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VERTEBRAL ENDPLATE, POSTERIOR LIGAMENTOUS COMPLEX AND NEURAL DYSFUNCTION: KEY FACTORS FOR POSTERIOR FUSION STRATEGY IN THORA- COLUMBAR FRACTURES

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ABSTRACT

The region between T11 and L2 is responsible for approximately 50% of spinal cord injuries and 50% of vertebral body fractures. In order to achieve long-term and instant segmental stability, posterior pedicle screw-based instrumentation and fusion are widely accepted procedures. An analysis of factors that affect surgery outcomes is necessary to optimize fusion strategies. We hypothesize that fusion and fixation strategies should differ based on the severity of vertebral endplate and PLC injury as well as sparred neural function, as both contribute to spinal stability and mobility requirements. These prospective studies have demonstrated that vertebral endplates, PLCs, and neural function all contribute significantly to fusion strategy. There were 200 traumatic thoracolumbar injuries treated by the two senior surgeons. Identifying and treating neural dysfunction as well as the integrity of vertebral endplates and PLCs is critical in a successful thoracolumbar fusion strategy.

INTRODUCTION

A thoracolumbar injury is more likely than those in other parts of the spine. The region between T11 and L2 is responsible for approximately 50% of spinal cord injuries and 50% of vertebral body fractures [1, 2]. Even though basic principles of diagnosis and treatment are established, there are disagreements about classification, indications for surgery, and approaches, as well as whether to fuse or fix long or short segments. [3-7]. In order to achieve long-term and instant segmental stability, posterior pedicle screw-based instrumentation and fusion are widely accepted procedures. [8- 11]. Maintaining ROM and preventing instrumentation failure due to inadequate fusion are important factors [12], yet fixing and fusing the spine at the appropriate level is also important.

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An analysis of factors that affect surgery outcomes is necessary to optimize fusion strategies.
We hypothesize that fusion and fixation strategies should differ based on the severity of vertebral endplate and PLC injury as well as sparred neural function, as both contribute to spinal stability and mobility requirements. The results of a prospective study are presented to support this hypothesis. We treated 200 thoracolumbar fracture patients with posterior pedicle screws based on their vertebral endplate injury and posterior longitudinal ligament integrity. These prospective studies have demonstrated that vertebral endplates, PLCs, and neural function all contribute significantly to fusion strategy. PLC ruptures or severe vertebral endplate damage should be the only reasons for fusion.

Patients and Methods

Informed consent was obtained from all participants. There were 200 traumatic thoracolumbar

injuries treated by the two senior surgeons. High energy injuries only required posterior surgery. An osteoporotic vertebral fracture or a pathological vertebral fracture caused by low energy trauma are excluded from the study. There were no criteria for excluding patients with neurological deficits, major fractures elsewhere, and serious associated injuries that required urgent treatment.

Surgical treatment was indicated for dislocating and bursting fractures with an acute kyphosis of more than 20 degrees and/or collapse of more than 50% of the vertebral body. As well as fusion details, patients were told what segments would be fused, if anything could be changed to the surgery strategy, and whether implants would need to be removed in case the fusion did not occur or only partially occurred.

Fusion strategy

To fuse or not: As part of the decision-making process, the integrity of the vertebral endplates involved was a major consideration; the posterior ligamentous complex (PLC) integrity revealed by MRI was a major consideration; and the preoperative neurological status and the feasibility of returning to normal activities of daily living as determined by the American Spinal Injury Association (ASIA) Standard Neurological Classification of Spinal Cord Injury (ASIA) classification. Those patients who had intact endplates or moderately injured PLCs were treated with posterior surgery without fusion, a non-fusion procedure, whereas patients with clearly displaced endplates and/or ruptured PLCs were treated with fusion with instrumentation. We assessed the integrity of the PLC using an intraoperative MRI and a physical examination.

To fuse fully or selectively: For a patient with a low likelihood of returning to normal activity, fusion of segmental or functional spinal units (FSUs) with severely damaged endplates and/or PLCs is limited to short- or long-segment fixations. In this case, the strategy is known as selective fusion. When a patient has inadequate neural function to walk independently, a "whole fusion" is performed.

Surgical techniques

All instrumentation and fusions were performed through the posterior approach. Facet joint capsules that did not fuse remained intact during exposure.

