational mechanism in addition to the mechanism of one of the types described above. Within this grid, the injuries are hierarchically ranked according to the progressive severity of the pathomorphological findings and the instability caused. This in turn makes it possible to suggest a prognosis for recovery, and to choose the most suitable method of treatment.[46] However, more than 50 fracture types are not very easy to use in clinical praxis. The mean interobserver agreement is 67%, when only the three main types (A, B, C) are used. The corresponding kappa value of the interobserver reliability shows a coefficient of 0.33. The reliability decreased by increasing the categories.[91]

McCormack and Gaines developed the Load Sharing Classification (LSC).[48] (Figure 11 )This classification was the result of an analysis of fixation failures after treatment with transpedicular short-segment fixation. Three aspects of the fracture are graded with a point system: comminution of the body, apposition of the fracture segments, and deformity correction. If the LSC score is seven or higher, dorsal fixation alone may not be sufficient.

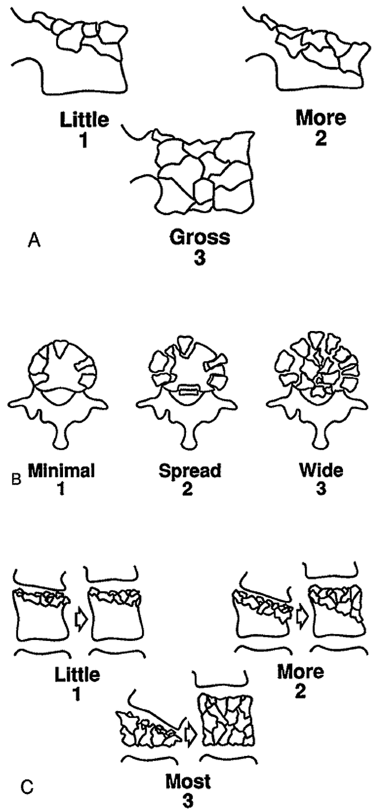


Figure 11. Load Sharing Classification according to McCormack.[48]

Based on MRI, Öner describes six different types of intervertebral disc: normal disc, black disc, Schmorl-type change, anterior collaps, central herniation and degenerated disc.[41] A more extensive categorization was made on, based on 100 fractures.[40] The clinical relevance was shown, but further development of prognostic criteria is necessary.[36] It is difficult to establish a relationship between MRI findings and existing classification systems.[40] These classifications will help rationalize the decisions about treatment options.Vaccaro *et al*. developed a classification system (Thoraco-Lumbar Injury Classification and Severity Score (TLICS), using three major categories: the morphology of the injury, the integrity of the posterior ligamentous complex, and the neurologic status of the patient. Based on the severity of these categories, specific points are allocated, and the sum of the points defines the possible treatment.[55,56] (Table 1)

**Table 1.** Thoracolumbar Injury Classification and Severity Score (TLICS)

| Component | Qualifier | Points |
|---|---|---|
| Morphology type: | | |
| Compression | Compression fracture | 1 |
| | Burst fracture | 1 |
| Translational/rotational | | 3 |
| Distraction | | 4 |
| Neurological involvement: | | |
| Intact | | 0 |
| Nerve root | | 2 |
| Cord, conus medullaris | Incomplete | 3 |
| | Complete | 2 |
| Cauda equina | | 3 |
| Posterior ligamentous complex: | | |
| Intact | | 0 |
| Injury suspected/indeterminate | | 2 |
| Injured | | 3 |

Injury morpology is based on plain radiographs, CT, and MRI and classified as compression, translation/rotation, or distraction.

Integrity of the Posterior Ligamentous Complex (PLC) can be examined clinically by palpation, and by imaging studies. The condition of the PLC is classified as intact, indeterminate, or disrupted. Neurological status is categorized as intact, nerve root or complete spinal cord injury (ASIA A), and incomplete spinal cord or cauda equina injury (ASIA B, C, or D).

A TLICS of 3 or less suggests that the injury amy be addressed nonoperatively, whereas a patient with a score of 5 or greater may benefit from surgery. A TLICS of

4 is regarded as "gray zone", treatment will be determined by the surgeon's opinion and patient issues.

## TREATMENT

Goals of the treatment of thoracolumbar spine fractures are: preventing (further) neurological damage and restoration of the mechanic and protecting function of the spine.

### Non-operative

Stable fractures without serious deformities can be treated conservatively, with early mobilization and physiotherapy aimed at improving posture and the strength of the abdominal and back muscles.

There is no class I or II evidence to support optimal nonoperative management for burst fractures. Bracing is universally used, but the role/duration of bed rest is not clear.[92] In our group unstable thoracolumbar spine fractures are treated with a course of six weeks on a rotorest bed.[58] A physiotherapy scheme is used to train trunk musculature. A Jewett hyperextension orthosis can be fitted and the patients are instructed to wear the brace at all times, except when bathing, for three months.[58] The orthosis functions by preventing gross motions of the trunk rather than preventing intervertebral mobility, but it reminds and helps the patient to keep the trunk straight.[59]

Follow-up is performed with plain radiographs of the thoracic and lumbar spine in two directions. When kyphosis is worsening it is probably an indication that the AO type A fracture is a type B instead.[38] MRI can be used to diagnose injury to the PLC. [36, 38]

### Operative

For most surgeons an absolute indication for operative treatment is a progressive, neurological deficit and an open spine fracture. In general most thoracolumbar spine fractures with accompanying neurologic deficit, the AO type B and C fractures are also considered to be indications for operative treatment.

There is much controversy about the indication for operative treatment of A3 fractures. Accompanying injury, age and general condition of the patient are always taken into account in the final decision to operate or not.

Spinal fractures should be considered a special category, similar to 'articular' injuries, because of the motion segment involving disc, facet joints, ligamentous structures and at least one adjacent vertebra. These injuries cannot always be 'reconstructed' in an anatomical fashion. AO principles can be applied: reconstruction of the anatomy, stable fixation respecting fundamental mechanic principles of the spine, short-segment fixation to maintain a maximum of mobile motion segments, and early mobilization. (Figure 12)

There are only two prospective randomized studies comparing conservative and surgical interventions.[60,61] The interpretation of the study of Woods et al. is complicated by the diversity of the patient groups. The study of Siebenga et al. is presented in this thesis.

Several questions remain unanswered, such as whether kyphotic deformity is associated with early or late manifestations of pain. Some studies argue that the degree of kyphosis does not correlate to clinical outcomes, others have demonstrated a relationship between significant deformity and increased pain.[62,63]

Spinal canal stenosis and its treatment have also not been shown to be associated with neurological symptoms. Surgical decompression does not appear to affect existing neurological deficits, probably because these arose at the time of the accident.[64] In fact, surgical decompression appears to improve the prognosis only when there is neurological deterioration in patients with an incomplete spinal cord injury (incidence of 3.4%).[65] Moreover, stenosis of the spinal canal resolves spontaneously with time as a result of remodelling.[66]

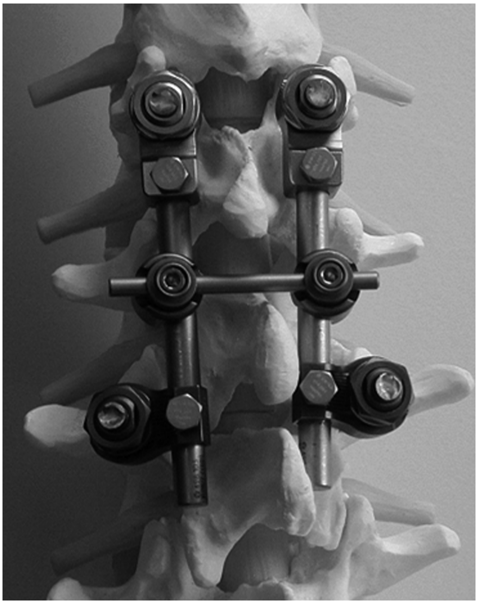


**Figure 12.** Universal Spine System Synthes Dorsal stabilization sytem with pedicle screws.

Evaluation of the functional outcome also provides no indication of whether conservative or surgical treatment is to be preferred. Some retrospective studies of unstable thoracolumbar fractures, without further subdivision by fracture type or neurological status, showed surgery to provide better results than conservative treatment.[67] However, conservative treatment also provides good results.[68,69] For example, in their prospective, non-randomized study, Shen et al compared the results of surgical dorsal stabilization and conservative treatment in 80 patients with a burst fracture at the thoracolumbar junction (T11–L2).[70] At 2 years spinal alignment was clearly better after surgery whereas there was no difference in functional outcome between the two types of treatment. A major advantage of surgery is the shorter period of immobilization, an argument that has long since been accepted when it comes to the treatment of many other fractures.

## Surgical Approaches

### Dorsal

The dorsal instrumentation of thoracolumbar spine fractures with angle-stable transpedicular anchored fixation systems is a mature and established treatment. There are different implants which can be used with minimal risk and with relative small operation trauma to secure a reconstruction of the spinal column. The intrinsic stability of these systems permit early mobilisation of the patient. The construction with a fixateur interne with rods, pedicle screws, and special joints which hold the pedicle screws in a stable angle, gives an effective dorsal fracture reposition and retention. (Figure 13 and 14)

The development of an angle-stable implant and pedicle screws, made it possible to go from multisegmental fixation to bisegmental fixation, thereby preserving the mobility of healthy motion segments not directly involved in the fracture. When necessary, pedicle screws can be used as a lever in the correction of kyphotic deformity and/or for distraction. As a result of distraction, fracture fragments causing spinal canal stenosis can be moulded into position (ligamentotaxis) if the posterior longitudinal ligament is intact. Fracture fragments that are not amenable to remoulding in this indirect manner can be left in place. A multicentre study in Germany showed that two-thirds of 682 patients underwent dorsal stabilization as sole treatment.[71]

A persisting problem with only dorsal stabilization is the loss of enduring stable reconstruction of the ventral portion of the vertebra in the long run. Even the method for transpedicular spongioplasty introduced by Daniaux et al[72] cannot prevent the increase in kyphosis caused by removal of fixation material.[73,74] Knop et al. observed that the surgical improvement of alignment, from kyphosis of mean –15.6 degrees to lordosis of mean 4 degrees, was largely lost when the fixative material was removed. In two-thirds of cases, transpedicular spongiosa-plasty is not effective. Narrowing of the intervertebral space also plays a role in the deterioration of alignment.[41,75,76]

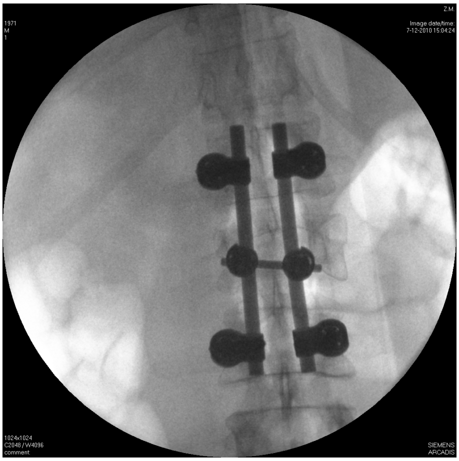


**Figure 13.** L2 fracture treated with USS AP view

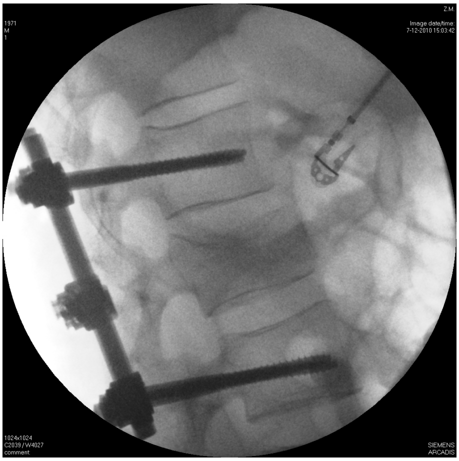


**Figure 14.** USS lateral view

McCormack et al observed in their cases that material failure was correlated with the nature of the fracture, which prompted them to develop a classification system.[48] This "load-sharing classification" (LSC) is solely intended to determine, preoperatively, whether dorsal stabilization will be sufficient or whether ventral stabilization will be necessary to prevent material failure and its consequences. In this system, the severity of comminution, the position of fracture fragments, and the extent to which kyphosis should be corrected are scored from 1 to 3. (See figure 11 on page 30) (LSC) The authors consider a score higher than 7 to indicate that dorsal fixation alone is inadequate.

### Ventral

Depending on the level of the lesion, the spinal column is operated on via thoracotomy, thoracophrenicolaparotomy, or retroperitoneal lumbotomy or laparatomy. In rare cases, in high thoracic fractures, the spinal column can be approached via partial sternotomy. The ventral/ventrolateral approach to the spinal column is undoubtedly more demanding than the dorsal approach in terms of duration of surgery, blood loss, and risk of pulmonary and gastrointestinal complications[71]; however, it does have a number of advantages. An advantage of this approach is that decompression can be performed under direct visualization. Bone fragments can be removed from the spinal canal without the need to mobilize the dural sack. Several authors recommend this approach for all burst fractures with neurological symptoms and significant spinal canal stenosis.[78,79] Increased use of minimally invasive
techniques will substantially reduce operative trauma.[77]

A high loading stability can be achieved with an autogenic/allogenic bone strut, for example a tricortical iliac strut graft or a cage with cancellous bone, in combination with anterior fixation techniques.[80,81] In more than 90% of cases, ventrally stabilized fractures result in successful spondylodesis, which allows a better maintenance of alignment.[72,82] Standard practice is to bridge two segments to achieve spondylodesis between the vertebra caudal and cranial to the fractured vertebra. In some cases, especially with incomplete burst fractures in which the inferior end plate is intact, it is possible to achieve interbody fusion of one segment.[83]

Literature showes an advantage for the use of distractable cages instead of iliac bone strut grafts. Iliac bone graft harvesting causes major complications in 10% and minor complications in 39%.[96] Even 1 year after surgery a significant rate of the patients have persistent pain and morbidity with functional limitations.[97] After a follow-up of 30 months distractable cages showed a significantly better radiological results with less kyphotic deformity and loss of correction.[98]

### Combined

A dorsal stabilization can be performed in the acute stadium and a ventral stabilization a few days later. The advantages of the dorsal stabilization (relatively simple acces, possibility of acute decompression, short operation time, good reduction and minor bloodloss) are combined with advantages of the ventral stabilization (reconstruction of the ventral column, with more load bearing capacity and the possibility of complete decompression under direct vision)[85] (Figure 15 and 16)

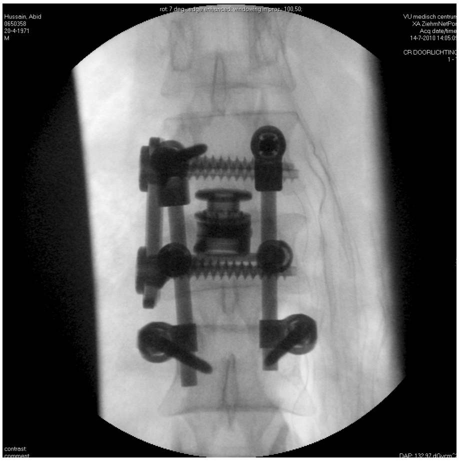


**Figure 15.** Combined anterior and posterior stabilization AP view

**Figure 16.** Combined stabilization lateral view

## Currrent developments

In accordance with the tendency in surgery for minimal invasive treatment this is also true for the stabilization of thoracolumbar fractures. Minimal invasive dorsal techniques as well as anterior approaches have been developed the last decades. De main advantage is the reduction in operative trauma, but less pain, faster mobilization, less bloodloss and a reduction in length of stay has also been demonstrated.[88, 89] (Figure 17 and 18)

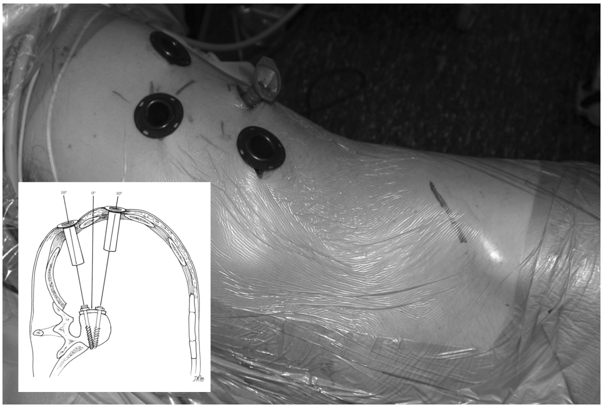


**Figure 17.** Per-operative view of minimal invasive combined approach to thoracolumbar spine

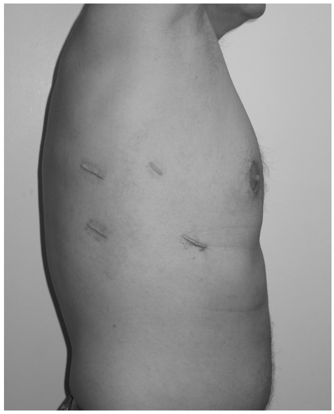


**Figure 18.** Postoperative result of minimal invasive combined anterior end posterior stabilization

Nowadays, most companies offer minimal invasive products for anterior constructs and for dorsal stabilization like cages (Synex® / Synthes, Obelisc® / Ulrich)[87] and plate and rod systems (i.e. MACS TL® / Aesculap), thoracolumbar spine locking plate, Synthes).[88] The complication rate of the endoscopic procedure is of the same scale as that known from the open procedures, with clear advantages in terms of reduced access morbidity associated with minimally invasive techniques.[88, 89] (Figure 19)

There has been significant development in navigation techniques. Initial aim of navigation was to increase the accuracy of pedicle screw placement, another positive effect is the reduced radiation exposure for the patient, surgeon and operating team.[93, 94] 3D C-arms are being used more often and can be connected to navigation systems for planning and controlling screw positions.[95]

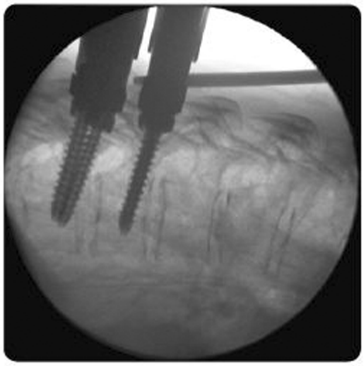


**Figure 19.** The CD-Horizon Longitude from Medtronic ® for minimal invasive posterior stabilization.

## References

1. Hu R, Mustard CA, Burns C. Epidemiology of incident spinal fracture in a complete population. Spine 1996 Feb 15;21(4):492-9.
2. Breasted JH. The Edwin Smith surgical papyrus. University of Chicago; 1930.
3. Lyons AS, Petrucelli RJ, II. Medicine - An Illustrated History. New York: Abradale Press and Harry N. Abrams, Inc., Publishers; 1987.
4. Chadwick J, Mann WN. The medical works of Hippocrates. 1950.
5. Clendening L. Source book of medical history. New York: Dover; 1942.
6. Orbanius. Oeuvres d'Oribase. Paris: Darenberg Edition; 1862.
7. Brok AJ. Greek medicine. London: J.M. Dent & Sons; 1929.
8. Ball JM. Andreas Vesalius. St. Louis Medical Science Press; 1910.
9. Pare A. Oeuvres. Paris: 1958.
10. Wiltse LL. The History of Spinal Disorders. In: Frymoyer JW, Ducker BD, Kostuik JP, Hadler NM, Weinstein JN, Whitecloud III TS, editors. The Adult Spine - Principles and Practice. 1 ed. New York: Raven Press; 1991. p. 3-41.
11. Wilkins BF. Separation of the vertebrae with protrusion of hernia between the same-operation-cure. St Louis Med Surg J 1888;(54):340-1.
12. Hadra BE. Wiring the spinous processes in Pott's disease. Trans Amer Orthop Assoc 1891;(4):206-10.
13. Lange F. Support for the spondylitic spine by means of buried steel bars, attached to the vertebrae. Am J Orthop Surg 1910;(8):344-61.
14. Albee FH. Transplantation of a portion of the tibia into the spine for Pott's disease. JAMA 1911;(57):885.
15. Bohler J. [Conservative treatment of spinal injuries yesterday and today]. Z Orthop Ihre Grenzgeb 1992;130(6):445-6.
16. Szyszkowitz R. Lorenz Böhler (1885-1973). AO Dialogue 2002 Jun;15(1):16-7.
17. Wilson PDSr, Danforth MS. The use of a metal plate fastened to the spinous processes. 1952. Ann Arbor, Michigan, American Academy of Orthopaedic Surgeons Instructional Course Lecture.
18. King D. Internal fixation for lumbosacral fusion. J Bone Joint Surg Am 1948;(30):560-5.
19. Boucher HH. A method of spinal fusion. J Bone Joint Surg Br 1959;(41b):248-59.

20. Harrington PR. Treatment of scoliosis: Correction and internal fixation by spine instrumentation. J Bone Joint Surg Am 1962;(44a):591-610.
21. Harrington PR. Technical details in relation to the successful use of instrumentation in scoliosis. Orthop Clin North Am 1972;3(1):49-67.
22. Harrington PR, Dickinson JH. Spinal instrumentation in the treatment of severe progressive spondylolisthesis. Clin Orthop 1971;(117):157-63.
23. Luque ER. The anatomic basis and development of segmental spinal instrumentation. Spine 1982;(7):256-9.
24. Luque ER. Interpenduncular segmental fixation. Clin Orthop 1986;(203):54-7.
25. Roy Camille R, Saillant G, Mazel C. Internal fixation of the lumbar spine with pedicle screw fixation. Clin Orthop 1986;(203):7-17.
26. Louis R. Fusion of the lumbar and sacral spine by internal fixation with screw plates. Clin Orthop 1986;(203):18-33.
27. Magerl F. External skeletal fixation of the lower thoracic and upper lumbar spine. Current concepts of external fixation of fractures.Berlin: Springer Verlag; 1982.
28. Aebi M, Etter C, Kehl T, Thalgott J. The internal skeletal fixation system. A new treatment of thoracolumbar fractures and other spinal disorders. Clin Orthop 1988;227:30-43.
29. Dick W, Kluger P, Magerl F, Woersdorfer O, Zach G. A new device for internal fixation of thoracolumbar and lumbar spine fractures: the 'fixateur interne'. Paraplegia 1985;23(4):225-32.
30. Knop C, Blauth M, Buhren V, Hax PM, Kinzl L, Mutschler W, et al. [Surgical treatment of injuries of the thoracolumbar transition. 1: Epidemiology]
[Operative Behandlung von Verletzungen des thorakolumbalen Ubergangs. Teil 1: Epidemiologie.]. Unfallchirurg 1999 Dec;1999 Dec;102(12):924-35.
31. Siebenga J, Segers MJ, Elzinga MJ, Bakker FC, Haarman HJ, Patka P. Spine fractures caused by horse riding. Eur Spine J 2006 Apr;15(4):465-71.
32. Holdsworth F. Fractures, dislocations, and fracture-dislocations of the spine. J Bone Joint Surg 1963 Feb;45B(1):6-20.
33. Reid DC, Henderson R, Saboe L, Miller JD. Etiology and clinical course of missed spine fractures. J Trauma 1987;27(9):980-6.
34. Kewalramani LS, Taylor RG. Multiple non-contiguous injuries to the spine. Acta Orthop Scand 1976 Feb;47(1):52-8.

35. Saifuddin A, Noordeen H, Taylor BA, Bayley I. The role of imaging in the diagnosis and management of thoracolumbar burst fractures: current concepts and a review of the literature. Skeletal Radiol 1996 Oct;25(7):603-13.
36. Oner FC, van Gils AP, Faber JA, Dhert WJ, Verbout AJ. Some complications of common treatment schemes of thoracolumbar spine fractures can be predicted with magnetic resonance imaging: prospective study of 53 patients with 71 fractures. Spine 2002 Mar 15;2002 Mar 15;27(6):629-36.
37. Harrington RM, Budorick T, Hoyt J, Anderson PA, Tencer AF. Biomechanics of indirect reduction of bone retropulsed into the spinal canal in vertebral fracture. Spine 1993;18(6):692-9.
38. Leferink VJ, Veldhuis EF, Zimmerman KW, ten Vergert EM, ten Duis HJ. Classificational problems in ligamentary distraction type vertebral fractures: 30% of all B-type fractures are initially unrecognised. Eur Spine J 2002 Jun;2002 Jun;11(3):246-50.
39. Goldberg AL, Daffner RH, Schapiro RL. Imaging of acute spinal trauma: an evolving multimodality approach. Clin Imaging 1990 Mar;14(1):11-6.
40. Oner FC, van Gils AP, Dhert WJ, Verbout AJ. MRI findings of thoracolumbar spine fractures: a categorisation based on MRI examinations of 100 fractures. Skeletal Radiol 1999 Aug;28(8):433-43.
41. Oner FC, van der Rijt RR, Ramos LM, Dhert WJ, Verbout AJ. Changes in the disc space after fractures of the thoracolumbar spine. J Bone Joint Surg Br 1998 Sep;1998 Sep;80(5):833-9.
42. White AI, Panjabi MM. Clinical Biomechanics of the spine.Philadelphia: J.B. Lippincott; 1978.
43. Denis F. The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. Spine 1983 Nov;8(8):817-31.
44. Ferguson RL, Allen-BL J. A mechanistic classification of thoracolumbar spine fractures. Clin Orthop 1984 Oct;(189):77-88.
45. Gertzbein SD, Court-Brown CM. Flexion-distraction injuries of the lumbar spine. Mechanisms of injury and classification. Clin Orthop 1988 Feb;227:52-60.
46. Magerl F, Aebi M, Gertzbein SD, Harms J, Nazarian S. A comprehensive classification of thoracic and lumbar injuries. Eur Spine J 1994;3(4):184-201.
47. McAfee PC, Yuan HA, Fredrickson BE, Lubicky JP. The value of computed tomography in thoracolumbar fractures. An analysis of one hundred consecutive cases and a new classification. J Bone Joint Surg Am 1983;65(4):461-73.

48. McCormack T, Karaikovic E, Gaines RW. The load sharing classification of spine fractures. Spine 1994;19(15):1741-4.
49. Watson-Jones R. The results of postural reduction of fractures of the spine. J Bone Joint Surg 1938;20:567-86.
50. Nicoll EA. Fractures of the dorso-lumbar spine. J Bone Joint Surg Br 1949;31B(3):376-94.
51. Holdsworth F. Fractures, dislocations, and fracture-dislocations of the spine. J Bone Joint Surg Am 1970 Dec;52(8):1534-51.
52. Dewald RL. Burst fractures of the thoracic and lumbar spine. Clin Orthop 1984;(189):150-61.
53. Kelly RP, Whitesides-TE J. Treatment of lumbodorsal fracture-dislocations. Ann Surg 1968 May;167(5):705-17.
54. McAfee PC, Yuan HA, Lasda NA. The unstable burst fracture. Spine 1982;7(4):365-73.
55. Lee JY, Vaccaro AR, Lim MR, Oner FC, Hulbert RJ, Hedlund R, et al. Thoracolumbar injury classification and severity score: a new paradigm for the treatment of thoracolumbar spine trauma. J Orthop Sci 2005 Nov;10(6):671-5.
56. Vaccaro AR, Baron EM, Sanfilippo J, Jacoby S, Steuve J, Grossman E, et al. Reliability of a novel classification system for thoracolumbar injuries: the Thoracolumbar Injury Severity Score. Spine 2006 May 15;31(11 Suppl):S62-S69.
57. Magnus G. Die Behandlung und begutachtung des Wirbelbruches. Archiv für Orthopädische und Unfall-Chirrugie 1930 Oct 3;29(19):277-83.
58. Hartman M.B., Chrin A.M., Rechtine G.R. Non-operative treatment of thoracolumbar fractures. Paraplegia 1995;33(2):73-6.
59. Axelsson P., Johnsson R., Stromqvist B. Effect of lumbar orthosis on intervertebral mobility. A roentgen stereophotogrammetric analysis. Spine 1992;17(6):678-81.
60. Siebenga J, Leferink VJ, Segers MJ, Elzinga MJ, Bakker FC, Haarman HJ, et al. Treatment of traumatic thoracolumbar spine fractures: a multicenter prospective randomized study of operative versus nonsurgical treatment. Spine 2006 Dec 1;31(25):2881-90.
61. Wood K, Butterman G, Mehbod A, Garvey T, Jhanjee R, Sechriest V. Operative compared with nonoperative treatment of a thoracolumbar burst fracture without neurological deficit. A prospective, randomized study. J Bone Joint Surg Am 2003 May;2003 May;85-A(5):773-81.
62. Gertzbein SD. Scoliosis Research Society. Multicenter spine fracture study. Spine 1992 May;17(5):528-40.

63. Weinstein JN, Collalto P, Lehmann TR. Thoracolumbar "burst" fractures treated conservatively: a long- term follow-up. Spine 1988;13(1):33-8.
64. Korovessis P, Piperos G, Sidiropoulos P, Karagiannis A, Dimas T. Spinal canal restoration by posterior distraction or anterior decompression in thoracolumbar spinal fractures and its influence on neurological outcome. Eur Spine J 1994;3(6):318-24.
65. Gertzbein SD. Neurologic deterioration in patients with thoracic and lumbar fractures after admission to the hospital. Spine 1994;19(15):1723-5.
66. Klerk LWLd. Burst fractures of the thoracic and lumbar spine; Operative versus Conservative treatment University Hospital Rotterdam, Department of Orthopaedics; 1994.
67. Denis F, Armstrong GW, Searls K, Matta L. Acute thoracolumbar burst fractures in the absence of neurologic deficit. A comparison between operative and nonoperative treatment. Clin Orthop 1984;(189):142-9.
68. Cantor JB, Lebwohl NH, Garvey T, Eismont FJ. Nonoperative management of stable thoracolumbar burst fractures with early ambulation and bracing. Spine 1993;18(8):971-6.
69. Chow GH, Nelson BJ, Gebhard JS, Brugman JL, Brown CW, Donaldson DH. Functional outcome of thoracolumbar burst fractures managed with hyperextension casting or bracing and early mobilization [see comments]. Spine 1996 Sep 15;21(18):2170-5.
70. Shen WJ, Liu TJ, Shen YS. Nonoperative treatment versus posterior fixation for thoracolumbar junction burst fractures without neurologic deficit. Spine 2001 May 1;2001 May 1;26(9):1038-45.
71. Knop C, Blauth M, Buhren V, Hax PM, Kinzl L, Mutschler W, et al. [Surgical treatment of injuries of the thoracolumbar transition. 2: Operation and roentgenologic findings] Unfallchirurg 2000 Dec;2000 Dec;103(12):1032-47.
72. Daniaux H. [Transpedicular repositioning and spongioplasty in fractures of the vertebral bodies of the lower thoracic and lumbar spine]
Transpedikulare Reposition und Spongiosaplastik bei Wirbelkorperbruchen der unteren Brust- und Lendenwirbelsaule. Unfallchirurg 1986 May;89(5):197-213.
73. Alanay A, Acaroglu E, Yazici M, Oznur A, Surat A. Short-segment pedicle instrumentation of thoracolumbar burst fractures: does transpedicular intracorporeal grafting prevent early failure? Spine 2001 Jan 15;2001 Jan 15;26(2):213-7.
74. Knop C, Fabian HF, Bastian L, Blauth M. Late results of thoracolumbar fractures after posterior instrumentation and transpedicular bone grafting. Spine 2001 Jan 1;2001 Jan 1;26(1):88-99.

75. Knop C, Blauth M, Bastian L, Lange U, Kesting J, Tscherne H. [Fractures of the thoracolumbar spine. Late results of dorsal instrumentation and its consequences]
Unfallchirurg 1997 Aug;100(8):630-9.
76. Lindsey RW, Dick W. The fixateur interne in the reduction and stabilization of thoracolumbar spine fractures in patients with neurologic deficit. Spine 1991;16(3 Suppl):S140-5.
77. Buhren V, Beisse R, Potulski M. [Minimally invasive ventral spondylodesis in injuries to the thoracic and lumbar spine]
Chirurg 1997 Nov;1997 Nov;68(11):1076-84.
78. An HS, Lim TH, You JW, Hong JH, Eck J, McGrady L. Biomechanical evaluation of anterior thoracolumbar spinal instrumentation. Spine 1995 Sep 15;1995 Sep 15;20(18):1979-83.
79. Shono Y, McAfee PC, Cunningham BW. Experimental study of thoracolumbar burst fractures. A radiographic and biomechanical analysis of anterior and posterior instrumentation systems. Spine 1994;19(15):1711-22.
80. Knop C, Bastian L, Lange U, Oeser M, Zdichavsky M, Blauth M. Complications in surgical treatment of thoracolumbar injuries. Eur Spine J 2002 Jun;11(3):214-26.
81. Vieweg U, Solch O, Kalff R. [Vertebral body replacement system Synex in unstable burst fractures of the thoracic and lumbar spine--a retrospective study with 30 patients]. Zentralbl Neurochir 2003;64(2):58-64.
82. Haas N, Blauth M, Tscherne H. Anterior plating in thoracolumbar spine injuries. Indication, technique, and results. Spine 1991;16(3 Suppl):S100-11.
83. Miyakoshi N, Abe E, Shimada Y, Hongo M, Chiba M, Sato K. Anterior decompression with single segmental spinal interbody fusion for lumbar burst fracture. Spine (Phila Pa 1976 ) 1999 Jan 1;24(1):67-73.
84. Been HD, Bouma GJ. Comparison of two types of surgery for thoraco-lumbar burst fractures: combined anterior and posterior stabilisation vs. posterior instrumentation only. Acta Neurochir (Wien 1999;1999;141(4):349-57.
85. Bakker FC, Segers MJ, Patka P, Haarman HJThM. Operative Treatment of Thoracolumbar Spine Fractures. Osteosynthesis and Trauma Care 2005;13:208-13.
86. Prokop A, Lölein F, Chmielnicki M, Volbracht J. Minimal-invasive perkutane Instrumentation bei Wirbelsäulenfrakturen. Der Unfallchirurg 2009 Jul 1;112(7):621-8.
87. Reinhold M, Schmölz W, Canto F, Krappinger D, Blauth M, Knop C. Ein verbessertes Wirbelkörperersatzimplantat für die thorakolumbale Wirbelsäule. Der Unfallchirurg 2007 Apr 12;110(4):327-33.

88. Beisse R. Endoscopic surgery on the thoracolumbar junction of the spine. European Spine Journal 2010 Mar 1;19(0):52-65.
89. Kim DH, Jahng TA, Balabhadra RSV, Potulski M, Beisse R. Thoracoscopic transdiaphragmatic approach to thoracolumbar junction fractures. The Spine Journal 2005 May;4(3):317-28.
90. CBO. Richtlijn acute traumatische wervelletsels opvang, diagnostiek, classificatie en behandeling. 2009
91. Blauth M, Bastian L, Knop C et al. [Inter-observer reliability in the classification of thoracolumbar spinal injuries]. Orthopade 1999;28:662-81.
92. Sekhon L.H.S. Non-operative and Surgical Management of Thoracolumbar Burst Fractures: A Systematic Review. Chapter 37, p 369-382. In Vaccaro A.R., Fehlings M.G., Dvorak M.F. Spine and Spinal Cord Trauma - Evidence-Based Management.Thieme, New York 2011
93. Linhardt O., Perlick L., Luring C., Stern U., Plitz W., Grifka J. extracorporeal single dose and radiographic dosage in image-controlled and fluoroscopic navigated pedicle screw implantation. Z Orthop Ihre Grenzgeb. 205; 143: 175-179
94. Nolte L.P., Zamorano L., Visarius H., Berlemann U., Langlotz F., Arm E., Schwarzenbach O. Clinical evaluation of a system for precision enhancement in spine surgery. Clin Biochem (Bristol, Avon) 1995; 10: 293-303
95. Jarvers J.S., Katscher S., Franck A., Glasmacher S., Schmidt C., Blattert T., Josten C. 3D-based navigation in posterior stabilisations of the cervical and thoracic spine: problems and benefits. Results of 451 screws. Eur J Trauma Emerg Surg (2011) 37: 109-119
96. Banwart JC, Asher MA, Hassanein RS. Iliac crest bone graft harvest donor site morbidity. A statistical evaluation. Spine 1995 May 1;1995 May 1;20(9):1055-60
97. Kim DH, Rhim R, Ling L, Martha J, Swaim BH, Banco RJ, Jenis LG, Tromanhauser SG. Prospective study of iliac crest bone graft harvest site pain and morbidity. Spine J 2009 9(11): 886-92
98. Reinhold M, Knop C, Beisse R et al. [Operative treatment of traumatic fractures of the thoracic and lumbar spinal column: Part III: Follow up data]. Unfallchirurg 2009;112:294-316

What do we do on other fractures if the usual means do not suffice to keep the parts well adapted? We do the most natural thing in the world; we fix them to each other by direct means – clamps, nails, wires, sutures and so on. Now, there is no good reason why vertebral fractures should not enjoy similar advantages.
*Hadra (1891). Hadra, B. E.: Wiring the vertebrae as a means of immobilization in fractures and Pott's disease. Trans Am Orthop Assoc, 4: 206.*

# Chapter 3

## Treatment of Traumatic Thoracolumbar Spine Fractures: A Multicenter Prospective Randomized Study of Operative Versus Nonsurgical Treatment.

Siebenga, J.
Leferink, VJM.
Segers, MJM.
Elzinga, MJ.
Bakker, FC.
Haarman, HJThM.
Rommens, PM.
Ten Duis, H-J.
Patka, P.

*Spine. 2006; 31(25):2881-2890*

## Abstract

### Study design

Multi-center prospective randomized trial.

### Objective

To test the hypotheses that thoracolumbar AO type A spine fractures without neurological deficit, managed with short segment posterior stabilization will show an improved radiographical outcome and at least the same functional outcome as compared to non-surgically treated thoracolumbar fractures.

### Summary of Background Data

There are various opinions regarding the ideal management of thoracolumbar type A spine fractures without neurological deficit. Both operative and non-surgical approaches are advocated.

### Methods

Patients were randomized for operative or non-surgical treatment. Data sampling involved demographics, fracture classifications, radiographical evaluation and functional outcome.

### Results

Sixteen patients received non-surgical therapy, and eighteen received surgical treatment. Follow-up was completed for 32 (94%) of the patients after a mean of 4.3 years.

At the end of follow-up both local and regional kyphotic deformity was significantly less in the operatively treated group. All functional outcome scores (VAS Pain, VAS Spine Score and RMDQ-24) showed significantly better results in the operative group. The percentage of patients returning to their original jobs was found to be significantly higher in the operative treated group.

### Conclusions

Patients with a type A3 thoracolumbar spine fracture without neurological deficit should be treated by short segment posterior stabilization.

## Introduction

Most of the vertebral fractures are located in the thoracolumbar region Th10 – L4. AO type A fractures comprise approximately 66% of these fractures.[1] Despite the fact that these AO type A fractures are common, there are various opinions regarding the ideal management, especially in patients without an associated neurological deficit.

Both operative[2-17,17-22] and non-surgical[23-32,32-39] approaches are advocated.

Open reduction, internal fixation and spondylodesis offer the possibility of correction of deformity, early mobilization, reduced reliance on orthotic containment, and the protection against spinal malalignment or late neurological injury.[4,22,40-42] Non-operative care offers the avoidance of surgical intervention with its attendant morbidity.[43-47] Assessment of the success rate of the treatment modality should include radiological parameters, clinical results and complications as well as patient-reported outcomes regarding pain, daily function and return to work. A minimal follow-up time of two years is necessary to evaluate late effects.

Until now only one prospective randomized study comparing the operative and non-surgical treatment of thoracolumbar fractures regarding all the above mentioned parameters has been published.[48] However in this study different surgical techniques are employed including two to five-level posterior stabilization and spinal arthrodesis with pedicle screw-hook instrumentation and anterior two-level fibular and rib-strut constructs.[48] This heterogeneous operative group is difficult to compare with a group of non-operatively managed patients.

In this prospective multicenter study, patients with thoracolumbar AO type A fractures without associated neurological deficits are randomized for either surgical intervention using posterior short-segment transpedicular screw fixation[49] or non-surgical treatment consisting of a period of bed rest followed by mobilization with a Jewitt-type orthotic device.[50] The purpose of this study was to test the hypothesis that neurologically intact patients with a thoracolumbar AO type A vertebral fracture (AO type A1.1 excluded) who were managed with short segment posterior stabilization would have an improved long term radiographic outcome and at least the same level of long term functional outcome as compared to non-surgically treated patients with thoracolumbar fractures.

## Materials and Methods

### Inclusion and exclusion criteria

Three University Hospitals agreed to participate in a prospective randomized study. Patients were included on the following criteria: traumatic fracture of Th10 – L4, AO type A (compression fracture), no neurological deficit (ASIA/Frankel E), age 18 – 60 years and period between trauma and operative treatment less than 10 days. Exclusion criteria were AO type A.1.1 fracture, pregnancy, pathologic or osteoporotic fracture, patients with end-stage disease (ASA IV), patients with a history of previous back surgery, patients with a recent psychiatric history, patients using drugs or other illegal substances or patients presenting with any accompanying injury that might interfere with the treatment of the spine fracture or the mobilization scheme after hospital discharge (i.e. lower extremity injuries prohibiting early weight bearing motion).

