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Therapeutic Decision Making in Thoracolumbar Spine Trauma

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Study Design. Systematic literature review.

Objective. A systematic review was designed to answer 3 primary research questions: (1) What is the most useful classification system for surgical and nonsurgical decision-making with regard to thoracolumbar (TL) spine injuries? (2) For a TL burst fracture with incomplete neurologic deficit, what is the optimal surgical approach and stabilization technique? (3) Is complete disruption of the posterior ligamentous complex an indication for surgical intervention for TL burst fractures?

Summary of Background Data. Despite a long history of descriptive and clinical series, there remains considerable controversy and wide variation in the treatment of traumatic TL spine injuries.

Methods. A comprehensive search of the English literature was conducted using Medline and the Cochrane Database of Systematic Reviews. Standardized grading systems were used to assess the level of evidence and quality of articles impacting the research questions.

Results. Recommendations for the primary research questions were as follows: (1) Thoracolumbar Injury Classification System seems to be the best system available for therapeutic decision-making for TL spine injuries (strength of recommendation: weak; quality of evidence: low). (2) There is no specific surgical approach in the case of a TL burst fracture with incomplete neurologic deficit that has any advantage with regard to neurologic recovery (strength of recommendation: weak; quality of evidence: low). (3) Complete disruption of the posterior ligamentous complex as determined collectively by morphologic criteria using plain radiographs and computed tomography is an indication for surgical intervention in TL burst fractures (strength of recommendation: strong; quality of evidence: low).

Conclusion. Based on this systematic review of the literature only very low to moderate quality studies could be identified to address clinical questions related to TL spine trauma. These findings suggest the need for further study, including emphasis on higher quality studies.

Key words: trauma, thoracolumbar spine, classification, surgery, review. **Spine 2010;35:S235–S244**

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Despite a long history of descriptive and clinical series and attempts to classify, there is still a high degree of controversy and wide variation in the treatment of traumatic thoracolumbar (TL) spine injuries. There are no universally accepted algorithms to decide whether a patient needs surgical intervention and if so what the appropriate surgical technique should be.

Concerning clinical decision-making in traumatic injuries of the thoracic and lumbar spine, 3 questions were identified through consensus following discussion among a panel of experts (Spine Trauma Study Group). A systematic review was designed to answer these primary research questions based on available literature. These questions were as follows:

1. What is the most useful classification system for surgical and nonsurgical decision-making with regard to TL spine injuries?
2. For a TL burst fracture with incomplete neurologic deficit, what is the optimal surgical approach and stabilization technique?
3. Is complete disruption of the posterior ligamentous complex (PLC) an indication for surgical intervention for TL burst fractures?

■ Materials and Methods

A comprehensive search of the English literature was conducted using Medline and the Cochrane Database of Systematic Reviews. The articles impacting the research question were graded into levels of evidence using 2 previously described approaches. The articles were graded according to levels of evidence guidelines of Wright *et al*,[1] with levels from I through V as follows: Level I (well done randomized controlled studies or systematic reviews of such studies), Level II (prospective cohort studies, poor-quality randomized controlled trials, or systematic reviews of such studies), Level III (case-control studies, retrospective cohort studies, or systematic reviews of such studies), Level IV (case series with no, or historical, control group), and Level V (expert opinion). The level of evidence was also graded according to the system of Schünemann *et al*,[2] in which the quality of studies is classified as follows: high quality (randomized controlled trials or meta-analysis of randomized controlled trials), moderate quality (downgraded high quality studies, nonrandomized trials, prospective cohort studies), low quality studies (retrospective observational, retrospective cohort and case control studies), and very low quality studies (case series, case reports, reviews).

Grading of recommendations provided in the present study was based on the system of Schünemann *et al*,[2] in which recommendations are classified as strong or weak. In addition to classifying the recommendation as strong or weak, specifica-

Table 1. Articles Providing Assessment of Classification Systems for Traumatic Thoracolumbar Spine Injuries