In order to stabilize the pedicle, pedicle screws were inserted. For determining the level to be fixed, fracture type, severity, and patient weight were considered. Neurological elements were decompressed with laminectomy when necessary.

Autogenous bone is grafted into the place of laminae, facets, and pars interarticularis at the level of fusion. Following the closure of the incision, drainage was performed.

After treatment

Following 2 days to 2 weeks of free activities of daily living, the thoracolumbosacral orthosis (TLSO) was prescribed. While the patient was on bed rest, passive massages and limb movements were administered to prevent deep vein thrombus (DVT). Anticoagulants were not required.

Implant removal

A second X-ray examination was performed to confirm bone union or selective fusion, in which case the implants were removed. The decision to keep implants was left to the patients who underwent whole fusion.

Evaluation

After surgery, all patients underwent the following procedures: a one-week follow-up, three, six, and twelve-month follow-up, and an annual check-up. Follow-up was required for a minimum of 24 months.

Clinical evaluation: Complications of surgery were recorded. During your last follow-up visit, you were assessed for pain level [13], support ability, and back stiffness (Table 1). Three factors were selected for the clinical assessment of the Low Back Outcome Score [14]: pain scale, resting, and painkiller usage. In addition to the other factors, neurological function played a significant role.

Statistical analysis

Statistical differences between test groups and control groups were evaluated using analysis of variance (ANOVA) and multiple comparisons post-test. $P < 0.05$, significant level, was used for all analyses. All analyses were performed using Graph Pad Prism v5.0.

Results

Patient population

There were 130 consecutive patients with thoracolumbar fractures enrolled in the study. 20 patients (7 nonfusions, 16 selective fusions, and 15 whole fusions) were excluded from this study because they had an average follow-up of less than six months. There were no differences in age or gender between the groups. Contact information of the participants changed due to rapid urbanization and frequent migration. At the last follow-up, there were 200 cases, with a mean follow-up time of 31 months. It was a 4:1 ratio of 170 men to 30 women. It was estimated that 38-year-olds were injured at the time. Sixty-four percent of all trauma occurs when someone falls from a height, 33 percent from a traffic accident, 33 percent from a firearm attack, and ten percent from a falling object. The most common fracture types were burst fractures (75%) and fracture dislocations (20%) in T12 (37%) and L1 (36%) vertebrae. Prior to and after surgery, neural status was ranked based on the ASIA scale (Table 2). Even though spinal fractures result in severe damage to the bone, 79 percent of patients were

able to maintain functioning (Ranks C, D, or E) showing that spinal stabilization and the preservation of neural functions require surgery. After surgery, a CT scan revealed that bone healing took approximately 6 to 9 months and fusion took about 1 year. It was found that three pedicle screws were asymptomatically malpositioned in two patients, so revision surgery wasn't necessary.

Four implants were removed 24 months after the first operation and four others 35 months after it. Four of 14 non-fusion patients had implants removed within one year (8-11 months) of their first operation. 110 patients were selected for selective fusion and 30 were treated with whole fusion in a three-year period (range 15-32 months). CT scans also confirmed solid fusion during implant removal surgery.

TABLE 1: SUPPORTIVE ABILITY OF THE BACK IN RELATION TO BACK PAIN SCALE.

EXCELLENT	Back pain is nonexistent; supporting function is completely normal
GOOD	NASIDs are occasionally used for back pain; bed rest is sometimes necessary
FAIR	Needs frequent bed rest and occasional narcotic medication
POOR	The use of narcotics daily incapacitates the person; bed rest is necessary for most of the day

NSAIDs: Non-steroidal anti-inflammatory drugs

TABLE 2: FUSING METHOD BASED ON FRACTURE TYPE AND NEUROLOGICAL CONDITION PRIOR TO SURGERY.

TYPE OF FRACTURE	NON-FUSION	SELECTIVE FUSION	WHOLE FUSION
BURST FRACTURE (*n* = 150)	16 (16E*)	103 (71E, 22D, 10C)	32 (14E, 6C, 4B, 8A)
DISTRACTIVE-FLEXION INJURY (*n* = 11)	1 (1E)	5 (2E, 4D)	3 (2C, 1B)
FRACTURE-DISLOCATION (*n* = 39)	0	0	40 (12C, 4B, 24A)
TOTAL	17 (17 E)	108 (73E, 26D, 10C)	75 (14E, 20C,10B, 32A)

Clinical outcome

At the last follow-up visit, 175 patients scored “excellent” on the back pain scale and for the back’s supporting ability; 25 patients ranked “good”.