All patients were included based on written informed consent. This study was approved by the local ethical committees of the three participating university medical centers.

### Work-up before treatment randomization

In a four and a half year period (1998 – 2002) thirty-four patients met the inclusion criteria and agreed to participate in this multicenter prospective randomized study. All factors contributing to the trauma mechanism were elucidated and physical examination was carefully performed with special emphasis on signs pointing towards AO type B (distraction) fractures such as large hematomas or ecchymosis on the backside, sharp pain at palpation of the spinous processes or a palpable gap between the spinous processes. Secondary and tertiary surveys were routinely performed to exclude other injuries compromising inclusion in this study. Standard radiological work-up consisted of plain lateral and anterior – posterior radiographs in focus with the injured spinal segment and extending at least two spinal levels cranial and caudal and a CT-scan with consecutive 3.0 millimeter or thinner axial slices including the same spinal levels as the radiographs. With use of the axial CT-scan images, 2.0 millimeter sagittal and coronal planar reconstruction images were made. MRI studies were not routinely performed. Fractures were classified according to both the AO comprehensive classification and the Load Sharing Classification

(LSC) of thoracolumbar fractures as described in the original publications.[1,51]

On admission all participants indicated their pre-existing and actual severity of pain on a 100 millimeter visual analog scale (VAS Pain) and completed a Roland-Morris Disability Questionnaire (RMDQ-24)[52] and VAS Spine Score[53] to assess any thoracolumbar dysfunction that they may have had before the injury.

**Methods of treatment**

After randomization, sixteen patients received non-surgical therapy, and eighteen received surgical treatment. The patients who were managed non-surgically were treated with a rehabilitation course on a Circ-O-Lectric® (Stryker Corporation, Kalamazoo, U.S.A.) or Rotorest® bed (KCI, San Antonio, U.S.A.).[50] Patients receiving non-surgical treatment had horizontal bed rest for a minimum period of five days, depending on pain and assessment of fracture instability. A standardized physiotherapy scheme was followed to train trunk musculature. Nadroparine 2850 IU daily was given as an anti-coagulant until the patient was discharged to the rehabilitation clinic. A Jewett hyperextension orthosis was fitted and the patients were instructed to wear the brace at all times, except when bathing, for three months.[50] The orthosis functions by preventing gross motions of the trunk rather than preventing intervertebral motion, but it reminds and helps the patient to keep the trunk in an upright position.[54] Compliance was not monitored after discharge from the hospital. Patients were advised not to engage in heavy work and sports for three months, except swimming or aqua therapy under strict control of a physiotherapist, but the patients were allowed normal daily activities and sedentary work when capable.

The patients who were randomized to receive operative intervention were managed with a short segment posterior stabilization using the titanium version of the Universal Spine System (Synthes, Bettlach, Switzerland).[49,55] Patients were taken to the operation room on a priority rather than an emergency basis. Gross reduction of kyphotic deformity was indirectly performed by positioning in a lordosing way on the operation table. Fine-tuning of regional sagittal alignment and restoration of vertebral body height was performed by manipulation of the pedicle screw construct. Pedicle screws were positioned in the levels above and below the fractured vertebra thus obtaining a bisegmental stabilization in all patients. A cross-link was used for added stability of the construct in case of a complete burst fracture (AO type

A3.3).[55-60] Autogenous bone-graft was harvested from the posterior pelvic crista for transpedicular spongioplasty or posterolateral monosegmental fusion at the discretion of the operating surgeon.[61] The intervertebral disc was not resected preceding a transpedicular spongioplasty.[62,63] Intraoperative neurological monitoring was not performed. Preoperative 1500 milligrams of cefuroxime was given intravenously as prophylactic antibiotic. Three days postoperative the patients were mobilized wearing a Jewett hyperextension orthosis for the next three months. A standardized physiotherapy scheme was followed to train trunk musculature. The same instructions with regard to activity and mobilization were given as in the non-operative treated group. After a period of nine to twelve months, the implant materials were removed to release moving segments, to reduce stress on neighboring vertebrae and to prevent screw breakage. Posterior implant materials were not removed in two patients with intraoperatively recognized AO type B fractures.

**Data sampling, follow-up and statistics**

Data were sampled for demographics, trauma mechanism, AO and LSC fracture classification, method of treatment, treatment associated complications, length of hospital stay, return to work and forced adjustments in professional careers. The patients were seen in the outpatient clinic every three months in the first two years and every six months in the following years. Radiographical evaluation took place at three, six, nine and twelve months after injury followed by yearly controls. Minimal follow-up was two years, definitive follow-up of all patients was at two years after closure of patient inclusion. Local sagittal angels (LSA) and regional sagittal angels (RSA) were measured, using digital radiological imaging systems as available in the different clinics. Kyphotic angulation was indicated with a minus sign and lordotic angulation with a plus sign. The local sagittal angle is the angle made by the upper and lower endplate of the fractured vertebra. Regional sagittal angulation is measured by the angle made by the upper endplate of the vertebra superior of the fractured vertebra and the lower endplate of the vertebra inferior to the fractured vertebra. (*figure 1*)

RMDQ-24, VAS Pain and VAS Spine Score were used to evaluate the patients' wellbeing. RMDQ-24 is a validated questionnaire to measure self-assessed disability due to back pain. The disability questionnaire was constructed by choosing statements from the Sickness Impact Profile.[52] Patients are given a score of one point for each of the 24 items of the questionnaire that were ticked. A patient's score could thus vary from zero (no disability) to 24 (severe disability).[52] The VAS Spine Score is developed in Hannover, Germany. The questionnaire is composed of 19 questions which are scored on a 100 millimeter visual analogue scale. The patient's perception of pain and restriction in activities, related to problems of the back, is measured. The score is calculated by taking the average score of all questions and can be any value between zero (severe disability) and 100 (no disability).[53] These functional scores were obtained every three months and at closure of the study, and were compared to the baseline-data directly before the accident. All scores were measured by an independent observer.

During every follow-up visit patients were asked whether or not they had resumed their professional careers and the date of return to work was estimated.[64,65] Any forced adjustments in careers or changes for physically less demanding occupations were notified. Working on therapeutic base or (non-voluntary) part time work were considered as forced adjustments.

Statistical evaluation included the use of the Mann-Whitney test as a non-parametric test to compare the distributions in the two treatment groups.

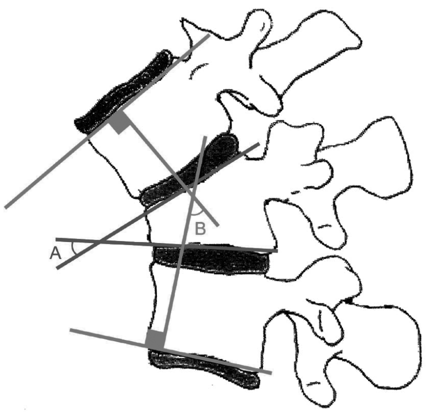



**Figure 1.** (A) Local sagittal angle (LSA). (B) Regional sagittal angle (RSA)

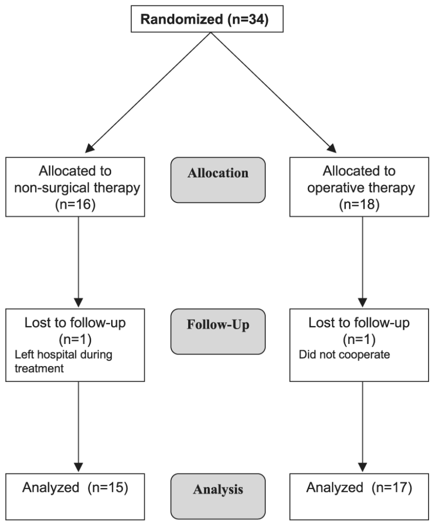



**Figure 2.** CONSORT diagram showing patient flow

Pearson's Chi square test was used for the analysis of categorical frequency data. Pearson's rank correlation test was performed to calculate correlation between radiographical results and functional outcome. The tests were performed using SPSS 12.0.1 for Windows (SPSS Inc., Chicago). The level of significance was set at $p < 0.05$.

## Results

### Patient demographics and fracture characteristics

Originally 34 patients could be included in this study. (diagram 1) Two patients were lost for follow-up. One of these two patients who received non-surgical therapy left the hospital against medical advice after one week of horizontal bed rest and could not be contacted again. The other patient was treated operatively and after an uneventful hospital stay he refused to cooperate in this study. The remaining 32 patients (94%) completed at least 2-year functional and radiological follow-up. Seventeen patients were randomized for operative treatment and 15 patients received non-surgical therapy. Mean age was 45.7 years (range 27 – 59) in the operatively treated patients and 37.3 years (range 18 – 53) in the non-surgical group (age difference not significant). The male to female ratio was 10:7 in the operative and 10:5 in the non-surgical group (not significant). More than 80% of the fractures appeared at the levels Th12 and L1, without a significant difference concerning fracture localization in the two treatment groups. The predominant trauma mechanisms leading to the thoracolumbar fracture were motor-vehicle accident and fall from height. At hospital admission 25 fractures (78%) were classified as type A3, 5 fractures as type A1 and 2 fractures as type A2 according to the comprehensive classification. There is no significant difference in distribution of various type A fractures between the two groups. During operation two type B fractures (distraction type) were identified showing evidence of injuries to the posterior ligamentous complex. (*Figure 2*). Both fractures were included in the study based on the intention to treat principle. In these two specific patients hardware was not removed. MRI studies were not routinely performed so the number of unrecognized type B fractures in the non-surgical group is unknown. As stated by Leferink et al. 30% of all B-type fractures are initially unrecognized.[66] The mean LSC score in the operatively treated patients was 6.5 (SD 1.12, range 4 – 8) and in the non-surgical group 6.1 (SD 0.96, range 4 – 9). Considering the LSC scores there was no significant difference between both groups.

Mean length of follow-up for both the operatively treated patients and for the non-surgical group was 4.3 years (SD 16.5, range 2.0 – 6.6 years operative group; SD 15.2, 2.0– 6.2 years non-surgical group).

An overview of all demographical and fracture related data is given in *table 1*.

### Treatment and complications

Seventeen patients received operative treatment consisting of a bisegmental posterior stabilization with either a transpedicular cancellous bone graft at the injured level or an attempted monosegmental posterolateral fusion between the injured level and the neighboring cranial spine segment. Average hospital stay accounted for 14.6 days (range 9 – 21). In the operative group five complications occurred in seventeen patients (29%). One patient suffered from severe pain at the side of the posterior pelvic crista where the cancellous bone graft for posterolateral fusion was harvested, leading to a prolonged period of analgetic medication. One patient suffered a deep wound infect which resulted in early hardware removal at one month after the initial surgery followed by a prolonged period of oral antibiotics. Another patient needed early implant removal at 6 months because of mechanical irritation of the transpedicular screws without signs of low grade infection or implant failure.

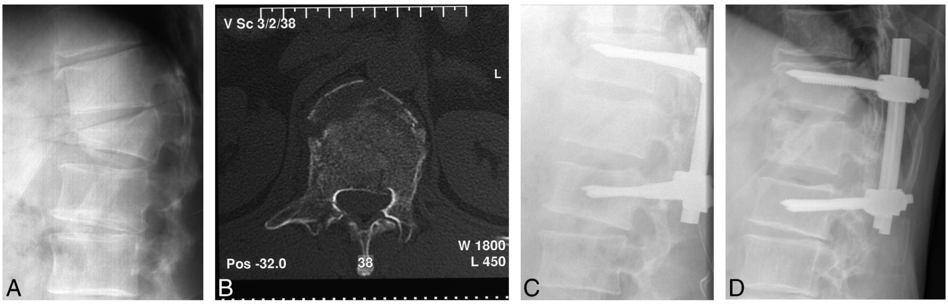



**Figure 3.** Patient with Type B.1.2 type fracture of L1 discovered during operation. Because of the posterior ligamentous injury, no instrumentation removal was performed. At final follow-up, this patient had a VAS Spine Score of 90 and a RMDQ-24 of 2. (A) Lateral radiograph on admission; (B) CT on admission; (C) Postoperative; (D) Final follow-up after 38 months.

**Table 1.** Patient Demographics and Fracture-Related Data

| Case No. | Gender | Age (yr) | Level | AO Type | LSC | Cause |
|---|---|---|---|---|---|---|
| Operative group | | | | | | |
| 1 | Female | 58 | L1 | A.3.1 | 6 | Fall |
| 2 | Male | 42 | L1 | A.3.3 | 8 | MVA |
| 3 | Male | 31 | L1 | A.3.2 | 7 | Sports related |
| 4 | Male | 36 | L1 | A.3.2 | 6 | Industrial accident |
| 5 | Female | 27 | L1 | A.3.3 | 7 | Fall |
| 6 | Male | 59 | L1 | A.1.2 | 5 | MVA |
| 7 | Male | 57 | L1 | A.3.1 | 7 | Fall |
| 8 | Male | 52 | L4 | A.2.3 | 8 | MVA |
| 9 | Male | 55 | T12 | A.3.1 | 6 | Fall |
| 10 | Female | 42 | L1 | A.3.1 | 5 | Fall |
| 11 | Male | 59 | L3 | A.3.3 | 6 | Fall |
| 12 | Female | 56 | T12 | A.3.3 | 7 | Fall |
| 13 | Female | 32 | L3 | A.2.3 | 7 | Fall |
| 14 | Female | 31 | L1 | A.3.2 | 6 | Sports related |
| 15 | Male | 53 | L1 | A.3.3* | 8 | Fall |
| 16 | Male | 48 | L1 | A.3.3* | 7 | Industrial accident |
| 17 | Female | 39 | L2 | A.3.1 | 4 | Sports related |
| Average | | 45.7 | | | 6.5 | |
| Nonsurgical group | | | | | | |
| 18 | Male | 18 | T12 | A.3.2 | 7 | Fall |
| 19 | Male | 53 | L1 | A.3.3 | 7 | Fall |
| 20 | Female | 21 | T12 | A.3.1 | 6 | MVA |
| 21 | Male | 36 | L1 | A.1.2 | 4 | MVA |
| 22 | Female | 58 | L1 | A.3.1 | 5 | Fall |
| 23 | Male | 46 | T12 | A.3.1 | 6 | Fall |
| 24 | Male | 46 | T12 | A.1.2 | 6 | Fall |
| 25 | Female | 53 | T12 | A.3.3 | 8 | MVA |
| 26 | Male | 39 | T12 | A.3.1 | 6 | Fall |
| 27 | Male | 32 | L1 | A.3.2 | 6 | MVA |
| 28 | Male | 19 | L1 | A.1.2 | 6 | Fall |
| 29 | Female | 29 | L1 | A.3.3 | 6 | Fall |
| 30 | Male | 18 | L3 | A.1.2 | 6 | Fall |
| 31 | Female | 44 | L2 | A.3.1 | 5 | Fall |
| 32 | Male | 47 | L1 | A.3.2 | 7 | MVA |
| Average | | 37.3 | | | 6.1 | |

MVA, motor vehicle accident.
*Intraoperative recognized B.1.2 fracture.

One patient showed breakage of two transpedicular screws without any clinical consequences. The fifth complication concerned a patient who had a superficial wound infection after implant removal treated with delayed skin closure.

Fifteen patients were randomized for non-surgical treatment. Hospital stay in this group averaged 12.2 days (range 6 – 25) before transfer to a rehabilitation clinic or ambulatory treatment on an out-patient basis. Three complications (20%) occurred in the non-surgical group. One patient developed signs of a conus medullaris syndrome and was prescribed distigmine bromide and tamsulosin hydrochloride for bladder dysfunction. (*Figure 3*). Another patient could not mobilize without orthotic containment even five years after the accident, suffered a severe depression and kept irrational fear for neurological detoriation. The third patient developed a scoliosis of 14° with late signs of nerve root compression one level caudal of the injured spinal segment. The prevalence of complications between the two groups was not found to be significantly different.

**Radiographic results**

On admission the average local (LSA) and regional sagittal angles (RSA) for the non-surgical group are -15.7° and -13.1° respectively. During follow-up this group showed an increasing kyphosis resulting in average LSA and RSA of -19.8° and -19.5° at final follow-up.

In the surgical group the pre-operative averages of LSA and RSA were -16.8° and -10.9° respectively, not significantly different from the non-surgical patients. After operative reduction and stabilization these angles decreased to -4.4° and -1.9° respectively, corresponding with a correction of 12.4° and 9° for LSA and RSA. During follow-up kyphotic deformity gradually increased to -8.4° and -8.6° for LSA and RSA. At final follow-up examination at closure of the study both local and regional kyphotic deformity were significantly less in the operative treated group. ($p<0.0001$) Radiological results are summarized in *table 2* and *figure 4*.

**Functional results**

For assessment of the functional results five different parameters were employed: VAS Pain, VAS Spine Score, RMDQ-24, percentage of patients that returned to work and time interval before return to work.

**Table 2.** Radiologic and Functional Outcome After Mean Length of Follow-up 4.3 Years*

| Case No. | Local Kyphosis at Admission | Regional Kyphosis at Admission | Local Kyphosis at Final Follow-up | Regional Kyphosis at Final Follow-up | VAS Pain Baseline |
|---|---|---|---|---|---|
| Operative group | | | | | |
| 1 | 24 | 15 | 3 | 8 | 78 |
| 2 | 13 | 22 | 7 | 20 | 100 |
| 3 | 24 | 15 | 15 | 15 | 95 |
| 4 | 10 | 10 | 10 | 14 | 85 |
| 5 | 20 | 16 | 14 | 14 | 100 |
| 6 | 18 | 6 | 3 | 1 | 100 |
| 7 | 20 | 14 | 12 | 12 | 100 |
| 8 | 18 | 3 | 12 | 0 | 100 |
| 9 | 17 | 17 | 15 | 17 | 95 |
| 10 | 20 | 10 | 1 | 2 | 79 |
| 11 | 5 | 2 | 0 | 1 | 100 |
| 12 | 12 | 10 | 26 | 22 | 95 |
| 13 | 9 | 0 | 6 | 4 | 97 |
| 14 | 17 | 8 | 9 | 12 | 99 |
| 15 | 30 | 22 | 8 | 12 | 89 |
| 16 | 25 | 15 | 6 | 9 | 80 |
| 17 | 4 | 0 | 0 | 8 | 99 |
| Average | 16.8 | 10.9 | 8.6 | 8.4 | 94 |
| Nonsurgical group | | | | | |
| 18 | 22 | 20 | 29 | 26 | 95 |
| 19 | 4 | 4 | 15 | 20 | 99 |
| 20 | 25 | 24 | 26 | 30 | 95 |
| 21 | 14 | 8 | 15 | 14 | 100 |
| 22 | 21 | 20 | 28 | 23 | 75 |
| 23 | 17 | 18 | 17 | 20 | 100 |
| 24 | 21 | 18 | 26 | 28 | 100 |
| 25 | 16 | 20 | 24 | 28 | 95 |
| 26 | 18 | 10 | 18 | 10 | 100 |
| 27 | 16 | 11 | 20 | 21 | 100 |
| 28 | 21 | 14 | 21 | 14 | 100 |
| 29 | 5 | 0 | 12 | 12 | 97 |
| 30 | 8 | 0 | 12 | 0 | 85 |
| 31 | 10 | 9 | 15 | 14 | 90 |
| 32 | 17 | 20 | 19 | 32 | 82 |
| Average | 15.7 | 13.1 | 19.8 | 19.5 | 94 |

*Range: operative group, 2.0 to 6.6 years; nonsurgical group, 2.0 to 6.6 years.

| VAS Pain at Final Follow-up | VAS Spine Baseline | VAS Spine at Final Follow-up | RMDQ-24 Baseline | RMDQ-24 at Final Follow-up | Follow-up (mo) |
|---|---|---|---|---|---|
| | | | | | |
| 55 | 61 | 45 | 6 | 14 | 75 |
| 100 | 100 | 100 | 0 | 0 | 79 |
| 95 | 99 | 99 | 0 | 0 | 70 |
| 76 | 86 | 58 | 0 | 13 | 69 |
| 90 | 100 | 94 | 0 | 2 | 62 |
| 100 | 87 | 86 | 0 | 0 | 64 |
| 100 | 100 | 100 | 0 | 0 | 58 |
| 100 | 66 | 65 | 1 | 2 | 52 |
| 95 | 62 | 62 | 0 | 0 | 54 |
| 79 | 74 | 74 | 0 | 1 | 44 |
| 100 | 100 | 86 | 0 | 0 | 43 |
| 70 | 98 | 89 | 0 | 6 | 41 |
| 82 | 100 | 76 | 0 | 5 | 38 |
| 99 | 93 | 92 | 0 | 0 | 38 |
| 86 | 90 | 90 | 0 | 2 | 38 |
| 80 | 75 | 74 | 3 | 3 | 28 |
| 77 | 95 | 88 | 0 | 4 | 24 |
| 87 | 87 | 81 | 0.6 | 3.1 | 51.6 |
| | | | | | |
| 80 | 90 | 80 | 2 | 4 | 74 |
| 60 | 98 | 29 | 0 | 15 | 72 |
| 65 | 100 | 55 | 0 | 10 | 70 |
| 15 | 87 | 11 | 0 | 24 | 69 |
| 65 | 97 | 54 | 0 | 9 | 69 |
| 98 | 100 | 94 | 0 | 0 | 52 |
| 90 | 100 | 82 | 0 | 13 | 51 |
| 65 | 89 | 53 | 0 | 14 | 42 |
| 100 | 100 | 100 | 0 | 0 | 48 |
| 100 | 100 | 86 | 0 | 0 | 43 |
| 65 | 74 | 34 | 0 | 15 | 42 |
| 65 | 100 | 56 | 0 | 10 | 41 |
| 80 | 99 | 80 | 0 | 0 | 41 |
| 55 | 88 | 46 | 0 | 15 | 40 |
| 80 | 94 | 62 | 0 | 5 | 24 |
| 72 | 94 | 61 | 0.1 | 8.9 | 51.9 |

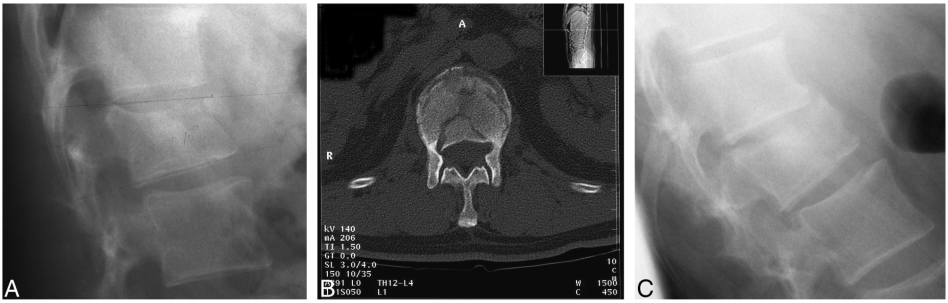



**Figure 4.** Patient with a Type A.3.3 fracture of L1 who presented without neurologic deficit but developed a conus medullaris syndrome. At final follow-up, this patient had a VAS Spine Score of 29 and a RMDQ-24 of 15. (A) Lateral radiograph on admission; (B) CT on admission; (C) Final follow-up after 72 months.

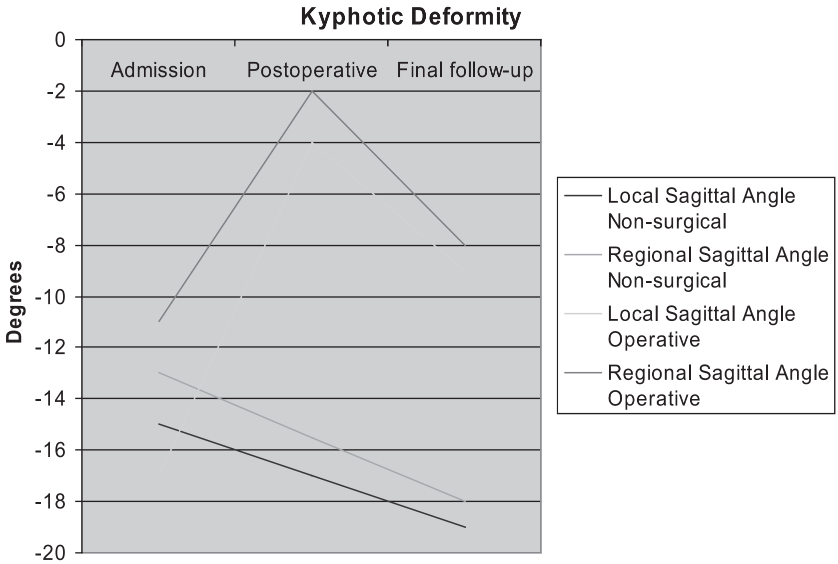



**Figure 5.** Development of kyphotic deformity from hospital admission to final follow-up. Mean length of follow-up was 4.3 years (range: operative group, 2.0–6.6 years; nonsurgical group, 2.0–6.2 years) Difference between operative and nonsurgical local and regional sagittal

The estimated pre-injury pain scores as measured by VAS Pain (0 = worst pain imaginable, 100 = no pain at all) averaged 94 mm (range 75 – 100) for the non-surgical group and also 94 mm (range 78 – 100) for the operative group. At final follow-up at closure of the study the average scores were 72 mm (15 – 100) and 87 mm (55 – 100) for the non-surgical and operative groups respectively. A significant difference in pain score was found in favor of the operative treated patients (p=0.033).

The estimated pre-injury VAS Spine Scores (0 = worst pain imaginable, 100 = no pain at all) averaged 94 (74 – 100) in the non-surgical group and 87 (61 – 100) in the operative group.(ns) At final follow up the VAS Spine scores measured 61 (11 – 100) for the non-surgical group versus 81 (45 – 100) for the operative group. This difference in score in favor of the operative treatment was significant (p=0.020).

The RMDQ-24 pre-injury functional disability scores (0 = no disability at all, 24 = severe disability) which were estimated on hospital admission, show no significant difference between the two treatment groups: with an average of 0.1 (0 - 2) for the non-surgical group and 0.6 (0 – 6) for the operative group. At final follow-up the average score measured 8.9 (0 – 24) for the non-surgical group and 3.1 (0 – 14) for the operative group. The patients receiving non-surgical treatment were found to have a significantly higher RMDQ-24 score in comparison with the operative group. (p=0.030)

**Table 3.** Summary of Functional Outcome Scores After Mean Length of Follow-up 4.3 Years*

| | Nonsurgical | Operative | P |
|---|---|---|---|
| VAS pain | 72 | 87 | 0.033 |
| VAS Spine | 61 | 81 | 0.020 |
| RMDQ | 9 | 3 | 0.030 |
| Return to work | 5/13 (38%) | 11/13 (85%) | 0.018 |
| Average time before return to work (mo) | 13.8 | 6.7 | NS |

NS, not significant. VAS Pain and VAS Spine Score: 0 worst pain imaginable;
100 no pain at all. RMDQ-24: 0 no disability; 24 complete disability.
*Range: operative group, 2.0 to 6.6 years; nonsurgical group, 2.0 to 6.6 years.

In both groups the Pearson's rank correlation test found no correlation between the final amount of local and regional kyphotic deformity and disability according to RMDQ-24 ($r = -0.30$, $p = 0.09$ for correlation with LSA and $r = -0.29$, $p = 0.11$ for correlation with RSA), VAS Spine Score ($r = 0.22$, $p = 0.23$ LSA and $r = 0.16$, $p = 0.39$ RSA) and VAS pain ($r = 0.20$, $p = 0.29$ LSA and $r=0.17$, $p=0.38$ RSA). An overview of functional results is given in *table 2* and a summary in *table 3*.

Five of thirteen (38%) patients with an employment record in the non-surgically treated group resumed their professional careers. Three of them returned to the same profession and two patients changed careers for physically less demanding employment. Average time between accidents and return to work was 13.8 months (range 6 – 33). Eleven of thirteen (85%) working patients in the operative group returned to their previous job and none of them was forced to change careers. Average time between the accident and return to work in the operative group was 6.7 months (range 1 – 18). The percentage of patients resuming their professional careers was found to be significantly higher in the operative group. ($p=0.018$) A significant difference concerning time before returning to work could not be shown.

## Discussion

Despite the fact that type A thoracolumbar spine fractures are common, there are various opinions regarding the optimal management, especially in patients with no neurological deficit. Until now there is no evidence based guideline for the treatment of traumatic thoracolumbar spine fractures and only one prospective, randomized study comparing non-surgical and operative treatment of neurologically intact patients with a thoracolumbar burst fracture is available.[48,67] This present study is, as far as we know, the second prospective randomized study comparing the two treatment modalities regarding both radiographic results as well as functional results such as pain, daily function and return to work after long term follow-up.[48]

The two treatment groups in our study were well matched for age, gender distribution, trauma mechanism, level of injury, AO type and LSC fracture classification.

Evaluation of different radiographic parameters such as local and regional sagittal angles could not demonstrate any significant difference with respect to sagittal malalignment between the two groups on admission. After surgical stabilization a significant reduction of local and regional sagittal angles could be shown. Although a considerable part of this reduction of kyphotic deformity was lost during follow-up, the operatively treated patients still showed a highly significant difference concerning sagittal malalignment compared to the non-surgical group. Pedicle screw-rod constructs have a temporary protective effect against collapse of the intervertebral space, but cannot prevent complete disc collapse after implant removal.[62,68] As in both treatment groups local and regional sagittal angles gradually increased after hospital discharge this could probably be explained by the combination of upper end-plate fracture settling with disc remnants creeping in a central bony depression under weight bearing motion and disc degeneration with intervertebral disc space narrowing. [62,68,69] Neither a transpedicular autologous bone graft nor an attempted monosegmental posterolateral fusion could completely prevent this sequence of events leading to recurrent kyphosis. In comparison with the prospective randomized study of Wood et al. we accomplished more intraoperative reduction of kyphosis.[48] This is probably a reflection of a different surgical technique i.e. employing the bisegmental pedicle screws as lever arms for reduction instead of multi-segmental pedicle screw-hook instrumentation or an anterior two-level fibular and rib strut grafts. Although Wood et al advocated the use of a Risser-like cast table for obtaining spinal alignment in the non-surgically treated patients this could not prevent an additional 2.50 of kyphosis at final follow-up as compared to the radiographs at admission. In this study the radiographical end results showed an increase in local kyphosis of 4.10 and 6.7° for regional kyphosis in the non-surgical group. No significant correlation could be shown between the degree of kyphotic deformity at the end of follow-up and functional outcome as measured by VAS Pain, VAS Spine Score or RMDQ-24. This notable lack of correlation between radiological results and functional outcome was already observed in 1987 and was also described in several other cohort studies including operative as well as non-operatively treated patients.[37,70-72] Until now we did not find any published data with an explanation for this phenomenon. As we compare the treatment groups we did find significantly less local and regional kyphotic deformity in the surgical group, but on an individual base we failed to show a relation between radiological and functional outcomes. One possible explanation may be purely statistical. (i.e. a statistical type 2 mistake: inadequate number of included patients to show a correlation that in fact does exist). However, the consistency of this lack of correlation throughout several decades offers room for speculation about other explanations: stabilization of the damaged spinal segments and indirect tensioning of the anterior and posterior longitudinal ligaments with a bisegmental transpedicular construct may protect for pain arising from interfragmentary micro movement especially in flexion and lateral bending. The vicious circle of micro movement, pain, hypertonic long back musculature and more pain may be mitigated by the motion limiting potential of the construct. Another reason may be a subjective feeling of security as the patients acknowledge that 'all has been done' to protect their spine from neurological damage. Perhaps this reassuring feeling makes these patients more compliant to the early rehabilitation physiotherapy schemes. Subsequent radiological controls in the outpatient clinic showing minimal or no changes in kyphotic angles may amplify this feeling of security.

Both for the pain level and functional outcomes, significant differences were found in favor of the operative treatment at final follow-up examination. Several other non-randomized studies are supporting this favorable outcome. [6,13,18,20,73,74] In the non-operative group one patient (no. 21) could be considered as an extreme negative outlier. In this patient VAS Pain deteriorated from 100 to 15, VAS Spine from 87 to 11 and RMDQ-24 from 0 to 24. An explanation for this outlier in the non-operative group is the possibility of an unrecognized AO type B fracture as we did not perform MRI imaging in this study protocol. Chronic ligamentous posterior instability may well provoke severe lower back pain. Another possibility in this case is a very strong psychosomatic component. Even nearly six years after the accident, the patient described extreme fears for acute neurological detoriation and has a subjective feeling of instability. As the patient did not have any history of psychiatric disorders, he was included in the study. During follow-up he progressively deteriorated in spite of consultation of several pain specialist anesthesiologists and use of both neuroleptic analgesics as well as anti-depressive medication. It is clear that the functional outcome parameters in this patient have a negative influence on the overall results in the non-operative group. If we disregard this patient and compare the functional outcome results, the p-values change but still remain (nearly) significant in favor of a surgical approach: VAS Pain $P=0.057$, VAS Spine $P=0.035$ and RMDQ $P=0.046$.

The VAS Pain and functional results are also in contradiction with the previously mentioned randomized study by Wood. Different explanations can be considered. VAS Pain can be influenced by a more extensive surgical approach needed for a multi-level posterior stabilization or by post-thoracotomy pain after an anterior approach. Wood *et al*. do not mention the removal of the posterior implants which can cause mechanical complaints and influence functional mobility of neighboring spinal motion units. Finally synchronous musculoskeletal injuries effecting weight bearing motion are neither described nor mentioned in the exclusion criteria of that study.[48] The difference between VAS Spine scores of 20 mm in favor of the operated group, can be considered clinically important.[75] Strikingly the RMDQ-24 scores of the two treatment groups at final follow-up examination in our study are completely reversed as compared to the final results of the previously mentioned randomized study by Wood. We found a significant difference of 6 in favor of operative treatment, this also can be considered as a clinical important result.[75] These results are reflected by the 85% of operated patients that could return to their former level of employment. Good results regarding return to work after surgical treatment are reported in several studies.[6,13,18,20] The patients that received non-surgical treatment had significantly worse results concerning this item as was previously described by other authors.[13,39,76,77] In average the patients treated operatively also returned to work 7.1 months earlier than the non-surgically treated group. Because of the wide range in times before return to work in both groups a significant difference concerning this item could not be shown. In general it is difficult to compare the duration for return to work with other studies because these results are probably a reflection of Dutch and German welfare systems and insurance policies.

The complication rate in our study is in agreement with those reported in other studies on both operative[78,79] and non-surgical treatment.[6,29,50] Neurological deterioration in non-surgically treated patients has earlier been reported.[6,29] Knop and also Garin reported a deep wound infection leading to hardware removal.[59,68] Pain at the donor site caused by harvesting cancellous bone is a common problem[80-82] and after the introduction of transpedicular bone grafting by Daniaux[61] several studies have appeared in which the benefit of these bone grafts is disputed.[83-85] A recent systematic review of the literature on techniques in the treatment of traumatic thoracolumbar spine fractures failed to show any advantage of transpedicular spongioplasty.[67] The efficacy of posterolateral cancellous bone grafts to obtain a monosegmental arthrodesis is also not equivocally proven.[68,86] In a future perspective the introduction of osteoconductive or even osteoinductive bone substitute materials could obliviate the need for autologous bone grafts and its related morbidity.

Interpretation of the results in our study has its limitations. Very strict exclusion criteria, especially the exclusion of patients with co-existing musculoskeletal injuries, has led to a small study group size. Results should be interpreted in perspective with this group size and with a wide range of data points inevitably leading to larger standard deviations and confidence intervals.[87] Although a power study is preferable when performing randomized controlled trials of this nature, well designed studies with sufficiently large group sizes are unavailable at this moment and are unlikely to appear in the near future. On the other hand, the employed inclusion and exclusion criteria and the strict protocols in this study have lead to very homogenous patient groups.[87] In the future the combination of different prospective randomized studies with sufficiently homogenous patient groups into a meta-analysis will provide more definitive answers regarding the ideal treatment of compression type thoracolumbar spinal fractures.

The purpose of this study was to test the hypotheses that neurologically intact patients with a thoracolumbar AO type A fracture (type A1.1 excluded) who were managed with short segment posterior stabilization would have an improved long term radiographical outcome and at least the same long term functional results compared to non-surgically treated patients. With respect to our findings these hypotheses seem valid.

Based on this study we advocate operative spinal deformity reduction and a short segment posterior stabilization for patients with AO type A3 thoracolumbar spine fractures (burst fracture) without neurological deficit. The included numbers of patients with AO type A1 and A2 fractures are too small to draw any firm conclusions regarding operative or non-operative treatment of these kind of fractures.

## REFERENCES


1 Magerl F, Aebi M, Gertzbein SD, Harms J, Nazarian S. A comprehensive classification of thoracic and lumbar injuries. Eur Spine J 1994;3(4):184-201.

2 Esses SI, Botsford DJ, Wright T, Bednar D, Bailey S. Operative treatment of spinal fractures with the AO internal fixator. Spine 1991;16(3 Suppl):S146-50.

3 Aebi M, Etter C, Kehl T, Thalgott J. The internal skeletal fixation system. A new treatment of thoracolumbar fractures and other spinal disorders. Clin Orthop 1988;227:30-43.

4 Akalm S, Kis M, Benli IT, Citak M, Mumcu EF, Tuzuner M. Results of the AO spinal internal fixator in the surgical treatment of thoracolumbar burst fractures. Eur Spine J 1994;3(2):102-6.

5 Danisa OA, Shaffrey CI, Jane JA, Whitehill R, Wang GJ, Szabo TA, et al. Surgical approaches for the correction of unstable thoracolumbar burst fractures: a retrospective analysis of treatment outcomes. J Neurosurg 1995;83(6):977-83.

6 Denis F, Armstrong GW, Searls K, Matta L. Acute thoracolumbar burst fractures in the absence of neurologic deficit. A comparison between operative and nonoperative treatment. Clin Orthop 1984;(189):142-9.

7 Esses SI, Botsford DJ, Kostuik JP. Evaluation of surgical treatment for burst fractures. Spine 1990;15(7):667-73.

8 Jacobs RR, Casey MP. Surgical management of thoracolumbar spinal injuries. General principles and controversial considerations. Clin Orthop 1984;(189):22-35.

9 Parker JW, Lane JR, Karaikovic EE, Gaines RW. Successful short-segment instrumentation and fusion for thoracolumbar spine fractures: a consecutive 41/2-year series. Spine 2000 May 1;2000 May 1;25(9):1157-70.

10 Schnee CL, Ansell LV. Selection criteria and outcome of operative approaches for thoracolumbar burst fractures with and without neurological deficit. J Neurosurg 1997 Jan;86(1):48-55.

11 Sturmer KM, Koeser K, Schax M, Hanke J. [Results of surgical management of unstable fractures of the thoracic and lumbar vertebrae]. Aktuelle Probl Chir Orthop 1994;43:67-81.

12 Gertzbein SD, Macmichael D, Tile M. Harrington instrumentation as a method of fixation in fractures of the spine. J Bone Joint Surg Br 1982;64(5):526-9.

13 Gotzen L, Puplat D, Junge A. [Indications, technique and results of monosegmental dorsal spondylodesis in wedge compression fractures (grade II) of the thoracolumbar spine]. Unfallchirurg 1992;95(9):445-54.

14 Lindahl S, Willen J, Irstam L. Unstable thoracolumbar fractures. A comparative radiologic study of conservative treatment and Harrington instrumentation. Acta Radiol Diagn Stockh 1985;26(1):67-77.
15 Romero J, Vilar G, Bravo P. Fractures of the dorsolumbar spine with neurological lesions. A comparison of different treatments. Int Orthop 1994;18(3):157-63.
16 Soreff J, Axdorph G, Bylund P, Odeen I, Olerud S. Treatment of patients with unstable fractures of the thoracic and lumbar spine: a follow-up study of surgical and conservative treatment. Acta Orthop Scand 1982 Jun;53(3):369-81.
17 Willen J, Lindahl S, Nordwall A. Unstable thoracolumbar fractures. A comparative clinical study of conservative treatment and Harrington instrumentation. Spine 1985;10(2):111-22.
18 Domenicucci M, Preite R, Ramieri A, Ciappetta P, Delfini R, Romanini L. Thoracolumbar fractures without neurosurgical involvement: surgical or conservative treatment? J Neurosurg Sci 1996 Mar;1996 Mar;40(1):1-10.
19 Yazici M, Atilla B, Tepe S, Calisir A. Spinal canal remodeling in burst fractures of the thoracolumbar spine: a computerized tomographic comparison between operative and nonoperative treatment. J Spinal Disord 1996 Oct;9(5):409-13.
20 Leferink VJM, Keizer H.J.E., Oosterhuis J.K., Sluis C.K.van der, Duis HJ ten. Functional outcome in patients with thoracolumbar burst fractures treated with dorsal instrumentation and transpedicular cancellous bone grafting. Eur Spine J 2003;12(3):261-7.
21 Dick W. [Dorsal stabilization of thoracic and lumbar vertebral injuries]. Langenbecks Arch Chir Suppl Kongressbd 1992;290-2.
22 Mayer H, Schaaf D, Kudernatsch M. [Use of internal fixator in injuries of the thoracic and lumbar spine]. Chirurg 1992;63(11):944-9.
23 Aglietti P, Di Muria GV, Taylor TK, Ruff SJ, Marcucci M, Novembri A, et al. Conservative treatment of thoracic and lumbar vertebral fractures. Ital J Orthop Traumatol 1983;9 Suppl:83-105.
24 Bohler J. [Conservative treatment of spinal injuries yesterday and today]. Z Orthop Ihre Grenzgeb 1992;130(6):445-6.
25 Cantor JB, Lebwohl NH, Garvey T, Eismont FJ. Nonoperative management of stable thoracolumbar burst fractures with early ambulation and bracing. Spine 1993;18(8):971-6.
26 Chow GH, Nelson BJ, Gebhard JS, Brugman JL, Brown CW, Donaldson DH. Functional outcome of thoracolumbar burst fractures managed with hyperextension casting or bracing and early mobilization [see comments]. Spine 1996 Sep 15;21(18):2170-5.