Authors	Classification System				Reproducibility	Utility-Treatment	Utility-Prognosis	Study Type	Level/Quality Evidence*
	Denis[5]	AO[3]	Load-Sharing[6]	TLICS[7]					
Bono *et al*[8]				x	x	x	x	Review	Level III/very low
Dai and Jin[9]			x		x			Original	Level II/low
Harrop *et al*[10]				x	x	x	x	Original	Level III/very low
Lee *et al*[11]				x	x	x	x	Review	Level V/very low
Oner *et al*[12]	x	x			x			Original	Level III/low
Oner *et al*[13]		x			x		x	Original	Level III/low
Panjabi *et al*[14]	x						x	Original	Level II/moderate
Patel *et al*[15]				x	x	x		Original	Level II/moderate
Raja Rampersaud *et al*[16]				x	x	x		Original	Level III/very low
Ratliff *et al*[17]				x	x	x		Original	Level III/very low
Rihn *et al*[18]				x	x	x	x	Review	Level V/very low
Schweitzer *et al*[19]				x	x			Original	Level IV/very low
Vaccaro *et al*[20]				x	x	x	x	Original	Level IV/very low
Vaccaro *et al*[21]				x	x	x	x	Original	Level V/very low
Vaccaro *et al*[22]				x	x	x	x	Original	Level III/low
Wang *et al*[23]			x			x		Original	Level II/moderate
Whang *et al*[24]				x	x	x	x	Original	Level III/low
Willén *et al*[25]	x					x	x	Original	Level III/low
Wood *et al*[26]	x	x			x			Original	Level II/moderate

*Level of evidence (I–V) is based on criteria of Wright *et al*[1] and quality of evidence (high, moderate, low, very low) is based on criteria of Schünemann *et al.*[2]
TLICS indicates Thoracolumbar Injury Classification System; AO, Arbeitsgemeinschaft für Osteosynthesefragen.

tion is made as to whether it is made based on high-, moderate-, low-, or very low quality evidence.[2]

For the first question, which focused on the usefulness of classification systems for TL spine injuries, the literature was searched from 1990 through June of 2009, with search terms including "thoracic," "lumbar," "thoracolumbar," "trauma," and "classification." Articles on the subject of classification of traumatic fractures or injuries of the thoracic and lumbar spine, defined as from the first thoracic to the fifth lumbar vertebra, were included. Articles on pathologic fractures caused by primary or metastatic tumors or osteoporotic fractures caused by physiologic forces without any apparent traumatic event were excluded.

For the second question, which addressed the optimal surgical treatment for TL burst fracture with incomplete neurologic deficit, the literature was searched from 1975 through June of 2009. Search terms included "thoracolumbar fracture," "thoracolumbar burst fracture," "incomplete neurologic deficit," "surgery for thoracolumbar burst fractures," and "surgery for incomplete neurologic deficits." The fracture was to be acute and traumatic, and treatment was to be within 6 weeks of injury. In this study, adults aged 18 to 70 years were included. The fracture was to be a burst fracture (T10–L2) with or without posterior ligamentous injury (Arbeitsgemeinschaft für Osteosynthesefragen [AO] types[3]: A3 and B). The neurologic deficit was to be incomplete (*e.g.*, Frankel grades[4]: B, C, or D). Specific exclusion criteria included the following: articles in which the specific neurologic deficit was not described, fractures due to senile osteoporosis, biomechanical reports, studies that did not specify spinal level of fractures, studies that did not specify whether a decompression was performed, studies of multiple surgical approaches that did not link directly to the neurologic deficit, reports of nonoperative treatment, reports of patients less than 18 years of age, radiology-only studies, reports of series of less than 10 individuals, studies of only patients without neurologic deficit, and studies in which surgical treatment was initiated later than 6 weeks following injury. In addition, articles that focused on patients with complete spinal cord or no spinal cord injury were excluded, and studies in which the neurologic status was not described as that by Frankel *et al*[4] were excluded. A total of 1078 were identified and reviewed. Based on inclusion and exclusion criteria, 104 articles were reviewed in detail to determine their appropriateness and subsequently narrowed to 34 articles for further study.

With regard to the third question, a systematic review was performed to assess whether complete disruption of the PLC is an indication for surgical intervention based on literature from 1975 through June of 2009. The search terms "posterior," "ligament," "ligamentous," "complex," "injury," "fracture," lumbar, and thoracic were searched individually and in combination. A total of 497 abstracts were identified and reviewed. A total of 67 articles were reviewed in detail to assess whether they were germane in answering the research question. The analysis included a determination of (1) If magnetic resonance imaging (MRI) accurately and reproducibly assesses disruption of the PLC and (2) If complete disruption of the PLC is a strong indication for surgical intervention.

The results of the literature review for each of the primary research questions, including evidentiary tables and preliminary conclusions, were subjected to a consensus-based decision-making process using a modified Delphi approach.

■ Results and Discussion

Question 1: What Is the Most Useful Classification System for Surgical and Nonsurgical Decision-Making With Regard to TL Spine Injuries?