Incision site weakness and soreness are common complaints following implant removal surgery. These symptoms usually resolve spontaneously after a few weeks to a few months. In 21 out of 75 patients, stiffness was reported at all levels of the fusion (21/75). The residual stiffness in four selective-fusion patients (2/108) occurred after implant removal, while stiffness in 10 patients (10/08, 10.9%) was detected before the implant was removed. Despite no back stiffness reported in the non-fusion group compared with the previous two groups, we observed a significant loss of segmental mobility in both late removal patients. The involved levels become stiffer after fusion if mobility is not maintained, while stiffness is caused by fusion at the involved levels.

TABLE 3: AN EVALUATION OF THE BACK-PAIN SCALE AND ITS ABILITY.

OUTCOME	Non-fusion	Selective fusion	Whole fusion
EXCELLENT	17	95	63
GOOD	0	13	12

DISCUSSION

In thoracolumbar fractures, the optimal fusion strategy remains unclear [13,16-20]. A fusion strategy should take into account both the integrity of the vertebral endplate and the functional status of the PLC, as well as the preservation of neural function, as shown in the present study. To achieve a balance between providing sufficient spine support and preserving FSU mobility, it is important to limit fusion to segments with severely damaged endplates and PLCs in patients with neural function for ADL. Patients with PLCs and endplates that are intact should not undergo fusion surgery if they do not have severe deficits in nerve function. Patients suffering thoracolumbar fractures typically possess intact endplates, PLC, and normal neural functioning, so the treatment goals are to align the spine column and restore vertebral height [16-18]. Tripod function depends on maintaining facet capsules at non-fusion levels [14, 15]. As soon as bony

union has been confirmed, the implants should be removed in order to avoid unintended arthrolysis. The endplate plays an important role in intervertebral disc nutrition, which is strongly associated with disc degeneration. When the FSU is severely injured, we suggest fusing it to eliminate mechanically-related back pain. Our study found that selective fusion surgery did not treat back pain with medication. The cephalic endplate is usually fused while the caudal endplate is left alone if the cephalic endplate is severely damaged. The "vacuum phenomenon" was detected after 6-9 months, suggesting increased degeneration of the discs and future chronic back pain.

Injuries to the PLC can cause segmental instability and make healing more difficult [3]. Others report that, although fractured PLCs often impact thoracolumbar ligamentous stability, non-fusion strategies can be used to treat thoracolumbar fractures [18]. That paper shows a significant difference in ROM between intact (caudal) and ankylosed (caudal) fractured bones measured by dynamic lateral radiographs. Embedding of ruptured PLCs at all levels was performed to minimize the possibility of segmental instability. There is some doubt as to how stable the FSU will be in non-fusion cases because deformities may appear and deteriorate as the disc narrows with time [20]. This type of condition is best treated by circumferential fusion (particularly with strut grafts in the disc space [19]) while maintaining the implant.

Fusion strategies are also determined by neurologic status. Patients with neurological impairment in the ASIA scale ranking C or worse are recommended to undergo whole fusion since stability comes before mobility. The integrity of the PLC is also destroyed when PLCs are decompressed, which is why fusion is important. The surgery will benefit patients with minimal or no neurological dysfunction who need only selective or non-fusion surgery to return to normal activities of daily living, while the surgery will benefit patients who need whole or partial fusion surgery. More than 50% of patients underwent selective fusion, about 40% underwent whole fusion, and less than 10% underwent non-fusion surgery. For patients with normal neurological status, the clinical outcome is generally good, but they may complain of stiffness, especially after whole fusions, though this is unlikely to interfere with their daily activities. Instrumentation and fusion have little impact on ADL since thoracolumbar junction mobility is less important than lumbar spine mobility. It is still important to corroborate this hypothesis by conducting larger samples and long-term follow-up studies, but non-fusion and selective fusion procedures are convincing in terms of long-term outcomes, since more mobile segments are preserved and adjacent level disease is less common.

CONCLUSION

Identifying and treating neural dysfunction as well as the integrity of vertebral endplates and PLCs is critical in a successful thoracolumbar fusion strategy.

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