27 Kinoshita H, Nagata Y, Ueda H, Kishi K. Conservative treatment of burst fractures of the thoracolumbar and lumbar spine. Paraplegia 1993;31(1):58-67.

28 Krompinger WJ, Fredrickson BE, Mino DE, Yuan HA. Conservative treatment of fractures of the thoracic and lumbar spine. Orthop Clin North Am 1986 Jan;17(1):161-70.

29 Mumford J, Weinstein JN, Spratt KF, Goel VK. Thoracolumbar burst fractures. The clinical efficacy and outcome of nonoperative management. Spine 1993;18(8):955-70.

30 Nicoll EA. Fractures of the dorso-lumbar spine. J Bone Joint Surg Br 1949;31B(3):376-94.

31 Reid DC, Hu R, Davis LA, Saboe LA. The nonoperative treatment of burst fractures of the thoracolumbar junction. J Trauma 1988 Aug;28(8):1188-94.

32 Shen WJ, Shen YS. Nonsurgical treatment of three-column thoracolumbar junction burst fractures without neurologic deficit. Spine 1999 Feb 15;1999 Feb 15;24(4):412-5.

33 Watson-Jones R. The results of postural reduction of fractures of the spine. J Bone Joint Surg 1938;20:567-86.

34 Weinstein JN, Collalto P, Lehmann TR. Thoracolumbar "burst" fractures treated conservatively: a long- term follow-up. Spine 1988;13(1):33-8.

35 Kaltenecker G, Kwasny O, Maier R, Schurawitzki H, Hertz H. [Results after conservatively managed vertebral fractures of the thoracolumbar level with special reference to bony stenosis of the spinal canal]. Unfallchirurg 1992;95(3):118-23.

36 Klerk LWLd. Burst fractures of the thoracic and lumbar spine; Operative versus Conservative treatment University Hospital Rotterdam, Department of Orthopaedics; 1994.

37 Resch H, Rabl M, Klampfer H, Ritter E, Povacz P. [Surgical vs. conservative treatment of fractures of the thoracolumbar transition]
[Operative vs. konservative Behandlung von Frakturen des thorakolumbalen Ubergangs.]. Unfallchirurg 2000 Apr;2000 Apr;103(4):281-8.

38 Steindl A, Schuh G. [Late results after lumbar vertebrae fracture with Lorenz Bohler conservative treatment]. Unfallchirurg 1992;95(9):439-44.

39 Tropiano P., Huang R.C., Louis Ch.A., Poitout D.G., Louis R.P. Functional and radiographic outcome of thoracolumbar and lumbar burst fractures managed by close orthopaedic reduction and casting. Spine 2003;28(21):2459-65.

40 Dickson JH, Harrington PR, Erwin WD. Results of reduction and stabilization of the severely fractured thoracic and lumbar spine. J Bone Joint Surg Am 1978;60(6):799-805.

41 Jacobs RR, Nordwall A, Nachemson A. Reduction, stability, and strength provided by internal fixation systems for thoracolumbar spinal injuries. Clin Orthop 1982;(171):300-8.

42 McAfee PC, Yuan HA, Lasda NA. The unstable burst fracture. Spine 1982;7(4):365-73.

43 Rechtine G.R.2nd, Cahill D., Chrin A.M. Treatment of thoracolumbar trauma: comparison of complications of operative versus nonoperative treatment. J Spinal Disord 1999;12(5):406-9.

44 Shen WJ, Liu TJ, Shen YS. Nonoperative treatment versus posterior fixation for thoracolumbar junction burst fractures without neurologic deficit. Spine 2001 May 1;2001 May 1;26(9):1038-45.

45 Speth MJ, Oner FC, Kadic MA, de Klerk LW, Verbout AJ. Recurrent kyphosis after posterior stabilization of thoracolumbar fractures. 24 cases treated with a Dick internal fixator followed for 1.5-4 years. Acta Orthop Scand 1995 Oct;1995 Oct;66(5):406-10.

46 Vanichkachorn JS, Vaccaro AR, Cohen MJ, Cotler JM. Potential large vessel injury during thoracolumbar pedicle screw removal. A case report. Spine 1997 Jan 1;22(1):110-3.

47 Weinstein JN, Rydevik BL, Rauschning W. Anatomic and technical considerations of pedicle screw fixation. Clin Orthop 1992 Nov;(284):34-46.

48 Wood K, Butterman G, Mehbod A, Garvey T, Jhanjee R, Sechriest V. Operative compared with nonoperative treatment of a thoracolumbar burst fracture without neurological deficit. A prospective, randomized study. J Bone Joint Surg Am 2003 May;2003 May;85-A(5):773-81.

49 Dick W, Kluger P, Magerl F, Woersdorfer O, Zach G. A new device for internal fixation of thoracolumbar and lumbar spine fractures: the 'fixateur interne'. Paraplegia 1985;23(4):225-32.

50 Hartman M.B., Chrin A.M., Rechtine G.R. Non-operative treatment of thoracolumbar fractures. Paraplegia 1995;33(2):73-6.

51 McCormack T, Karaikovic E, Gaines RW. The load sharing classification of spine fractures. Spine 1994;19(15):1741-4.

52 Roland M, Morris R. A study of the natural history of back pain. Part I: development of a reliable and sensitive measure of disability in low-back pain. Spine 1983 Mar;8(2):141-4.

53 Knop C, Oeser M, Bastian L, Lange U, Zdichavsky M, Blauth M. [Development and validation of the Visual Analogue Scale (VAS) Spine Score] [Entwicklung und Validierung des VAS-Wirbelsaulenscores.]. Unfallchirurg 2001 Jun;2001 Jun;104(6):488-97.

54 Axelsson P., Johnsson R., Stromqvist B. Effect of lumbar orthosis on intervertebral mobility. A roentgen stereophotogrammetric analysis. Spine 1992;17(6):678-81.

55 Korovessis P, Baikousis A, Deligianni D, Mysirlis Y, Soucacos P. Effectiveness of transfixation and length of instrumentation on titanium and stainless steel transpedicular spine implants. J Spinal Disord 2001 Apr;2001 Apr;14(2):109-17.

56 Dick JC, Zdeblick TA, Bartel BD, Kunz DN. Mechanical evaluation of cross-link designs in rigid pedicle screw systems. Spine 1997 Feb 15;1997 Feb 15;22(4):370-5.

57 Lynn G, Mukherjee DP, Kruse RN, Sadasivan KK, Albright JA. Mechanical stability of thoracolumbar pedicle screw fixation. The effect of crosslinks. Spine 1997 Jul 15;1997 Jul 15;22(14):1568-72.

58 Brodke D.S., Bachus K.N., Mohr A., Nguyen B.-K.N. Segmental pedicle screw fixation or cross-links in multilevel lumbar constructs: a biomechanical analysis. Spine J 2001;1(5):373-9.

59 Marti Garin D, Villanueva Leal C, Bago Granell J. Stabilization of the lower thoracic and lumbar spine with the internal spinal skeletal fixation system and a cross-linkage system. First results of treatment. Acta Orthop Belg 1992;58(1):36-42.

60 Pintar F.A., Maiman DJ, Yoganandan N, Droese K.W., Hollowell J.P., Woodard E. Rotational stability of a spinal pedicle screw/rod system. J Spinal Disord 1995;8(1):49-55.

61 Daniaux H. [Transpedicular repositioning and spongioplasty in fractures of the vertebral bodies of the lower thoracic and lumbar spine] Transpedikulare Reposition und Spongiosaplastik bei Wirbelkorperbruchen der unteren Brust- und Lendenwirbelsaule. Unfallchirurg 1986 May;89(5):197-213.

62 Oner FC, van der Rijt RR, Ramos LM, Dhert WJ, Verbout AJ. Changes in the disc space after fractures of the thoracolumbar spine. J Bone Joint Surg Br 1998 Sep;1998 Sep;80(5):833-9.

63 Rudig L, Runkel M, Kreitner KF, Seidel T, Degreif J. [Magnetic resonance tomography examination of thoracolumbar spinal fractures after fixateur interne stabilization] [Kernspintomographische Untersuchung thorakolumbaler Wirbelfrakturen nach Fixateur-interne-Stabilisierung.]. Unfallchirurg 1997 Jul;1997 Jul;100(7):524-30.

64 Dasinger LK, Krause N, Deegan LJ, Brand RJ, Rudolph L. Duration of work disability after low back injury: a comparison of administrative and self-reported outcomes. Am J Ind Med 1999 Jun;35(6):619-31.

65 van Poppel MN, de Vet HC, Koes BW, Smid T, Bouter LM. Measuring sick leave: a comparison of self-reported data on sick leave and data from company records. Occup Med (Lond) 2002 Dec;52(8):485-90.

66 Leferink VJ, Veldhuis EF, Zimmerman KW, ten Vergert EM, ten Duis HJ. Classificational problems in ligamentary distraction type vertebral fractures: 30% of all B-type fractures are initially unrecognised. Eur Spine J 2002 Jun;2002 Jun;11(3):246-50.

67 Verlaan JJ, Diekerhof CH, Buskens E, van dT, I, Verbout AJ, Dhert WJ, et al. Surgical treatment of traumatic fractures of the thoracic and lumbar spine: a systematic review of the literature on techniques, complications, and outcome. Spine 2004 Apr 16;29(7):803-14.

68 Knop C, Blauth M, Bastian L, Lange U, Kesting J, Tscherne H. [Fractures of the thoracolumbar spine. Late results of dorsal instrumentation and its consequences] [Frakturen der thorakolumbalen Wirbelsaule. Spatergebnisse nach dorsaler Instrumentierung und ihre Konsequenzen.]. Unfallchirurg 1997 Aug;100(8):630-9.

69 Lindsey RW, Dick W. The fixateur interne in the reduction and stabilization of thoracolumbar spine fractures in patients with neurologic deficit. Spine 1991;16(3 Suppl):S140-5.

70 Briem D, Linhart W, Lehmann W, Bullinger M, Schoder V, Meenen NM, et al. [Investigation of the health-related quality of life after a dorso ventral stabilization of the thoracolumbar junction]. Unfallchirurg 2003 Aug;106(8):625-32.

71 Knop C, Blauth M, Buhren V, Arand M, Egbers HJ, Hax PM, et al. [Surgical treatment of injuries of the thoracolumbar transition--3: Follow-up examination. Results of a prospective multi-center study by the "Spinal" Study Group of the German Society of Trauma Surgery] [Operative Behandlung von Verletzungen des thorakolumbalen Ubergangs--Teil 3: Nachuntersuchung. Ergebnisse einer prospektiven multizentrischen Studie der Arbeitsgemeinschaft "Wirbelsaule" der Deutschen Gesellschaft fur Unfallchirurgie.]. Unfallchirurg 2001 Jul;2001 Jul;104(7):583-600.

72 Butler JS, Walsh A, O'Byrne J. Functional outcome of burst fractures of the first lumbar vertebra managed surgically and conservatively. Int Orthop 2005 Feb;29(1):51-4.

73 Dai LD. Low lumbar spinal fractures: management options. Injury 2002 Sep;2002 Sep;33(7):579-82.

74 Gertzbein SD. Scoliosis Research Society. Multicenter spine fracture study. Spine 1992;17(5):528-40.

75 Ostelo RW, de Vet HC. Clinically important outcomes in low back pain. Best Pract Res Clin Rheumatol 2005 Aug;19(4):593-607.

76 Burnham RS, Warren SA, Saboe LA, Davis LA, Russell GG, Reid DC. Factors predicting employment 1 year after traumatic spine fracture. Spine 1996 May 1;21(9):1066-71.

77 Kraemer W.J., Schemitsch E.H., Lever J., McBroom R.J., McKee M.D., Waddell JP. Functional outcome of thoracolumbar burst fractures without neurological deficit. J Orthop Trauma 1996;10(8):541-4.

78 McLain RF, Sparling E, Benson DR. Early failure of short-segment pedicle instrumentation for thoracolumbar fractures. A preliminary report [see comments]. J Bone Joint Surg Am 1993;75(2):162-7.

79 Benson DR, Burkus JK, Montesano PX, Sutherland TB, McLain RF. Unstable thoracolumbar and lumbar burst fractures treated with the AO fixateur interne. J Spinal Disord 1992;5(3):335-43.

80 Ebraheim NA, Elgafy H, Xu R. Bone-graft harvesting from iliac and fibular donor sites: techniques and complications. J Am Acad Orthop Surg 2001 May;2001 May-Jun;9(3):210-8.

81 Banwart JC, Asher MA, Hassanein RS. Iliac crest bone graft harvest donor site morbidity. A statistical evaluation. Spine 1995 May 1;1995 May 1;20(9):1055-60.

82 Hill NM, Horne JG, Devane PA. Donor site morbidity in the iliac crest bone graft. Aust N Z J Surg 1999 Oct;1999 Oct;69(10):726-8.

83 Alanay A, Acaroglu E, Yazici M, Oznur A, Surat A. Short-segment pedicle instrumentation of thoracolumbar burst fractures: does transpedicular intracorporeal grafting prevent early failure? Spine 2001 Jan 15;2001 Jan 15;26(2):213-7.

84 Knop C, Fabian HF, Bastian L, Blauth M. Late results of thoracolumbar fractures after posterior instrumentation and transpedicular bone grafting. Spine 2001 Jan 1;2001 Jan 1;26(1):88-99.

85 Sjostrom L, Jakobsson O, Karlstrom G, Pech P. Transpedicular bone grafts misplaced into the spinal canal. J Orthop Trauma 1992;6(3):376-8.

86 Briem D, Rueger JM, Linhart W. [Osseous integration of autogenous bone grafts following combined dorso-ventral instrumentation of unstable thoracolumbar spine fractures]. Unfallchirurg 2003 Mar;106(3):195-203.

87 Schulz FK, Grimes DA. Sample size calculations in randomized trials: mandatory and mystical. Lancet 2005;365(9467):1348-53.

I will see if I can see.
*James Joyce. Ulysses Proteus. 1922*

# CHAPTER 4

## Inter- and intraobserver agreement on the Load Sharing Classification of thoracolumbar spine fractures.

Elzinga MJ.
Segers MJM.
Siebenga J.
Heilbron E.
Lange de Klerk SM.
Bakker FC.

*Injury 2012; 43(4): 416-422*

## Abstract

The Load Sharing Classification (LSC) allocates one to three points to each of three different radiological characteristics of traumatic thoracolumbar fractures: the vertebral body involved in the fracture, the displacement of the fracture parts and the kyphotic deformity. Added up, a minimal score of three and a maximal score of nine can be obtained. When the LSC score is three to six, a short segment pedicle screw fixation suffices. When the LSC score is seven to nine, a high rate failure in patients with a short segment pedicle screw fixation exists. In these cases an anterior stabilising procedure of the spine is advised. The LSC has been validated by Dai and Jin et al., who claim an almost perfect inter- and intraobserver agreement, according to the Landis and Koch criteria. Dai et al. only present results for the separate three items of the LSC and for the total LSC scores. Observer agreement for the two LSC score categories (three to six and seven to nine) have not been studied.

The aim of this study is to validate the LSC for the total score, the three separate items and also for the two LSC score categories. Three observers determine twice the LSC scores of forty traumatic thoracolumbar fractures. The average standard Cohen's kappa values for the separate LSC items range between 0.06 and 0.48. For the total LSC score the average standard Cohen's kappa and weighted kappa values are 0.22 and 0.67 respectively. For the two LSC score categories, there is unanimous agreement in 55% of the cases and a majority agreement in 40%. In the remaining 5% of the fractures there is a split decision. Standard Cohen's kappa value for the two LSC score categories is 0.53. The standard Cohen's kappa values can be rated as fair to moderate.

The LSC can be regarded as a significant aid in discriminating those who will benefit from an anterior approach from those who will only need a short segment fixation with pedicle screws.

## Introduction

Short segment posterior stabilization has become increasingly popular since the introduction of transpedicular screws by Roy-Camille. [26] The possibilities for reduction of segmental kyphotic deformities are good and the posterior approach carries a low morbidity. However, many reports have revealed failures of short-segment pedicle screw instrumentation due to the lack of anterior support or rotational instability.[22,25,28,32,34] These failures are non-fusion, loss of reduction of kyphotic deformities, pedicle screw migration or screw breakage.[22,23,27,31] Anterior stabilization offers superior anterior support and the loss of reduction of kyphotic deformities appears to be smaller than in short-segment posterior stabilization only.[10,15,16] Disadvantages of this approach are a higher morbidity due to the more extensive, open approach i.e. thoracotomy, lumbotomy or thoraco-phrenico-lumbotomy at the thoracolumbar junction, and intraoperative reduction is more difficult. Although the recent application of thoracoscopic surgery has decreased this morbidity significantly.[16] To support decisions about the best surgical approach for unstable thoracolumbar fractures McCormack et al. introduced the Load Sharing Classification (LSC) of spine fractures.[21] This classification allocates one to three points to each of three different radiological characteristics of traumatic thoracolumbar fractures: the amount of comminution/involvement of the vertebral body, the amount of apposition/displacement of the fracture fragments and the amount of correction of kyphotic deformity. In this way, a minimal total LSC score of three and a maximal score of nine can be obtained. Using this system, McCormack et al. point out that spine fractures with low LSC scores (three to six points) can be managed with short-segment posterior stabilization only, whereas burst fractures with high LSC scores (seven to nine points) require anterior stabilization to prevent failure of the posterior implant.[1,13,21,24]

In the retrospective study of McCormack et al. it was stated that the LSC can be used preoperatively to: 1) predict pedicle screw failures in short segment posterior stabilizations, 2) describe any spinal injury for retrospective studies, 3) select spinal fractures for anterior short segment reconstruction with strut grafts in fractures with LSC scores of seven and higher.[1,21,24] This classification cannot be used to make decisions on surgical indications as it takes no account of ligamentous disruptions or the mechanisms of injury. Moreover, the LSC has been developed specifically to be applied preoperatively, after the indication for surgical treatment has been made, for an optimal assessment of the injured vertebral body and the subsequent optimal approach.[1,21,24]

For any classification to be useful, consistency between different observers is essential. The LSC has been validated by Dai et al. who report an almost perfect inter- and intraobserver agreement, according to the Landis and Koch criteria.[11] This is remarkable as many other inter- and intraobserver studies on other fracture classifications can only claim a fair to moderate observer agreement.[4-6,8,12,14,29] Furthermore, Dai et al. only present results for the three separate LSC items and the total LSC scores, whereas the two LSC score categories, i.e. three to six and seven to nine, are not studied. Consequently Dai et al. present no data on the validity to use the LSC to discriminate between an anterior or posterior stabilising procedure of the spine, the discerning feature of the LSC.

The purpose of the present study is to determine intra- and interobserver agreement for the total LSC score, for the scores of each of the three radiological fracture characteristics, as well as for the two score categories, and to compare the findings, with the values reported in literature.[11]

## Materials and Methods

The LSC of spine fractures uses three radiological characteristics of the fracture and allocates one to three points to each of these items (Fig.1).

Comminution/involvement (item A): According to McCormack et al., the comminution is assessed using the 2D sagittal CT-scan reconstruction images. 21 Spine fractures with a comminution/involvement up to 30% of the vertebral body are allocated one point, two points are given for a comminution/involvement up to 60% and three points when the vertebra is comminuted over 60%.

Apposition/displacement (item B): The apposition is assessed on the axial slices of the CT-scan. One point is attributed when the displacement of the fracture fragments is 0-1 mm, two points for displacement of at least 2 mm in less than 50% of the cross-sectional area of the vertebral body and three points for displacement greater than 2 mm in more than 50% of the cross sectional area.

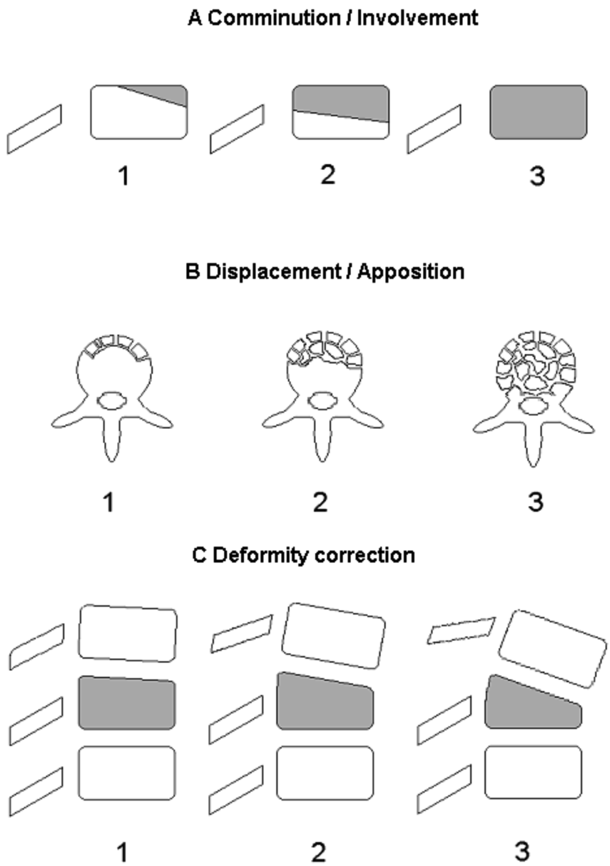



**Figure1. A:** Comminution/Involvement of the vertebral body on 2D sagittal plane CT-scan reconstruction: <30% = 1, 30-60% = 2, >60% = 3. **B:** Displacement/apposition of fracture parts: 0-1 mm = 1, displacement ≥2mm and less than 50% of the cross-sectional area of the body = 2, displacement ≥2mm and involvement more than 50% of the circumferential area = 3. **C:** Correction of kyphosis deformity: < 3°deformity = 1, 4°- 9° deformity = 2, >9° deformity =3

Deformity correction (item C): The amount of correction of kyphotic deformity is calculated from the lateral plain preoperative radiographs: the kyphotic angle of the fractured element is measured from the inferior endplate of the vertebra above and the superior endplate of the vertebra below the fractured segment. The physiologic kyphosis of the cranial and caudal neighbouring spine elements are measured

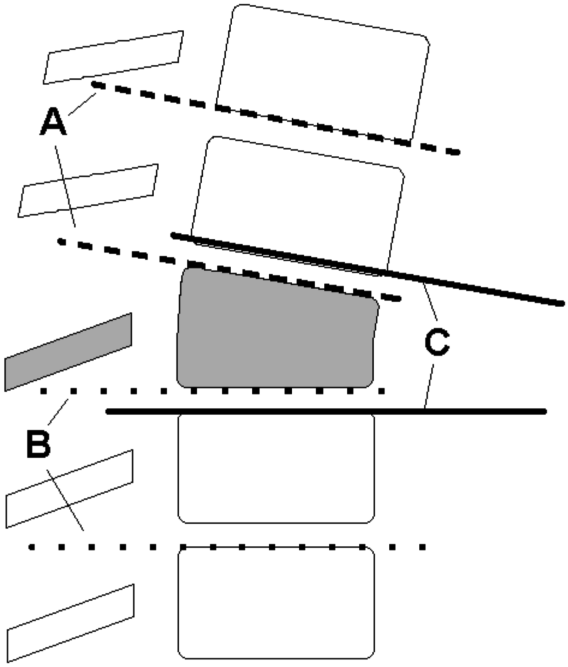



**Figure 2.** Measurement of the deformity correction: the traumatic kyphosis of the fractured vertebra (C) is distracted from the average kyphosis of the adjacent spinal motion segments (A+B /2). Correction of deformity: (A+B / 2) – C. [1,21]

likewise and their mean value is subtracted from the kyphotic angle of the fractured element (Fig.2). One point is given when this kyphotic deformity is 3°or less, two points for 4°- 9° correction and three points for 10°and more correction.[1,21]

For determination of the inter- and intraobserver agreement on the LSC preoperative radiographs of a consecutive series of 40 operatively stabilized fractures of the thoracolumbar spine (levels T11-L3) are reviewed (n=40). For inclusion these thoracolumbar spine fractures comply with three criteria: 1) all fractures have a traumatic origin excluding non-acute osteoporotic vertebral body collapse, 2) all fractures show a compression component of the vertebral body, for the LSC classifies the comminution of the vertebral body: AO Comprehensive Classification types A3.1-3, B 1.2, B 2.3 and C1.1-3 [20], distraction fractures and complex rotational fractures without evident vertebral body compression are excluded and 3) a complete and legible preoperative radiological work-up consisting of: plain lateral and anterior-posterior radiographs in focus with the injured spinal segment and extending at least two spinal levels cranial and caudal and a CT-scan with consecutive 3 mm (or thinner) axial slices including the same spinal levels as the radiographs and 2mm 2D sagittal planar reconstruction images. The preoperative radiological materials are inspected on distinguishing marks. All marks are removed before any observer started classifying. Three observers, two trauma surgeons and one radiologist score the LSC of the selected fractures independently, on two separate occasions. All observers are experienced in the radiological interpretation of thoracolumbar fractures and have a copy of the original article and all relevant correspondence at their disposal.[1,21] None of the observers have used the LSC in standard daily practice before this study. The observations are conducted in the same room, using the same equipment. All four observers make use of the lateral radiographs and the axial CT-scan slices besides the 2D sagittal reconstructions to estimate the comminution/involvement of the vertebral body.

Data are analyzed using StatXact statistical software. For the statistic analysis of the inter- and intraobserver agreement on the three separate LSC items standard Cohen's kappa tests are performed for six pairs of observers. Values of standard Cohen's kappa can vary between –1 (complete disagreement between observers) and +1 (perfect interobserver agreement). The same statistic analysis, including 95% confidence intervals, is employed for inter- and intraobserver agreement on total LSC scores. As both the LSC scores per item and total LSC scores vary on a continuous numerical scale, inter- and intraobserver agreement can also be calculated by a weighted kappa test. In contrast to standard Cohen's kappa this statistical test discriminates the quantitative amount of variation in the six pairs of observers, smaller variations will lead to an increase of the weighted kappa value in comparison to standard Cohen's kappa, whereas larger variations cause a decrease. Finally, agreement between all observers concerning the LSC score categories (scores three to six and seven to nine) as described by McCormack et al., is analyzed.[21] Biometric interpretation of the standard Cohen's kappa and weighted kappa values is performed according to the criteria of Landis and Koch as described in Table 1.[18] The kappa values of this study are compared with the inter- and intraobserver data of other fracture classification systems.

## Results

The inter- and intraobserver reliability of any classification can be measured by its kappa values. The stronger the reliability, the higher the kappa values are. Kappa values can be anywhere from -1 (disagreement) to +1 (agreement).

**Inter- and intraobserver agreement on the scores of three separate items of the Load Sharing Classification.**

The standard Cohen's kappa and weighted kappa scores per item for six pairs of observers are presented in Tables 1 till 3.

The standard Cohen's kappa values for the interobserver agreement of comminution/involvement (item A) range from 0.23 to 0.73 with a mean value of 0.48; weighted kappa values for the interobserver agreement of item A: 0.47- 0.85, mean value 0.58. The standard Cohen's kappa values for the interobserver agreement of apposition/displacement (item B) range from 0.15 to 0.52 with a mean value of 0.37; weighted kappa values for the interobserver agreement of item B: 0.14-0.73, mean value 0.46. Finally the standard Cohen's kappa values for the interobserver

Table 1:Interobserver agreement on item A of the Load Sharing Classification

| | Observers | Kappa values | Stnd. Dev. | Stnd. Dev. 0 |
|---|---|---|---|---|
| Kappa | 1 vs 2[a] | 0.2331 | 0.1140 | 0.1144 |
| | 1 vs 2[b] | 0.4297 | 0.1101 | 0.1061 |
| Weighted Kappa | 1 vs 2[a] | 0.4680 | 0.1007 | 0.1394 |
| | 1 vs 2[b] | 0.6829 | 0.0722 | 0.1391 |
| Kappa | 1 vs 3[a] | 0.7258 | 0.0930 | 0.1127 |
| | 1 vs 3[b] | 0.5313 | 0.1125 | 0.1128 |
| Weighted Kappa | 1 vs 3[a] | 0.8545 | 0.0546 | 0.1541 |
| | 1 vs 3[b] | 0.7209 | 0.0736 | 0.1520 |
| Kappa | 2 vs 3[a] | 0.4049 | 0.1132 | 0.1195 |
| | 2 vs 3[b] | 0.5528 | 0.1123 | 0.1166 |
| Weighted Kappa | 2 vs 3[a] | 0.5491 | 0.1104 | 0.1507 |
| | 2 vs 3[b] | 0.7284 | 0.0805 | 0.1533 |

**Table 1:** Interobserver agreement on comminution/involvement of the vertebral body (item A of the LSC) for three observers (numbers 1,2 and 3) , as measured on two separate occasions (superscripted a en b).

agreement of the deformity correction (item C) vary between 0.06 and 0.28 with a mean value of 0.20; weighted kappa values for the interobserver agreement of item C: 0.13-0.50, mean value 0.31. The difference in standard Cohen's kappa and weighted kappa values between the estimation of comminution/involvement and the other two items of the LSC is not statistically significant. According to the Landis and Koch criteria (Table 4) the average results for the interobserver agreement are rated as fair (standard Cohen's kappa) to substantial (weighted kappa) for comminution/involvement (item A) and slight (standard Cohen's kappa) to substantial (weighted kappa) for apposition/displacement (item B) and slight (standard Cohen's kappa) to fair (weighted kappa) for deformity correction (item C).

The results for intraobserver agreement on the LSC are presented in tables 5 and 6. The standard Cohen's kappa values for the intraobserver agreement of comminution/involvement (item A) range from 0.58 to 0.60 with a mean value of 0.59. The standard Cohen's kappa values for the intraobserver agreement of apposition/displacement (item B) range from 0.27 to 0.63 with a mean value of 0.47. Finally the standard Cohen's kappa values for the intraobserver agreement of the deformity correction (item C) vary between -0.03 and 0.35 with a mean value of 0.18.

| Z value | P value | N | 95% conf.int. |
|---|---|---|---|
| 2.0384 | 0.0208 | 40 | 0.0098 - 0.4564 |
| 4.0513 | 0.0000 | 40 | 0.2139 - 0.6454 |
| 3.3569 | 0.0004 | 40 | 0.2705 - 0.6654 |
| 4.9082 | 0.0000 | 40 | 0.5414 - 0.8244 |
| 6.4396 | 0.0000 | 40 | 0.5436 - 0.9079 |
| 4.7110 | 0.0000 | 40 | 0.3107 - 0.7518 |
| 5.5459 | 0.0000 | 40 | 0.7474 - 0.9615 |
| 4.7438 | 0.0000 | 40 | 0.5766 - 0.8652 |
| 3.3871 | 0.0004 | 40 | 0.1830 - 0.6268 |
| 4.7410 | 0.0000 | 40 | 0.3328 - 0.7729 |
| 3.6432 | 0.0001 | 40 | 0.3326 - 0.7655 |
| 4.7506 | 0.0000 | 40 | 0.5705 - 0.8863 |

Table 2: Interobserver agreement on item B of the Load Sharing Classification

| | Observers | Kappa values | Stnd. Dev. | Stnd. Dev. 0 |
|---|---|---|---|---|
| Kappa | 1 vs 2[a] | 0.3854 | 0.1231 | 0.1279 |
| | 1 vs 2[b] | 0.1538 | 0.0937 | 0.1006 |
| Weighted Kappa | 1 vs 2[a] | 0.2991 | 0.1530 | 0.1403 |
| | 1 vs 2[b] | 0.4647 | 0.0726 | 0.1077 |
| Kappa | 1 vs 3[a] | 0.5165 | 0.1089 | 0.1291 |
| | 1 vs 3[b] | 0.4697 | 0.1130 | 0.1108 |
| Weighted Kappa | 1 vs 3[a] | 0.1447 | 0.1725 | 0.1520 |
| | 1 vs 3[b] | 0.7255 | 0.0692 | 0.1530 |
| Kappa | 2 vs 3[a] | 0.2009 | 0.1075 | 0.1076 |
| | 2 vs 3[b] | 0.4937 | 0.0999 | 0.1173 |
| Weighted Kappa | 2 vs 3[a] | 0.4085 | 0.1219 | 0.1190 |
| | 2 vs 3[b] | 0.6610 | 0.1076 | 0.1570 |

**Table 2:** Interobserver agreement on apposition/displacement of fracture (item B of the LSC) for three observers (numbers 1,2 and 3) , as measured on two separate occasions (superscripted a en b).

Table 3: Interobserver agreement on item C of the Load Sharing Classification

| | Observers | Kappa values | Stnd. Dev. | Stnd. Dev. 0 |
|---|---|---|---|---|
| Kappa | 1 vs 2a | 0.2334 | 0.1070 | 0.0948 |
| | 1 vs 2b | 0.0625 | 0.0771 | 0.0802 |
| Weighted Kappa | 1 vs 2a | 0.1935 | 0.1213 | 0.1034 |
| | 1 vs 2b | 0.1304 | 0.0872 | 0.0918 |
| Kappa | 1 vs 3a | 0.3143 | 0.1246 | 0.1203 |
| | 1 vs 3b | 0.1288 | 0.1183 | 0.1065 |
| Weighted Kappa | 1 vs 3a | 0.3284 | 0.1333 | 0.1364 |
| | 1 vs 3b | 0.4298 | 0.1032 | 0.1453 |
| Kappa | 2 vs 3a | 0.2804 | 0.1094 | 0.1152 |
| | 2 vs 3b | 0.2213 | 0.1073 | 0.1058 |
| Weighted Kappa | 2 vs 3a | 0.4639 | 0.1119 | 0.1439 |
| | 2 vs 3b | 0.4954 | 0.1035 | 0.1242 |

**Table 3:** Interobserver agreement on correction of deformity (item C of the LSC) for three observers (numbers 1,2 and 3) , as measured on two separate occasions (superscripted a en b).

| Z value | P value | N | 95% conf.int. |
|---|---|---|---|
| 3.0129 | 0.0013 | 40 | 0.1441 - 0.6267 |
| 1.5292 | 0.0631 | 40 | 0.0298 - 0.3374 |
| 2.1311 | 0.0165 | 40 | -0.0008 - 0.5989 0 |
| 4.3127 | 0.0000 | 40 | 0.3224 - 0.607 |
| 4.0000 | 0.0000 | 40 | 0.3030 - 0.7300 |
| 4.2397 | 0.0000 | 40 | 0.2481 - 0.6913 |
| 0.9524 | 0.1704 | 40 | -0.1933 - 0.4827 |
| 4.7426 | 0.0000 | 40 | 0.5899 - 0.8611 |
| 1.8666 | 0.0310 | 40 | -0.0098 - 0.4116 |
| 4.2103 | 0.0000 | 40 | 0.2978 - 0.6896 |
| 3.4333 | 0.0003 | 40 | 0.1695 - 0.6474 |
| 4.2103 | 0.0000 | 40 | 0.4501 - 0.8720 |

| Z value | P value | N | 95% conf.int. |
|---|---|---|---|
| 2.4616 | 0.0069 | 40 | 0.0236-0.4431 |
| 0.7792 | 0.2179 | 40 | -0.0887- 0.2137 |
| 1.8718 | 0.0306 | 40 | -0.0442- 0.4313 |
| 1.4209 | 0.0777 | 40 | -0.0404 - 0.3013 |
| 2.6124 | 0.0045 | 40 | 0.0701 - 0.5584 |
| 1.2094 | 0.1133 | 40 | -0.1030 - 0.3606 |
| 2.4079 | 0.0080 | 40 | 0.0670 - 0.5897 |
| 2.9580 | 0.0015 | 40 | 0.2275 - 0.6322 |
| 2.4332 | 0.0075 | 40 | 0.0661 - 0.4948 |
| 2.0918 | 0.0182 | 40 | 0.0110 - 0.4316 |
| 3.2231 | 0.0006 | 40 | 0.2445 - 0.6832 |
| 3.9874 | 0.0000 | 40 | 0.2926 - 0.6982 |

Table 4: Landis and Koch Criteria

| Kappa Statistic | Strength of Agreement |
|---|---|
| <0.00 | Poor |
| 0.00-0.20 | Slight |
| 0.21-0.40 | Fair |
| 0.41-0.60 | Moderate |
| 0.61-0.80 | Substantial |
| 0.80-1.00 | Almost Perfect |

**Table 4:** Landis and Koch criteria for interobserver agreement

Table 5: Intraobserver reliability for the total score of the LSC

| Observer | Kappa | K value | StDev | StDev0 | Z | Prob | N | 95% confidence interval |
|---|---|---|---|---|---|---|---|---|
| 1 | Standard | 0,0313 | 0,0553 | 0,0547 | 0,5731 | 0,2833 | 40 | -0,077 - 0,1397 |
| 1 | Weighted | 0,5856 | 0,1041 | 0,1422 | 4,1179 | 0,0000 | 40 | 0,3816 - 0,7895 |
| 2 | Standard | 0,4184 | 0,0966 | 0,0811 | 5,1568 | 0,0000 | 40 | 0,2291 - 0,6078 |
| 2 | Weighted | 0,7794 | 0,0632 | 0,157 | 4,9636 | 0,0000 | 40 | 0,6555 - 0,9033 |
| 3 | Standard | 0,4247 | 0,0911 | 0,0705 | 6,0277 | 0,0000 | 40 | 0,2461 - 0,6032 |
| 3 | Weighted | 0,7471 | 0,0696 | 0,1486 | 5,0288 | 0,0000 | 40 | 0,6107 - 0,8836 |

Table 6: Intraobserver reliability for the separate items of the LSC

| Observer | Subscale | Kappa | Std.Error | P value |
|---|---|---|---|---|
| 1 | Item A | 0,580 | 0,108 | 0,000 |
| 1 | Item B | 0,271 | 0,094 | 0,008 |
| 1 | Item C | -0,030 | 0,050 | 0,632 |
| 2 | Item A | 0,603 | 0,106 | 0,000 |
| 2 | Item B | 0,521 | 0,134 | 0,000 |
| 2 | Item C | 0,349 | 0,113 | 0,002 |
| 3 | Item A | 0,602 | 0,107 | 0,000 |
| 3 | Item B | 0,639 | 0,102 | 0,000 |
| 3 | Item C | 0,228 | 0,114 | 0,042 |

**Table 5 and 6:** Intraobserver agreement on the separate items and the total score of the LSC for three observers.

**Inter- and intraobserver agreement on the total scores of the Load Sharing Classification.**

The standard Cohen's kappa and weighted kappa scores for the interobserver agreement on the total LSC score for six pairs of observers are presented in Table 7. Standard Cohen's kappa values are between 0.01 and 0.40 with a mean value of 0.22. Weighted kappa values: 0.57-0.86 with a mean value of 0.67. Ninety-five percent confidence intervals are also shown. According to Landis and Koch the mean standard Cohen's kappa value for the interobserver agreement on total LSC score is rated as fair and the mean weighted kappa value as substantial. The standard Cohen's kappa values for the intraobserver agreement on the total LSC score the deformity correction (item C) vary between 0.03 and 0.78 with a mean value of 0.50, a moderate agreement.