Many classification systems have been proposed and used since the first scheme by Böhler, but only recently some of these schemes were assessed critically and systematically. Results of the literature search on the issue of classification systems are summarized in Table 1. We have identified 4 TL injury classification schemes widely

used and reported during the last 2 decades: Denis Classification,[5] AO (Comprehensive) Classification,[3] Load-sharing Classification,[6] and Thoracolumbar Injury Classification and Severity Score (TLICS).[7]

Although classification systems have been used implicitly to aid surgeons in deciding the best treatment option for individual patients, many of these schemes have not been specifically designed for this purpose. A clinically relevant classification system should not only take into account the natural history of an injury pattern but should also predict outcome in a variety of treatment alternatives. Ideally, such a system should provide a universal language to describe all spinal injuries and should guide clinical decision-making. This system must be easy to remember and use in clinical practice and should provide a platform for prospective research on spinal injuries. The system must be able to stratify injury severity and suggest the prognosis of a given injury. Furthermore, a classification system must be reasonably reliable, *i.e.*, have an acceptable inter- and intraobserver reproducibility. In short, a clinically useful classification system should have good reproducibility, reliable estimation of prognosis, and suggestion of a treatment modality.

Classification systems have commonly been used in traumatology, but their validity has been only recently questioned. Audige *et al* suggested a 3-phase process by which a classification system should be validated.[27] The first development phase involves clinical experts developing proposals for the classification system, as well as defining the classification process (*e.g.*, clinical information, imaging methods, measurement aids, training of surgeons, *etc.*). This phase defines a common language with which surgeons should be able to see and describe injuries similarly. Successive pilot agreement studies are conducted to ensure that clinical experts can accomplish this. At this stage, the predictive clinical value of any proposed system is at best suspected by expert opinion, and its quantification would remain speculative.

The second phase involves a multicenter study to ensure that future users with less clinical experience can also apply the classification system. This creates the basis for a classification tool to be used for documentation and evaluation of treatment options. After these first 2 phases have been completed, the classification system can be implemented for prospective clinical study.

None of the earlier schemes (Denis, AO, load-sharing) have been developed by a process similar to this methodology. The Denis and AO schemes have been assessed years after their introduction and widespread adoption and have been found to have poor to moderate reproducibility.[12–14,25,26] Furthermore, they were criticized for the lack of clear treatment suggestions and prognostic utility with which these systems could be verified based on real-world clinical results. These schemes represented simply radiologic pattern-recognition processes without a clear prognostic or therapeutic utility. Poor to moderate reproducibility of these schemes may be related to their lack of therapeutic utility. The load-sharing classification, on the other hand, has been proposed with a primarily therapeutic utility as a predictor of failure of posterior short-segment fixation.[6] Although not extensively studied, 2 articles on the load-sharing classification show a much better reproducibility than the Denis or AO schemes.[9,23] This is an interesting finding as the load-sharing classification is basically also a simple pattern-recognition on diagnostic imaging and should be expected to have similar poor to moderate reproducibility. This might imply that surgeons may be better in agreement if the result of the pattern recognition suggests one or another therapeutic approach. Although this aspect has not been studied properly, it is possible that psychologically surgeons are better in recognizing certain patterns if this recognition results in a real choice of treatment for a real patient.

It is generally accepted that perfect reproducibility is likely not achievable for a classification system for traumatic injuries. However, there is no consensus on what should be considered an acceptable level of reproducibility for complex patterns observed in spinal trauma.[12,27]

TLICS[7] is a recently developed system, which has been designed based on criticisms of previous classification systems by an international panel of experts (Spine Trauma Study Group) following a process similar to what was proposed by Audige *et al*[27] This scheme defines a spinal injury severity score (ISS) and bases the classification on this score. This injury score is based on evaluation of following 3 separate components of injury: mechanism or morphology, integrity of the PLC, and neurologic involvement.

Several validation studies have been conducted, mainly by groups affiliated with the Spine Trauma Study Group.[7,8,10,11,15–18,21,22,24,28] According to Bono, phases 1 and 2 of Audige's 3-phase process have been essentially completed with these studies.[8] One important aspect of the TLICS system is that it is not only a classification system, but a numerical TLISS can also be calculated from the separate components. On the basis of this score, a treatment suggestion can be formulated.

An interesting result from these validation studies is the distinction between injury morphology *versus* injury mechanism, which may reflect psychological processes involved in clinical decision-making. Many of the classification systems in the past have been designed "mechanistically," meaning that a mechanism of injury (such as compression, distraction, *etc.*) was inferred from the observed images. Arguing that many different mechanisms can lead to similar injury patterns and that this retrospective inference of mechanism from images may lead to systematic errors, the group that developed TLICS decided not to use mechanism but morphology as a category.[10] The reasoning was that a description of the injury (morphology) without any reference to mechanism leading to this injury would be more reliable. However, a separately designed study on this subject showed that the participating surgeons had better agreement if they used the mechanism instead of morphology.[24] This might in-

Table 2. Articles Providing Assessment of Surgical Approach and Stabilization Technique for Traumatic Thoracolumbar Burst Fractures With Incomplete Neurological Deficit

Authors	Follow-up	Study Design	Treatment	Results	Radiology	Level/Quality Evidence*
Schnee and Ansell[30]	Not reported	Retrospective study of 25 pts	14 pts treated anteriorly; 9 treated combined anterior and posterior	3 of 4 Frankel B improved to C; all 7 Frankel C improved to D; 4 of 8 Frankel 3 improved to E	All fused; preoperative kyphosis of 17° corrected to 3°	Level IV/very low
Starr and Hanley[31]	12–91 mo	Retrospective study of 22 pts, 12 with incomplete deficits	Posterior spine fusion and instrumentation without decompression	11 of 12 improved 1.8 Frankel grades average	Preoperative kyphosis of 16° corrected to 4°	Level IV/very low
Kaneda *et al*[32]	2 yr 2 mo–4 yr 10 mo	Retrospective review of 20 pts	Anterior decompression with fusion and instrumentation	1 Frankel C improved to D; 14 D to E	19/20 fused; kyphosis correction 26°–12°–14°	Level IV/very low
Carl *et al*[33]	24–84 mo	Retrospective chart review of 36 pts, 26 with incomplete lesions	Anterior corpectomy and fusion and instrumentation	All 26 improved one Frankel grade	All fused. kyphosis corrected from 32° to 11° to 15°	Level IV/very low
Dai *et al*[34]	4–7 yr	Prospective randomized study of 65 pts, 12 pts with incomplete lesions in allograft group; 11 pts in cage group	Anterior decompression and either structural allograft (32) or titanium mesh cage (33)	No difference in neurological improvement	No difference in correction: 23°–3°	Level II/low
Yuan *et al*[35]	12–24 mo	Retrospective review of 16 pts; 9 burst fractures, 7 incomplete lesions	Anterior decompression fusion and instrumentation	All conus lesions normalized; all root injuries improved	Kyphosis corrected from 11.5° to 2°	Level IV/very low
Gertzbein *et al*[36]	1–4 yr	Retrospective review of 33 incomplete lesions	Treatment with either anterior decompression with or without anterior or posterior instrumentation *vs.* posterior instrumentation alone (no decompression)	No difference in Frankel grade improvement: 88% of anterior improved one or more grades; 83% of posterior improved one or more grades	Kyphosis not reported. Postoperative canal compression 6% in anterior group; 26% posterior group ($P < 0.01$)	Level III/very low
Gertzbein *et al*[37]	12–56 mo	Retrospective review of 14 pts, with incomplete lesions of T11–L2	Anterior decompression and fusion and posterior instrumentation	81% of incomplete pts improved at least one Frankel grade	Kyphosis from 21.8° to 17°	Level IV/very low
Garfin *et al*[38]	6–24 mo	Retrospective review of 8 pts all with incomplete neurology	Posterior decompression and Harrington rod instrumentation and fusion	Average improvement 1 Frankel grade. 2 B improved to D; 1 D remained D	Kyphosis not reported. All fused	Level IV/very low
Hardaker *et al*[39]	25–70 mo	Retrospective review of 58 pts, All with fractures T10–L2; 40 with incomplete lesions	Posterolateral transpedicular decompression, fusion and Harrington instrumentation	85% improved one or more grades: 3 B's to C 1 to D. 7 from C to D, 2 to E. 21 from D to E	Kyphosis not reported. All fused	Level IV/very low
Doerr *et al*[40]	Not reported	Retrospective chart review of 30 pts treated with posterior decompression and instrumentation	Posterior distraction rods (12 patients–5 with incomplete lesions) *vs.* AO Fixateur Interne transpedicular implants (13–4 incomplete)	Posterior distraction group: 2 A's to B. 3 no change. AO group: 2 D improved to E	No difference in amount of bone removed or canal clearance. Kyphosis not reported	Level III/low
Benson *et al*[41]	12–38 mo	Retrospective review of 21 pts, 9 with TL burst fractures and incomplete deficits.	Posterior spine fusion, instrumentation. No decompression	7/8 Frankel D improved to E. None deteriorated. One C improved to D with ant. decompression	Kyphosis corrected from 16° to −4° to 5°	Level IV/very low
Stambough *et al*[42]	Mean of 48.3 mo	Retrospective review of 55 pts; 12 with incomplete injuries of TL junction	12 with incomplete injuries treated with anterior and posterior surgery	10 of 12 improved 1.5 Frankel grades	17°corrected to 9° and 10.5° at follow-up	Level IV/very low

(*Continued*)