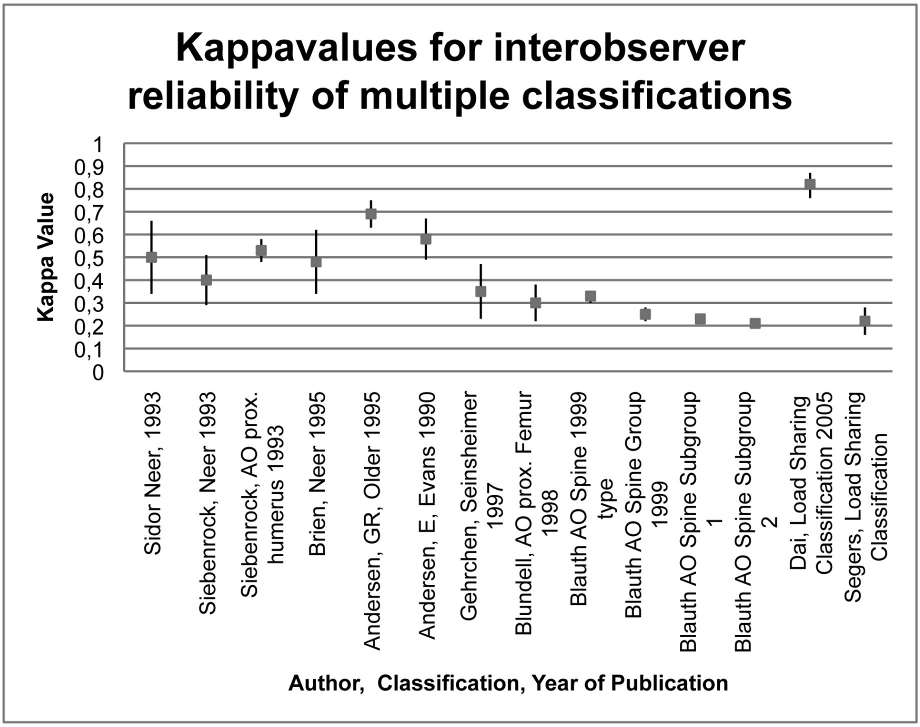



**Figure 3.** Forest plot of the mean kappa values of several interobserver studies on surgical classifications.[5,6,8,11,12,14,29,30,33]

Table 7: Interobserver agreement on total score of the Load Sharing Classification

| | Observers | Kappa values | Stnd. Dev. | Stnd. Dev. 0 |
|---|---|---|---|---|
| Kappa | 1 vs 2[a] | 0.3296 | 0.0916 | 0.0791 |
| | 1 vs 2[b] | 0.0244 | 0.0563 | 0.0559 |
| Weighted Kappa | 1 vs 2[a] | 0.5972 | 0.0995 | 0.1576 |
| | 1 vs 2[b] | 0.5148 | 0.0986 | 0.1382 |
| Kappa | 1 vs 3[a] | 0.4006 | 0.0900 | 0.0766 |
| | 1 vs 3[b] | 0.0102 | 0.0655 | 0.0616 |
| Weighted Kappa | 1 vs 3[a] | 0.8137 | 0.0498 | 0.1533 |
| | 1 vs 3[b] | 0.7110 | 0.0577 | 0.1459 |
| Kappa | 2 vs 3[a] | 0.3038 | 0.0968 | 0.0793 |
| | 2 vs 3[b] | 0.2627 | 0.2627 | 0.0703 |
| Weighted Kappa | 2 vs 3[a] | 0.6397 | 0.0988 | 0.1564 |
| | 2 vs 3[b] | 0.7033 | 0.0659 | 0.1478 |

**Table 7:** Interobserver agreement for the total LSC score for three observers (numbers 1,2 and 3) , as measured on two separate occasions (superscripted a en b).

### Inter- and intraobserver agreement on the LSC score categories of the Load Sharing Classification: LSC 3-6 versus LSC 7-9.

In 22 fractures (68%) there is full agreement between all four observers. In 10 fractures (18%) there is partial agreement with one of the observers having a different score concerning the LSC score categories. In six fractures (15%) a disagreement is seen in two out of six observations. In two fractures (5%) a disagreement is seen in three out of six observations.

### Comparison to the validation of other fracture classification systems.

The standard Cohen's kappa and values for interobserver validation of the total score of the Load Sharing Classification are compared to other validation studies of fracture classification systems in Figure 3. The kappa values in these other studies range from 0.18 to 0.69. Comparison with the study validating inter- and intraobserver agreement on the AO Comprehensive Classification of spine fractures shows that the kappa values in this study are in the same category as the AO type of spine fractures (AO fracture type A,B or C).[7]

| Z value | P value | N | 95% conf.int. |
|---|---|---|---|
| 4.1647 | 0.0000 | 40 | 0.1501 - 0.5091 |
| 0.4361 | 0.3314 | 40 | -0.0859 - 0.1346 |
| 3.7903 | 0.0001 | 40 | 0.4021 - 0.7923 |
| 3.7258 | 0.0001 | 40 | 0.3215 - 0.7081 |
| 5.2314 | 0.0000 | 40 | 0.2242 - 0.5771 |
| 0.1655 | 0.4343 | 40 | -0.1182 - 0.1385 |
| 5.3067 | 0.0000 | 40 | 0.7162 - 0.9113 |
| 4.8739 | 0.0000 | 40 | 0.5978 - 0.8241 |
| 3.8296 | 0.0001 | 40 | 0.1142 - 0.4934 |
| 3.7382 | 0.0001 | 40 | 0.0963 - 0.4290 |
| 4.0917 | 0.0000 | 40 | 0.4460 - 0.8335 |
| 4.7600 | 0.0000 | 40 | 0.5741 - 0.8325 |

## Discussion

An important aim of a fracture classification system is to assist in choosing the most appropriate treatment. Given sufficient reliability, such systems also enable surgeons to compare treatment outcomes of specific groups of patients. Employing classification systems before their reliability is determined can lead to conflicting and non-consistent clinical conclusions.[9] An assessment of the reproducibility must take inter- and intraobserver variability into account.

Since LSC scores may vary from 3 to 9 points (three separate items: 1-3 points per item) not only inter- and intraobserver (dis)agreement per se is important, the magnitude of inter- and intraobserver variance should be considered too. Consequently, in addition to the standard Cohen's Kappa values, the weighted Kappa values need to be calculated as well. Larger inter- and intraobserver differences will show a decrease in weighted Kappa values as compared to standard Cohen's kappa values whereas smaller differences will show an increase. Statistical analysis employing standard and weighted Cohen's Kappa tests is partially dependent on the frequency distribution of the specific options within a classification system.

In this specific study there is an overrepresentation of LSC scores five to eight with a general average of the total LSC scores of 6.3. This can be explained by the fact that the inclusion criteria are formulated with the purpose to approximate the clinical dilemma of the surgical approach in spine fractures as closely as possible (posterior or anterior stabilisation). Moreover, McCormack et al. also based the LSC on a study of the posterior implant in operatively treated patients, with an average LSC score of 6.9. It makes sense to test the reliability of the LSC in a similar population. If conservatively treated fractures would have been included the average scores would likely have been lower. The result now is a studied population with an average LSC score of 6.3, right between the lower LSC scores of 3 to 6 (in which case a posterior stabilisation is sufficient) and the higher LSC scores of 7 to 9 (in which case an anterior reconstruction is advised).

Considering the inter- and intraobserver agreement on the three separate items of the LSC there is notable difference between (weighted) Kappa values of item A (comminution/involvement) and the other two items. This higher degree of consensus for item A may be due to the fact that all observers also made use of the axial slices of the CT-scan besides the 2D sagittal and coronal reconstructions to assess the amount of comminution. The use of the axial slices of the fractured vertebra together with the 2D sagittal reconstructions gives a more detailed insight to what extend the vertebral body is involved, especially in case of spine fractures with a burst-split morphology (AO type A3.2). Although on every CT-scan a scale is present on all the axial slices to estimate the proportions of the scan, the assessment of item B (apposition/displacement) seems less reproducible. This scale can be used in the visual assessment of the distance of the displacement.

The other aspect of apposition, the percentage of the cross sectional area of the vertebral body, may well be influenced by interpretation of different (consecutive) axial slices. It was not clear for the observers in this study whether this assessment of apposition should be based on one "worse scenario" slice or more axial CT-scan slices together, possibly showing involvement of a larger part of the cross-sectional area. Calculation of the deformity correction in item C appears to be more complex than anticipated beforehand. Assessment of deformity correction is based on measurements of the anatomical alignment of both the proximal and distal adjacent spinal motion segments. The measurement of kyphosis on conventional X-rays is influenced by the architecture of the vertebra. The accuracy of repeated angle measurements of a normal spinal segment (one vertebra and its adjacent intervertebral discs) is around 7.9 degrees thus an erroneous calculation of an angle between two spinal motion segments may be expected.[2] The measurement of the angle between an intact and an injured segment can furthermore be affected by the deformity of the fractured vertebra.[2] To draw lines on the endplates of fractured vertebrae requires an uniform interpretation of certain fracture patterns in determining the course of the endplates. This manifests itself in particular in distraction type fractures with a compression component of the anterior superior part of the vertebral body (AO type B 2.3).

We found in this study a moderate interobserver agreement for the two LSC score categories, LSC scores three to six and LSC scores seven to nine. It is worthwhile to note that in 86 % of the included cases the observers agree about the LSC score categories. This implies that, when using the LSC, in one out of seven patients with unstable spine fractures with an anterior compression component, doubts will remain about the anterior stability of the spinal column.

Standard Cohen's Kappa for the average interobserver agreement on the total LSC scores of 40 operatively treated thoracolumbar fractures is 0.22 and would be rated as fair according to the Landis and Koch criteria. In contrast the weighted Kappa value for the average interobserver agreement reaches a much higher level at 0.67, pointing out that differences in total LSC scores between the paired observers were small.

In a study on the interobserver reliability of the AO comprehensive classification of thoracolumbar fractures 22 expert observers had to classify 14 spine fractures and the average standard Cohen's Kappa reached 0.33 for AO type.[7] In contrast to the 7 different options of the LSC score, the AO comprehensive classification knows only 3 types but the difficulties in recognizing certain B type fractures are generally acknowledged.[19] In comparison to other frequently used classifications the average standard Cohen's Kappa for the total LSC score is in the same range as the interobserver agreement on different classification systems for fractures of the distal radius and the proximal femur (fig. 3). Interobserver reliability of the Neer and AO classifications concerning proximal humeral fractures are fair and moderate respectively. The Lauge Hansen and Weber classifications for ankle fractures and the Older classification for fractures of the distal radius are in fact the only classifications with a substantial interobserver agreement according to the Landis and Koch criteria.

Up till now, only one study on the reliability of the LSC of thoracolumbar fractures has been published.[11] It is remarkable that, Dai et al. report an almost perfect interobserver agreement values in contrast to what is found for many other fracture classification systems (fig.3). One explanation may be that Dai et al. studied only fractures with the highest (nine) and the lowest (three) of LSC score. These LSC scores are obtained when each of the three categories get the highest (three) or lowest score (one). Consequently little room is left for variability. In contrast, a total LSC score of six or seven can be obtained in six or seven different ways and thus generates room for disagreement (for example a total LSC score of 4 can be calculated in three ways: A=1, B=1 and C=2 or A=1, B=2 and C=1 or A=2, B=1 and C=1).

In accordance with McCormack et al. we state that the combination of comminution as quantified by radiomorphologic criteria, ligamentous disruptions and discal injuries will ultimately control the development of deformity and this amount of deformity can have a relation with long term functional outcome.[3,17,23,25] Nowadays, in selected cases a posterior short segment instrumentation and fracture reduction will be followed by minimal invasive techniques for anterior stabilization. This minimal invasive anterior approach will assure a more permanent kyphosis correction without the historically related morbidity. The LSC can be regarded as a quantitative aid in selecting these patients.

The use of the Load Sharing Classification of spine fractures did not prove to be as intuitive for novel observers as originally thought but the level of interobserver agreement is well within the range of other frequently used fracture classification systems.

## REFERENCES

1. Alanay A, Acaroglu E, Yazici M et al. Thoracolumbar spine fractures. Spine 2001;26:840-1.
2. Alanay A, Pekmezci M, Karaeminogullari O et al. Radiographic measurement of the sagittal plane deformity in patients with osteoporotic spinal fractures evaluation of intrinsic error. Eur.Spine J. 2007;16:2126-32.
3. An HS, Vaccaro A, Cotler JM et al. Low lumbar burst fractures. Comparison among body cast, Harrington rod, Luque rod, and Steffee plate. Spine 1991;16:S440-S444.
4. Andersen DJ, Blair WF, Steyers CM, Jr. et al. Classification of distal radius fractures: an analysis of interobserver reliability and intraobserver reproducibility. J.Hand Surg.[Am.] 1996;21:574-82.
5. Andersen E, Jorgensen LG, Hededam LT. Evans' classification of trochanteric fractures: an assessment of the interobserver and intraobserver reliability. Injury 1990;21:377-8.
6. Andersen GR, Rasmussen JB, Dahl B et al. Older's classification of Colles' fractures. Good intraobserver and interobserver reproducibility in 185 cases. Acta Orthop.Scand. 1991;62:463-4.
7. Blauth M, Bastian L, Knop C et al. [Inter-observer reliability in the classification of thoraco-lumbar spinal injuries]. Orthopade 1999;28:662-81.
8. Blundell CM, Parker MJ, Pryor GA et al. Assessment of the AO classification of intracapsular fractures of the proximal femur. J.Bone Joint Surg.Br. 1998;80:679-83.
9. Burstein AH. Fracture classification systems: do they work and are they useful? J.Bone Joint Surg.Am. 1993;75:1743-4.
10. Carl AL, Tromanhauser SG, Roger DJ. Pedicle screw instrumentation for thoracolumbar burst fractures and fracture-dislocations. Spine 1992;17:S317-S324.
11. Dai LY, Jin WJ. Interobserver and intraobserver reliability in the load sharing classification of the assessment of thoracolumbar burst fractures. Spine 2005;30:354-8.
12. Flikkila T, Nikkola-Sihto A, Kaarela O et al. Poor interobserver reliability of AO classification of fractures of the distal radius. Additional computed tomography is of minor value. J.Bone Joint Surg.Br. 1998;80:670-2.
13. Gaines RW, Jr., Carson WL, Satterlee CC et al. Experimental evaluation of seven different spinal fracture internal fixation devices using nonfailure stability testing. The load-sharing and unstable-mechanism concepts. Spine 1991;16:902-9.

14. Gehrchen PM, Nielsen JO, Olesen B et al. Seinsheimer's classification of subtrochanteric fractures. Poor reproducibility of 4 observers' evaluation of 50 cases. Acta Orthop.Scand. 1997;68:524-6.
15. Kaneda K, Taneichi H, Abumi K et al. Anterior decompression and stabilization with the Kaneda device for thoracolumbar burst fractures associated with neurological deficits. J.Bone Joint Surg.Am. 1997;79:69-83.
16. Kim DH, Jahng TA, Balabhadra RS et al. Thoracoscopic transdiaphragmatic approach to thoracolumbar junction fractures. Spine J. 2004;4:317-28.
17. Kraemer WJ, Schemitsch EH, Lever J et al. Functional outcome of thoracolumbar burst fractures without neurological deficit. J.Orthop.Trauma 1996;10:541-4.
18. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159-74.
19. Leferink VJ, Veldhuis EF, Zimmerman KW et al. Classificational problems in ligamentary distraction type vertebral fractures: 30% of all B-type fractures are initially unrecognised. Eur.Spine J. 2002;11:246-50.
20. Magerl F, Aebi M, Gertzbein SD et al. A comprehensive classification of thoracic and lumbar injuries. Eur.Spine J. 1994;3:184-201.
21. McCormack T, Karaikovic E, Gaines RW. The load sharing classification of spine fractures. Spine 1994;19:1741-4.
22. McLain, Burkus JK, Benson DR. Segmental instrumentation for thoracic and thoracolumbar fractures: prospective analysis of construct survivla and five-year follow-up. Spine 2001, 310-323. 9-1-2001.
Ref Type: Generic
23. McLain RF, Sparling E, Benson DR. Early failure of short-segment pedicle instrumentation for thoracolumbar fractures. A preliminary report. J.Bone Joint Surg.Am. 1993;75:162-7.
24. Parker JW, Lane JR, Karaikovic EE et al. Successful short-segment instrumentation and fusion for thoracolumbar spine fractures: a consecutive 41/2-year series. Spine 2000;25:1157-70.
25. Reinhold M, Knop C, Beisse R et al. [Operative treatment of traumatic fractures of the thoracic and lumbar spinal column: Part III: Follow up data]. Unfallchirurg 2009;112:294-316.
26. Roy-Camille R, Roy-Camille M, Demeulenaere C. [Osteosynthesis of dorsal, lumbar, and lumbosacral spine with metallic plates screwed into vertebral pedicles and articular apophyses]. Presse Med. 1970;78:1447-8.

27. Sasso RC, Cotler HB, Reuben JD. Posterior fixation of thoracic and lumbar spine fractures using DC plates and pedicle screws. Spine 1991;16:S134-S139.
28. Scholl BM, Theiss SM, Kirkpatrick JS. Short segment fixation of thoracolumbar burst fractures. Orthopedics 2006;29:703-8.
29. Sidor ML, Zuckerman JD, Lyon T et al. The Neer classification system for proximal humeral fractures. An assessment of interobserver reliability and intraobserver reproducibility. J.Bone Joint Surg.Am. 1993;75:1745-50.
30. Siebenrock KA, Gerber C. The reproducibility of classification of fractures of the proximal end of the humerus. J.Bone Joint Surg.Am. 1993;75:1751-5.
31. Tasdemiroglu E, Tibbs PA. Long-term follow-up results of thoracolumbar fractures after posterior instrumentation. Spine 1995;20:1704-8.
32. Tezeren G, Kuru I. Posterior fixation of thoracolumbar burst fracture: short-segment pedicle fixation versus long-segment instrumentation. J.Spinal Disord.Tech. 2005;18:485-8.
33. Thomsen NO, Overgaard S, Olsen LH et al. Observer variation in the radiographic classification of ankle fractures. J.Bone Joint Surg.Br. 1991;73:676-8.
34. Verlaan JJ, Diekerhof CH, Buskens E et al. Surgical treatment of traumatic fractures of the thoracic and lumbar spine: a systematic review of the literature on techniques, complications, and outcome. Spine (Phila Pa 1976.) 2004;29:803-14.

# CHAPTER 5

## Loss of reduction of short-segment stabilized spinal fractures relates to a high preoperative LSC score.


Elzinga MJ[1],
Siebenga J[2]
Segers MJM[3]
ESM de Lange - de Klerk[4]
Patka P[5]
Bakker FC[1]

[1] Department of Trauma Surgery, VU University Medical Centre, Amsterdam, the Netherlands.
[2] Department of Surgery, Atrium Medical Centre, Heerlen, the Netherlands.
[3] Department of Surgery, Antonius Hospital, Nieuwegein, the Netherlands.
[4] Department of Epidemiology and Biostatistics, VU University Medical Centre, Amsterdam, the Netherlands.
[5] Department of Trauma Surgery, Erasmus University Medical Centre, Rotterdam, the Netherlands.


*Submitted*

## Keywords

Fracture; loss of reduction; load sharing classification; surgery; implant failure

## Summary

Postoperative changes in Cobbs' angle and the relationship thereof with the severity of thoracolumbar fractures are studied retrospectively in 58 patients, stabilized by a short-segment posterior implant alone or by a short-segment posterior stabilization in combination with an anterior reconstruction.

Cobb's angle is measured before operation, immediately postoperatively, and at 3-6 months and 12-18 months thereafter. The severity of the fracture is graded with the Load-Sharing Classification (LSC) from three to nine, which quantifies (a) the amount of the vertebral body involved in the fracture , (b) the apposition/displacement of fracture parts, and (c) the kyphosis needed to regain anatomic alignment.

Three groups of patients are distinguished: Group I (n=15): LSC 3-6, posterior stabilization; Group II (n=24): LSC 7-9, posterior stabilization; Group III (n=19) LSC 7-9, posterior stabilization plus anterior reconstruction. A significant reduction is achieved through surgery in all groups from 12.1 ± 15.3° to 4.9 ±8.1° in Group I , from 7.7 ± 14.7° to 0.7 ± 9.4° in Group II, and from 15.8 ± 15.3° to 9.7 ± 15.8° in Group III. After 3-6 months Cobb's angle increases in Group I and II to 8.7 ± 9.2° and 3.8 ± 9.5° respectively. In Group III no change of Cobb's angle is found after 3-6 months. After 12-18 months, however, Cobb's angle in Group II shows a significant further increase to 9.2 ± 10.5°.

After 12-18 months, loss of reduction is small but significant in Group III (11.4 ± 17.5°). In high LSC score fractures, loss of reduction at 12-18 months is larger in patients with posterior stabilization alone (Group II) (8.5 ± 2.9°) than the 1.7 ± 5.4° found in patients with a combined anterior-posterior procedure (Group III). It is concluded that loss of reduction after posterior stabilization in patients with low LSC scores occurs up till the first 3-6 months, after which period no further loss occurs. But in patients with a high LSC score, stabilized in the same way, loss of reduction continues to increase till at least up to 12-18 months. Loss of reduction between 3-6 and 12-18 months occurs also in patients with high LSC

scores treated with a posterior stabilization in combination with an anterior reconstruction. However this loss is significantly smaller than in patients with high LSC scores stabilized by a posterior implant alone.

## Introduction

In general, surgical treatment of fractures of the thoracic and lumbar spine is deemed necessary if the biomechanical stability of the spine is compromised and/or if a neurologic deficit is developing or already present. The aim of treatment of traumatic fractures of the thoracolumbar spine is to provide a stable spinal column capable to maintain the peroperative reduction of kyphotic deformities. To maintain alignment and promote fracture healing and fusion, fixation of the operative alignment with biomechanically stable constructs is regarded mandatory in unstable spinal fractures. To achieve this, a choice has to be made between various surgical techniques for the reduction and fixation of spinal fractures.

Advantages of a posterior stabilization over an anterior reconstruction are the lower operative morbidity and the good opportunity it offers to perform an easy reduction of any traumatic deformity. However, such implants may fail, showing pedicle screw migration, breakage or dislocation, and even without implant failure an appreciable amount of the kyphotic reduction gained during the posterior stabilization procedure can be lost thereafter.[1-5] Anterior reconstruction provides, as compared with posterior stabilization, superior biomechanical stability, but is associated with a higher morbidity and higher costs, and in anterior reconstruction some loss of reduction also occurs. Although the use of limited- and minimally invasive techniques have reduced the morbidity of the anterior reconstruction, as compared to the open approach, significantly.[6-9]

In order to increase the successful application of the posterior stabilization and to select patients for anterior reconstruction, McCormack et al. developed the Load Sharing Classification (LSC) of spine fractures.[10] This classification scores fractures by quantifying (a) the amount of comminution / involvement of the vertebral body, (b) the amount of apposition/displacement of the fracture fragments, and (c) amount of correction of the kyphotic deformity, by using a three–point system for each of these three characteristics; (1 to 3 each, total score from 3 to 9 points). The authors point out that spine fractures with low LSC scores (3-6 points) can be managed with short-segment posterior stabilization only.[11] They also state that, in accordance with Whitesides et al, burst fractures with high LSC scores (7-9 points) require anterior stabilization to prevent failure of the posterior implant.[12;13]

The forces related to implant failure may well be the same acting in loss of reduction. It is therefore of interest to find out if - and if so, how - loss of reduction relates to the choice of surgery, as well as to the preoperative LSC score. This is the first question posed in the present study.

Although loss of reduction is a very well known phenomena, up till now little attention has been given to its relationship with preoperative LSC scores. In a study on conservative treatment of thoracolumbar burst fractures Li-Yang Dai et al find a significant correlation between the LSC score on admission and the local kyphotic angle at final follow up.[14] On the other hand, in a retrospective review on short-segment posterior instrumentation of 46 thoracolumbar fractures Gelb et al find no relationship between loss of reduction and the LSC (< 6 or > 7).[15]

In contrast to implant failure, such as acute bending, dislocation, or breaking of any part of the implant, loss of reduction is a continuous process progressing over time after operation. Till now almost all studies compare postoperative kyphotic angle only with the angle found at the moment of (final) follow up. Since maintenance of the peroperative reduction of kyphotic deformities is one of the aims of surgical treatment of thoracolumbar fractures the second question posed is to what extent the peroperative reduction is lost at different moments in time after operation in patients with a low (LSC≤6) or high (LSC≥7) LSC score.

Both questions are pursued in a retrospective study of patients with low and high LSC scores and a posterior stabilization, as well as in patients with high LSC scores who had also an anterior reconstruction.

## Methods

Fifty-eight consecutive patients, surgically treated between January 1998 and December 2002 with short-segment stabilization for an unstable thoracolumbar compressive fracture of the spine take part in this study. These unstable fractures include AO Comprehensive Classification types A3.1-3, B1.2, B2.3 and C1.1-3.16

Patients with osteoporotic fractures, complex rotational fractures without evident vertebral body compression, pathological fractures, and fractures stabilized over more than two motion segments are excluded.

Posterior stabilization is indicated for instability of the thoracolumbar fracture according to the AO classification, without neurological dysfunction, to reduce the kyphotic deformity. If there exists significant encroachment of the spinal canal or concomitant loss of neurological function, anterior reconstruction is performed to regain stability at the fractured site. Posterior stabilization is done with a pedicle-based system consisting of screws and rods. It is not accompanied by transpedicular bone grafting because it does not necessarily bring intervertebral fusion or prevent loss of reduction.[17-20] When an anterior reconstruction is called for, a plate and/or a cage are placed through a thoracotomy on the anterolateral side of the fractured vertebral body. All but one of the anterior reconstructions is done in combination with posterior stabilization.

In patients with posterior stabilization the implant is routinely removed at 12 months to promote mobilization of the fixed motion segments and to reduce the risk for irreversible degenerative changes in facet joints. In patients with also an anterior reconstruction the posterior implant is removed only if the patient experiences problems with the implant or if it is necessary to regain mobility over a single motion segment in cases in which only one motion segment is stabilized with an anterior implant.

Demographic and injury related data, including age, gender, trauma mechanism, concomitant spinal fractures, the Injury Severity Score (ISS), and ASIA classification are obtained from the medical reports. The ISS is an anatomical scoring system that provides an overall score for patients with multiple injuries.[21] Preoperative radiological work-up consisting of conventional radiography, axial CT scans, and two-dimensional planar reconstructions are reviewed. The images obtained are used to assess the injury level and to classify fractures according to both the AO classification and the LSC, the Load Sharing Classification.[16;22] The AO classification and LSC scores of the 58 thoracolumbar fractures have been determined in consensus by three observers.

All X-rays made before surgery and during follow-up are used to assess loss of reduction and implant failure. Cobb's angle, defined as the angle between the proximal endplate of the proximal adjacent vertebra and the distal endplate of the distal adjacent vertebra in degrees, is scored in all patients postoperatively, 3-6 months after operation, and 12-18 months after operation. Kyphosis is noted as a positive value, lordosis as a negative one. Loss of reduction is calculated by determining the absolute difference in kyphotic angle between the moment of follow up and the angle measured postoperatively. Implant failure is defined as acute bending, dislocation, or breaking of any part of the implant during treatment and is assessed in all patients.

Three patient groups are distinguished on the basis of the LSC score and the stabilization procedure: Group I. patients with an LSC score of 3 to 6, and a posterior stabilization; Group II. patients with an LSC score of 7 to 9 and a posterior stabilization; Group III. patients with an LSC score of 7 to 9 and an anterior reconstruction in addition to posterior stabilization (see above). This distinction in three groups enables a review of the effect of different surgical techniques in patients with the same (high) LSC score and the influence of a different LSC score in patients with the same (posterior) stabilizing procedure.

The data are presented as the mean ± standard deviation (SD). Statistical analysis was done with the aid of SPSS 16.0. To determine the relation between the LSC score and postoperative loss of reduction a linear regression analysis is applied. To compare loss of reduction in patients with a high LSC score who were underwent different surgical procedures, Student's t tests were applied. P values of $<0.05$ are considered significant

## Results

### Patients

Of the 58 patients included in this study 39 are stabilized by a posterior implant, 15 of which have a LSC score from 3 to 6 ( Group I; table 1A) whereas 24 have a LSC score of 7 or more (Group II; table 1B), the 19 patients with an additional anterior reconstruction (Group III; table 2) have also LSC scores from 7 to 9.  No significant differences are found between the three groups in age and gender composition. The events causing the injuries are similar for the groups: most fractures,  47%

for Group I, 67 % for Group II and 68% for Group III, result from a fall from height, whereas traffic and sport accidents feature much less frequently. The injury severity score (ISS) for Group I is 10.6 ± 4.8 while 14.6 ± 7.9 is found for Group II, and 15.3 ± 9.5 for Group III. In all groups most fractures are classified as A3 according to the AO-Magerl Comprehensive Classification of Spinal Fractures; altogether 45 of the 58 patients have compression fractures (A type).16 Most fractures are found in the thoracolumbar region (Th11-L2), 11 in Group I, 20 in Group II, and 11 in Group III; in total there are 5 thoracic (T7-T10) and eight lower lumbar fractures (L3-L4). One patient has two non contingent fractures which are stabilized separately. Neurological impairment is evident in three patients of Group II, two thereof have an incomplete paraplegia (American Spinal Injury Association D) which deficit is fully restored by laminectomy, one patient has a complete paraplegia (ASIA A) at admittance. Five patients in Group III have a neurological impairment at admittance, three of which have an incomplete paraplegia (ASIA D). The symptoms of these three patients completely recovered after surgery. One patient in Group III had an incomplete paraplegia graded ASIA C and one ASIA B. These patients improved at least one point in the ASIA classification after surgery, but some complaints of paraesthesia remained in these two patients during follow-up.

**Posterior implants**

Table 1 shows that operative posterior stabilization reduces the average Cobb's angle from 12.1° to 4.9° in Group I, and from 7.7° to 0.7° in Group II.

Cobb's angle increases on average 3 to 6 months after operation again by 3.8° in Group I and by 3.1° in Group II. In Group I, at 12-18 months, hardly any increase of Cobb's angle is found as compared to the value at 3- 6 months (1.2°). Apparently loss of reduction does, after the first half year, not advance further with time in patients with low LSC scores. However, in Group II with the high LSC scores Cobb's angle does increase after 3-6 months from 3.8° to 9.2° at 12-18 months (figure 1.).

On the basis of these results it is of interest to learn whether or not a significant correlation exists between the individual LSC scores and the corresponding losses of reduction of the 39 patients with a posterior stabilization at 12-18 months

**Table 1a and 1b.** Patient characteristics, fracture characteristics, and Cobb's angle in patients with a posterior implant.

**1a.** Group I (LSC 3-6)

| | patient characteristics | | | | fracturecharacteristics | | | | Cobb's angle (degrees) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| n | age | sex | event | ISS | level | type | ASIA | LSC | preop | postop | 3-6m | 12-18m |
| 1 | 26 | F | MVA | 9 | L1 | A1.1 | E | 6 | 14 | 3 | 4 | 4 |
| 2 | 34 | F | MVA | 26 | L3 | A3.2 | E | 3 | 3 | 9 | 11 | 12 |
| 3 | 22 | F | MVA | 9 | T12 | A1.3 | E | 6 | 17 | 12 | 16 | 16 |
| 4 | 27 | M | Sports related | 9 | T12 | A1.2 | E | 6 | 29 | 10 | 15 | 16 |
| 5 | 56 | M | Fall from height | 9 | L3 | A3.1 | E | 4 | 0 | 2 | 3 | 0 |
| 6 | 20 | M | Sports related | 9 | T12 | A3.1 | E | 6 | 21 | 16 | 18 | 22 |
| 7 | 62 | F | Sports related | 9 | L1 | A3.1 | E | 3 | 8 | 3 | 5 | 11 |
| 8 | 55 | M | Fall from height | 9 | T12 | A1.2 | E | 6 | 20 | 10 | 14 | 16 |
| 9 | 42 | M | Fall from height | 4 | L1 | A1.2 | E | 5 | 27 | 2 | 8 | 11 |
| 10 | 53 | F | Fall from height | 13 | L1 | A2.1 | E | 5 | 7 | 6 | 9 | 8 |
| 11 | 34 | M | Fall from height | 9 | L1 | A3.1 | E | 6 | 12 | 6 | 17 | 18 |
| 12 | 23 | F | Fall from height | 9 | L2 | A2.1 | E | 5 | 4 | 3 | 3 | 2 |
| 13 | 32 | M | Fall from height | 13 | L3 | A3.1 | E | 5 | 21 | 2 | 6 | 19 |
| 14 | 45 | M | MVA | 13 | L4 | C1.1 | E | 6 | -31 | -2- | -18 | -14 |
| 15 | 26 | F | MVA | 9 | T12 | A2.1 | E | 6 | 30 | 10 | 18 | 18 |
| | | | | | | | | mean | 12.1 | 4.9 | 8.7 | 9.9 |
| | | | | | | | | ± sd | ± 15.3 | ± 8.1 | ± 9.2 | ± 9.1 |

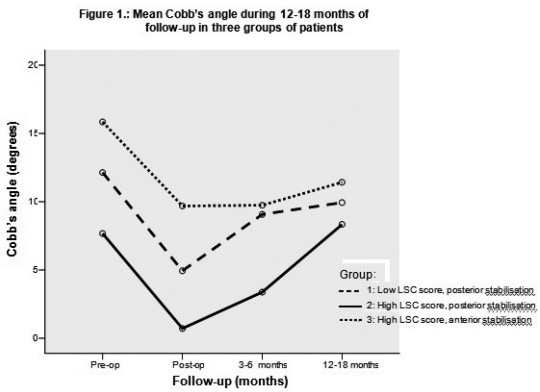



**Figure 1.** Mean Cobb's angle in three groups of patients with a traumatic thoracolumbar fracture of the spine during follow-up

**1b.** Group II (LSC 7-9)

| | patient characteristics | | | | fracturecharacteristics | | | | Cobb's angle (degrees) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *n* | age | sex | event | ISS | level | type | ASIA | LSC | preop | postop | 3-6m | 12-18m |
| 1 | 43 | M | Fall from height | 21 | L2 | A3.2 | E | 9 | -7 | -5 | 4 | 13 |
| 2 | 35 | M | Fall from height | 9 | L1 | A3.1 | E | 7 | 8 | 5 | 16 | 17 |
| 3 | 59 | M | Fall from height | 9 | T12 | A3.3 | E | 9 | 15 | 11 | 15 | 17 |
| 4 | 47 | M | Fall from height | 13 | L3 | A3.3 | E | 7 | 6 | -2 | 3 | 7 |
| 5 | 54 | F | Fall from height | 9 | L2 | A3.3 | E | 8 | -2 | -17 | -12 | -5 |
| 6 | 25 | F | Fall from height | 13 | L1 | A3.3 | E | 9 | 17 | 4 | 1 | 15 |
| 7 | 59 | F | Fall from height | 9 | L1 | A3.1 | E | 9 | 15 | 6 | 6 | 3 |
| 8 | 48 | M | Fall from height | 29 | T12 | B2.3 | E | 9 | 24 | 6 | 10 | 17 |
| 9 | 47 | F | Sports related | 9 | T12 | A3.2 | E | 9 | 17 | 5 | 5 | 16 |
| 10 | 22 | M | Fall from height | 22 | L1 | A3.2 | E | 8 | 16 | -2 | -5 | 17 |
| 11 | 18 | F | Fall from height | 9 | L1 | C1.2 | E | 9 | 25 | 5 | 10 | 12 |
| 12 | 27 | F | Blunt trauma | 34 | L1 | A3.3 | E | 7 | 16 | 5 | 1 | 8 |
| 13 | 21 | F | Sports related | 9 | T12 | A3.2 | E | 8 | 18 | -5 | 2 | 9 |
| 14 | 57 | M | Fall from height | 9 | L1 | A3.1 | E | 7 | 14 | 7 | 10 | 7 |
| 15 | 32 | M | Blunt trauma | 18 | L2 | A3.2 | E | 9 | 11 | 3 | 7 | 11 |
| 16 | 21 | F | MVA | 5 | L1 | A3.3 | E | 8 | 5 | 137 | 7 | 10 |
| 17 | 44 | M | Fall from height | 8 | L1 | A3.1 | E | 7 | 19 | 7 | 12 | 17 |
| 18 | 36 | F | Blunt trauma | 13 | L1 | B1.2 | E | 8 | 12 | 2 | 13 | 15 |
| 19 | 36 | F | Sports related | 4 | L2 | A1.1 | E | 8 | 3 | 2 | 2 | 12 |
| 20 | 33 | M | MVA | 27 | L3 | C1.3 | E | 7 | -31 | -20 | -9 | -9 |
| 21 | 44 | M | Fall from height | 18 | L1 | A3.2 | E | 8 | 16 | 16 | 18 | 22 |
| 22 | 44 | M | Fall from height | 18 | L4 | A3.3 | E | 8 | -33 | -20 | -20 | -22 |
| 23 | 32 | M | Fall from height | 22 | L2 | C1.2 | E | 8 | 0 | -1 | 6 | 19 |
| 24 | 17 | M | Fall from height | 13 | L3 | A3.1 | E | 7 | 0 | -8 | -11 | -7 |
| | | | | | | | | mean | 7.7 | 0.7 | 3.8 | 9.2 |
| | | | | | | | | ± sd | ± 14.7 | ± 9.4 | ± 9.5 | ± 10.5 |

(Group I and II). Loss of reduction is calculated (not presented) per patient by subtracting the postoperative Cobb's angle from the angle measured at 12-18 months (table 1a,b). A regression analysis of the loss of reduction and LSC score reveals a relationship between the two, that can be characterized as linear (figure 2. and 3.).

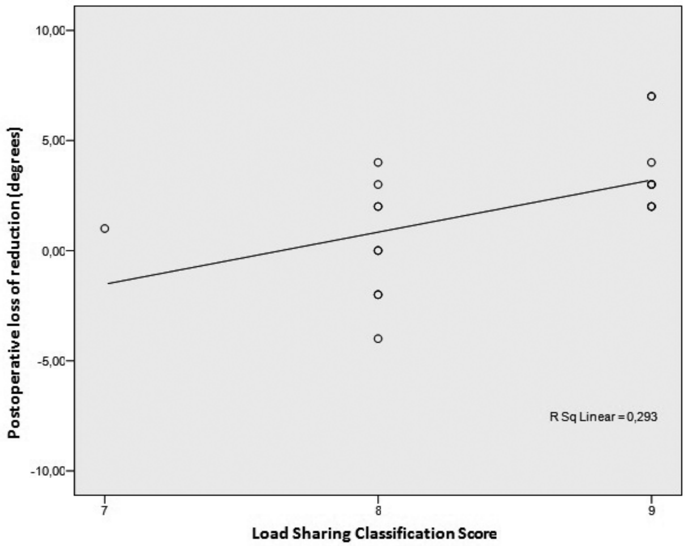



**Figure 2.** Linear regression analysis of the Load Sharing Classification and postoperative loss of reduction during 12-18 months after surgery of 39 patients a posterior stabilization.

### Anterior Reconstructions

The preoperative Cobb's angle of Group III of 15.8° ± 15.3° (table 2) is not significantly different from that of Group II (table 1b), although the mean value is substantially higher. Anterior reconstruction reduces the angle to a mean value of 9.7°. At the 3-6 months follow up this value appears to be unchanged (9.7°). Then at 12-18 months Cobb's angle increases by 1.7° to a value of 11.4° ± 17.5° (figure 1). This angle is higher than the one immediately after operation, and also when compared to the angle at 3-6 months (table 2).

**Table 2.** Patient characteristics, fracture characteristics and Cobb's angle in patients with an anterior reconstruction. Group III (LSC 7-9)

| | patient characteristics | | | | fracturecharacteristics | | | | Cobb's angle (degrees) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *n* | age | sex | event | ISS | level | type | ASIA | LSC | preop | postop | 3-6m | 12-18m |
| 1 | 44 | M | MVA | 29 | T7 | A1.2 | E | 8 | 33 | 35 | 32 | 35 |
| 2 | 37 | F | Sport accident | 9 | T7 | A1.2 | E | 7 | 16 | 15 | 16 | 17 |
| 3 | 23 | F | Fall from height | 18 | L1 | A3.3 | E | 9 | 30 | 21 | 26 | 28 |
| 4 | 31 | M | Fall from height | 13 | L1 | C1.2 | C | 9 | 20 | 8 | 8 | 15 |
| 5 | 35 | M | MVA | 4 | T7 | A3.1 | E | 9 | 29 | 27 | 25 | 28 |
| 6 | 32 | F | Fall from height | 9 | L1 | A3.3 | E | 9 | 20 | 11 | 7 | 11 |
| 7 | 35 | F | Fall from height | 21 | L3 | A3.3 | D | 9 | 6 | -10 | -13 | -10 |
| 8 | 48 | M | Fall from height | 9 | L2 | C1.3 | E | 9 | 12 | 14 | 11 | 14 |
| 9 | 25 | M | MVA | 9 | T7 | A3.3 | E | 9 | 25 | 18 | 25 | 27 |
| 10 | 27 | M | Fall from height | 9 | T12 | A3.1 | E | 9 | 19 | 24 | 23 | 25 |
| 11 | 58 | F | Fall from height | 34 | L3 | B2.3 | B | 8 | -21 | -22 | -25 | -25 |
| 12 | 21 | F | Fall from height | 9 | L1 | A3.2 | E | 8 | 19 | 3 | 5 | 7 |
| 13 | 20 | M | MVA | 36 | L10 | B2.3 | E | 8 | 32 | 24 | 28 | 28 |
| 14 | 50 | F | Sport accident | 9 | L2 | A3.2 | E | 8 | 2 | -10 | -10 | -12 |
| 15 | 34 | F | Fall from height | 9 | L1 | A3.2 | E | 8 | 2 | 2 | 2 | 4 |
| 16 | 31 | F | Fall from height | 23 | L3 | C1.2 | D | 8 | -16 | -16 | -16 | -20 |
| 17 | 44 | F | Fall from height | 9 | L1 | B2.3 | E | 9 | 30 | 25 | 23 | 25 |
| 18 | 30 | F | Fall from height | 9 | L1 | C1.3 | D | 8 | 21 | 1 | 1 | 5 |
| 19 | 32 | M | Fall from height | 22 | L2 | A3.2 | E | 8 | 21 | 14 | 17 | 15 |
| | | | | | | | | mean | **15.8** | **9.7** | **9.7** | **11.4** |
| | | | | | | | | ± sd | ± 15.3 | ± 15.8 | ± 16.6 | ± 17.5 |

Since Group II and III have the same high LSC scores but differ in the way the patients are treated a comparison is made of the loss of reduction at 12-18 months. Mean values and standard deviations are 8.5° ± 2.9° and 1.7° ± 5.4° for Group II and III respectively. This implies that at 12-18 months loss of reduction in patients with a posterior stabilization is larger than in patients with an anterior reconstruction.