Table 2. Continued

Authors	Follow-up	Study Design	Treatment	Results	Radiology	Level/Quality Evidence*
Stancic *et al*[43]	9 mo–2 yr 9 mo	Prospective trial of pts with incomplete neurological injuries T12–L2	anterior decompression and fusion (13) *vs.* posterior reduction and pedicle screw fixation with or without laminectomy (12)	Neuro improvement similar: 1.5 average (1–2) Frankel improvement with anterior group; 1.57 average improvement with posterior (1–3)	Hospital cost, OR time, blood loss and hospital stay all statistically longer with anterior surgery	Level II/low
Butt *et al*[44]	49–68 mo	Retrospective review of 50 patients; 10 unstable burst fractures with incomplete neurological injuries	Posterior spine fusions with instrumentation	Average 1.5 Frankel grade improvement; all improved	Kyphosis correction from 23° to 16° to 18° at follow-up	Level IV/very low
Sasso *et al*[45]		Retrospective study of 53 pts	Posterior group treated with pedicle screw fixation and fusion; anterior with decompression and instrumented fusion	4 of 5 treated posteriorly improved 1–3 Frankel grades; 91% of anterior group improved 1–3 grades	Posterior only group lost 8° *vs.* 1.8° for anterior group all fused.	Level III/very low
Danisa *et al*[46]	Mean = 27 mo	Retrospective study of 49 pts treated surgically for TL burst fractures; 22 with incomplete neurologic injuries	3 groups: A (8): anterior decompression and fusion with instrumentation, B (11) posterior decompression and fusion; and C (3) Combined anterior-posterior surgery	Anterior group: 3 of 8 improved 1 Frankel grade; posterior group 8 pts improved 1 grade and 2 improved 2 grades; Combined group: 2 of 3 improved 1 grade	Posterior group much less OR time, blood loss, and units transfused; and less length of stay. Complication rate similar. Kyphosis correction not statistically different	Level III/very low
Liu *et al*[47]	Mean = 24.7 mo	Retrospective study of 20 pts; 9 with incomplete neurology and TL burst fractures	Posterior spine decompression and instrumented fusion	Average Frankel improvement of 0.77 grades. (0–2) 1 B improved to D; 1 C improved to E	Kyphosis corrected from 16° to 4° to 4.8° at follow-up	Level IV/very low
Kaya and Aydin[48]	2–4 yr	Retrospective review of 28 pts, 23 with burst fractures at the TL junction	Drilling the pedicle to remove retropulsed bone without damaging the posterior column. Stabilized with pedicle screws	10 improved 1 Frankel grade; 8 two grades, 4 three grades	Kyphosis corrected from 18° to 8° and 12° at final follow-up. 20% pseudarthrosis rate	Level IV/very low
Bradford and McBride[49]	Mean = 3.7 yr	59 pts reviewed retrospectively; 24 with burst fractures at the TL junction	Anterior spinal decompression (20) *vs.* posterior or lateral decompression (39)	No significant difference in recovery	30% of original enrollees refused to participate or could not be contacted; 1 nonunion	Level III/very low
Wang *et al*[50]	24–71 mo	Prospective review fusion *vs.* non-fusion group; 16 with incomplete lesions of TL junction	Postural and instrumentation reduction	Non-fusion: All improved average 1 grade. Fusion group: All improved average 1.1 grades	Kyphosis corrected from 16 to 2 to 11 at follow-up	Level IV/very low
Hitchon *et al*[51]	6 mo–8 yr	Retrospective cohort study of 63 individuals with TL junction fractures	Group A: anterior corpectomy and instrumentation Group B: posterior decompression or disimpacting plus instrumentation	No significant difference in Frankel grade improvement	Anterior group kyphosis correction from 12° to 2° to 4.5°; posterior group from 4° to 3.4° to 9.3°	Level III/low
Marco and Kushwaha[52]		Retrospective review of 28 pts, 25 from T10 to L2. 13 with incomplete motor deficits	Posterior stabilization and fusion and anterior vertebroplasty	Frankel grade improved by 1 or more grades in all 13 pts	Kyphosis improved from 17° to 7° at final follow-up 25% treatment related complications	Level IV/very low
Cho *et al*[53]	2.1–2.5 yr	Retrospective comparative study of 70 pts treated with (A) and without (B) vertebroplasty with fractures T12–L3	Posterior pedicle screw fixation and fusion with or without laminectomy	No difference in Frankel improvement; group A improved 1.2 Frankel grades, group B 0.8	Kyphosis correction loss much less in those treated with vertebroplasty (P = 0.0001) 22% instrumentation failure in group B	Level III/low

(*Continued*)

Table 2. Continued

Authors	Follow-up	Study Design	Treatment	Results	Radiology	Level/Quality Evidence*
Herndon and Galloway[54]	6–84 mo	Retrospective study of 24 pts with incomplete injuries and burst fractures T10–L2	Posterior fusion with Harrington rods and no specific decompression	Average Frankel grade improvement of 1.4 grades	Canal recovery to 79% of normal	Level IV/very low
Blondel *et al*[55]	3–29 mo	Retrospective study of 12 patients; with burst fractures and incomplete neurologic lesions T11–L2 (9 Frankel D, 3 Frankel C)	Posterior spine fusion and instrumentation and vertebroplasty	All improved; average 1.1 Frankel grades	Kyphosis corrected from 17° to 5° at follow-up	Level IV/very low
Toyone *et al*[56]	24–42 mo	Prospective consecutive series of 15 pts, with burst fractures T12–L3 and incomplete neurological deficits	Indirect reduction and posterior pedicle screw fixation without fusion plus vertebroplasty	All improved by at least 1 ASIA grade average 1.2 grades	Kyphosis improved from 20° to −1° to +1° at follow-up	Level IV/very low
Sasani and Ozer[57]	12–48 mo	Prospective Study of 14 pts; 6 with thoracolumbar level fractures and incomplete neurological injuries	Anterior corpectomy and cage placement and posterior instrumentation and fusion	Average improvement 0.8 Frankel grades	Kyphosis corrected from 24° to 18°	Level IV/very low

*Level of evidence (I-V) is based on criteria of Wright *et al*[1] and quality of evidence (high, moderate, low, very low) is based on criteria of Schünemann *et al*[2]
pts indicates patients; TL, thoracolumbar; AO, Arbeitsgemeinschaft für Osteosynthesefragen.

dicate that the human mind may unconsciously create a "story" of how something happened from the available clues. This might be consistent with modern psychological research on the issue of free classification[29] and warrants further investigation.

Summary. Fracture classification systems should aim to guide the therapeutic decision-making in spinal trauma. Surgeons likely show better agreement in their evaluations if the choice of a category has concrete consequences for treatment.

Reproducibility of classification systems remains a problematic issue. It is probably not realistic to expect very high reproducibility in the complex patterns created by the complex interactions of external violence with the bodies of individual patients.

Whether or not included in the scheme, surgeons probably infer a mechanism of injury from available imaging studies. This psychological phenomenon warrants further study.

Recommendation: TLICS seems to be the best system available for therapeutic decision-making for TL spine injuries. However, prospective studies are needed to decide whether this scheme leads to better agreement among surgeons around the world and better clinical results for trauma victims (strength of recommendation: weak; quality of evidence: low).

Question 2: For a TL Burst Fracture With Incomplete Neurologic Deficit, What is the Optimal Surgical Approach and Stabilization Technique?

Although surgical intervention in cases of incomplete neurologic involvement is generally recommended, there is no consensus on the best surgical approach in TL trauma.[21] One area of particular controversy is the commonly encountered case of a patient with a TL junction burst fracture and an incomplete neurologic deficit. We performed a systematic review of the literature to understand whether a surgical approach and stabilization technique should be preferred in this setting.

The results of the search are presented in Table 2. Surgical approaches were grouped into anterior decompression and fusion, posterior decompression and fusion, posterior fusion without decompression, combined anterior decompression and posterior stabilization, and posterior decompression and stabilization with cement injection into the fractured vertebral body.

There are many different surgical techniques described in the literature when treating incomplete burst fractures of the TL junction. Anterior approaches with vertebral corpectomy and decompression, posterolateral decompressions and fusions, costotransversectomies, posterior laminectomy with instrumented fusions have all been described with similar degrees of reported success. We chose to analyze the neurologic improvement as the primary outcome following treatment, with secondary outcomes being kyphosis correction and complications.

We were unable to identify a superior surgical approach or technique with regard to neurologic recovery. When comparisons between 2 techniques were made, there were no significant differences, and when case series were described, the Frankel improvement averaged between 0.8 and 1.5 grades, with the majority reporting an average of 1 Frankel grade improvement, without any significant difference among the surgical approaches. Pa-

Table 3. Articles Providing Assessment of the Posterior Ligamentous Complex in the Setting of Thoracolumbar Burst Fractures