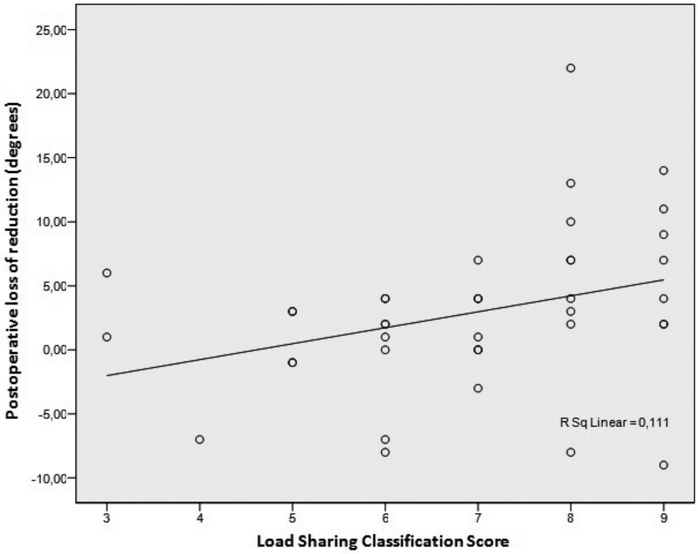



**Figure 3.** Linear regression analysis of the Load Sharing Classification and postoperative loss of reduction during 12-18 months after surgery of 19 patients with a high LSC score and an anterior reconstruction.

## Implant Failure

No implant failure is found 3-6 months after operation in Group I and II (table 4). However, after about 1 year three implants appear to have failed in Group II but none in Group I. This relatively limited number of failures implies that, up to 12-18 months no statistically significant implant failure in Group II occurs as compared to Group I, in spite of the high LSC scores. In one patient of Group III posterior implant failure was found at 12-18 months at removal of the implant (table 3).

**Table 3** Occurrence of implant failure during 12-18 months of follow-up after spinal instrumentation of thoracolumbar spine fractures

| | 3-6 months (non-failure/failure) | 12-18 months (non-failure/failure) |
|---|---|---|
| Group I | 15/0 | 15/0 |
| Group II | 24/0 | 21/3 |
| Group III | 19/0 | 18/1 |

## Discussion

Postoperative loss of reduction has been reported in a large number of studies. The systematic overview of Verlaan et al reports an average loss of 7.6° following a posterior short segment stabilization, and of 5.9° following a combined posterior-anterior intervention.[23] These estimates are based on 50 studies, and all studies in the respective subgroups do not take the severity of the spinal fracture into account, and do not inform about how loss of reduction progresses in time. The time of follow up ranged in the study of Verlaan et al from 12 to 79 months.[24] In fact very few studies relate loss of reduction to fracture severity and time following the intervention. Nevertheless those relationships are of interest to fully understand the consequences of the various treatment options of spinal fractures and to make an optimal choice thereof for individual patients.

The present study shows, in 39 patients with a traumatic thoracolumbar compressive fracture of the spine and subsequent posterior stabilization (Group I and II), that an appreciable amount of the preoperative 7° reduction of Cobb's angle, achieved through a posterior stabilization (table 1a and b), is lost soon after operation. Loss of reduction during the first 3-6 months appears to be on average 3.8° in Group I and 3.1° in Group II. This loss of reduction occurs without any apparent bending, dislocation or breaking of the implant (table 2).

After the first half a year loss of reduction does only increase slightly up till 12-18 months, in patients with LSC scores of 3 to 6 (Group I). In such patients the spinal can be qualified as being stable by then. In Group II with patients having LSC scores of 7 to 9, however, loss of reduction continues to increase after the first half year and reaches the significantly higher average value of 9.0° at 12-18 months. The finding that three of the implants in that high LSC group have failed at 12 months may be causally related to this ongoing change in the relationships between the vertebrae in the region of the fracture. Since a stable spinal column has been defined as the capacity to maintain the relationships between the vertebrae this implies that some instability remains when patients with spinal fractures and LSC scores of 7 to 9 are treated with a posterior stabilization procedure.[25]

In a study of 127 patients with thoracolumbar fractures, treated conservatively, Li-Yang Dai et al show for all LSC scores combined that the local kyphotic angle, significantly reduced by the conservative treatment, increases again gradually thereafter at the 3, 6, and 12 months follow ups, reaching an average value of 6.4° after more than 3 years.[26] Our results are in line with that observation, showing for high LSC scores, Cobb's angle to increase from 0.7° postoperatively to 3.8° at 3-6 months and to 9.2° at 12-18 months (table 1b). For low LSC scores (Group I) Cobb's angle does after 3-6 months only slightly increase further (table 1a); Li-Yang Dai et al, however, have not analyzed the postoperative change in kyphotic angle for different LSC scores.[27] The average loss of reduction of about 7.2° we find for the 39 patients of Group I and II together compares quite well with the 6.4° of Li-Yang Dai et al.28 Moreover, like Li-Yang Dai et al., the present study shows that the slope of the relationship between postoperative loss of reduction and the LSC scores is significant (fig. 2 and 3).

Gelb et al, in a retrospective study of 27 patients with thoracolumbar fractures treated with short-segment pedicle instrumentation, conclude in contrast that there is no relationship between loss of reduction and preoperative LSC scores.[29] They base their conclusion on the comparison of the loss of reduction in 18 patients with LSC scores of 3-6 with that in patients with an LSC score of 7-9. This observation does not correspond with our finding, as discussed above, that the slope of the relationship between the individual losses of reduction and the corresponding LSC scores is significant. Gelb et al have, however, not studied loss of reduction at different moments in time after operation for different LSC groups.[30] Therefore they are unable to note that in patients with high LSC scores the postoperative kyphotic angle continues to increase after 6 months which does not occur in patients with low LSC scores.

Apart from measurement errors of the kyphotic angle other factors may contribute to scatter of data in the relationship between LSC scores and corresponding reduction losses. Since the LSC assesses the degree of comminution, apposition and deformity correction of the vertebral body, it may not include all determinants of reduction loss.[31] Maintenance of spinal alignment may also be affected by the level of injury, injuries to the posterior column, intervertebral discs and ligaments, all not included in the LSC score. The present study does not provide specific information on this point. It is probably not even possible in patients to quantitatively assess the relative contributions of the vertebral body, the intervertebral disc, the posterior column to loss of reduction. Such questions can probably be more successfully pursued in experiments on isolated lumbar spines.

Our above conclusion that some instability remains when patients with spinal fractures and LSC scores of 7 to 9 are treated with a posterior stabilization procedure corresponds with the views of McCormack et al who originally developed and introduced the Load Sharing Classification.[32] Those authors conclude that in thoracolumbar fractures with a high LSC score an increased risk is seen for failure of the posterior implant. Remarkably this increased risk of failure is not seen in a study by Scholl et al. in 22 high LSC score fractures, stabilized with a posterior implant.[33] More precise, McCormack et al. report 10 implant failures in a group of 19 patients with high LSC scores. This is significantly more than the 3 failure we find in the 24 patients of Group II. This difference may well be explained by the difference in the length of the follow up period. McCormack et al studied their patients after at least 3 years after operation while in the present study the implants in Group II were removed after 12 months. The occurrence of implant failure more than one year after operation, together with the ongoing changes in Cobb's angle up to 12-18 months in Group II (table 1a,b), suggest that after severe spine fractures the relationships between the vertebrae keep changing over time. To get a better understanding of the healing processes of stabilized vertebrae longer term studies on loss of reduction and implant failure are worthwhile to pursue. Monitoring in vivo the loads on the internal fixation device has shown to be promising.[34]

A stable spinal column - i.e. a column able to maintain relations between vertebrae under physiological loads without neurological defects, incapacitating deformity, or intractable pain, and with minimal complications is the primary treatment aim of spinal fractures.[35,36] Achieving this is leading in the choice between a posterior or an anterior approach. Minimizing the postoperative loss of reduction may well be a logical, secondary goal. The outcomes of Group III show (table 2) that when also an anterior reconstruction is done no loss of reduction is found 3-6 months, while at 12 – 18 months a significant reduction loss of 1.7° has become manifest. Apparently, irrespective of the operative procedure followed, relationships between the vertebrae in patients with severe thoracolumbar fractures keep changing for at least 12-18 months. However, this is less after an anterior reconstruction than following a posterior stabilization (8.5° loss at 12-18 months for

Group II) and does not occur within 3-6 months after the operation. The practical implications of this conclusion depend of course ultimately on a comparison of the clinical outcomes, negative and positive, of the two procedures.

The systematic review of Oprel et al. comparing in 755 patients combined anterior-posterior surgery versus posterior surgery for thoracolumbar fractures claims that the "higher kyphotic correction and improvement of vertebral height (sagittal index) observed for the combined anterior-posterior group is cancelled out by more blood loss, longer operation time, longer hospital stay, higher costs, and a possible higher intra- and postoperative complication rate requiring re-operation and the possibility of a worsened Hannover spine score".[37] Although nowadays such negative consequences can avoided by the use of limited- and minimally invasive surgical techniques, like the thoracoscopically assisted procedures. Although significantly less than the open procedure, the overall complication rate of a thoracoscopic anterior stabilisation is still 11.4%., including such events as aortic injury, pneumothorax and cerebrospinal fluid leak[13,14] As far as the positive clinical outcomes are concerned it remains uncertain whether or not anterior reconstructions in patients with LSC scores from 7 to 9, do eventually result in less incapacitating deformity or intractable pain than posterior stabilizations. Just a few authors observed increased discomfort or pain in patients with an increase of post-traumatic kyphotic deformity in the absence of implant failure.[38] Most did not find kyphotic deformity to be associated with increased discomfort or pain.[39-44] On the other hand it has been reported that the clinical consequences of implant failure can be severe including loss of function and pain.[45,46]

In conclusion, this study shows that after posterior stabilization of thoracolumbar fractures with LSC scores between 3 and 6 months loss of reduction increases up to about 4° during the first half year after operation but remains stable thereafter; no implant failure is found in these patients. However, in patients with fractures having LSC scores from 7 to 9, and operated with the same procedure, loss of reduction of continues to rise for at least another year to about 9°; in 12.5% of those patients implants fail between 6 and 12 months after operation. When an anterior reconstruction is done to treat fractures with LSC scores from 7-9 during the first half year no loss of reduction is found. During the next year, however, a limited but significant increase of Cobb's angle develops. High, preoperative LSC scores are thus related to loss of reduction occurring between 3-6 and 12-18 months after surgical treatment. Therefore, the claim of McCormack et al that the LSC score "can be used preoperatively to predict screw breakage when short segment, posteriorly placed pedicle screw implants are being used" is complemented by this study in the sense that it can be used to predict also loss of reduction of Cobb's angle more than 3-6 months after operation irrespective of whether a posterior implant or anterior reconstruction is performed.[47]

## References


1. Alanay A, Acaroglu E, Yazici M et al. Short-segment pedicle instrumentation of thoracolumbar burst fractures: does transpedicular intracorporeal grafting prevent early failure? Spine (Phila Pa 1976.) 2001;26:213-7.
2. Knop C, Fabian HF, Bastian L et al. Late results of thoracolumbar fractures after posterior instrumentation and transpedicular bone grafting. Spine 2001;26:88-99.
3. Leferink VJ, Zimmerman KW, Veldhuis EF et al. Thoracolumbar spinal fractures: radiological results of transpedicular fixation combined with transpedicular cancellous bone graft and posterior fusion in 183 patients. Eur.Spine J. 2001;10:517-23.
4. Speth MJ, Oner FC, Kadic MA et al. Recurrent kyphosis after posterior stabilization of thoracolumbar fractures. 24 cases treated with a Dick internal fixator followed for 1.5-4 years. Acta Orthop.Scand. 1995;66:406-10.
5. Sanderson PL, Fraser RD, Hall DJ et al. Short segment fixation of thoracolumbar burst fractures without fusion. Eur.Spine J. 1999;8:495-500.
6. Danisa OA, Shaffrey CI, Jane JA et al. Surgical approaches for the correction of unstable thoracolumbar burst fractures: a retrospective analysis of treatment outcomes. J.Neurosurg. 1995;83:977-83.
7. Gurr KR, McAfee PC, Shih CM. Biomechanical analysis of anterior and posterior instrumentation systems after corpectomy. A calf-spine model. J.Bone Joint Surg.Am. 1988;70:1182-91.
8. Gurwitz GS, Dawson JM, McNamara MJ et al. Biomechanical analysis of three surgical approaches for lumbar burst fractures using short-segment instrumentation. Spine 1993;18:977-82.
9. Khoo LT, Beisse R, Potulski M. Thoracoscopic-assisted treatment of thoracic and lumbar fractures: a series of 371 consecutive cases. Neurosurgery 2002;51:S104-S117.
10. McCormack T, Karaikovic E, Gaines RW. The load sharing classification of spine fractures. Spine 1994;19:1741-4.
11. McCormack T, Karaikovic E, Gaines RW. The load sharing classification of spine fractures. Spine 1994;19:1741-4.
12. McCormack T, Karaikovic E, Gaines RW. The load sharing classification of spine fractures. Spine 1994;19:1741-4.
13. Whitesides TE, Jr. Traumatic kyphosis of the thoracolumbar spine. Clin.Orthop.Relat Res. 1977;78-92.

14. Dai LY, Jiang LS, Jiang SD. Conservative treatment of thoracolumbar burst fractures: a long-term follow-up results with special reference to the load sharing classification. Spine (Phila Pa 1976.) 2008;33:2536-44.
15. Gelb D, Ludwig S, Karp JE et al. Successful treatment of thoracolumbar fractures with short-segment pedicle instrumentation. J.Spinal Disord.Tech. 2010;23:293-301.
16. Magerl F, Aebi M, Gertzbein SD et al. A comprehensive classification of thoracic and lumbar injuries. Eur.Spine J. 1994;3:184-201.
17. Alanay A, Acaroglu E, Yazici M et al. Short-segment pedicle instrumentation of thoracolumbar burst fractures: does transpedicular intracorporeal grafting prevent early failure? Spine (Phila Pa 1976.) 2001;26:213-7.
18. Knop C, Fabian HF, Bastian L et al. Late results of thoracolumbar fractures after posterior instrumentation and transpedicular bone grafting. Spine 2001;26:88-99.
19. Knop C, Fabian HF, Bastian L et al. Fate of the transpedicular intervertebral bone graft after posterior stabilisation of thoracolumbar fractures. Eur.Spine J. 2002;11:251-7.
20. Leferink VJ, Zimmerman KW, Veldhuis EF et al. Thoracolumbar spinal fractures: radiological results of transpedicular fixation combined with transpedicular cancellous bone graft and posterior fusion in 183 patients. Eur.Spine J. 2001;10:517-23.
21. Baker SP, O'Neill B, Haddon W, Jr. et al. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J.Trauma 1974;14:187-96.
22. McCormack T, Karaikovic E, Gaines RW. The load sharing classification of spine fractures. Spine 1994;19:1741-4.
23. Verlaan JJ, Diekerhof CH, Buskens E et al. Surgical treatment of traumatic fractures of the thoracic and lumbar spine: a systematic review of the literature on techniques, complications, and outcome. Spine (Phila Pa 1976.) 2004;29:803-14.
24. Verlaan JJ, Diekerhof CH, Buskens E et al. Surgical treatment of traumatic fractures of the thoracic and lumbar spine: a systematic review of the literature on techniques, complications, and outcome. Spine (Phila Pa 1976.) 2004;29:803-14.
25. Panjabi MM, White AA, III. Basic biomechanics of the spine. Neurosurgery 1980;7:76-93.
26. Dai LY, Jiang LS, Jiang SD. Conservative treatment of thoracolumbar burst fractures: a long-term follow-up results with special reference to the load sharing classification. Spine (Phila Pa 1976.) 2008;33:2536-44.

27. Dai LY, Jiang LS, Jiang SD. Conservative treatment of thoracolumbar burst fractures: a long-term follow-up results with special reference to the load sharing classification. Spine (Phila Pa 1976.) 2008;33:2536-44.
28. Dai LY, Jiang LS, Jiang SD. Conservative treatment of thoracolumbar burst fractures: a long-term follow-up results with special reference to the load sharing classification. Spine (Phila Pa 1976.) 2008;33:2536-44.
29. Gelb D, Ludwig S, Karp JE et al. Successful treatment of thoracolumbar fractures with short-segment pedicle instrumentation. J.Spinal Disord.Tech. 2010;23:293-301.
30. Gelb D, Ludwig S, Karp JE et al. Successful treatment of thoracolumbar fractures with short-segment pedicle instrumentation. J.Spinal Disord.Tech. 2010;23:293-301.
31. McCormack T, Karaikovic E, Gaines RW. The load sharing classification of spine fractures. Spine 1994;19:1741-4.
32. McCormack T, Karaikovic E, Gaines RW. The load sharing classification of spine fractures. Spine 1994;19:1741-4.
33. Scholl BM, Theiss SM, Kirkpatrick JS. Short segment fixation of thoracolumbar burst fractures. Orthopedics 2006;29:703-8.
34. Rohlmann A, Graichen F, Weber U et al. 2000 Volvo Award winner in biomechanical studies: Monitoring in vivo implant loads with a telemeterized internal spinal fixation device. Spine (Phila Pa 1976.) 2000;25:2981-6.
35. Panjabi MM, White AA, III. Basic biomechanics of the spine. Neurosurgery 1980;7:76-93.
36. Panjabi MM, Oxland TR, Kifune M et al. Validity of the three-column theory of thoracolumbar fractures. A biomechanic investigation. Spine 1995;20:1122-7.
37. Oprel P, Tuinebreijer WE, Patka P et al. Combined anterior-posterior surgery versus posterior surgery for thoracolumbar burst fractures: a systematic review of the literature. Open.Orthop.J. 2010;4:93-100.
38. Daniaux H. [Transpedicular repositioning and spongioplasty in fractures of the vertebral bodies of the lower thoracic and lumbar spine]. Unfallchirurg 1986;89:197-213.
39. Shi J, Mei X, Liu J et al. The influence of correction loss in thoracolumbar fractures treated by posterior instrumentation: a minimum 7-year follow-up. J.Clin.Neurosci. 2011;18:500-3.
40. Lakshmanan P, Jones A, Mehta J et al. Recurrence of kyphosis and its functional implications after surgical stabilization of dorsolumbar unstable burst fractures. Spine J. 2009;9:1003-9.

41. Defino HL, Canto FR. Low thoracic and lumbar burst fractures: radiographic and functional outcomes. Eur.Spine J. 2007;16:1934-43.
42. Yi L, Jingping B, Gele J et al. Operative versus non-operative treatment for thoracolumbar burst fractures without neurological deficit. Cochrane.Database.Syst.Rev. 2006;CD005079.
43. Butler JS, Walsh A, O'Byrne J. Functional outcome of burst fractures of the first lumbar vertebra managed surgically and conservatively. Int.Orthop. 2005;29:51-4.
44. Verlaan JJ, Diekerhof CH, Buskens E et al. Surgical treatment of traumatic fractures of the thoracic and lumbar spine: a systematic review of the literature on techniques, complications, and outcome. Spine (Phila Pa 1976.) 2004;29:803-14.
45. McLain RF, Burkus JK, Benson DR. Segmental instrumentation for thoracic and thoracolumbar fractures: prospective analysis of construct survival and five-year follow-up. Spine J. 2001;1:310-23.
46. Weng XS, Qiu GX, Zhang J et al. [Complications associated with the technique of pedicle screw fixation]. Zhongguo Yi.Xue.Ke.Xue.Yuan Xue.Bao. 2002;24:294-7.
47. McCormack T, Karaikovic E, Gaines RW. The load sharing classification of spine fractures. Spine 1994;19:1741-4.

There is no progress in evolution. The fact of evolutionary change through time doesn't represent progress as we know it. Progress isn't inevitable. Much of evolution is downward in terms of morphological complexity, rather than upward. We're not marching toward some greater thing. Stephen Jay Gould in *The Third Culture - Beyond the Scientific Revolution by John Brockman. 1995*

# CHAPTER 6

## A Prospective Cohort Study Comparing the VAS Spine Score and Roland-Morris Disability Questionnair in Patients with a Type A Traumatic Thoracolumbar Spinal Fracture.

Siebenga, J.
Leferink, VJM.
Segers, MJM.
Elzinga, MJ.
Bakker, FC.
Rommens, PM.
Ten Duis, H-J.
Patka, P.

*Eur Spine J. 2008; 17(8):1096-1100*

## Introduction

To judge clinical outcome of patients with a traumatic thoracolumbar spinal fracture, functional scores are used. Judging back pain by comparing radiographs shows that clinical severity is not related to radiological parameters.[12,16,20] Some authors even refer to radiological results as surrogate outcome.[6,8] Clinical practice puts emphasis on pain, but pain is a complex physiological, psychological, and behavioral phenomenon that is difficult to evaluate and to quantify in the clinical situation.[17]

Because of these limitations, outcome of treatment is evaluated by measuring physical impairment and disability. Physical impairment is an anatomical or pathological abnormality leading to loss of normal body ability. Disability is the diminished capacity for everyday activities. Physical impairment is objective structural limitation; disability is the resulting loss of function, usually reported subjectively.

The Roland-Morris Disability Questionnaire (RMDQ-24) and the VAS Spine Score have been used regularly to measure and to monitor changes in functional outcome in patients with back pain.[5,11,14] Both scales were developed to assess functional disability in patients with low back pain, the RMDQ-24 in degenerative disease, and the VAS Spine in trauma patients. This study is the first that compares both scores prospectively in a cohort of patients with a spinal fracture.

The aim of this study is to compare these scores and to see if there is a correlation in patients with a traumatic thoracolumbar spinal fracture. The assessment of this correlation and the strength and linearity of the relationship between these two functional disability scales were addressed in the present study. In spine research it is important to have objective measurements, so that different studies can be compared. If there is a good correlation between the two scores, then it is possible to compare studies that assess functional outcome with one of these scales.

## Materials and Methods

The studied population was enrolled between October 1998 until October 2003. Thirty-four patients with a fracture of the thoracolumbar spine were included. Inclusion criteria were: traumatic fracture of Th10 – L4, AO Comprehensive

Classification type A, neurologically intact, and age 18 – 60 years.[9] Exclusion criteria were pathologic or osteoporotic fracture, patients with a history of operation on the back, type A.1.1 fracture, or accompanying injury that interferes with the functional outcome.

On admission all participants completed a 'pre-trauma' Roland-Morris Disability Questionnaire (RMDQ-24) and VAS Spine Score to asses any thoracolumbar dysfunction that they may have had before the injury. Every three months a questionnaire was send to the patients, until the end of follow-up.

The *RMDQ-24* was developed by Roland and Morris as a validated questionnaire to measure disability due to back pain. The disability questionnaire was constructed by choosing statements from the Sickness Impact Profile. The phrase 'because of my back' was added to each statement to distinguish disability due to other causes. The RMDQ-24 is validated for the German language.[19] Patients are given a score of one for each of the 24 items of the questionnaire that were ticked. A patient's score could thus vary from zero (no disability) to 24 (severe disability). The questionnaire is shown in *table 1*.

The VAS Spine Score was developed in Hannover, Germany. The questionnaire is composed of 19 questions, which are scored on a 10 centimeter visual analogue scale (VAS). A VAS scale is a 10 cm. line with the left end being a low score and the right end being a high score. The line is not divided into parts. The VAS is a well excepted measurement tool for pain.[10,13,15] The patient's perception of pain and restriction in activities, related to problems of the back, is measured. The score is calculated by taking the average score of all questions and can be any value between zero (severe disability) and 100 (no disability). The VAS questionnaire is shown in *table 2*.

The questionnaires were used to evaluate the functional outcome of the studied population. All scores were measured by an independent observer. For statistical evaluation, the score for the RMDQ-24 was transformed to a percentage by the following formula: (1-(n/24)) x 100. This resulted in a score of 0 when the RMDQ-24 was 24, indicating severe disability, and a score of 100 when the RMDQ-24 was 0, indicating no disability at all. The VAS Spine Score is a score from 0 to 100 so no transformation was needed. To prevent bias because of therapy the group was divided in conservative and operative treated patients.

Statistical evaluation included the use of the Pearson product-moment correlation coefficient and the Spearman rank correlation coefficient. The Pearson product-moment correlation coefficient makes the implicit assumption that the two variables are jointly normally distributed. When this assumption is not justified, a non-parametric measure such as the Spearman Rank Correlation Coefficient is more appropriate. A correlation of -1 means that there is a perfect negative linear relationship between variables, whereas a correlation of 0 means there is no linear relationship between the two variables. A correlation of +1 means that there is a perfect positive linear relationship between variables. The level of significance was set at $p < 0.05$. Considering that each scale is measuring the same construct, they would be expected to demonstrate a good correlation within both patient groups.

RMDQ-24

When your back hurts, you may find it difficult to do some of the things you normally do.

This list contains some sentences that people have used to describe themselves when they have back pain. When you read them, you may find that some stand out because they describe you today. As you read the list. Think of yourself today. When you read a sentence that describes you today, put a ticket against it. If the sentence does not describe you, then leave the space blank and go on to the next one. Remember, only tick the sentence if you are sure that it describes you today.

1. I stay at home most of the time because of my back.
2. I change position frequently to try and get my back comfortable.
3. I walk more slowly than usual because of my back.
4. Because of my back I am not doing any of the jobs that I usually do around the house.
5. Because of my back, I use a handrail to get upstairs.
6. Because of my back, I lie down to rest more often.
7. Because of my back, I have to hold on to something to get out of an easy chair.
8. Because of my back, I try to get other people to do things for me.
9. I get dressed more slowly than usual because of my back.
10. I only stand for short periods of time because of my back.
11. Because of my back, I try not to bend or kneel down.
12. I find it difficult to get out of a chair because of my back.
13. My back is painful almost all the time.
14. I find it difficult to turn over in bed because of my back.
15. My appetite is not very good because of my back pain.
16. I have trouble putting on my socks (or stockings) because of the pain in my back.
17. I only walk short distances because of my back pain.
18. I sleep less well because of my back.
19. Because of my back pain, I get dressed with help from someone else.
20. I sit down for most of the day because of my back.
21. I avoid heavy jobs around the house because of my back.
22. Because of my back pain, I am more irritable and bad tempered with people than usual.
23. Because of my back, I go upstairs more slowly than usual.
24. I stay in bed most of the time because of my back.

**Table 1:** RMDQ-24

VAS Spine score

1. How often is your sleep disturbed by back pain?
2. How often do you have back pain while you rest?
3. When you have back pain in rest, how strong is this pain?
4. How often do you have back pain with physical activities?
5. When you have back pain with physical activities, how strong is this pain?
6. How often do you have to take painkillers for back pain?
7. How good are the painkillers then?
8. How long can you sit without back pain?
9. How much does back pain restrict bending forward? (e.g. when washing the dishes)
10. How much restriction gives back pain in your profession?
11. How much is lifting restricted by back pain?
12. How much does back pain restrict your housekeeping?
13. How long can you stand without back pain?
14. How long can you walk without back pain?
15. How much does back pain restrict running? (e.g. jogging)
16. How much does back pain restrict your daily activities? (e.g. eating, washing)
17. How long can you travel without back pain? (e.g. driving a car, travelling by train)
18. How much does back pain restrict your sex life?
19. How much does back pain restrict your weight bearing?

Questions are scored on a VAS
See figure 1

**Table 2:** VAS Spine score

**Figure 1:** Visual Analogue Scale

## Results

Of the thirty-four patients, two patients were lost to follow-up and could not be contacted. Thus, thirty-two (94%) were followed. The patients were treated between 1998 and 2004. Mean follow up was almost four years (18 months – 5.5 years). The most common etiology of the fracture was a fall from a height. More males were affected than females. Mean age was 42 (18 – 59). As expected, most thoracolumbar fractures occurred at Th12 and L1. Most common fracture type was a burst fracture, AO type A3. The demographic and clinical statistics of the thirty-two patients are presented in *table 3*.

The comparison of the two disability scores is presented in *table 4*.

Patients treated operatively had a lower mean score (5.1 [0 – 24]) on the RMDQ-24 than non-operatively treated patients (6.6 [0 – 24]) $p < 0.05$, indicating les disability for the operative treated group. The VAS Spine score showed a similar pattern (82.9 [16 – 100]) for the operatively treated patients and (65.9 [9 – 100]) for the non-operatively treated group ($p < 0.001$).

The Pearson correlation coefficients between the two scales in each of the two groups were 0.91 ($p < 0.001$) and 0.83 ($p < 0.001$) for the operatively and non-operatively treated patients, respectively. The Spearmann rank correlation in the operatively treated group was 0.87 ($p < 0.001$) and in the non-operatively treated group 0.83 ($p < 0.001$). The plot reveals a strong positive relationship. (*see plot 1*)

## Discussion

Few studies have compared functional disability scales for patients with back complaints because of a traumatic spine fracture.[6,8,11] This is the first study to compare the RMDQ-24 and VAS Spine in spinal fracture patients. Most studies have evaluated functional disability scales in patient groups with low back pain without a traumatologic cause.[2,3,21] In this study the scales were used for patients with low back pain because of a spinal fracture.

A spinal fracture can lead to severe long term impairment in a relatively young patient population.[1,4] Effective management of these kind of injury, with lim-

| | Non-operatively treated (n=15) | Operatively treated (n=17) |
|---|---|---|
| Mean age (years) | 37 (18 – 58) | 46 (27 – 59) |
| Male:Female | 10:5 | 10:7 |
| Cause: | | |
| MVA | 5 | 3 |
| Fall | 10 | 10 |
| Sports | - | 2 |
| Horse riding | - | 2 |
| Level of fracture: | | |
| Th12 | 6 | 2 |
| L1 | 7 | 11 |
| L2 | 1 | 1 |
| L3 | 1 | 2 |
| L4 | - | 1 |
| CC-Type: | | |
| A1 | 4 | 1 |
| A2 | - | 2 |
| A3 | 11 | 14 |

**Table 3**

itation of functional impairment is therefore of utmost concern. The main goal of treatment is to maximize the functional outcome in these patients. For the evaluation of outcome, specific and sensitive tools are needed. This study shows that the RMDQ-24 and VAS Spine have a significant positive correlation as well as in conservative treated patients as in operative treated patients. The correlation of the VAS Spine with the RMDQ-24 justifies the theory that functional outcome in thoracolumbar spine fractures is determined by chronic back pain.

To see if our data is representative, we made a comparison with other groups that used the RMDQ-24 or VAS Spine score. Compared to prior results of Leferink in nineteen operated patients, our operated patient collective showed a RMDQ-24 score only one point higher (5.1 instead of 4).[8] In the non-operative group the

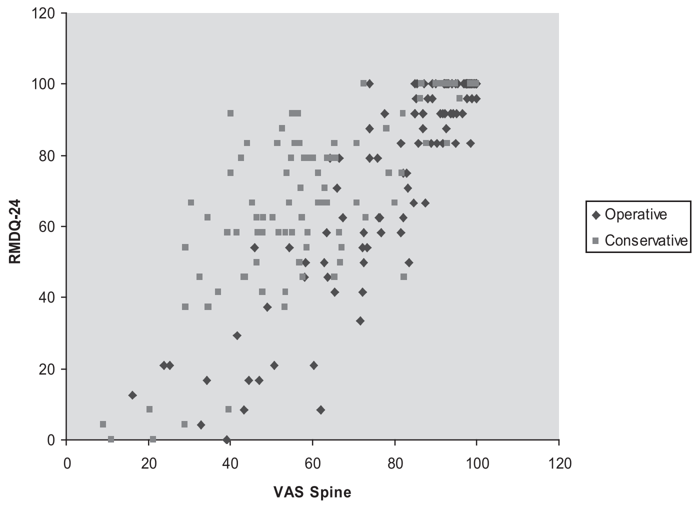
| Disability scale | | Non-operatively treated group (n=15) | Operatively treated group (n=17) |
|---|---|---|---|
| | Total number of questionnaires | 118 | 140 |
| RMDQ | | | |
| | Mean (range) | 6.6 (0 – 24) | 5.1 (0 – 24) |
| | SD | 6.2 | 6.9 |
| | Median | 5.5 | 2 |
| VAS Spine | | | |
| | Mean (range) | 65.9 (9 – 100) | 82.9 (16 – 100) |
| | SD | 24.5 | 19.2 |
| | Median | 61 | 91 |
| Pearson's r | | 0.83* | 0.91* |
| Spearman's rs | | 0.83* | 0.87* |

*p < 0.001

Attention: RMDQ-24: lower is better

VAS Spine: higher is better

**Table 4**




**Plot 1:** Scatter plot of conservatively and operatively treated group

RMDQ of 6.6 was a little less than the score of 5.2 found in the group of Post after a follow-up of 5 years.[11] Our results are favorable compared to other series which showed RMDQ-24 scores of 10.9 to 15.6.[6,7,18]

With regard to the VAS Spine score the non-operative group performed comparable with the group of Knop (65.9 vs. 66.1) and less than a group of non-operative treated patients in a study of Post (65.9 vs. 79) but this was after 5 years of follow-up.[11] Our operative group showed comparable VAS Spine scores with the group of Leferink (82.9 vs. 79.4).[5,8] Considering this comparison our patient collective is a small but representative group in comparison with literature.

RMDQ-24 and VAS Spine have a strong positive correlation in measuring disability in a group of patients with back pain because of a spinal fracture. In both non-operatively and operatively treated groups, this correlation is significant. The RMDQ-24 and VAS Spine are valid to evaluate the functional disability of patients after a thoracolumbar spinal fracture.

## References

1 Denis F, Armstrong GW, Searls K, Matta L. Acute thoracolumbar burst fractures in the absence of neurologic deficit. A comparison between operative and nonoperative treatment. Clin Orthop 1984;(189):142-9.

2 Grotle M, Brox JI, Vollestad NK. Concurrent comparison of responsiveness in pain and functional status measurements used for patients with low back pain. Spine 2004 Nov 1;29(21):E492-E501.

3 Jordan K, Dunn KM, Lewis M, Croft P. A minimal clinically important difference was derived for the Roland-Morris Disability Questionnaire for low back pain. J Clin Epidemiol 2006 Jan;59(1):45-52.

4 Knop C, Blauth M, Bastian L, Lange U, Kesting J, Tscherne H. [Fractures of the thoracolumbar spine. Late results of dorsal instrumentation and its consequences] [Frakturen der thorakolumbalen Wirbelsaule. Spatergebnisse nach dorsaler Instrumentierung und ihre Konsequenzen.]. Unfallchirurg 1997 Aug;100(8):630-9.

5 Knop C, Oeser M, Bastian L, Lange U, Zdichavsky M, Blauth M. [Development and validation of the Visual Analogue Scale (VAS) Spine Score] [Entwicklung und Validierung des VAS-Wirbelsaulenscores.]. Unfallchirurg 2001 Jun;2001 Jun;104(6):488-97.

6 Kraemer W.J., Schemitsch E.H., Lever J., McBroom R.J., McKee M.D., Waddell JP. Functional outcome of thoracolumbar burst fractures without neurological deficit. J Orthop Trauma 1996;10(8):541-4.

7 Leclaire R, Blier F, Fortin L, Proulx R. A cross-sectional study comparing the Oswestry and Roland-Morris Functional Disability scales in two populations of patients with low back pain of different levels of severity. Spine 1997 Jan 1;1997 Jan 1;22(1):68-71.

8 Leferink VJM, Keizer H.J.E., Oosterhuis J.K., Sluis C.K.van der, Duis HJ ten. Functional outcome in patients with thoracolumbar burst fractures treated with dorsal instrumentation and transpedicular cancellous bone grafting. Eur Spine J 2003;12(3):261-7.

9 Magerl F, Aebi M, Gertzbein SD, Harms J, Nazarian S. A comprehensive classification of thoracic and lumbar injuries. Eur Spine J 1994;3(4):184-201.

10 Ohnhaus EE, Adler R. Methodological problems in the measurement of pain: a comparison between the verbal rating scale and the visual analogue scale. Pain 1975 Dec;1(4):379-84.

11 Post RB, Keizer HJ, Leferink VJ, van der Sluis CK. Functional outcome 5 years after non-operative treatment of type A spinal fractures. Eur Spine J 2006 Apr;15(4):472-8.

12 Resch H, Rabl M, Klampfer H, Ritter E, Povacz P. [Surgical vs. conservative treatment of fractures of the thoracolumbar transition] [Operative vs. konservative Behandlung von Frakturen des thorakolumbalen Ubergangs.]. Unfallchirurg 2000 Apr;2000 Apr;103(4):281-8.

13 Revill SI, Robinson JO, Rosen M, Hogg MI. The reliability of a linear analogue for evaluating pain. Anaesthesia 1976 Nov;31(9):1191-8.

14 Roland M, Morris R. A study of the natural history of low-back pain. Part II: development of guidelines for trials of treatment in primary care. Spine 1983 Mar;8(2):145-50.

15 Scott J, Huskisson EC. Graphic representation of pain. Pain 1976 Jun;2(2):175-84.

16 Shen WJ, Liu TJ, Shen YS. Nonoperative treatment versus posterior fixation for thoracolumbar junction burst fractures without neurologic deficit. Spine 2001 May 1;2001 May 1;26(9):1038-45.

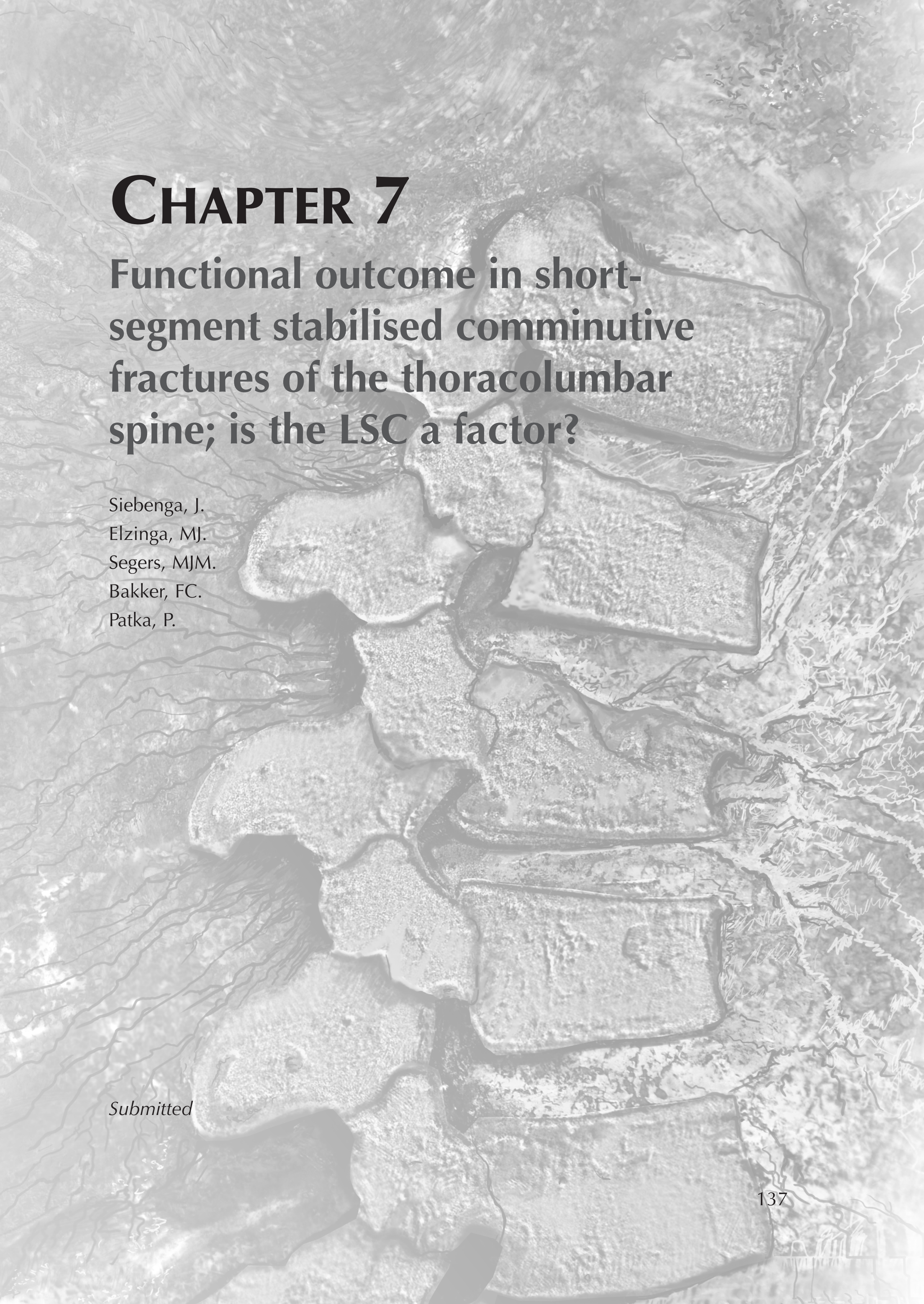
17 Waddell G, Main CJ. Assessment of severity in low-back disorders. Spine 1984 Mar;9(2):204-8.