Authors	Follow-up	Study Design	Treatment	Impact on Decision	Results	Radiology	Level/Quality Evidence*
Oner *et al*[13]	Not reported	Retrospective. 70 pts with 100 TL fractures of	Surgical and nonoperative. 33 pts treated operatively (posterior approach)	No definite pattern between injuries of PLC structures and AO classification	Wide variations in state of PLC structures	Complete rupture of PLL seen in 10 fractures, which was combined with complete rupture of the PLC in 8	Level III/very low
Brightman, *et al*[60]	Not reported	Retrospective 24 pts	Surgical and nonoperative	PLL disrupted in all paraplegic pts. Surgery generally performed if PLL disruption	PLL disrupted in 8 of 12 thoracic, 5 of 6 TL, 1 of 6 lumbar fractures	PLL evaluated on T-2 or proton density-weighted MRI	Level IV/very low
Petersilge *et al*[61]	18 of 21 (86%) pts with follow-up	Retrospective. 21 pts with 25 TL burst fractures	Surgical and nonoperative	6 pts with SSL disruption, 4 were treated with posterior stabilization and 2 were not	Based on MRI: 15 pts (71%) had normal posterior ligaments and 6 (28%) SSL disruption	T2-weighted MRI demonstrates high signal intensity in interspinous ligaments at level of burst fracture	Level III/very low
Emery *et al*[62]	Not reported	Retrospective 37 pts (31 with thoracic or lumbar fractures)	Surgical and nonoperative	None listed	MRI detected ligamentous injury in 17 of 19 cases. MRI sensitivity 90% and specificity 100%	MRI findings: discontinuity of SSL and high signal between spinous processes	Level III/very low
Lee *et al*[63]	Not reported	Comparison of MRI and operative findings	Surgical	All patients had surgery	MRI evaluation of SSL had 92.9% sensitivity, 80% specificity, and 90.9% accuracy	T2-weighted MRI was a highly sensitive, specific, and accurate for evaluating PLC	Level II/ moderate
Haba *et al*[64]	Not reported	Retrospective. 3 radiologists independently evaluated. 35 pts	Surgical. All pts underwent posterior surgery	25 (71.4%) pts sustained a fracture of the posterior elements of the injured vertebrae. In 23 patients (65.7%), both the SSL and ISL were disrupted	For SSL injury on MRI, sensitivity = 89.4%, specificity = 92.3%, diagnostic accuracy = 90.5%.	The injury of PLC was diagnosed on sagittal T1- or T2-weighted MRI	Level III/very low
Dai *et al*[65]	Not reported	Retrospective. 61 pts	Surgical and nonoperative	When the results were compared between patients with and without ligamentous injuries, no significant differences regarding fracture severity or neurologic function	ISL, SSL, and PLL injuries were diagnosed by consensus in 32, 34, and 32 of the 61 pts, respectively	Overall inter-observer agreement, based on kappa coefficient ranged from 0.441 to 0.738 for PLC injuries	Level III/very low
Alanay *et al*[66]	31 (range, 24–51) mo	Prospective. Consecutive. 15 pts	Nonoperative. An underarm thoracolumbosacral cast was applied in the reduced position to stabilize the fracture externally	Patients with burst fractures between T11 and L2, without neurologic compromise and without PLC injury, as determined by MRI. Indication for nonsurgical management based solely on the integrity of PLC	Final deformity was same or greater in 9 pts (60%), smaller in 6 (40%). 1 pt (7%) without pain, 10 (66%) with minimal pain, 3 (20%) with manageable moderate pain, and 1 pt (7%) with long-lasting moderate pain	PLC alone cannot prevent loss of correction provided by closed reduction; however, the residual deformity is not bigger than the original, and patient satisfaction is high	Level II/ moderate

(*Continued*)

Table 3. Continued

Authors	Follow-up	Study Design	Treatment	Impact on Decision	Results	Radiology	Level/Quality Evidence*
Vaccaro *et al*[67]	Not reported	Prospective diagnostic imaging study	Surgical. 42 pts with 62 levels of injury who Required surgical treatment	Integrity of the PLC based on MRI should not be used in isolation to determine treatment. The accuracy of MRI is most limited in pts with less severe injuries	Specificity was 53 to 65% for the various PLC components. Sensitivity in the range of 79.2% to 91.7	Sensitivity and specificity of MRI for diagnosing injury of PLC are lower than previously reported	Level II/ moderate

*Level of evidence (I-V) is based on criteria of Wright *et al*[1] and quality of evidence (high, moderate, low, very low) is based on criteria of Schünemann *et al.*[2] pts indicates patients; PLL, posterior longitudinal ligament; TL, thoracolumbar; MRI, magnetic resonance imaging; SSL, supraspinous ligament; PLC, posterior ligamentous complex; ISL, interspinous ligament; LF, ligamentum flavum.

tients with Frankel B tended to improve to C or D, occasionally to E; Frankel C's improved to D and E, and most D's improved to E as well, again without clear differences among the operative techniques.