18 Weinstein JN, Collalto P, Lehmann TR. Thoracolumbar "burst" fractures treated conservatively: a long- term follow-up. Spine 1988;13(1):33-8.

19 Wiesinger GF, Nuhr M, Quittan M, Ebenbichler G, Wolfl G, Fialka-Moser V. Cross-cultural adaptation of the Roland-Morris questionnaire for German-speaking patients with low back pain. Spine 1999 Jun 1;24(11):1099-103.

20 Wood K, Butterman G, Mehbod A, Garvey T, Jhanjee R, Sechriest V. Operative compared with nonoperative treatment of a thoracolumbar burst fracture without neurological deficit. A prospective, randomized study. J Bone Joint Surg Am 2003 May;2003 May;85-A(5):773-81.

21 Zerbini C, Ozturk ZE, Grifka J, Maini M, Nilganuwong S, Morales R, et al. Efficacy of etoricoxib 60 mg/day and diclofenac 150 mg/day in reduction of pain and disability in patients with chronic low back pain: results of a 4-week, multinational, randomized, double-blind study. Curr Med Res Opin 2005 Dec;21(12):2037-49.



# CHAPTER 7

## Functional outcome in short-segment stabilised comminutive fractures of the thoracolumbar spine; is the LSC a factor?

Siebenga, J.
Elzinga, MJ.
Segers, MJM.
Bakker, FC.
Patka, P.

*Submitted*

## KEYWORDS

Spine fracture – Load Sharing Classification – Short-segment implant – Functional outcome

## Introduction

Short-segment posterior stabilization for unstable thoracolumbar fractures has become a more common treatment modality. Although this therapy enables early mobilization of patients, long-term results are not always satisfactory.[1-4] To increase the feasability of short-segment stabilising implants, McCormack et al. developed the Load Sharing Classification of Spinal fractures in 1994 (LSC).[5] This classification should make an appropriate choice between multiple operative strategies (posterior with for example a pedicle screw based implant, or anterior through corporectomy). The classification system assigns from one to three points to three radiological characteristics of the traumatic thoracolumbar fracture: 1. the amount of comminution/involvement of the vertebral body, 2. the amount of apposition/displacement of the fracture fragments and 3. the amount of correction of kyphotic deformity. In total, a minimum LSC score of three and a maximum score of nine can be obtained. According to the LSC, spine fractures with LSC scores of three to six (low) can be managed safely with a short-segment posterior stabilization, without risk of implant failure.[6] An anterior stabilization is advised for burst fractures with LSC scores of seven to nine (high).

If a high LSC type fracture is only stabilised with a short-segment posterior stabilising implant, loss of the peroperative applied reduction and an increased risk of implant failure are evident.[5,6] It still remains uncertain whether this increased loss of reduction and increased risk of implant failure leads to significant loss of function in these patients.

This study analyses the functional outcome after 18 months of follow-up of patients with an unstable burst fracture of the thoracolumbar spine, treated with a short-segment stabilising procedure (anterior and/or posterior).[7,8] The goal of this study was to evaluate the prognostic value of the Load Sharing Classification for the functional outcome of patients with short-segment stabilised burst fractures of the thoracolumbar spine. Main question is whether patients with a high LSC fracture, stabilised only with a posterior stabilising implant have a worse functional outcome than patients stabilised according to the LSC.

## Materials and Methods

This retrospective study consists of a consecutive series of 58 patients, admitted between January 1998 and October 2002 with a traumatic, unstable burst fracture of the thoracolumbar spine. These unstable fractures included types A3.1-3, B 1.2, B 2.3, and C1.1-3 according to the AO comprehensive classification.[9] These are fracture types in which comminution of the vertebral body is present. Patients with spinal disorders in their medical history, osteoporotic fractures, distraction fractures, complex rotational fractures without evident vertebral body compression, pathological fractures, and fractures stabilized over more than two motion segments were excluded.

Posterior reconstruction to reduce the kyphotic deformity, was indicated for unstable fractures of the thoracolumbar spine according to the AO classification. Three patients with discrete neurologic deficit were treated with a posterior stabilisation in combination with a laminectomy, after which their neurologic function completely restored. If there was significant encroachment of the spinal canal or concomitant loss of neurological function, anterior reconstruction was performed, to regain biomechanical stability at the fractured site. Posterior stabilization was achieved with a pedicle-based system consisting of screws and rods, whereas anterior stabilization was done with a plate and/or cage, placed via thoracotomy or retroperitoneal lumbotomy, on the anterolateral side of the fractured vertebral body. A combined anetero-posterior stabilization utilized both techniques. Posterior stabilization was not accompanied by posterior bone grafting because it does not necessarily lead to a reliable intervertebral fusion or prevent loss of angular corrections.[10,11]

In patients with both anterior and posterior stabilization, the posterior implant was removed only if the patient experienced problems with the implant or if it was necessary to regain mobility over a single motion segment in cases in which only one motion segment was stabilized with an anterior implant.

Selected epidemiological factors were gender, age, fracture level, AO classification, kyphotic deformity, neurological function (ASIA scale), Injury Severity Score (ISS), ICU stay, time to surgery, hospital stay and implant failure. Demographic and injury-related data including age, gender, trauma mechanism, concomitant spinal fractures, the Injury Severity Score (ISS) and ASIA classification were obtained from the medical reports. The ISS is a scoring system that uses the Abbreviated Injury Scale (AIS), in order to identify the severity of trauma of the multiple injured patient.[12]

Kyphotic deformity was measured by local kyphosis (the angle between the endplates of the fractured vertebra in degrees) and regional kyphosis (the angle between the proximal endplate of the proximal adjacent vertebra and the distal endplate of the distal adjacent vertebra in degrees as defined by Kaneda et al. (fig. 1)).[13] Kyphosis was measured preoperatively, immediate after surgery and at 18 months of follow-up. Loss of the surgical applied reduction during follow-up was calculated through distraction of these respective values.[14] Implant failure was defined as acute bending, dislocation or breaking of any part of the implant during the course of follow-up.

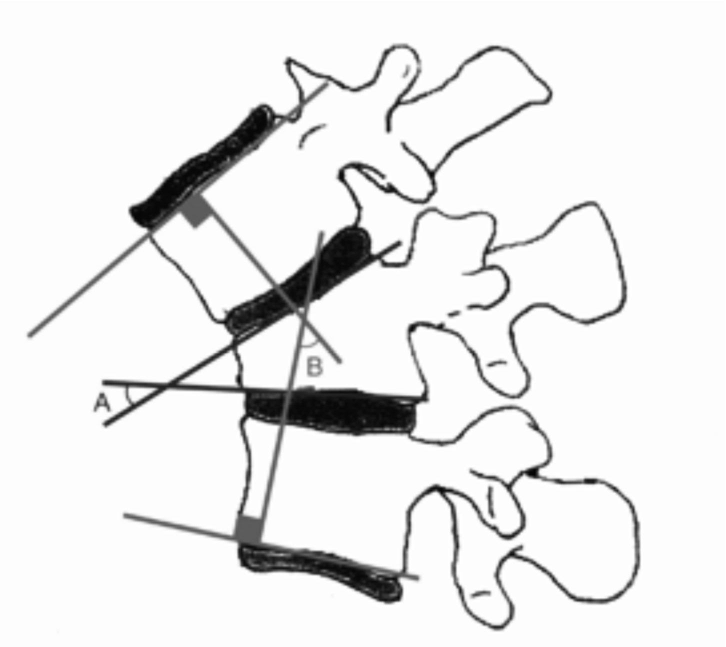



**Figure 1: A=** local kyphosis, the angle in degrees between the plates of the fractured vertebra.
**B=** regional kyphosis the angel in degrees between the cranial plate of the cranial adjacent vertebra and the distal plate of the distal adjacent vertebra.

The functional outcome after 18 months was measured in all patients. To measure restrictions in activities after eighteen months of follow-up, all patients received a questionnaire consisting of the Visual Analogue Scale (VAS) Spine Score and the Roland Morris Disability Questionnaire (RMDQ).[15-17] The RMDQ was developed and validated by Roland and Morris to measure disability related to back pain. The disability questionnaire has been constructed out of specific statements from the Sickness Impact Profile. According to the RMDQ a score of one has to be awarded to each positive answer to one of the 24 items of the questionnaire in order to assess (dis)ability. As a result, the patient's score varies between zero (representing no disability) and 24 (severe disability). The questionnaire is shown in figure 1.

The VAS Spine Score (Hannover Rücken Score) is composed of 19 questions which are scored on a 100 millimetre Visual Analogue Scale (VAS). This VAS scale is a 100 mm line with the left end representing a negative answer (0 mm, disability) and the right end representing a positive answer (100mm, ability). The patient's perception of pain and restriction in activities, related to problems of the back, can be measured. The score is calculated by taking the average score of all questions and can be any mean value between 0mm (disability) and 100mm (ability). The questionnaire is shown in figure 2. The VAS is a well excepted measurement tool for pain.[18-20]

Statistical analysis was done by a multivariate regression analyses (SPSS 12.0.1 for Windows, SPSS Inc., Chicago).

## Results

This study describes the functional outcome of 58 patients with burst fractures of the thoracolumbar spine, treated with a short-segment stabilisation.

Age varied in the studied population from 18 to 62 years with a male: female ratio of 1:1. Fracture levels in these patients varied from Th7 to L4, of which 42 out of 58 fractures were seen at the thoracolumbar junction (Th10-L2).

Injury Severity Scores varied from 4 to 36, 19 patients sustained an ISS equal or greater than 13. Time to surgery varied from 0 to 24 days. Hospital stay was longer for anterior stabilised patients, but did not differ significantly between the groups. In total fifteen of the fifty-two patients were admitted to the ICU for a certain period of time (1-52 days).

RMDQ-24

When your back hurts, you may find it difficult to do some of the things you normally do.

This list contains some sentences that people have used to describe themselves when they have back pain. When you read them, you may find that some stand out because they describe you today. As you read the list. Think of yourself today. When you read a sentence that describes you today, put a ticket against it. If the sentence does not describe you, then leave the space blank and go on to the next one. Remember, only tick the sentence if you are sure that it describes you today.

1. I stay at home most of the time because of my back.
2. I change position frequently to try and get my back comfortable.
3. I walk more slowly than usual because of my back.
4. Because of my back I am not doing any of the jobs that I usually do around the house.
5. Because of my back, I use a handrail to get upstairs.
6. Because of my back, I lie down to rest more often.
7. Because of my back, I have to hold on to something to get out of an easy chair.
8. Because of my back, I try to get other people to do things for me.
9. I get dressed more slowly than usual because of my back.
10. I only stand for short periods of time because of my back.
11. Because of my back, I try not to bend or kneel down.
12. I find it difficult to get out of a chair because of my back.
13. My back is painful almost all the time.
14. I find it difficult to turn over in bed because of my back.
15. My appetite is not very good because of my back pain.
16. I have trouble putting on my socks (or stockings) because of the pain in my back.
17. I only walk short distances because of my back pain.
18. I sleep less well because of my back.
19. Because of my back pain, I get dressed with help from someone else.
20. I sit down for most of the day because of my back.
21. I avoid heavy jobs around the house because of my back.
22. Because of my back pain, I am more irritable and bad tempered with people than usual.
23. Because of my back, I go upstairs more slowly than usual.
24. I stay in bed most of the time because of my back.

**Figure 2:** The separate items of the Roland-Morris Disability Questionnaire. One point is given for every positive answered item.

VAS~Score

1 Wie oft stören Rückenschmerzen ihren Schlaf?

2 Wie oft haben Sie in körperlicher Ruhe die Rückenschmerzen?

3 Wie stark sind dann in körperlichen Ruhe die Rückenschmerzen?

4 Wie oft haben Sie bei körperlichen Belastung Rückenschmerzen?

5 Wie stark sind dann bei körperlichen Belastung die Rückenschmerzen?

6 Wie oft nehmen Sie Schmerzmittel gegen Rückenschmerzen ein?

7 Wie gut wirken die Schmerzmittel dann?

8 Wie lange können Sie ohne Rückenbeschwerden sitzen?

9 Wie stark schränken Rückenbeschwerden das Vorbeugen ein? (Wie zB beim Abwaschen)

10 Wie stark schränken Rückenbeschwerden Ihren Beruf ein?

11 Wie stark schränken Rückenbeschwerden das Hochheben ein?

12 Wie stark schränken Rückenbeschwerden Hausarbeiten ein?

13 Wie lange können Sie ohne Rückenbeschwerden stehen?

14 Wie lange können Sie ohne Rückenbeschwerden gehen?

15 Wie stark schränken Rückenbeschwerden das Laufen ein? (Jogging, Waldlauf, etc)

16 Wie stark schränken Rückenbeschwerden Aktivitäten des taglichen Lebens ein? (zB Essen, Waschen etc )

17 Wie lange können Sie ohne Rückenbeschwerden reisen? (zB Autofahren, Zugfahren etc )

18 Wie stark schränken Rückenbeschwerden Ihr Sexualleben ein?

19. Wie stark schränken Rückenbeschwerden das Tragen ein?

**Figure 3:** The original version of the Hannover Rücken Score VAS Spine score and its separate items

Mean local kyphosis was preoperatively 17°, surgical procedure reduced this kyphosis in 9°. At 18 months local kyphosis was increased to a mean 12° of local kyphosis. Regional kyphosis in group one was preoperatively 13°, after surgery 6° and after 18 months of follow-up mean regional kyphosis was 11°. Patients with high LSC fractures and a solitary posterior stabilising implant showed significant loss of reduction, compared to patients with high LSC score fractures and an anterior implant (p<0,001).

Injury Severity Scores varied from 4 to 36, 19 patients sustained an ISS equal or greater than 13. Time to surgery varied from 0 to 24 days. Hospital stay was longer for anterior stabilised patients, but did not differ significantly between the groups. In total fifteen of the fifty-two patients were admitted to the ICU for a certain period of time (1-52 days). Implant failure was observed in 4 cases. In 3 of the 21 patients with a high LSC score and a posterior implant and in 1 of the 17 patients with an anterior implant a pedicular screw breakage was seen.

Functional outcome was measured in all patients. The RMDQ showed a mean value of 8.5 positive items after 18 months. The VAS score was 66 mm after 18 months follow-up. There was no relation between LSC score and RMDQ and no relation between LSC and VAS score.

## Discussion

To provide anatomic alignment and a stable spinal column is the goal of surgical management of unstable thoracolumbar fractures of the spine. Accepted methods for operative management of unstable thoracolumbar fractures include posterior stabilization with pedicle screws and stabilization using anterior procedures. These techniques can be used alone or in combination.[21-25] Posterior stabilization provides good opportunities to perform reduction of the kyphotic deformity with low morbidity. The anterior stabilising procedure provides better biomechanical stability, but connected to considerable perioperative morbidity in the classic open approach.

| | Age | Gender (m:f) | Days to surgery | Admittance (days) | ICU stay (days) | ISS | Type of Trauma (: n) | Mean ISS |
|---|---|---|---|---|---|---|---|---|
| *(n=58)* | 36<br>(17-62) | 1:1 | 10<br>(0-43) | 26<br>(7-132) | 3<br>(1-52) | 13<br>(4-36) | Fall from height: 35<br>MVA: 11<br>Sport: 9<br>Other: 3 | 14<br>(4-29) |

**Table 1:** Demographic data from our studied population of patients with a thoracolumbar fracture treated through a short-segment stabilising procedure. (MVA= Motor Vehicle Accident)

To aid in the choice between these operative strategies, McCormack et al. designed the Load Sharing Classification of Spinal Fractures (LSC).[5] In the case of an LSC score of seven to nine (high) an anterior stabilisation is advised. In the case of a thoracolumbar fracture with a LSC score of three to six (low), a posterior fixation and stabilization alone is considered to be sufficient. Earlier studies have indicated that high LSC score, fractures only stabilised with a posterior implant show loss of reduction and are exposed to an increased risk of implant failure.[5,6] These findings are also seen in our studies (tables 2 and 3). The aforementioned studies all demonstrate that the LSC has a prognostic value for the radiological outcome of short-segment stabilised thoracolumbar fractures. Whether the LSC has a prognostic value for the functional outcome of these patients has not yet been studied.

| | AO (: n) | Fracture level (: n) | Mean LSC | ASIA (: n) |
|---|---|---|---|---|
| (n=58) | A3: 45 | Th7: 4 | 8,1 | A: 1 |
| | B1: 1 | Th10: 1 | | B: 1 |
| | B2: 4 | Th12: 10 | | C: 1 |
| | C1: 8 | L1: 23 | | D: 4 |
| | | L2: 9 | | E: 51 |
| | | L3: 9 | | |
| | | L4: 2 | | |

**Table 2:** Fracture characteristics of 58 patients with a thoracolumbar fracture. ASIA scores are the preoperative values

| *t* (months) | *preop* (0) | *postop* (1) | *Follow-up* (18) | *Loss of reduction* |
|---|---|---|---|---|
| Mean Local Kyphosis | 17° | 9° | 12° | 3° |
| Mean Regional Kyphosis | 13° | 6° | 11° | 5° |

**Table 3:** Mean local and regional kyphosis during the course of treatment in 58 patients.

In our study the differences in radiological outcome between the groups did not lead to significant differences in functional outcome (table 4). The mean functional

| Author | Group | N | Follow-up (years) | Positive items Mean | Positive items SD |
|---|---|---|---|---|---|
| Leclaire et al.[17] | Simple low back pain (mean duration 2.3 weeks) | 99 | - | 10.9 | 4.7 |
| | Low back pain with radiculopathy (mean duration 28.1 weeks) | 97 | - | 14.2 | 5.2 |
| Weinstein et al.[28] | Conservatively treated thoracolumbar burst fractures | 42 | 20.2 | 13.2 | - |
| Kraemer et al.[26] | Thoracolumbar burst fractures (operative and non-operative) | 24 | 3.8 | 15.6 | 6.5 |
| Leferink et al.[27] | Thoracolumbar burst fractures after USS | 19 | 4.5 | 4.0 | 6.0 |
| This study | Thoracolumbar burst fractures (anterior and/or posterior) | 52 | 1.5 | 8.5 | 8.3 |

**Table 4:** Comparison of Roland Morrison Disability Questionnaire (RMDQ) values in patients with low back pain and operatively treated spinal fractures.

impairment after 18 months is 8.5 positive items according to the Roland Morris Disability Questionnaire (RMDQ). These findings are comparable with RMDQ scores in patients with low back pain, radiculopathy or thoracolumbar fractures at 3.8, 4.5 and 20.2 years of follow-up (table 5).[17,26-28] The VAS Spine Score revealed a mean functional outcome score of 66 mm after 18 months of follow-up.[15,27]

| | Values in uninjured people(15) (n=136) | Hannover study (15) Before trauma (n=53) | Hannover study (15) At implant removal (7-13 months) (n=51) | Hannover study (15) At follow-up (23 months) (n=53) | Leferink study (27) (54 months) (n=19) | Current study (18 months) (n=52) |
|---|---|---|---|---|---|---|
| Mean | 92.0 | 89.6 | 58.3 | 66.1 | 79.4 | 66.7 |
| Median | 94 | 95 | 59 | 70 | 90.5 | 76.5 |
| SD | 7.5 | 14.9 | 22.2 | 25.0 | 25.0 | 28.7 |
| Range | 58-100 | 21-100 | 13-97 | 15-100 | 17.3-100 | 5-100 |

**Table 5:** Comparison of the Visual Analogue Scale Spine Score with other studies on low back pain after an operatively treated spinal fracture.

These findings show that the LSC has no prognostic value for the functional outcome in patients with a short-segment stabilised traumatic thoracolumbar fracture.

Since the LSC only addresses the damaged vertebral body and does not take damage to ligaments into account, it can only be used complementary to other spinal classifications. Neurological deficit, instability of the fracture, compromise of the canal and vertebral deformity are the only arguments for operative treatment. The LSC is not a diagnostic tool or argument to found the choice for a non-operative or operative treatment on. It has to be used later in the diagnostic process, after the choice for operative treatment has been made. Than the LSC can be used as an aid, to choose between multiple operative treatment strategies.

The absence of a correlation between the radiological and functional outcome suggested that there was no relation between the quality of reduction and fixation, and the functional outcome.[29] A possible relation may be unrecognised because of the relative uniformity of the local and regional kyphosis and of changes in those values, over the course of follow-up.[27]

The current study indicates that both the comminution and the traumatic kyphotic deformity of the vertebral body, in which case the LSC score is high, are not a prognostic factor for final functional outcome of short-segment stabilised fractures. Furthermore, these findings substantiate the data from other studies regarding the relation between functional and radiological outcome of operatively treated fractures of the spine.[3,7,11,22,30-37]

This study has also its limitations. The patients were not randomised to treatment and there are no controls. There was a mixture of both neurologically intact and injured patients, and treatment included patients who underwent anterior decompression as well as posterior stabilization. These facts must be recognised, but they do not negate the value of the observations made.

## References


1. Gaebler C, Maier R, Kukla C, Vecsei V. Long-term results of pedicle stabilized thoracolumbar fractures in relation to the neurological deficit. Injury 1997 Nov;28(9-10):661-6.
2. McAfee PC, Weiland DJ, Carlow JJ. Survivorship analysis of pedicle spinal instrumentation. Spine 1991 Aug;16(8 Suppl):S422-S427.
3. McLain RF, Sparling E, Benson DR. Early failure of short-segment pedicle instrumentation for thoracolumbar fractures. A preliminary report. J Bone Joint Surg Am 1993 Feb;75(2):162-7.
4. West JL, III, Ogilvie JW, Bradford DS. Complications of the variable screw plate pedicle screw fixation. Spine 1991 May;16(5):576-9.
5. McCormack T, Karaikovic E, Gaines RW. The load sharing classification of spine fractures. Spine 1994 Aug 1;19(15):1741-4.
6. Parker JW, Lane JR, Karaikovic EE, Gaines RW. Successful short-segment instrumentation and fusion for thoracolumbar spine fractures: a consecutive 41/2-year series. Spine 2000 May 1;25(9):1157-70.
7. Daniaux H. [Transpedicular repositioning and spongioplasty in fractures of the vertebral bodies of the lower thoracic and lumbar spine]. Unfallchirurg 1986 May;89(5):197-213.
8. Dick W. The "fixateur interne" as a versatile implant for spine surgery. Spine 1987 Nov;12(9):882-900.
9. Magerl F, Aebi M, Gertzbein SD, Harms J, Nazarian S. A comprehensive classification of thoracic and lumbar injuries. Eur Spine J 1994;3(4):184-201.
10. Knop C, Fabian HF, Bastian L, Rosenthal H, Lange U, Zdichavsky M, et al. Fate of the transpedicular intervertebral bone graft after posterior stabilisation of thoracolumbar fractures. Eur Spine J 2002 Jun;11(3):251-7.
11. Walchli B, Heini P, Berlemann U. [Loss of correction after dorsal stabilization of burst fractures of the thoracolumbar junction. The role of transpedicular spongiosa plasty]. Unfallchirurg 2001 Aug;104(8):742-7.
12. Baker SP, O'Neill B, Haddon W, Jr., Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974 Mar;14(3):187-96.

13. Kaneda K, Taneichi H, Abumi K, Hashimoto T, Satoh S, Fujiya M. Anterior decompression and stabilization with the Kaneda device for thoracolumbar burst fractures associated with neurological deficits. J Bone Joint Surg Am 1997 Jan;79(1):69-83.

14. Leferink VJ, Zimmerman KW, Veldhuis EF, ten Vergert EM, ten Duis HJ. Thoracolumbar spinal fractures: radiological results of transpedicular fixation combined with transpedicular cancellous bone graft and posterior fusion in 183 patients. Eur Spine J 2001 Dec;10(6):517-23.

15. Knop C, Oeser M, Bastian L, Lange U, Zdichavsky M, Blauth M. [Development and validation of the Visual Analogue Scale (VAS) Spine Score]. Unfallchirurg 2001 Jun;104(6):488-97.

16. Roland M, Morris R. A study of the natural history of back pain. Part I: development of a reliable and sensitive measure of disability in low-back pain. Spine 1983 Mar;8(2):141-4.

17. Leclaire R, Blier F, Fortin L, Proulx R. A cross-sectional study comparing the Oswestry and Roland-Morris Functional Disability scales in two populations of patients with low back pain of different levels of severity. Spine 1997 Jan 1;22(1):68-71.

18. Ohnhaus EE, Adler R. Methodological problems in the measurement of pain: a comparison between the verbal rating scale and the visual analogue scale. Pain 1975 Dec;1(4):379-84.

19. Revill SI, Robinson JO, Rosen M, Hogg MI. The reliability of a linear analogue for evaluating pain. Anaesthesia 1976 Nov;31(9):1191-8.

20. Scott J, Huskisson EC. Graphic representation of pain. Pain 1976 Jun;2(2):175-84.

21. Aligizakis AC, Katonis PG, Sapkas G, Papagelopoulos PJ, Galanakis I, Hadjipavlou A. Gertzbein and load sharing classifications for unstable thoracolumbar fractures. Clin Orthop Relat Res 2003 Jun;(411):77-85.

22. Esses SI, Botsford DJ, Kostuik JP. Evaluation of surgical treatment for burst fractures. Spine 1990 Jul;15(7):667-73.

23. Katonis PG, Kontakis GM, Loupasis GA, Aligizakis AC, Christoforakis JI, Velivassakis EG. Treatment of unstable thoracolumbar and lumbar spine injuries using Cotrel-Dubousset instrumentation. Spine 1999 Nov 15;24(22):2352-7.

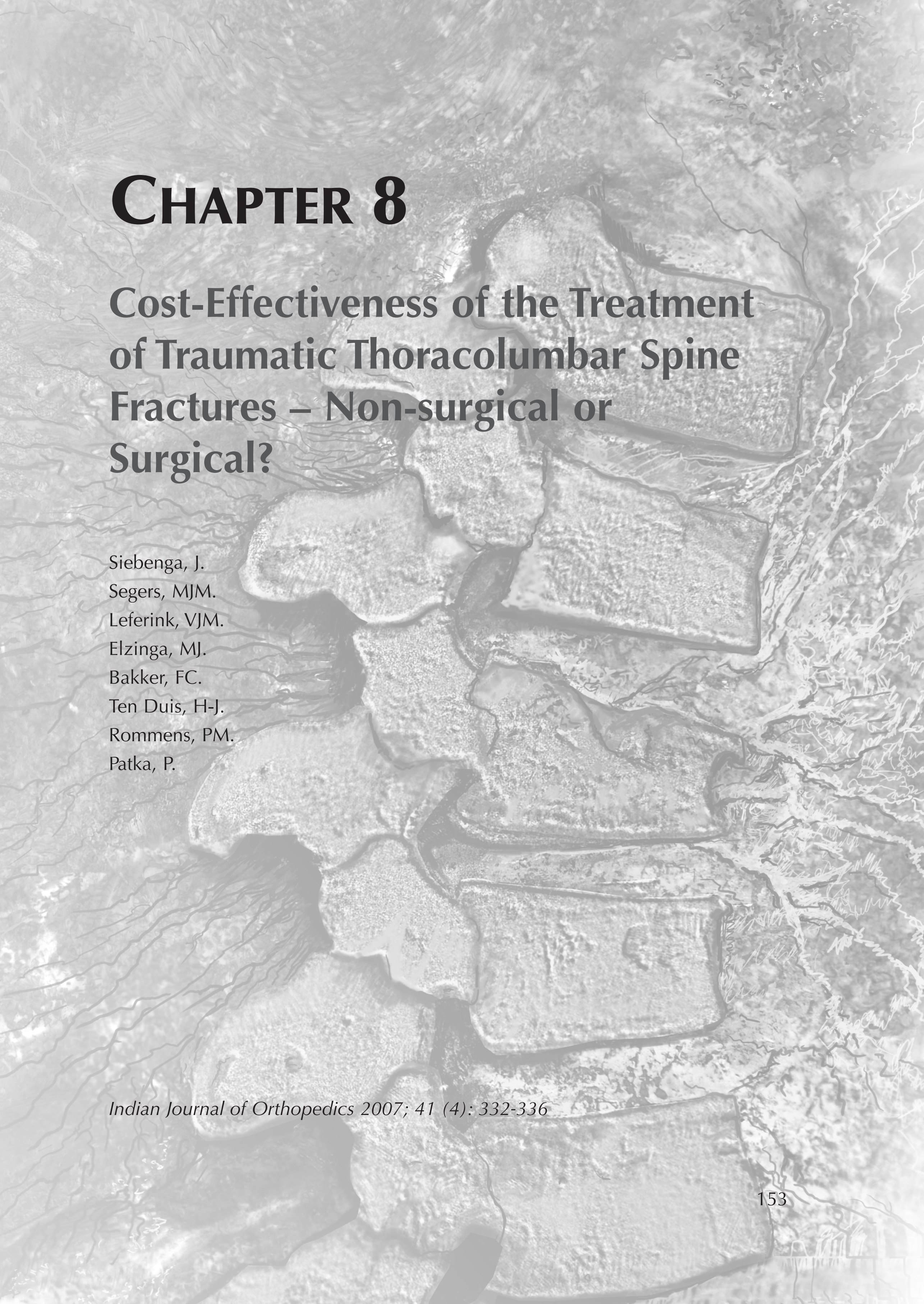
24. McNamara MJ, Stephens GC, Spengler DM. Transpedicular short-segment fusions for treatment of lumbar burst fractures. J Spinal Disord 1992 Jun;5(2):183-7.

25. Sjostrom L, Karlstrom G, Pech P, Rauschning W. Indirect spinal canal decompression in burst fractures treated with pedicle screw instrumentation. Spine 1996 Jan 1;21(1):113-23.

26. Kraemer WJ, Schemitsch EH, Lever J, McBroom RJ, McKee MD, Waddell JP. Functional outcome of thoracolumbar burst fractures without neurological deficit. J Orthop Trauma 1996;10(8):541-4.

27. Leferink VJ, Keizer HJ, Oosterhuis JK, van der Sluis CK, ten Duis HJ. Functional outcome in patients with thoracolumbar burst fractures treated with dorsal instrumentation and transpedicular cancellous bone grafting. Eur Spine J 2003 Jun;12(3):261-7.
28. Weinstein JN, Collalto P, Lehmann TR. Thoracolumbar "burst" fractures treated conservatively: a long-term follow-up. Spine 1988 Jan;13(1):33-8.
29. Knop C, Blauth M, Buhren V, Arand M, Egbers HJ, Hax PM, et al. [Surgical treatment of injuries of the thoracolumbar transition--3: Follow-up examination. Results of a prospective multi-center study by the "Spinal" Study Group of the German Society of Trauma Surgery]. Unfallchirurg 2001 Jul;104(7):583-600.
30. Benson DR, Burkus JK, Montesano PX, Sutherland TB, McLain RF. Unstable thoracolumbar and lumbar burst fractures treated with the AO fixateur interne. J Spinal Disord 1992 Sep;5(3):335-43.
31. Carl AL, Tromanhauser SG, Roger DJ. Pedicle screw instrumentation for thoracolumbar burst fractures and fracture-dislocations. Spine 1992 Aug;17(8 Suppl):S317-S324.
32. Danisa OA, Shaffrey CI, Jane JA, Whitehill R, Wang GJ, Szabo TA, et al. Surgical approaches for the correction of unstable thoracolumbar burst fractures: a retrospective analysis of treatment outcomes. J Neurosurg 1995 Dec;83(6):977-83.
33. Eysel P, Hopf C, Furderer S. [Kyphotic deformation in fractures of the thoracic and lumbar spine]. Orthopade 2001 Dec;30(12):955-64.
34. Knop C, Fabian HF, Bastian L, Blauth M. Late results of thoracolumbar fractures after posterior instrumentation and transpedicular bone grafting. Spine 2001 Jan 1;26(1):88-99.
35. Sasso RC, Cotler HB. Posterior instrumentation and fusion for unstable fractures and fracture-dislocations of the thoracic and lumbar spine. A comparative study of three fixation devices in 70 patients. Spine 1993 Mar 15;18(4):450-60.
36. Seybold EA, Sweeney CA, Fredrickson BE, Warhold LG, Bernini PM. Functional outcome of low lumbar burst fractures. A multicenter review of operative and nonoperative treatment of L3-L5. Spine 1999 Oct 15;24(20):2154-61.
37. Speth MJ, Oner FC, Kadic MA, de Klerk LW, Verbout AJ. Recurrent kyphosis after posterior stabilization of thoracolumbar fractures. 24 cases treated with a Dick internal fixator followed for 1.5-4 years. Acta Orthop Scand 1995 Oct;66(5):406-10.

Whereas quality improvement is producing significant benefits for patients, quality initiatives will continue to produce disappointing bottom-line savings as long as the capacity created is used to support growth in patient volume.
*Rauh SS. 10.1056/NEJMp1111662. 2011*



# Chapter 8

## Cost-Effectiveness of the Treatment of Traumatic Thoracolumbar Spine Fractures – Non-surgical or Surgical?

Siebenga, J.
Segers, MJM.
Leferink, VJM.
Elzinga, MJ.
Bakker, FC.
Ten Duis, H-J.
Rommens, PM.
Patka, P.

*Indian Journal of Orthopedics 2007; 41 (4): 332-336*

## Abstract

### Background

Back pain constitutes a major cause of absence for work and disablement. Spinal fractures can be an important cause for disabling back pain.

### Methods

Patients with a traumatic thoracolumbar spine fracture were prospectively randomized for operative or conservative treatment. Patients were sent a questionnaire every three months to inquire about work-status, additional health costs and doctor visits.

### Results

Of thirty-two patients, two were lost to follow-up. Thirty (94%) patients met the follow-up period of at least two years. Fourteen patients were randomized to receive conservative therapy, and sixteen were randomized for surgical treatment.

Direct costs of the treatment of conservatively treated patients were €10,608 ($12,730) and €18,769 ($22,523) for the operatively treated group. Indirect costs resulted in a total of €219,187 ($263,025) per non-operative treated patient. In the operative group this costs were €66,004 ($79,206).

### Conclusion

In the treatment of traumatic thoracolumbar spine fractures the indirect costs exceed the direct cost by far and make up 95.4% of the total costs for treatment in conservatively treated patients and 71.6% of the total costs in the operative group. In view of cost-effectiveness, the operative therapy of traumatic thoracolumbar spine fractures is to be preferred

Level of evidence: Level I

### Key words

RCT, cost-effectiveness, treatment, spine fracture

## Introduction

Back pain is a major health problem in industrialized countries. The magnitude of the problem is obvious when expressed as incidence and prevalence figures. The annual incidence of back pain in the United States has been reported to be about 5%[1], the yearly prevalence of back pain in the United States to be 15 – 20% and in European countries 25 – 40%, whereas the lifetime prevalence has been reported to exceed 70%.[2] Back pain is a frequent cause for visiting a GP or physical therapist and constitutes a major cause of absence for work and disablement.

The impact of back pain on society is usually estimated by examining the costs.[3] Although these costs are subject of many studies, the extrapolation to other societies may prove to be difficult. This may be so for differences in perception of the severity of pain, or related to the organization of health care.

The health care system in the Netherlands is strictly regulated by law. The government controls the health care facilities mainly by regulating all charges and fees in the health care sector by budgets and tariffs. Hospitals are paid a fee-for-service for all patients under a defined benefit package. In the Netherlands most of the lower income groups (over 60% of the population) are compulsory insured in sickness funds, the rest of the population usually have private health insurance. These are usual individual policies adjusted for risk, particularly age. Policies vary in the extent of coverage, co-payments and deductibles. The whole population is covered under compulsory insurance for serious and prolonged disability and sickness.[4,5]

Spinal fractures can be an important cause for disabling back pain. In this prospective randomized study the costs induced by conservatively and operatively treated patients with a traumatic thoracolumbar spine fracture, without neurological involvement were compared. Randomized trials are more suitable to detect unanticipated shifts in resource use and outcomes. As far as we know there has been no cost-effectiveness study for the treatment of this injury. This study evaluates not only the direct costs but also the indirect costs.

## Methods

From October 1998 until October 2003, 32 patients met inclusion criteria and agreed to participate. Inclusion criteria were a traumatic thoracolumbar spine fracture without neurological involvement. Patients were sent a questionnaire every three months to inquire about work-status, additional health costs and doctor visits.

The patients who were randomized to be managed conservatively were treated with an aggressive nonoperative course of six weeks on a Rotorest bed (KCI, San Antonio, U.S.A.).[6] Fraxiparine© (nadroparine) 2850 IU was given as an anti-coagulant until the patient was discharged. A Jewett hyperextension orthosis was fitted and the patients were instructed to wear the brace at all times, except when bathing, for three months.[6] A vigorous physiotherapy scheme was given to improve trunk musculature. The orthosis functions by preventing gross motions of the trunk rather than intervertebral mobility.[7] Compliance was not monitored after discharge from the hospital. Patients were discharged when their pain was in control and they were self sufficient. Patients were prohibited from engaging in heavy work and sports for three months, but were allowed activities of daily living and sedentary work if available.

The patients who were randomized to receive operative intervention were managed with a short segment posterolateral fixation with an AO titanium universal spine system (USS, Universal Spine System (Synthes, Bettlach, Switzerland)).[8,9] Patients were taken to the operation room on a priority rather than an emergent basis. Reduction was indirectly performed with positioning on the operating table. The procedure consisted of a midline incision centered over the fractured vertebra; exposure out of the tips of the transverse processes; placement of the pedicle screws in the level above and in the level below the fractured vertebra. Kyphosis and vertebral body height were corrected through manipulating the pedicle screws. An autogenous bone-graft was harvested from the posterior iliac crest for a transpedicular spongioplasty.[10] A cross-link was used for added stability of the construct.[9,11-15] Intra-operative neurologic monitoring was not used.

Preoperative 1500 milligrams of Zinacef® (cefuroxime) was given intravenously as prophylactic antibiotic. Fraxiparine® (nadroparine) 2850 IU was given as an anti-coagulant until the patient was discharged. After operation the patient was mobilized with a Jewett hyperextension orthosis for three months. A vigorous physiotherapy scheme was given to improve trunk musculature. After nine till twelve months, the USS was removed to prevent screw breakage.

Because costs have a skewed distribution, differences in costs cannot be statistically analyzed by parametric methods. Instead, the bootstrap method was used to test the significance of differences in costs and to calculate confidence intervals of these differences.

### Cost of illness

The approach most frequently used to estimate the cost of illness (COI) is the human capital approach. According to this approach the direct costs are estimated on the basis of market prices and the indirect costs by assessing the loss of productivity due to morbidity and premature mortality. This method was used to estimate the direct and indirect costs of the treatment. All costs are presented in Euros (€) and US dollars ($) using an exchange rate of 1.00:1.20.

### Direct costs

Direct costs consist primarily of medical costs of diagnosis, treatment, continuing care, prevention, rehabilitation and organization, but also includes non-medical expenditures caused by disease. Patients obtained a questionnaire each three months to register their expenditures.

#### Hospital care costs

The hospital care costs include the costs of clinical care and additional costs of treatment, diagnostics, paramedical care and operating rooms. The hospital care costs are divided in outpatient costs and inpatient costs. Since the data concerning medical equipment (i.e. surgical devices, radiological equipment) were not separately administrated, it was not possible to include these costs into this calculation.

The following cost categories were used from a former study performed in our clinic.[16]

- Costs of hospitalization days (normal care, special care and intensive care including costs of resident/physician and staff member, nursing staff, medication, overhead, cleaning, laundry and housing)
- Costs of laboratory tests
- Costs of blood products
- Costs of radiology (including X-rays and CT-scans of the thoracolumbar spine)
- Costs of physical therapy (staff and overhead)
- Costs of operation operating room, overhead, staff and implant
- Costs of spinal orthosis and cast
- Costs of outpatient visits (including costs of radiology).

**Medical specialist care costs.**
The costs of operations by medical specialists were calculated with the relevant costs for each operation. The costs used were the referring costs for the operation, for anesthesiology and for additional support.

**General practice care costs.**
Patients indicated how often and how long they visited a GP.

### Indirect costs

Indirect costs of disease are defined as production losses and related costs to society due to morbidity and mortality. In case of thoracolumbar spine fractures this can be the result of absence from work and disablement due to morbidity. There was no mortality rate in this patients population. In COI studies according to the human capital approach, which is based on the assumption that earnings reflect productivity, indirect costs are often restricted to the earnings lost. The social security system in the Netherlands is based on two laws prescribing the obligation to have insurance for the loss of income due to sickness, injury or disability. Under the Sickness Benefits Act (SBA) workers receive sick pay during absence, with a maximum of 52 weeks. If the worker is still unable to work after 52 weeks, the patient is entitled to a disability pension covered by the Disablement Insurance Act (DIA).

**Costs of absenteeism.**

In the present study estimated costs of absenteeism by multiplying the total number of sick days with the mean costs of one sick day has been used. The gross sick pay starts after two qualifying days for the sickness benefit and amounts to 70% of the daily wage. However, due to additional insurances or collective labour agreements almost every employee receives full wages during absenteeism. We therefore extrapolated the sick pay to 100%. Besides the insurance costs, the SBA also involves administration costs. In 1999 the total administration costs amounted to 5.5% of the total insurance costs. The administration costs were estimated by adding this proportion to the insurance costs.

**Costs of disablement.**

The total costs of disablement were estimated by multiplying the total days of disability with the mean daily pension in 2000. This was €18500 ($22200) for men and €12000 ($14400) for women.

## Results

Of thirty-two included patients, two were lost to follow-up and could not be contacted. Thirty (94%) patients met the follow-up period. The patients were included in the period of 1998 – 2003 with a follow-up of at least two years.

Fourteen patients were randomized to receive conservative therapy, and sixteen were randomized for surgical treatment.

The rates at which the patients returned to work were found to be significantly different between the two groups, in favor of the operative treated patients. ($p=0.04$) Five of eleven (46%) working patients in the non-surgical treated group returned to their job. Three of them to the same job and two did return to a job which was less demanding. Average returning time was 14 months (6 – 33). Nine of eleven (82%) working patients in the operative group returned to their previous job, none of them had changed to a physical less demanding job. Average returning time in the operative treated group was 7 months (1 – 18). Because of the spread of these numbers in returning time a significant difference could not be reached.

### Direct costs

**Hospital care costs.**

Direct costs of the treatment of conservatively treated patients was €9,900 ($11,880) and €18,300 ($21,960) for the operatively treated group.[16]

**General practice care costs.**

Costs of a GP are €47 ($56) per hour. Patients who were treated non-operatively visited the GP for 500 minutes. Total costs were €392 ($470), resulting in €28 ($34) per patient. Operative treated patients spend 214 minutes at their GP. Total costs were €169 ($203), and €11 ($13) per patient.

**Private expenditures of patient.**

Examples of made expenditures were clothing, education for a job change, physiotherapy, and transportation costs. In the conservative treated group this expenditures raised to a total of €9,525 ($11,430) or €680 ($816) per patient. The operative group spend €7,322 ($8,786) resulting in €458 ($550) per patient.

### Indirect costs

**Costs of absenteeism.**

In the non-operative treated group eleven patients did have a regular job. The total months of absence of these eleven patients were 115 months. These resulted in total costs of €120,500 ($144,600), or €8,607 ($10,329) per conservative treated patient. Twelve patients in the operative group had a regular job. The total months of absence were 78. These resulted in a total costs of €88,400 ($106,080), or €5,525 ($6,630) per operative treated patient. In the table 5.5% administration costs are added.

**Costs of disablement.**

In the non-operative treated group of patients, six were disabled. These were all men with a mean age of 39 years (18 – 58). One-hundred fifty-nine years have to be compensated. This results in a total of €2,941,500 ($3,529,800) or €210,107 ($252,128) per non-operative treated patient. In the operative group there were two patients disabled, one man aged 48 and one woman, aged 36. Thus a total of

46 years have to be compensated. This results in a total of €662,500 ($795,000) or €41,406 ($49,688) per operatively treated patient.

## Discussion

This is the first study which studies prospectively the costs that are made in the treatment of traumatic thoracolumbar spine fractures, and in which direct and indirect costs are calculated. We also took this opportunity the compare the costs for non-operative and operative treatment to see which therapy is more cost-effective. Cost effectiveness can be used as a rational way of deciding how to get the best health improvement from limited resources, which is a reasonable, even essential concern.[17]

Two studies reported direct costs of treatment of thoracolumbar spine fractures. The results for the direct costs of one of this studies are used in this report.[16] The estimated direct costs in the study of Hitchon et al. were higher than the costs in this study, $24,600 versus $10,608 for conservative treatment and $45,300 versus $22,523 for operatively treated patients.[18] Hospitalization days for patients treated conservatively were about the same in both studies. In the study of Hitchon, operatively treated patients had on average seven more hospitalization days. Unit prices may also have been higher in the study of Hitchon, explaining the difference in costs.[16,18]

Probably the total costs of treatment will be higher because of under registration, not taking into account for costs of supporting faculties like administration and kitchen, and costs for water and electricity.

The indirect costs exceed the direct costs by far and make up 95.4% of the total costs for treatment in conservatively treated patients and 71.6% of the total costs in the operative group. In comparative studies these indirect costs are never addressed, which results in charges for operative therapy that can be as much as four times higher than the charges for conservative therapy.[19] This study shows that indirect costs form the major cost factor in both treatment options, and non-operative treatment is 3.5 times more expensive than operative treatment when one takes in account both direct and indirect costs. Although the differences in health and insurance systems between the United States and the Netherlands make comparison difficult, it seems justified to state that in view of cost-effectiveness, the operative therapy of traumatic thoracolumbar spine fractures is to be preferred.

| Costs per patient | | Non-operative | Operative |
|---|---|---|---|
| Direct | | | |
| | Hospital costs | €9,900 | €18,300 |
| | | $11,880 | $21,960 |
| | Costs for GP | €28 | €11 |
| | | $34 | $13 |
| | Private expenditures | €680 | €458 |
| | | $816 | $550 |
| Subtotal | | **€10,608** | **€18,769** |
| | | **$12,730** | **$22,523** |
| Indirect | | | |
| | Costs of absenteeism | €8,607 | €5,525 |
| | | $10,329 | $6,630 |
| | Administration costs | €473 | €304 |
| | | $568 | $365 |
| | Costs of disablement | €210,107 | €41,406 |
| | | $252,128 | $49,688 |
| Subtotal | | **€219,187** | **€47,235** |
| | | **$263,025** | **$56,683** |
| Total | | **€229,795** | **€66,004** |
| | | **$275,755** | **$79,206** |

**Table 1**

## References


1 Frymoyer J.W., Cats-Baril W.L. An overview of the incidence and costs of low back pain. Orthop Clin North Am 1991;22(2):263-71.

2 Andersson G.B. Epidemiologic aspects on low-back pain in industry. Spine 1981;6(1):53-60.

3 Tulder MWv, Koes BW, Bouter LM. A cost-of-illness study of back pain in The Netherlands. Pain 1995;62:233-40.

4 Abel-Smith B. Cost containment and new priorities in the European community. Milbank Q 1992;70(3):417-22.

5 Abel-Smith B., Mossialos E. Cost containment and health care reform: a study of the European Union. Health Policy 1994;28(2):86-132.

6 Hartman M.B., Chrin A.M., Rechtine G.R. Non-operative treatment of thoracolumbar fractures. Paraplegia 1995;33(2):73-6.

7 Axelsson P., Johnsson R., Stromqvist B. Effect of lumbar orthosis on intervertebral mobility. A roentgen stereophotogrammetric analysis. Spine 1992;17(6):678-81.

8 Dick W, Kluger P, Magerl F, Woersdorfer O, Zach G. A new device for internal fixation of thoracolumbar and lumbar spine fractures: the 'fixateur interne'. Paraplegia 1985;23(4):225-32.

9 Korovessis P, Baikousis A, Deligianni D, Mysirlis Y, Soucacos P. Effectiveness of transfixation and length of instrumentation on titanium and stainless steel transpedicular spine implants. J Spinal Disord 2001 Apr;2001 Apr;14(2):109-17.

10 Daniaux H. [Transpedicular repositioning and spongioplasty in fractures of the vertebral bodies of the lower thoracic and lumbar spine] Transpedikulare Reposition und Spongiosaplastik bei Wirbelkorperbruchen der unteren Brust- und Lendenwirbelsaule. Unfallchirurg 1986 May;89(5):197-213.

11 Dick JC, Zdeblick TA, Bartel BD, Kunz DN. Mechanical evaluation of cross-link designs in rigid pedicle screw systems. Spine 1997 Feb 15;1997 Feb 15;22(4):370-5.

12 Lynn G, Mukherjee DP, Kruse RN, Sadasivan KK, Albright JA. Mechanical stability of thoracolumbar pedicle screw fixation. The effect of crosslinks. Spine 1997 Jul 15;1997 Jul 15;22(14):1568-72.

13 Brodke D.S., Bachus K.N., Mohr A., Nguyen B.-K.N. Segmental pedicle screw fixation or cross-links in multilevel lumbar constructs: a biomechanical analysis. Spine J 2001;1(5):373-9.

14 Marti Garin D, Villanueva Leal C, Bago Granell J. Stabilization of the lower thoracic and lumbar spine with the internal spinal skeletal fixation system and a cross-linkage system. First results of treatment. Acta Orthop Belg 1992;58(1):36-42.

15 Pintar F.A., Maiman DJ, Yoganandan N, Droese K.W., Hollowell J.P., Woodard E. Rotational stability of a spinal pedicle screw/rod system. J Spinal Disord 1995;8(1):49-55.

16 van der RN, de Bruyne MC, Bakker FC, van Tulder MW, Boers M. Direct medical costs of traumatic thoracolumbar spine fractures. Acta Orthop 2005 Oct;76(5):662-6.

17 Clark RE. Spine update: understanding cost-effectiveness [see comments]. Spine 1996 Mar 1;21(5):646-50.

18 Hitchon PW, Torner JC, Haddad SF, Follett KA. Management options in thoracolumbar burst fractures. Surg Neurol 1998 Jun;1998 Jun;49(6):619-26.

19 Wood K, Butterman G, Mehbod A, Garvey T, Jhanjee R, Sechriest V. Operative compared with nonoperative treatment of a thoracolumbar burst fracture without neurological deficit. A prospective, randomized study. J Bone Joint Surg Am 2003 May;2003 May;85-A(5):773-81.

De betekenis van de achterbenen is voor een paard dat hij er vaart mee kan maken, voor jou is de betekenis: angst.
*Wim Kayzer. De Waarnemer. 2004*

# Chapter 9

## Spine fractures caused by horse riding.


Siebenga, J.
Segers, MJM.
Elzinga, MJ.
Bakker, FC.
Haarman, HJTM.
Patka, P.


*Eur Spine J 2006; 15: 465–471*

## Abstract

### Objectives

Study of demographic data concerning spinal fractures caused by horse riding, classification of fractures according to the AO and Load Sharing classifications, evaluation of mid-term radiological results and long-term functional results.

### Methods

A review of medical reports and radiological examinations of patients presented to our hospital with horse riding-related spine fractures over a 13-year period; long-term functional follow-up is performed using the Roland Morris Disability Questionnaire (RMDQ-24).

### Results

Thirty-six spine fractures were found in 32 patients. Male to female ratio is 1:7. Average age is 33.7 years (8–58 years). The majority of the fractures (78%) are seen at the thoracolumbar junction Th11–L2. All but two patients have AO type A fractures. The average Load Sharing Classification score is 4.9 (range 3–9). Neurological examinations show ASIA/Frankel E status for all patients. Surgical treatment is performed on ten patients. Mean follow-up for radiological data is 15 months (range 3–63). Functional follow-up times range from 1 to 13 years with an average follow-up of 7.3 years. Mean RMDQ-24 score for all patients is 5.5 (range: 0–19), with significantly different scores for the non-operative and surgical group: 4.6 vs 8.1. Twenty-two percent of the patients have permanent occupational disabilities and there is a significant correlation between occupational disability and RMDQ-24 scores.

### Conclusions

Not only are short-term effects of spine fractures caused by horse riding substantial but these injuries can also lead to long-term disabilities.



### Keywords

Sports medicine, Spinal fractures, Horses, Review

## INTRODUCTION

Horse riding is frequently complicated by injuries. In the Netherlands, every year, one out of seven riders will sustain an injury, resulting in a total number of 74,500 injuries. All these injuries result in 9100 Emergency Department consultations, finally leading to over 900 hospital admissions. Annually the in-hospital mortality amongst horse riders is five; the number of pre-hospital casualties is unknown.[1] The overall risk of injury from horse riding and grooming related activities per hour has been determined to be higher than car racing or riding a motorcycle and is in the same order of magnitude as Australian rugby.[2-5] A full-grown horse can weigh over 500 kgs, gallops at speeds up to 50 - 65 km/h and can kick with a force of 1.8 times its bodyweight. The differences between horses and people predispose towards serious injury and are compounded by the potential for unpredictable behavior in both species.[6]

In this article spine fractures associated with equestrian activities are described. The aim of this retrospective study of our own patient collective is to look at demographic data, to classify the spine fractures according to the AO Comprehensive Classification and Load Sharing Classification (LSC) and to evaluate both the mid term radiological results and the long term functional results using the Roland Morris Disability Questionnaire (RMDQ-24). Additionally, a review of the literature concerning injuries caused by horse riding with emphasis on spine fractures is performed.

### Methods and materials

For this retrospective study covering a thirteen-year period (1990 – 2003) the medical reports and radiological examinations of patients presented to the Vrije Universiteit medisch centrum (VUmc) with horse riding related spinal injuries were reviewed. Classification of the spine fractures was performed according to the AO Comprehensive Classification and the Load Sharing Classification of spine fractures as described in the original articles.[7;8] Magnetic resonance imaging (MRI) was not routinely performed.

Standard mid term radiological evaluation involved the measurements of the local and regional sagittal angles and comparison with the original post-traumatic situation. Positive regional sagittal angles indicate lordosis, negative angles indicate kyphosis (*Figure 1*).

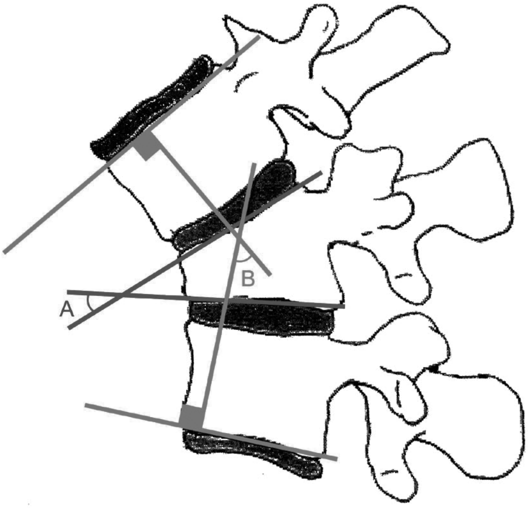



**Figure 1: A:** Local sagittal angle **B:** Regional sagittal angle

Long term functional results were reviewed using the RMDQ-24 scores which has been described in other studies concerning the evaluation of functional results on spine fractures.[9-11] The RMDQ-24 score ranges from 0 to 24 points with 0 points indicating no disability at all and 24 points indicating severe disability. RMDQ scores were obtained by written questionnaires and scoring was performed by an independent observer for statistical analysis, uninformed about treatment protocol. The Mann-Whitney test for statistical analysis was used to show a correlation between RMDQ-24 scores and permanent occupational disabilities.

A literature review concerning equestrian activities and spine fractures was performed using Medline database engines and restrictions for English and German language articles. Search terms involved were horse, injury and spine. With these search terms five articles were found that addressed spinal injuries related to equestrian activities. With cross-referencing additional literature was found.

## Results

In the period from December 1990 until December 2003 thirty-two patients with a total number of thirty-six spine fractures due to a horse riding accident were admitted to the VUmc. Females outnumber males by a factor seven (28 females, 4 males respectively). Mean age was 33.7 years (range 8-58 years).

Seventy-eight percent of the fractures occurred at the thoracolumbar junction (Th11 – L2). Only one patient was presented with cervical fractures of the transverse processes at levels C5 and C6. (*Figure 2*)

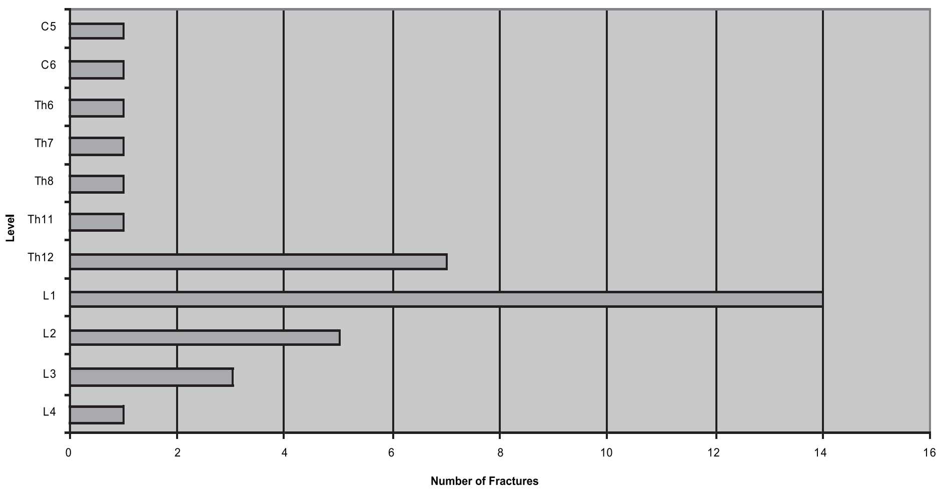



**Figure 2:** Fracture levels; total number of 36 fractures

According to the AO classification the 34 thoracolumbar fractures could be classified as: 15 A1 type, 17 A3 type and 2 B1 type fractures. (*Table 1*)

| | M:F | Age (y) | Level | AO | LSC | Local angle | Regional angle |
|---|---|---|---|---|---|---|---|
| 1 | Female | 33 | Th12 | A3.1 | 7 | -25 | -24 |
| 2 | Female | 17 | L2 | A1.2 | 3 | -8 | -6 |
| | | | L3 | A1.2 | 3 | -6 | -3 |
| 3 | Female | 27 | Th12 | A1.1 | 3 | -3 | -3 |
| | | | L2 | A1.2 | 3 | -5 | -7 |
| 4 | Female | 36 | L2 | A3.1 | 5 | -7 | -3 |
| 5 | Female | 48 | Th12 | A3.2 | 8 | -28 | -14 |
| 6 | Male | 52 | C5 | na | na | na | na |
| | | | C6 | na | na | na | na |
| 7 | Female | 29 | L2 | A1.1 | 3 | -7 | -7 |
| 8 | Male | 16 | L1 | A3.1 | 6 | -21 | -16 |
| 9 | Female | 37 | Th6 | A1.2 | 5 | -12 | -10 |
| 10 | Female | 37 | Th7 | A3.2 | 8 | -18 | -16 |
| 11 | Female | 36 | L1 | A1.2 | 4 | -14 | -9 |
| 12 | Female | 58 | L4 | A1.2 | 3 | -6 | -5 |
| 13 | Male | 29 | L1 | A3.1 | 5 | -10 | -10 |
| 14 | Female | 38 | Th12 | B1.2 | 7 | -18 | -20 |
| 15 | Female | 24 | Th11 | A1.2 | 4 | -8 | -3 |
| 16 | Female | 28 | L1 | A3.1 | 6 | -14 | -10 |
| 17 | Female | 49 | L3 | A3.1 | 4 | -5 | -5 |
| 18 | Female | 31 | L1 | A3.3 | 6 | -9 | -5 |
| 19 | Female | 29 | L1 | A3.3 | 5 | -5 | 0 |
| 20 | Male | 52 | L1 | A3.1 | 6 | -20 | -16 |
| 21 | Female | 25 | L1 | A3.1 | 6 | -20 | -14 |
| 22 | Female | 36 | L1 | A3.1 | 5 | -20 | -19 |
| 23 | Female | 8 | L1 | A1.2 | 3 | -5 | -2 |
| | | | L2 | A1.2 | 3 | -5 | 0 |
| 24 | Female | 37 | L1 | A1.2 | 5 | -10 | -8 |
| 25 | Female | 56 | L1 | A3.1 | 5 | -15 | -13 |
| 26 | Female | 38 | Th12 | A3.3 | 9 | -16 | -12 |
| 27 | Female | 11 | Th8 | A3.1 | 4 | -6 | 0 |
| 28 | Female | 23 | Th12 | A1.2 | 3 | -5 | 0 |
| 29 | Female | 39 | Th12 | A1.2 | 4 | -9 | -9 |
| 30 | Female | 31 | L1 | A1.2 | 4 | -8 | -7 |
| 31 | Female | 37 | L1 | B1.2 | 7 | -6 | -5 |
| 32 | Female | 31 | L1 | A3.1 | 5 | -4 | -5 |

**Table 1:** Demographic and fracture related data

Positive sagittal angles indicate lordosis, negative angles indicate kyphosis. na: not applicable

Additional MRI studies were performed to diagnose the ligamentous injury in one of the B1.2 type fractures. (*Figure 3*)

**Figure 3:** MRI of patient with AO type B 1.2 fracture showing a lesion of the posterior ligamentary complex between the spinous processes of Th11 and Th12, a peridural hematoma and a compression fracture of the upper endplate of Th12.

The mean LSC score of all thoracolumbar spine fractures was 4.9 (3 – 9), with mean LSC scores of the non-operative group and surgical group reaching 4.1 and 6.8 respectively. Statistical analysis showed a significant higher LSC in the surgical group. ($p<0.001$) Detailed physical examination did not point out neurological deficits based on spine fractures in any patient hence all patients were classified as ASIA/Frankel E. Accompanying injuries consisted of distal radial fractures in two patients and one patient with cervical spine fractures at levels C5 and C6 sustained a serious brachial plexus injury as well as a peripheral facial nerve injury which leaded to chronic impairment. A summary of all demographic and fracture related data is shown in *table 1*.

Twenty-two patients were managed non-operatively and ten patients received surgical therapy. Average hospital admittance times were 11.8 days for non-operatively managed patients with early functional treatment, 43.0 days for patients receiving late functional treatment and 17.3 days for surgically stabilized patients.

Three patients showed complications: one patient with an anterior stabilization had a superficial wound infection needing surgical debridement combined with a prolonged period of oral antibiotics and another patient had persistent mechanical complaints of the posterior implant materials without signs of infection which lead to early implant removal at 9 months. A non-operatively managed patient had a pulmonary embolism despite prophylactic LMW-heparins and was treated with intravenous heparines and a 12-month period of oral coumarines.

Mean local and regional sagittal angles measured -9.3° and -7.1° kyphosis respectively in the non-operatively treated group and -15.6° and -11.5° kyphosis in the surgical group. Surgical reduction corrected local and regional sagittal angles to -4.2° and -5.1° kyphosis. After a mean radiological follow-up of 15 months local and regional sagittal angles in the non-operatively treated group measured -13.5° and -11.2° kyphosis, resulting in a further loss of -4.2° and -4.1°. Mid term local and

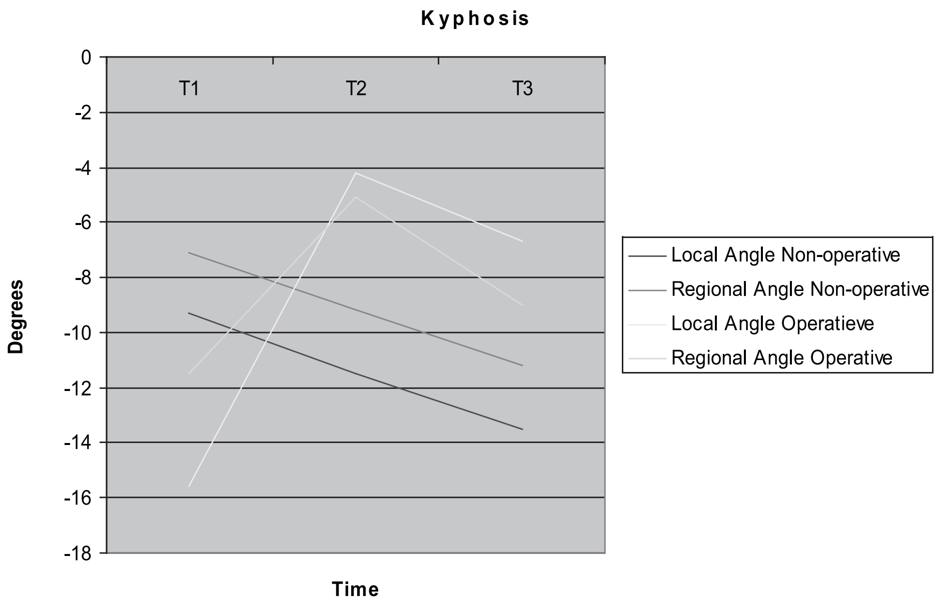



**Figure 4:** History of kyphosis in non-operatively treated group and surgically stabilized group; T1=hospital admission, T2= 1-3 months and T3= 9-12 months (after posterior implant removal)

regional sagittal angles in the operatively treated group were measured after implant removal. The follow-up results still showed a minimal correction, resulting in local and regional sagittal angles of -6.7°and -9.0° kyphosis (*Figure 4*).

Mean follow-up for the functional scores was 7.3 years (1 – 13 years). The response rate for RMDQ-24 scores was 84%. The RMDQ-24 is specifically developed for the measurement of disability of low-back pain so patient 6 with cervical injury was not included in the average RMDQ-24 scores.[12] The mean overall RMDQ-24 score was 5,5 (range: 0 – 18). Average RMDQ-24 scores for non-operatively treated patients and surgically stabilized patients showed a significant difference: 4.6 and 8.1 respectively. ($p<0.01$) A summary of all radiological and functional outcome data is shown in *table 2*.

| | Treatment | Hospital stay | Complications | FU local | FU regional | After (months) | RMDQ | Functional follow-up (months) |
|---|---|---|---|---|---|---|---|---|
| 1 | Early functional | 10 | | -26 | -30 | 63 | 2 | 57 |
| 2 | Early functional | 8 | | -15 | na | 12 | 4 | 47 |
| 3 | Early functional | 10 | | -10 | na | 13 | 5 | 25 |
| 4 | Posterior with posterolateral and transpedicular fusion | 13 | | -7 | -12 | 24 | 6 | 42 |
| 5 | Posterior with posterolateral and transpedicular fusion | 14 | Complaints of osteosythesis | -14 | -14 | 18 | 0 | 59 |
| 6 | Early functional | 20 | | na | na | na | na | 53 |
| 7 | Early functional | 3 | | -11 | -7 | 9 | 2 | 39 |
| 8 | Early functional | 11 | | -21 | -16 | 3 | 4 | 48 |
| 9 | Early functional | 14 | | -12 | -10 | 9 | 9 | 39 |
| 10 | Anterior with bisegmental fusion | 9 | | * | * | * | * | * |
| 11 | Early functional | 11 | | -14 | -11 | 9 | 3 | 48 |
| 12 | Early functional | 13 | | -6 | -5 | 9 | 7 | 33 |
| 13 | Early functional | 8 | | -15 | -15 | 12 | 0 | 68 |
| 14 | Anterior with bisegmental fusion | 27 | Superficial woundinfection | -1 | -7 | 12 | 15 | 11 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 15 | Early functional | 9 | | -14 | -3 | 12 | 0 | 16 |
| 16 | Posterior without attempted fusion | 16 | | -12 | -10 | 24 | 1 | 129 |
| 17 | Early functional | 11 | | -7 | -5 | 9 | 1 | 137 |
| 18 | Posterior with posterolateral fusion | 27 | | -2 | 0 | 24 | 2 | 156 |
| 19 | Late functional | 34 | | -12 | -12 | 15 | 0 | 132 |
| 20 | Posterior with posterolateral and transpedicular fusion | 22 | | -10 | -10 | 24 | 19 | 130 |
| 21 | Posterior with transpedicular fusion | 14 | | -1 | -10 | 24 | 14 | 104 |
| 22 | Late functional | 45 | Pulmonary embolism | -28 | -23 | 12 | 0 | 115 |
| 23 | Early functional | 15 | | -5 | na | 9 | 0 | 141 |
| 24 | Early functional | 7 | | * | * | * | * | * |
| 25 | Late functional | 50 | | -22 | -18 | 9 | 16 | 133 |
| 26 | Posterior with posterolateral and transpedicular fusion | 15 | | * | * | * | * | * |
| 27 | Early functional | 5 | | -8 | -2 | 9 | 2 | 117 |
| 28 | Early functional | 9 | | -12 | -5 | 9 | 18 | 143 |
| 29 | Early functional | 11 | | -12 | -10 | 8 | 2 | 111 |
| 30 | Early functional | 8 | | -7 | -7 | 9 | 12 | 118 |
| 31 | Anterior with bisegmental fusion | 16 | | * | * | * | * | * |
| 32 | Early functional | 14 | | * | * | * | * | * |

**Table 2** Clinical, radiological and functional outcome data. Positive sagittal angles indicate lordosis, negative angles indicate kyphosis. na: not applicable, * Lost for follow-up in other hospitals

Six patients (22%) have permanent occupational disabilities for their previous professions and four of those patients ended up in social welfare or stopped working while two patients continued in another profession on a therapeutic base. The Mann-Whitney test showed a significant relation between RMDQ-24 scores and permanent disability for work ($p<0.001$). All five patients with RMDQ-24 scores of 14 or higher had permanent occupational disability.

## Review of Literature

### General epidemiologic data of severe injuries caused by horse riding

Compared to other sports horse riding accounts for the largest number of hospital admittance days by far. [13] The incidence of serious injuries due to horse riding is higher than motorized sports and can only be equaled by Australian rules football.[2-5,14,15] In the western world 25% of all fatal sports accidents are caused by horse riding.[16-18] Horse riding is also the sport with the highest incidence of severe injuries and fatal accidents in children.[13,19] Craniocerebral injuries dominate in lethal horse riding injuries, indicating the importance of protecting helmets.[3,15,18,20]

### Spine fractures

In some countries 70% of all spine fractures caused by sports activities are sustained with equestrian activities.[21] In a German study on horse riding injuries spine fractures proved to be as common as clavicle fractures.[16] Another German study about fatal horse riding accidents showed that next to craniocerebral trauma thoracolumbar spine fractures were the most commonly encountered injury in all deadly victims with an overall incidence of 10%.[18] Several other studies confirmed that 7 – 10% of all riders requiring hospital admission will have a spinal injury.[14,22-25]

### Discussion and conclusions

The gender distribution in the VUmc patient population (male versus female 1:7) is conform the expectations based on data of the total group of riders as known by the Royal Dutch Horse Riding Federation.[26] As expected most of the spine fractures occur at the thoracolumbar junction Th11-L2 and this is simply a reflection of the most common location of compression type fractures. In the patient population only two AO type B fractures are found, but as described in literature it could be possible that other AO type B fractures, especially those with ligamentous posterior injuries, were not diagnosed because MRI was not routinely performed.[27] As expected average LSC scores are significantly higher for the surgically stabilized patients. The initial local and regional sagittal angles in the surgical group show more kyphosis then the non-operatively treated group. After operative reduction this sagittal alignment improves over the conservative group. Although a large part of the initial reduction is lost in the next 12 months, the operatively treated patients still have less kyphosis compared to the conservative group at mid term radiological follow-up (after posterior implant removal at 9-12 months).

The significant relation between the RMDQ-24 score and permanent occupational disability shows the usefulness of functional outcome scores like the RMDQ-24 in the follow-up of patients with spine injuries.

Consequences of injury caused by horse riding can be profound and the long-term effects should not be underestimated. Even years after a major trauma 43% of the patients have complaints and 11-20% will remain permanently unfit for work. [28] Spine and pelvic trauma are the most important risk factors for these long-term effects. [28]

In view of the many different injuries described in literature, one can say that there is no activity with horses which is entirely without risk of injury. It is a consideration to teach horse riders falling techniques as used in martial arts sports and parajumping. [16,29]

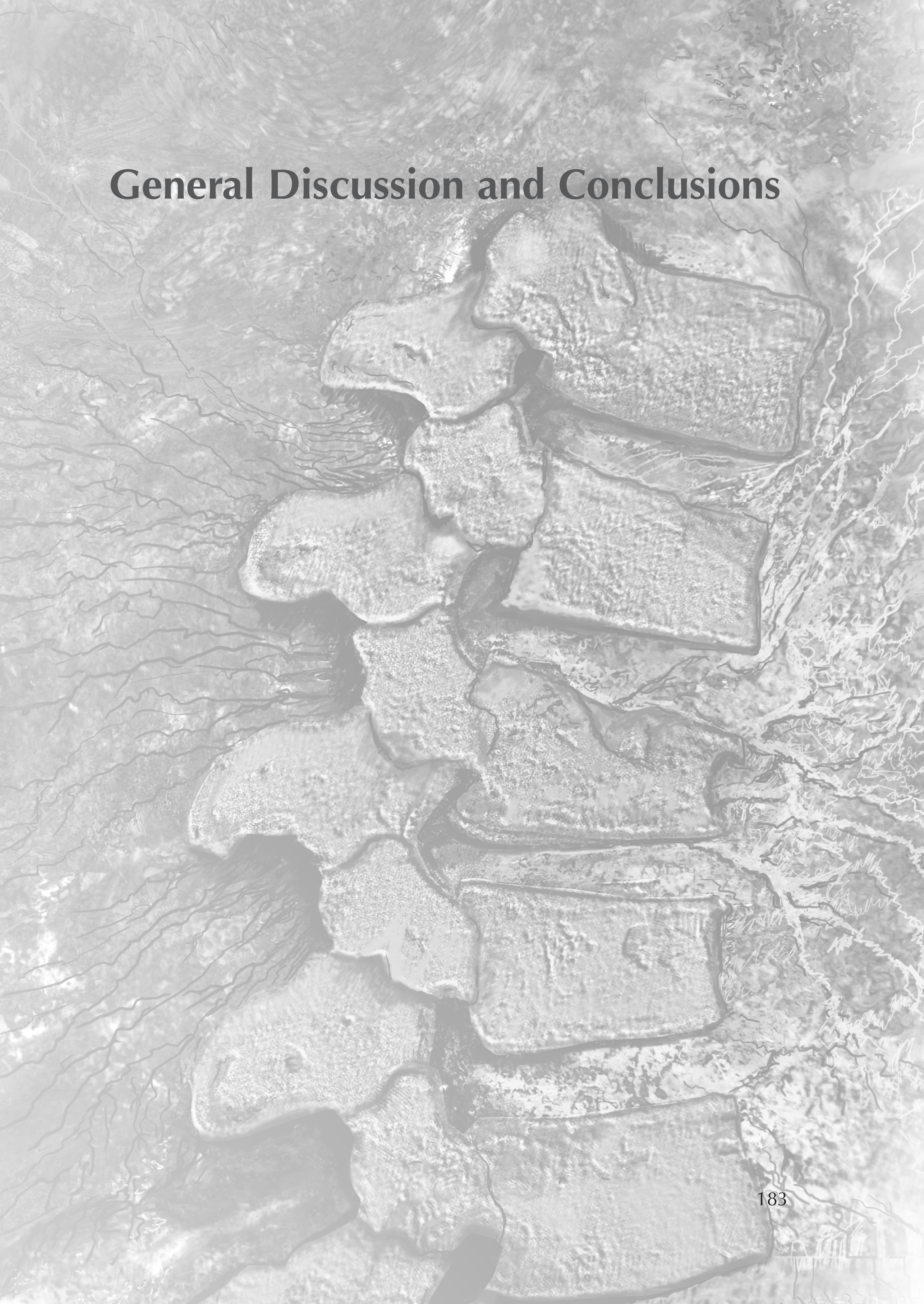
In conclusion we can state that the respect that riders show towards their horses is entirely justified.

## References


1. Nijland N, Hertog P.C.den, Ommeren P.van. How safe is Riding? A study in horse riding injuries (Hoe veilig is ruitersport. Een studie naar omvang, ernst en aard van ongevallen met paarden.). 1997. Amsterdam, [Netherlands Consumer Safety Institute] Stichting Consument en Veiligheid.
2. Chapman MA, Oni J. Motor racing accidents at Brands Hatch, 1988/9. Br.J.Sports Med. 1991;25:121-3.
3. Buckley SM, Chalmers DJ, Langley JD. Injuries due to falls from horses. Aust.J.Public Health 1993;17:269-71.
4. Danielsson LG, Westlin NE. Riding accidents. Acta Orthop.Scand. 1973;44:597-603.
5. Zachariae L. [Dog bites and other lesions caused by animals]. Ugeskr.Laeger 1973;135:2817-9.
6. Holland A.J.A., Roy G.T., Goh V. et al. Horse-related injuries in children. Med.J.Aust. 2001;175:609-12.
7. Magerl F, Aebi M, Gertzbein SD et al. A comprehensive classification of thoracic and lumbar injuries. .Eur.Spine.J. 1994;3:184-201.
8. McCormack T, Karaikovic E, Gaines RW. The load sharing classification of spine fractures. Spine 1994;19:1741-4.
9. Kraemer WJ, Schemitsch EH, Lever J et al. Functional outcome of thoracolumbar burst fractures without neurological deficit. J.Orthop.Trauma 1996;10:541-4.
10. Leferink VJ, Keizer HJ, Oosterhuis JK et al. Functional outcome in patients with thoracolumbar burst fractures treated with dorsal instrumentation and transpedicular cancellous bone grafting. Eur.Spine J. 2003;12:261-7.
11. Wood K, Butterman G, Mehbod A et al. Operative compared with nonoperative treatment of a thoracolumbar burst fracture without neurological deficit. A prospective, randomized study. J.Bone Joint Surg.Am. 2003;85-A:773-81.
12. Roland M, Morris R. A study of the natural history of back pain. Part I: development of a reliable and sensitive measure of disability in low-back pain. Spine 1983;8:141-4.
13. Schmidt B, Hollwarth ME. Sportunfalle im Kindes- und Jugendalter. Z.Kinderchir. 1989;44:357-62.
14. Silver JR. Spinal injuries resulting from horse riding accidents. Spinal Cord. 2002; Jun;40:264-71.

15. Sorli JM. Equestrian injuries: a five year review of hospital admissions in British Columbia, Canada. Inj.Prev. 2000;6:59-61.
16. Giebel G, Braun K, Mittelmeier W. Unfälle beim Pferdesport - Unfallhergang, Verletzungen und Prävention. Berlin: Springer-Verlag, 1994.
17. Ingemarson H, Grevsten S, Thoren L. Lethal horse-riding injuries. J.Trauma 1989;29:25-30.
18. Kricke E. [The fatal riding accident (author's transl)] Der todliche Reitunfall. Unfallheilkunde. 1980;83:606-8.
19. Du-Boullay CT, Bardier M, Cheneau J et al. [Sports injuries in children. Epidemiologic study] Les traumatismes sportifs de l'enfant. Etude epidemiologique. Chir Pediatr. 1984;25:125-35.
20. Chitnavis J.P., Gibbons C.L.M.H., Hirigoyen M. et al. Accidents with horses: what has changed in 20 years? Injury 1996;27:103-5.
21. Hipp E, von Gumppenberg S, Hackenbruch W et al. [Fracture of the vertebrae due to riding accidents] Die Wirbelfraktur als Reitunfall. Fortschr.Med. 1977;95:1567-71.
22. Barone GW, Rodgers BM. Pediatric equestrian injuries: a 14-year review. J.Trauma 1989;29:245-7.
23. Rathfelder FJ, Klever P, Nachtkamp J et al. [Injuries in horseback riding--incidence and causes].Sportverletz.Sportschaden. 1995;9:77-83.
24. Andermahr J, Schiffer G, Burger C et al. [Spinal injuries in jockeys. 2 case reports and review of the literature] Wirbelsaulenverletzung bei Jockeys. Zwei Fallberichte und Literaturubersicht. Unfallchirurg 2000;2000 Aug;103:688-92.
25. Kotilainen EM, Karki T, Satomaa OK. Traumatic cervical disc herniation--tetraparesis in a patient kicked by a horse. Acta Orthop.Scand. 1997;68:176-7.
26. Preventie paardrij-ongevallen; een overzicht van het gebruik van het handboek 'Veilig paardrijden' en de veiligheidseisen. 2003. Royal Dutch Equestrian Federation.
27. Leferink VJ, Veldhuis EF, Zimmerman KW et al. Classificational problems in ligamentary distraction type vertebral fractures: 30% of all B-type fractures are initially unrecognised. Eur.Spine J 2002;2002 Jun;11:246-50.
28. Dekker R, Groothof J.W., Eisma W.H. et al. Klinisch behandelde paardrijletsels in Groningen, 1990-1998: ernstige langetermijngevolgen. Ned.Tijdschr.Geneeskd. 2003;147:204-7.
29. Steinbruck K. [Spine injuries due to horse riding. Part 2 (author's transl)]. Unfallheilkunde. 1980;83:373-6.