Fractures treated with an anterior corpectomy and strut support fusion, with instrumentation either anteriorly or posteriorly, tended to retain kyphosis correction better than those treated with posterior instrumentation alone. However, the reported differences were small.

Complication rates among the various approaches were also similar, although they tended to be related to the incision (*e.g.*, anterior approaches with post-thoracotomy pain, effusions, *etc.*, and posterior incisions with a higher infection rate and instrumentation prominence, *etc.*).

These results are consistent with an earlier review of surgical treatment of thoracic and lumbar spine fractures by Verlaan *et al*.[58] There is no evidence for the choice of one or another surgical approach for the sake of better neurologic recovery. In the most recent published results of the German Trauma Association's prospective database, there was also no correlation between the neurologic recovery and the surgical approach.[59]

Summary. Although combined anterior/posterior approaches seem better able to retain kyphosis correction, it is not clear if this difference is clinically relevant.

Factors, such as the burden to the patient, morbidity, complication rates, costs, and disutility should be taken into account in the choice of surgical approach.

Recommendation: There is no specific surgical approach in the case of a TL burst fracture with incomplete neurologic deficit that has any advantage as far as neurologic recovery is concerned (strength of recommendation: weak; quality of evidence: low).

Question 3: Is Complete Disruption of the PLC an Indication for Surgical Intervention for TL Burst Fractures?

The PLC, consisting of the supraspinous ligament, interspinous ligament, ligamentum flavum, and the facet joint capsules is thought to contribute significantly to the stability of TL spine. Traditionally, TL injury classifications focused on fracture mechanism and/or morphology, and the integrity of the PLC was not directly assessed.[6,9,14,24,25] More recently, an increased recognition of the importance of the PLC in stability of the spine and the impact of disruption on treatment decision-making has occurred.

The results of the search are presented in Table 3. A number of studies have compared MRI with intraoperative direct observation of PLC disruption.[60–65] These studies have generally demonstrated a very high sensitivity and specificity of MRI with regard to identifying PLC injury. However, a more recent study has called into question the ability to accurately discriminate PLC injury in patients with less severe injuries.[67] Most of these studies have used surgical evaluation as the control and most indicated that PLC disruption was a factor in decision-making for performing the surgical intervention.[60–62,64,67,68] The information provided regarding the results of nonoperative treatment of PLC injury is limited and the results mixed.[61] Conversely, a prospective study by Alanay *et al* demonstrated that the presence of PLC integrity might not necessarily prevent loss of correction gained by nonsurgical management (casting) of burst fractures.[66]

Several articles have discussed the importance of the PLC complex as a component decision-making process for surgical intervention.[24,28,67] Both the TLISS and TLICS assess the integrity of the PLC as a principle factor in determining the need for surgical intervention.[20,28] Studies have demonstrated the TLISS and TLICS algorithms both exhibit excellent overall reproducibility and validity.[24,28,67] Despite increasing use of these classifications as treatment algorithms, no prospective or retrospective data are available to assess impact on treatment. A recent prospective study comparing preoperative MRI assessment and intraoperative findings found discrepancies between MRI and operative findings and recommended that the integrity of the PLC as determined by MRI should not be used in isolation to determine treatment.[67] There are no other studies that specifically address whether complete disruption of the PLC is an indication for surgical intervention. An association between severity of injury by other morphologic criteria determined by either computed tomography (CT) or plain

radiographs and the likelihood of PLC disruption has been noted.[13,67]

Summary. There is evidence that PLC injury can be reliably detected by MRI.

MRI evaluation of the PLC moderately correlates with the intraoperative findings.

There is no evidence that MRI findings of PLC disruption contributes significantly to surgical decision-making beyond what is determined by morphologic criteria using plain radiographs and CT.

Recommendation: Complete disruption of the PLC, as determined collectively by morphologic criteria using plain radiographs and CT, is an indication for surgical intervention in TL burst fractures (strength of recommendation: strong; quality of evidence: low).

■ Key Points

- Recommendation: The Thoracolumbar Injury Classification System seems to be the best system available for therapeutic decision-making for thoracolumbar spine injuries. However, prospective studies are needed to decide whether this scheme leads to better agreement among surgeons around the world and better clinical results for trauma victims (strength of recommendation: weak; quality of evidence: low).
- Recommendation: There is no specific surgical approach in the case of a thoracolumbar burst fracture with incomplete neurologic deficit that has any advantage with regard to neurologic recovery (strength of recommendation: weak; quality of evidence: low).
- Recommendation: Complete disruption of the PLC as determined collectively by morphologic criteria based on imaging studies is an indication for surgical intervention in TL burst fractures (strength of recommendation: strong; quality of evidence: low).

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