# General Discussion and Conclusions



## General Discussion and Conclusions

### Chapter 3

**Treatment of traumatic thoracolumbar spine fractures: a multicenter prospective randomized study of operative versus nonsurgical treatment.**

The way of treatment of thoracolumbar type A fractures with no neurologic deficit is still controversial. A multicenter prospective randomized trial was performed to test the following hypothesis:

'Thoracolumbar AO Type A spine fractures with no neurologic deficit, managed with short-segment posterior stabilization will show an improved radiographic outcome and at least the same functional outcome as compared with nonsurgically treated thoracolumbar fractures.'

After a mean follow-up of 4.3 years, both local and regional kyphotic deformity was significantly less in the operatively treated group. All functional outcome scores (VAS Pain, VAS Spine Score, and RMDQ-24) showed significantly better results in the operative group. Five of 13 (38%) patients with an employment record in the nonsurgically treated group resumed their professional careers. Three of them returned to the same profession and 2 patients changed careers for physically less demanding employment. Average time between accident and return to work was 13.8 months (range, 6–33 months). Eleven of 13 (85%) working patients in the operative group returned to their previous job and none of them was forced to change careers. Average time between the accident and return to work in the operative group was 6.7 months (range, 1–18 months). The percentage of patients resuming their professional careers was found to be significantly higher in the operative group ($p = 0.018$). A significant difference concerning time before returning to work could not be shown.

It has been concluded that patients with a Type A3 thoracolumbar spine fracture without neurologic deficit should be treated by short-segment posterior stabilization. This treatment will result in better outcome of treatment.

## Chapter 4

### Interobserver agreement on the Load Sharing Classification of thoracolumbar spine fractures.

The Load Sharing Classification (LSC) is a classification based on three radiological characteristics of CT imaging of spinal fractures and allocates one to three points to each of these items. It seems that the LSC is an useful addition to the AO classification. A minimal LSC score of three and a maximum LSC score of nine can be obtained. LSC scores of 7 to nine predict a high rate of pedicle screw migration and screw breakage. In these cases a ventral stabilization should be applied, otherwise a dorsal procedure will suffice. The cut-off points between LSC 3-6 and LSC 7-9 are especially interesting because this will have clinical consequences.

For any classification to be useful, reliable reproduction by different observers is essential. The central question in this study addresses the interobserver agreement on the LSC score and the agreement on the scores of the three separate radiological fracture characteristics. As with this classification scores of seven and higher have an impact on the choice of treatment, specific interest goes out to the interobserver correlation of two categorical scores: LSC 3-6 versus LSC 7-9. Four observers, two trauma surgeons and two radiologists scored the Load Sharing Classification of 40 consecutive fractures independently.

The average standard Cohen's kappa values for the separate LSC items range between 0.27 and 0.49. For the total LSC score the average standard Cohen's kappa and weighted kappa values are 0.34 and 0.67 respectively. With regard to the cut-off point there is unanimous agreement in 68% of the cases. Standard Cohen's kappa value for the two categorical scores is 0.53. Strength of the interobserver agreement can be rated as fair to moderate. These results are in the same range as many other frequently used fracture classification systems.

The use of the Load Sharing Classification of spine fractures did not prove to be as intuitive for novel observers as originally thought but the level of interobserver agreement is well within the range of other frequently used fracture classification systems.

The anterior approach will assure a more permanent kyphosis correction without the historically related morbidity. The LSC can be regarded as a quantitative aid in selecting eligible patients.

## Chapter 5

### Failure of short-segment stabilizations of traumatic thoracolumbar fractures, the predictive value of the Load Sharing Classification of spinal fractures.

The Load-Sharing Classification (LSC) of spinal fractures relates vertebral comminution to the risk of posterior implant failure after operative stabilization. According to this classification, a posterior implant suffices for fractures with a low LSC score, whereas anterior reconstruction should be performed for fractures with a high LSC score. The LSC does not take postoperative loss of reduction into account. In this study, both implant failure and postoperative loss of reduction were assessed in 58 patients with traumatic thoracolumbar fractures of the spine, stabilized with a short-segment implant. Implant failure was defined as acute bending or breaking of any part of the implant.

Implant failure was seen in four fractures with a high LSC score. One fracture had been stabilized with an anterior implant and three with a posterior implant. All fractures with a high LSC score with posterior stabilization showed a significant loss of reduction, unlike fractures with a high LSC score with anterior stabilization. The difference in loss of reduction for posterior versus anterior stabilized fractures was 3.4° versus 0.8° for local kyphosis ($p<0.238$), 7.6° versus 0.7° for regional kyphosis ($p<0.002$), -10% versus -2% for Beck's Index ($p<0.016$), and 9% versus 0% for vertebral collapse ($p<0.003$), respectively.

The sensitivity and specificity of the LSC for predicting loss of reduction is 0,92 and 0,44. The sensitivity and specificity of the LSC in this study, for predicting implant failure is respectively 1,0 and 0,28

These results suggest that an anterior implant should be used for comminutive fractures of the thoracolumbar spine. The recent development of minimally invasive thoracoscopic techniques means that anterior stabilization can be achieved without the morbidity associated with open procedures.

## Chapter 6

**A prospective cohort study comparing the VAS Spine Score and Roland-Morris Disability Questionnair in patients with a type A traumatic thoracolumbar spinal fracture.**

To judge clinical outcome of patients with a traumatic thoracolumbar spinal fracture, functional scores are used. Judging back pain by comparing radiographs shows that clinical severity is not related to radiological parameters. Clinical practice puts emphasis on pain, but pain is a complex physiological, psychological, and behavioral phenomenon that is difficult to evaluate and to quantify in the clinical situation.

Because of these limitations, outcome of treatment is evaluated by measuring physical impairment and disability. Physical impairment is an anatomical or pathological abnormality leading to loss of normal body ability. Disability is defined as the diminished capacity for everyday activities. Physical impairment is objective structural limitation; disability is the resulting loss of function, usually reported subjectively.

To measure the outcome after thoracolumbar spine fractures, different methods can be used, one of these is measuring functional outcome. Two scales are developed with special attention to back problems: the Roland-Morris Disability Questionnair (RMDQ) and the VAS Spine Score. The aim of this study is to compare these scores and to see if there is a correlation in patients with a traumatic thoracolumbar spinal fracture.

RMDQ-24 and VAS Spine have a strong positive correlation in measuring disability in a group of patients with back pain because of a spinal fracture. In both non-operatively and operatively treated groups this correlation is significant.

In spine research it is important to have objective measurements so that different studies can be compared. There is a good correlation between the two scores, so it is possible to compare studies which assess functional outcome with one of these scales.

### Chapter 7

**Functional outcome in short-segment stabilised comminutive fractures of the thoracolumbar spine; is the LSC a factor?**

When a high LSC type fracture is solitary stabilised with a short-segment posterior stabilising implant, loss of the peroperative applied reduction and an increased risk of implant failure are evident. It remains uncertain whether this increased loss of reduction and increased risk of implant failure lead to significant loss of function in these patients. This study analyses the functional outcome after 18 months of follow-up of patients with an unstable burst fracture of the thoracolumbar spine, treated with a short-segment stabilising procedure (anterior and/or posterior). The goal of this study was to research the prognostic value of the Load Sharing Classification for the functional outcome of patients with short-segment stabilised burst fractures of the thoracolumbar spine. Central question was whether patients with a high LSC fracture, stabilised only with a posterior stabilising implant have a worse functional outcome than patients stabilised according to the LSC.

Patients with high LSC fractures and a solitary posterior stabilising implant showed significant loss of reduction, compared to patients with high LSC score fractures and an anterior implant. There was no relation between LSC score and RMDQ and no relation between LSC and VAS score.

These findings show that the LSC has no prognostic value for the functional outcome in patients with a short-segment stabilised traumatic thoracolumbar fracture.

## Chapter 8

### Cost-effectiveness of the treatment of traumatic thoracolumbar spine fractures – nonsurgical or surgical therapy?

Spinal fractures can be an important cause for disabling back pain. Therefore in judging the cost-effectiveness of nonsurgical or surgical therapy not only direct costs but also the indirect costs should be calculated.

Direct costs of the treatment of nonsurgically treated patients were €10,608 ($12,730) and €18,769 ($22,523) for the operatively treated group. Indirect costs resulted in a total of €219,187 ($263,025) per non-operative treated patient. In the operative group this costs were €66,004 ($79,206). In the treatment of traumatic thoracolumbar spine fractures the indirect costs exceed the direct cost by far and make up 95.4% of the total costs for treatment in nonsurgically treated patients and 71.6% of the total costs in the operative group. In view of cost-effectiveness, the operative therapy of traumatic thoracolumbar spine fractures is to be preferred

## Chapter 9

### Spine fractures caused by horse riding.

In chapter 9 spinal fractures acquired in horse riding were evaluated. Thoracolumbar type A3 fractures at the thoracolumbar junction Th11-L2 are most common. The average Load Sharing classification is 3.9. No neurologic deficits were found.

Even with a follow-up of up to 13 years twenty-two percent of the patients had permanent occupational disability. Although the LSC in the operative treated group was significant higher (4.1 vs. 6.8) the Rolland Morris Disability Questionnaire-24 showed a significant better outcome for the operative treated patients with a score of 4.6 vs. 8.1 for the non-surgical treated group. There is a significant correlation between the RMDQ-24 and occupational disability. All patients with a RMDQ-24 score of 14 or higher had permanent occupational disability.

Not only are short-term effects of spine fractures acquired in horse riding substantial, but these injuries can also lead to long-term disabilities in at least every 5$^{th}$ patient.

## Recent developments

Stabilisation of the anterior portion of the vertebra is possible with angle stable, modular osteosynthesis which can be implanted completely endoscopically. Biomechanically they give a high primary stability and have all the advantages of a minimal invasive operation. There is no doubt about the technical possibility of minimal invasive spine surgery, so the indications for reconstruction of the ventral portion of the vertebra will be expanded. If minimal invasive ventral stabilisation operation techniques will advance and get a place in 'every day traumatology' has to be seen, especially with respect to cost-effectiveness.

Vertebroplasty and balloon vertebroplasty or kyphoplasty are other techniques for restoring the anatomy of the fractured vertebral body. In the treatment of osteoporotic compression fractures the feasibility and safety of this technique is proven. The use of these techniques for traumatic fractures is another minimal invasive possibility for stabilization of the anterior portion of the vertebra.

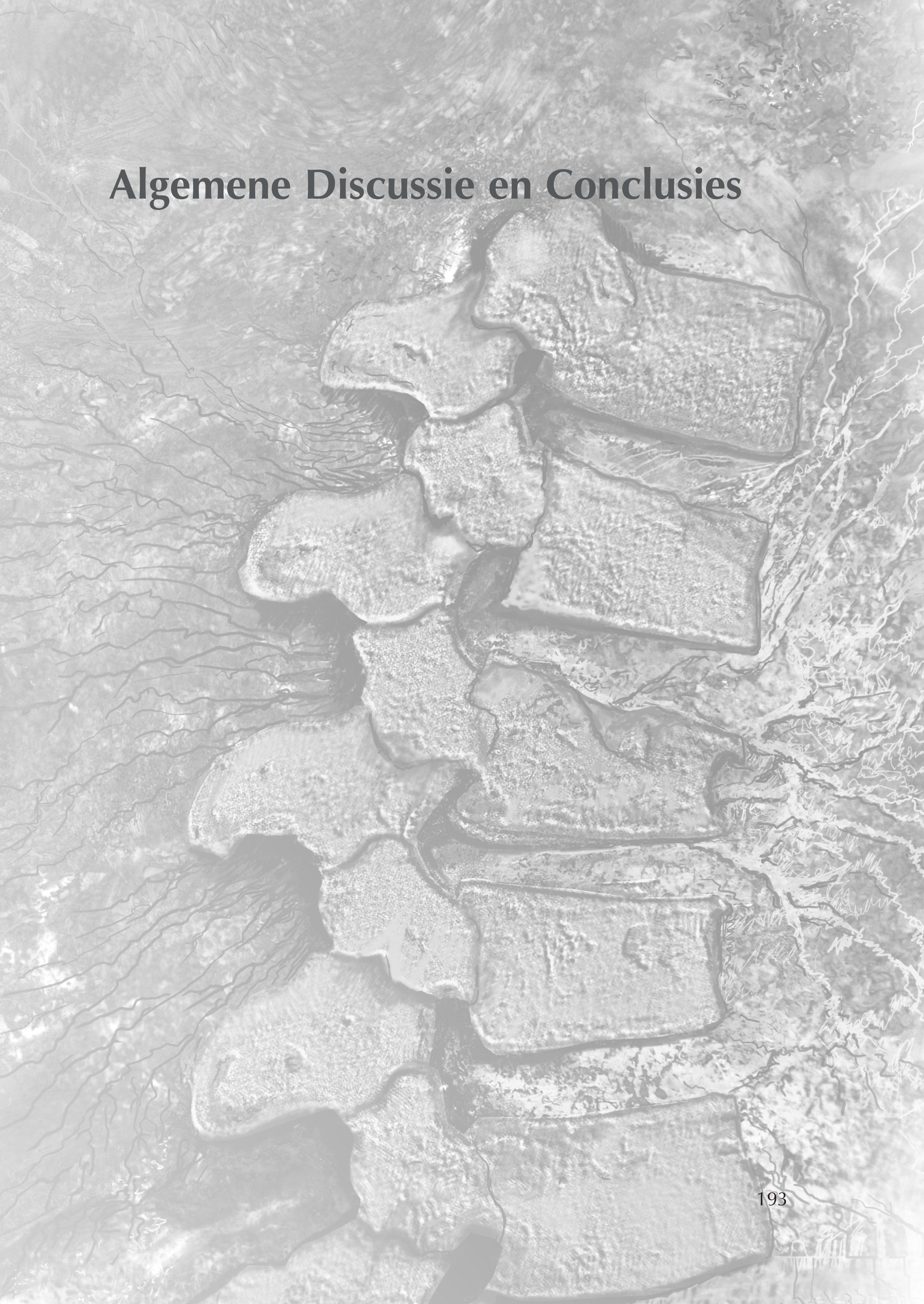
## Future developments

For a better differentiation between type A and B fractures more attention must be paid to the soft tissue and a MRI will become an important diagnostic tool in evaluation of these fractures.

To investigate the necessity of ventral stabilisation in type A fractures a prospective randomized study should be recommended.

Computer guided surgery will improve accuracy of surgical procedure and is an opportunity for safe minimal invasive spinal surgery.

# Algemene Discussie en Conclusies



## Algemene Discussie en Conclusies

### Hoofdstuk 3

**Behandeling van traumatische thoracolumbale wervelfracturen: een multi-center, prospectief gerandomiseerde studie naar operatieve versus niet operatieve therapie.**

De behandeling van type A thoracolumbale wervelfracturen zonder neurologische uitval is nog steeds controversieel. Een multicenter prospectief gerandomiseerde studie werd opgezet om de volgende hypothese te testen:

‘AO type A thoracolumbale wervelfracturen zonder neurologische uitval, behandeld door middel van een dorsale korte segment stabilisatie, zullen een betere radiologische uitkomst hebben en op zijn minst een gelijke functionele uitkomst in vergelijking met niet operatief behandelde thoracolumbale wervelfracturen.’

Na een mediane follow-up van 4,3 jaar, waren zowel de locale als de regionale kyfosering significant minder in de operatief behandelde groep. Alle functionele scores (VAS pijn, VAS Spine score en RMDQ-24) lieten een significant betere uitkomst zien in de operatief behandelde groep. Vijf van 13 (38%) patiënten uit de niet chirurgisch behandelde groep die werkzaam waren konden werk hervatten. Drie van hen konden hun oorspronkelijke werk hervatten en 2 patiënten veranderden van baan om een lichamelijk minder zwaar beroep te gaan beoefenen. De gemiddelde tijd tussen ongeval en terugkeer naar werk was 13,8 maanden (6 – 33 maanden). Elf van 13 (85%) werkende patiënten uit de chirurgisch behandelde groep konden weer terugkeren naar hun oorspronkelijke baan, geen een van hen moest van baan veranderen. Gemiddelde tijd tussen ongeval en terugkeer naar werk was 6,7 maanden (1 - 18 maanden). Het percentage van patiënten die werk konden hervatten was significant hoger in de operatieve groep (p=0,018). Een significant verschil in de tijd tussen ongeval en terugkeer naar werk kon niet worden aangetoond.

Concluderend kan worden gesteld dat een patiënt met een type A3 thoracolumbale wervelfractuur zonder neurologische uitval door middel van een dorsale, korte segment stabilisatie behandeld zou moeten worden. Deze behandeling resulteert in een beter uitkomst.

**Hoofdstuk 4**

**Interbeoordeelaarsbetrouwbaarheid met betrekking tot de Load Sharing Classification van thoracolumbale wervelfracturen.**

De Load Sharing Classification (LSC) is een classificatie gebaseerd op 3 radiologische karakteristieken van CT afbeeldingen van wervelfracturen en geeft aan elk hiervan 3 punten. De LSC lijkt een bruikbare aanvulling op de AO classificatie. De minimale LSA score is 3, de maximale score is 9. LSC scores van 7 of hoger voorspellen een vaker voorkomen van pedikelschroef migratie en schroefbreuk. In deze gevallen zou een ventrale stabilisatie moetten worden verrricht, terwijl in de andere gevallen een dorsale stabilisatie voldoende is. Met name de cut-off points tussen LSC 3-6 en LSC 7-9 zijn interessant vanwege de kliniche consequenties.

Een classificatie is pas bruikbaar als deze door verschillende observers betrouwbaar te reproduceren is. De centrale vraag in deze studie is het beoordelen van de interbeoordeelaarsbetrouwbaarheid van de LSC en de overeenstemming van scores van de drie verschillende radiologische eigenschappen. Omdat een LSC score van 7 of hoger klinische consequenties heeft, gaat er speciale aandacht uit naar de interbeoordelaarscorrelatie van 2 scores: LSC 3 – 6 versus LSC 7 – 9. Vier observers, 2 ongevalschirurgen en 2 radiologen scoorden onafhankelijk van elkaar de LSC op 40 wervelfracturen.

De gemiddelde standard Cohen's kappa waarden voor de verschillende LSC items varieerden tussen 0,27 en 0,49. Voor de totale LSC score de gemiddelde standaard Cohen's kappa en gewogen kappa waardes zijn 0,34 en 0,67 respectievelijk. Met betrekking tot de cut-off point is er overeenstemming in 68% van de gevallen. Standaard Cohen's kappa waarde voor de categorische score is 0,53. De sterkte van de interbeoordeelaarsbetrouwbaarheid kan worden gewaardeerd van redelijk tot gemiddeld. Deze waardes liggen in dezelfde spreiding als andere frequent gebruikte fractuur classificatie systemen.

Het gebruik van de LSC is niet zo intuitief als startende observers dachten maar het niveau van interbeoordeelaarsbetrouwbaarheid is binnen de range van andere veelgebruikte fractuurclassificatie systemen. De ventrale benadering zorgt voor een meer permanente correctie van de kyfose. De LSC kan worden gezien als een kwantitatief hulpmiddel voor het selecteren van patiënten.

**Hoofdstuk 5**

**Falen van kort segment stabilisatie van traumatische thoracolumbale fracturen, de voorspellende waarde van de Load Sharing Classification voor wervelfracturen.**

De Load Sharing Classification (LSC) van wervelfracturen relateert de fractuur comminutie aan dorsaal stabilisatie falen na operatie. Volgens deze classificatie voldoet een dorsale stabilisatie bij een lage LSC score, en moet bij een hogere LSC een ventrale stabilisatie plaatsvinden. De LSC houdt geen rekening met postoperatief hoogtreverlies. In deze studie, worden zowel implantaat falen en reductieverlies beoordeeld in 58 patiënten met een traumatische thoracolumbale wervelfractuur, gestabiliseerd met een kort segment stabilisatie. Implantaat falen werd gedefinieerd als buigen of breken van een van de implantaatonderdelen.

Implantaat falen werd gezien bij 4 fracturen met een hoge LSC score. Eén fractuur was verzorgd door middel van een ventraal implantaat en drie fracturen met een dorsaal implantaat. Alle fracturen met een hoge LSC en dorsale stabilisatie lieten een significant verlies aan reductie zien, in tegenstelling tot fracturen met een hoge LSC en ventrale stabilisatie. Het verschil in verlies in reductie tussen dorsaal en ventraal gestabiliseerde fracturen was 3.4° versus 0.8° voor lokale kyfose ($p<0.238$), 7.6° versus 0.7° voor regionale kyfose ($p<0.002$), -10% versus -2% voor Beck's Index ($p<0.016$), en 9% versus 0% voor wervellichaam collaps ($p<0.003$), respectievelijk.

De sensitiviteit en specificiteit van de LSC voor het voorspellen van reductieverlies is 0,92 en 0,44. De sensitiviteit en specificiteit van de LSC in deze studie voor het voorspellen van implantaat falen is respectievelijk 1,0 and 0,28

Deze resultaten suggereren dat een ventraal implantaat moet worden gebruikt voor comminutieve fracturen van de thoracolumbale wervelkolom. De recente ontwikkelingen van minimaal invasieve thoracoscopische technieken betekenen dat ventrale stabilisatie kan worden bereikt zonder de met open chirurgie geassocieerde morbiditeit.

## Hoofdstuk 6

**Een prospectieve cohort studie waarin de VAS Spine score en Roland-Morris Disability Questionnair bij patiënten met een traumatisch type A thoracolumbale wervelfractuur worden vergeleken.**

Om de klinische uitkomst van patiënten met een traumatische thoracolumbale wervelfractuur te beoordelen, worden functionele scores gebruikt. Voor het beoordelen van de klinische ernst is het beoordelen op radiologische parameters niet zinvol omdat hier geen relatie mee is. De klinische praktijk legt de nadruk op pijn, maar pijn is een complex fysiologisch, psychologisch en gedragsmatig fenomeen welke moeilijk te evalueren en te kwantificeren is in de klinische situatie.

Door deze beperkingen, wordt de uitkomst van behandeling beoordeeld door het meten van lichamelijke beperking en handicap. Lichamelijke beperking is een anatomische of pathologische afwijking die leidt tot verlies van lichaamsfunctie. Handicap is een verminderde mogelijkheid voor dagelijkse activiteiten. Lichamelijke beperking is een objectieve structurele limitatie; handicap is het resulterende verlies in functie, meestal subjectief.

Er zijn verschillende methodes om de uitkomst te meten na een thoracolumbale wervelfractuur. Er zijn 2 meetinstrumenten ontwikkeld die speciaal voor rugproblemen zijn ontwikkeld: de Roland-Morris Disability Questionnair (RMDQ-24) en de VAS Spine Score. Het doel van deze studie is om deze scores te vergelijken en om te zien of er een correlatie is bij mensen met een traumatische wervelfractuur.

De RMDQ-24 en de VAS Spine hebben een sterk positieve correlatie voor het meten van lichamelijke beperking in een groep van patiënten met rugpijn vanwege een wervelfractuur. In zowel de niet-operatief en operatief behandelde groep was deze correlatie significant.

In het onderzoek naar de rug is het belangrijk om objectieve metingen te hebben zodat verschillende studies met elkaar kunnen worden vergeleken. Er is een goede correlatie tussen de beide scores, het is dus mogelijk om studies die een van deze twee scores gebruiken, met elkaar te vergelijken.

### Hoofdstuk 7

**Functioneel resultaat bij kort segment gestabiliseerde comminutieve thoracolumbale wervelfracturen; is de LSC een factor?**

Als een fractuur met een hoge LSC gestabiliseerd wordt door middel van een kort segment dorsal stabilisatie, is er een grote kans op verlies van reductie en het faalen van het implantaat. Het is echter onduidelijk of dit verlies in reductie en faalen van het implantaat zich vertaalt naar een significant verlies van functie bij de patiënt. Deze studie analyseert het functionele resultaat na 18 maanden follow-up bij patiënten met een instabiele burst fractuur van de thoracolumbale wervelkolom, behandeld door middel van een kort segment stabilisatie (ventraal en/of dorsaal). Het doel van deze studie was om te zien of de LSC een voorspellende waarde heeft voor het functionele resultaat van patiënten met een kort segment stabilisatie bij een thoracolumbale wervelfractuur. Centrale vraag is of patiënten met een hoge LSC, die behandeld zijn met slechts een dorsale stabilisatie een slechter functioneel resultaat hebben dan patiënten die volgens hun LSC worden behandeld.

Patiënten met een hoge LSC en alleen een dorsale stabilisatie lieten een significant verlies in reductie zien in vergelijking met patiënten met een hoge LSC en een ventrale stabilisatie. Er was geen relatie tussen LSC en RMDQ-24 en er was geen relatie tussen LSC en VAS Spine score. Deze resultaten laten zien dat de LSC geen prognostische waarde heeft voor het functionele resultaat van patiënten die behandeld zijn met een kort-segment stabilisatie bij een traumatische thoracolumbale wervelfracturen.

### Hoofdstuk 8

**Kosten-effectiviteit van de behandeling voor traumatische thoracolumbale wervelfracturen – niet-chirurgische of chirurgische behandeling?**

Wervelfracturen zijn een belangrijke oorzaak voor invaliderende rugpijn. Daarom is het belangrijk om bij het bepalen van de kosten-effectiviteit van niet-chirurgische of chirurgische therapie niet alleen de direcet kosten maar ook de indirecte kosten te berekenen.

Directe kosten voor de niet-chirurgische behandeling waren €10,608 ($12,730) en €18,769 ($22,523) voor de operatief behandelde groep. Indirecte kosten waren totaal of €219,187 ($263,025) per niet-chirurgisch behandelde patiënt. In de operatieve groep waren deze kosten €66,004 ($79,206).

Bij de behandeling van traumatische thoracolumbale wervelfracturen overstijgen de indirect kosten ruimschoots de directe kosten en vormen 95,45% van de totale kosten voor de behandeling van niet-chirugisch behandelde patiënten en 71,6% van de totale kosten in de chirurgisch behandelde groep. In het kader van kosten-effectiviteit is de voorkeursbehandeling voor traumatische thoracolumbale wervelfracturen chirurgisch.

**Hoofdstuk 9**

**Wervelfracturen veroorzaakt door paardrijden.**

In hoofdstuk 9 worden wervelfracturen veroorzaakt door paardrijden besproken. Thoracolumbale type A3 fracturen op de thoracolumbale overgang Th11 – L2 komen het meest voor. De gemiddelde LSC is 3,9. Er werd geen neurologische uitval gevonden.

Zelfs na een follow-up van 13 jaar was 22% van de patiënten arbeids-ongeschikt. Hoewel de LSC in de chirurgisch behandelde groep significant hoger was (4,1 vs. 6,8), liet de RMDQ-24 een significant betere uitkomst zien voor de chirurgisch behandelde groep met een score van 4,6 vs. 8,1 voor de niet-chirurgische groep. Er is een significante correlatie tussen de RMDQ-24 en arbeidsongeschikt-heid. Alle patiënten met een RMDQ-24 score van 14 of meer waren arbeidsongeschikt.

Niet alleen de korte termijn effecten van een door paardrijden veroorzaakte wervelfractuur zijn ernstig, maar dit letsel kan ook tot lange-termijn beperkingen leiden in minstens 1 op de 5 patiënten.

**Recente ontwikkelingen**

Stabilisatie van het ventrale gedeelte van het wervellichaam is mogelijk met een hoek-stabiele, modulaire osteosynthese die volledig scopisch geïmplanteerd kan worden. Biomechanisch geven deze een hoge primaire stabiliteit en ze bieden de voordelen van een scopische operatie. Er is geen twijfel dat minimaal invasieve chirurgie technisch geschikt is voor de behandeling van wervelfracturen, en de indicaties voor reconstructie van het ventrale gedeelte van het wervellichaam zullen toenemen. Of de minimaal invasieve ventrale stabilisatie techniek een plaats zal krijgen in de 'alledaagse' ongevalschirurgie zal blijken, ook in relatie tot kosten-effectiviteit.

Vertebroplastiek en ballon vertebroplastiek of kyfoplastiek zijn andere technieken voor het herstel van de anatomie van een gefractureerd wervellichaam. Voor de behandeling van osteoporotische compressie fracturen is de toepasbaarheid en veiligheid van deze techniek reeds aangetoond. Het gebruik van deze technieken voor traumatische fracturen is een andere minimaal invasieve mogelijkheid voor de stabilisatie van het ventrale gedeelte van het wervellichaam.

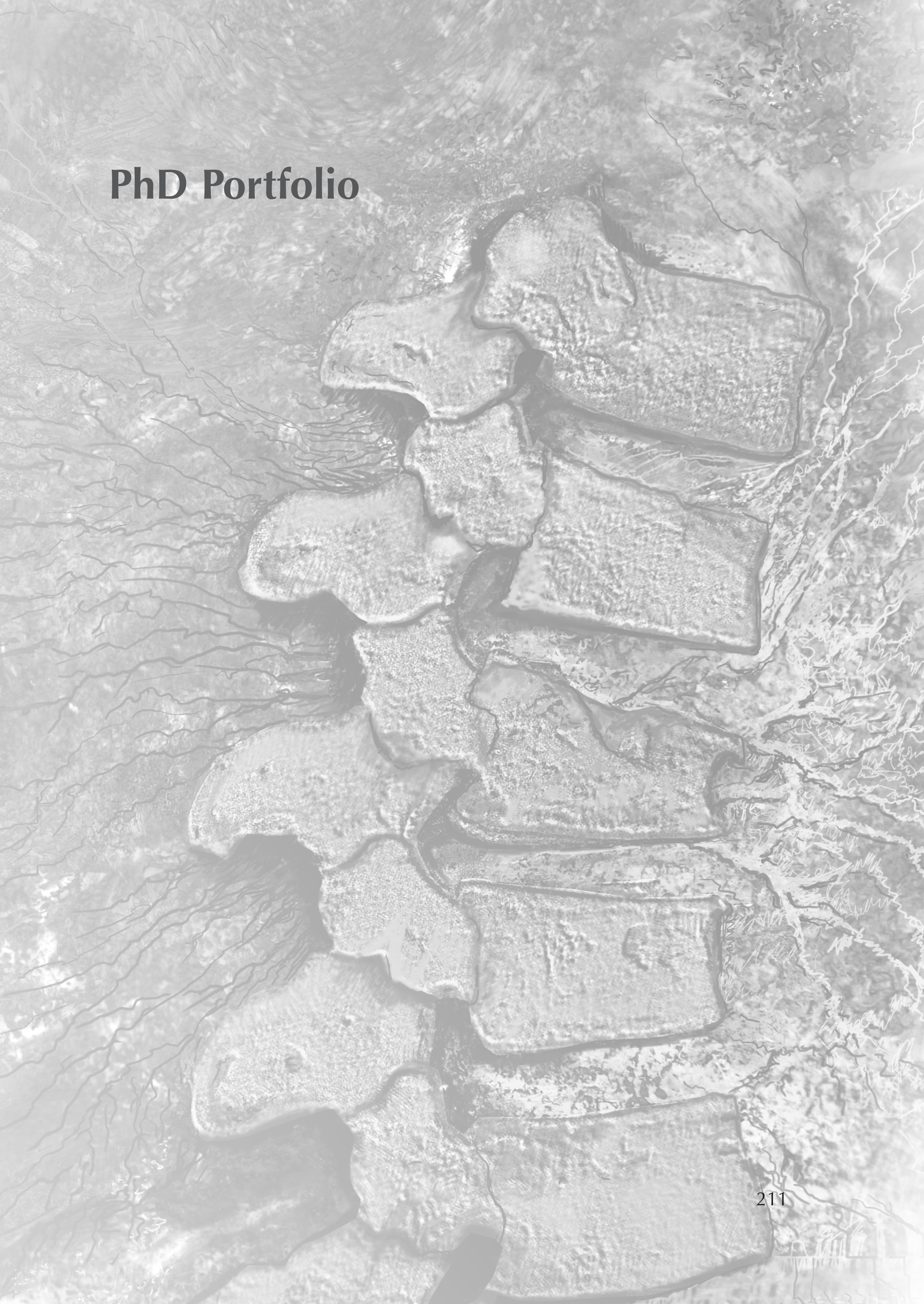
**Toekomstige ontwikkelingen**

Voor een betere differentiatie tussen type A en B fracturen zal meer aandacht moeten worden besteed aan de weke delen en MRI is een belangrijk diagnostisch middel voor het beoordelen van wervelfracturen.

Om de noodzaak van ventrale stabilisatie bij type A fracturen te beoordelen zou een prospectief gerandomiseerd onderzoek wenselijk zijn.

Computernavigatie zal de nauwkeurigheid van chirurgische procedures doen toenemen en is een mogelijkheid voor veilige minimaal invasieve wervelchirurgie.

He reflected that the progressive extension of the field of individual development and experience was regressively accompanied by a restriction of the converse domain of interindividual relations. *James Joyce Ulysses Ithaca*



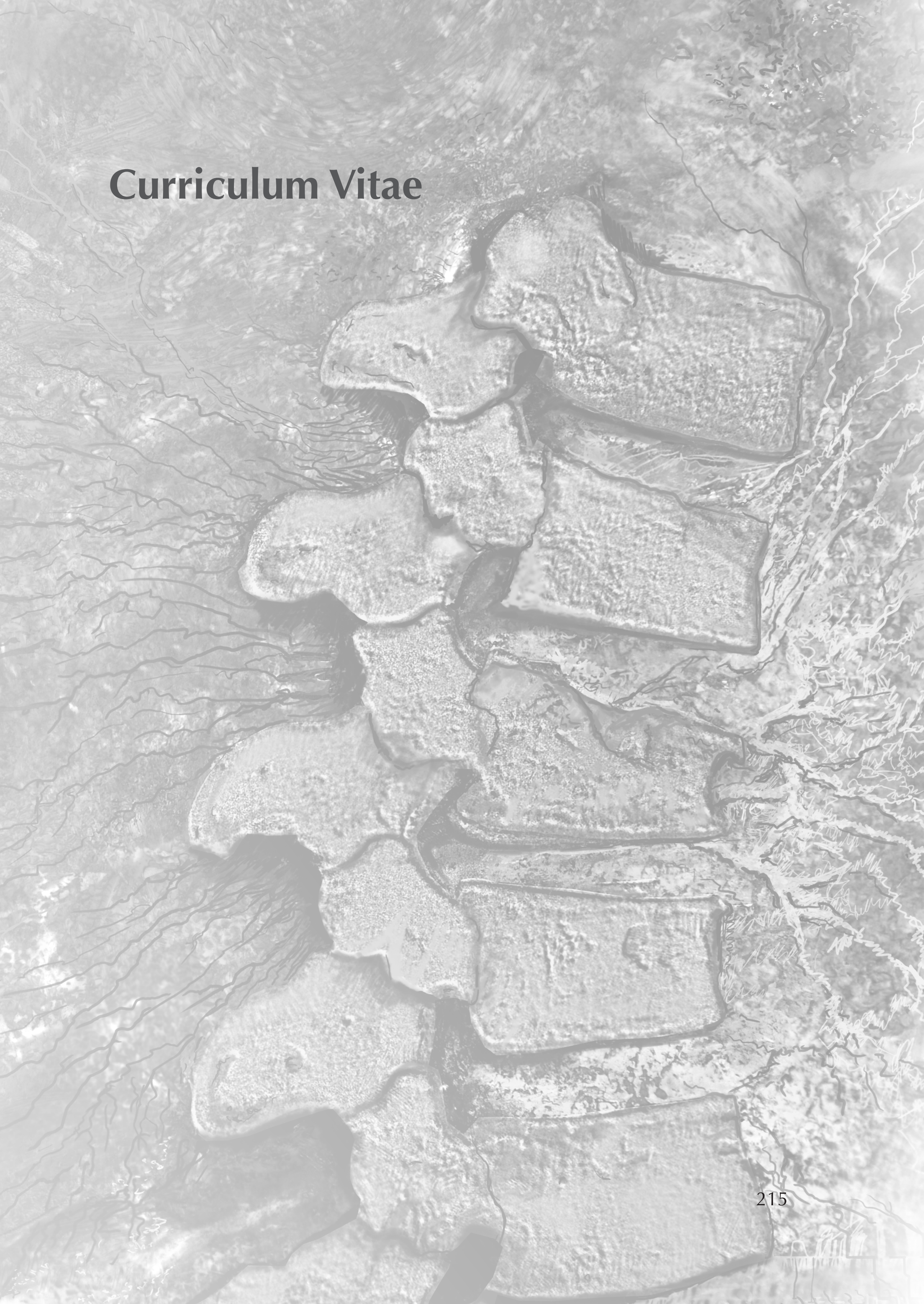
# PhD Portfolio

# PhD Portfolio

## Summary of PhD training and teaching

| | | |
|---|---|---|
| Name PhD student: J. Siebenga<br>Erasmus MC Department:Medicine | Promotor(s):P. Patka | |
| **1. PhD training** | | |
| | **Year** | **Workload (ECTS)** |
| **General courses** | | |
| - Statistics | 2001 | 1 |
| - Methodology | 2001 | 1 |
| **Specific courses (e.g. Research school, Medical Training)** | | |
| - Teach the Teacher | 2009 | 2 |
| - Media training | 2010 | 1 |
| - Training the Trainers Foundation Course | 2012 | 2 |
| **Presentations and International Conferences** | | |
| - National (35) | 1993 – | 35 |
| - International: | | |
| - European (8) | 1993 – | 8 |
| - International (7) | 1993 – | 7 |
| **2. Teaching** | | |
| | **Year** | **Workload (ECTS)** |
| **Supervising practicals and excursions, Tutoring** | | |
| - Assistent Anatomy | 1992 – 1994 | 6 |
| - Instructor SOSA | 1998 | 0,5 |
| - Instructor Emergency- and Disaster Medicine | 1998 – 2000 | 1 |
| - T-score for cardio-thoracic residents | 2006 | 0,5 |
| - Training residents for lungsurgery | 2006 – | 10 |
| - Training for Radiotherapists | 2007, 2012 | 1 |
| - Proctor c-VATS lobectomy | 2007 – | 10 |
| - CME for scrub nurses | 2008 – | 1 |
| - PAOG Thoracic wall diseases | 2008 | 0,5 |
| - PAOG Pectus Excavatum | 2008 | 0,5 |
| - Training Anaesthesists | 2008 | 0,5 |
| - Trainer Pulmonologists | 2011 | 1 |
| - Training surgeons for lungsurgery | 2011 – | |
| **Other** | | |
| - Best paper Medicine | 1994 | |
| - Stipendium Prof. Michaël-van Vloten fonds | 2000 | |
| - Schoemaker award for best Dutch international articel. Treatment of Traumatic Thoracolumbar Spine Fractures: a multicenter Prospective Randomized Study of Operative vs Nonsurgical Treatment | 2006 | |

# Curriculum Vitae



## Curriculum Vitae

Jan Siebenga was born as son of E. Siebenga and L.H. Bottelier on the fifth of January 1969 in Leiden, the Netherlands. He obtained his high school diploma in 1988 at the Christelijke Scholengemeenschap De Brug in Lelystad. The same year he did his tour of duty at the 425th Infanterie Beveiligings Compagnie, also called 'Van Heutz'. In 1989 he started training for Physiotherapy at the Hogeschool van Amsterdam and one year later he received his propadeuse. In 1990 he finally was able to start the study of Medicine at the Vrije Universiteit in Amsterdam. The doctoral exam was received in 1995 and in 1997 he did his medical qualifying examination which he received with cum laude.

He worked one year as an AGNIO Surgery at the Academisch Ziekenhuis Vrije Universiteit, were he started his surgical training in January 1999 (prof. dr. H.J.Th.M. Haarman). He obtained a research fellow-ship from the Prof. Michaël-van Vloten fund. At the Klinik und Poliklinik für Unfallchirurgie der Unikliniken Mainz in Germany he started a fellowship surgery in 2000 (prof. dr. P.M. Rommens). In January 2001 training was continued at the Medisch Centrum Alkmaar (dr. A.B. Bijnen) were he finished his training in December 2004. In January 2005 he started as CHIVO thoracic surgery at the Medisch Centrum Atrium in Heerlen (dr. Bollen). His registration as thoracic surgeon followed in July 2006. In 2006 he received the Schoemaker Award from the Association of Surgeons of the Netherlands for best Dutch international article: "Treatment of Traumatic Thoracolumbar Spine Fractures: A Multicenter Prospective Randomized Study of Operative versus Nonsurgical Treatment." Since November 2006, he is member of the surgical staff of Atrium Medical Centre in Heerlen. In January 2011 he became trainer for Lungsurgery and started as consultant Lungsurgery for the Integrated Cancer Centre Netherlands (IKNL). The surgical staff of Atrium Medical Centre and the surgical staff of Orbis Medical Centre associated in April 2011 which led to the institution of Maatschap Heelkunde Zuid-Limburg.

Together with his wife Joan Schollaart they have a twin, Isaak en Ezra, and two girls, Lea and Anna.