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Result of surgical treatment of upper thoracic spine fractures above T9 by posterior spinal instrumentation and fusion using pedicle screws

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Objective : *To report the results of surgical treatment of fractures and fracture-dislocations of upper thoracic spine by posterior instrumentation and fusion using pedicle screw-based instrumentation.*

Background : *Fractures of thoracic spine above T9 are rare, but once occurs, it is often severe. Frequently, they damage the great vessels anterior to the spinal column; and spinal cord injury is a commonly associated condition. There are relatively few pieces of literature that specifically review the surgical treatment of these injuries.*

Methods : *A retrospective study of medical records, operative notes and radiographs of a series of 13 patients who had thoracic spine fractures and/or fracture-dislocations at T9 or above and were treated by surgery, using pedicle screwed-based instrumentation, between January1995 and May 2000, at the Missouri Health Science Center, University of Missouri-Columbia, Missouri, USA. Results of the treatment were reviewed and analyzed.*

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Results : *There were 8 males and 5 females with their average age of 30.9 years(14 -78). The majority (10/13) were neurologically intact, while 2 had complete spinal cord injuries and 1 had a severe brain injury with incomplete spinal cord injury. There were 6 fracture-dislocations, 4 burst fractures, 2 compression fractures and 1 flexion-distraction injury. The average operative time was 3.5 hours (2 - 6) and the average estimated blood loss was 604 ml (200 - 1000). The period of follow-up ranged from 2 weeks to 50 months (average 9.2 months).The preoperative Load-sharing classification fracture score was 6.5 points (3 - 9). The preoperative, immediate postoperative and the latest follow-up radiographic kyphosis measured by Sagittal Index (SI) were: 20.6 (2-50), 14.2 (0 - 27) and 15.0 (3 -32) degrees, respectively. No patients had iatrogenic nerve root or spinal cord injuries; and there were neither hardware related complications nor postoperative infection. All patients who were followed-up more than 6 months achieved solid fusion on their radiographs and none of them reported a back pain that required narcotic medication.*

Conclusions : *The pedicle screw-based, constructed with 6.25 mm diameter rod, provided strong and stiff internal fixation for posterior spinal instrumentation for this series of high thoracic injuries. It allowed short fusions, good correction to normal alignment and retention of the correction without implant problems. Although pedicle screw based implants are not the only available implant of choice to be used, they should be an available option in the surgeon's armamentorium for posterior spinal instrumentation.*

Key words : *Thoracic spine, Fracture spine, Surgery, Pedicle Screw.*

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วัตถุประสงค์ : *เพื่อศึกษาและรายงานผลการรักษาโดยวิธีการผ่าตัดกระดูกสันหลังช่วงอกตอนบนหักหรือหักและเคลื่อน โดยการผ่าตัดเชื่อมกระดูกสันหลังทางด้านหลังและแก้ไขการผิดรูปด้วย Pedicle screw*

ที่มาและปัญหา : *การบาดเจ็บต่อกระดูกสันหลังบริเวณช่วงอกตอนบนตั้งแต่ระดับ T9 ขึ้นไปเป็นการบาดเจ็บที่พบได้ไม่บ่อย แต่ถ้าเกิดขึ้นมักจะรุนแรงมาก อาจมีการบาดเจ็บต่อเส้นเลือดใหญ่ที่อยู่ทางด้านหน้า และมักจะพบการบาดเจ็บของไขสันหลังร่วมด้วย อุบัติการณ์การเกิดไขสันหลังบาดเจ็บชนิดถาวรค่อนข้างสูง จากอดีตที่ผ่านมาจนถึงปัจจุบันมีการศึกษาวิจัยที่ศึกษาเฉพาะเกี่ยวกับวิธีการรักษาภาวะนี้น้อยมาก*

วัสดุและวิธีการ : *เป็นการศึกษาย้อนหลังและวิเคราะห์รายละเอียดผลการรักษาจากแฟ้มประวัติผู้ป่วย รายละเอียดการผ่าตัดและการวัดจากเอกซเรย์ ในผู้ป่วยจำนวน 13 ราย ที่ได้รับอุบัติเหตุกระดูกสันหลังช่วงอกตอนบนหัก และได้รับการผ่าตัดยึดด้วย Pedicle screw โดย Funnel Technique ในระหว่างเดือนมกราคม 2538 - พฤษภาคม 2543 ณ Missouri Health Science Medical Center, University of Missouri-Columbia ประเทศสหรัฐอเมริกา*

ผลการศึกษา : *มีผู้ป่วยจำนวน 13 ราย เป็นชาย 8 ราย, หญิง 5 ราย, อายุเฉลี่ยของผู้ป่วยขณะได้รับบาดเจ็บ 30.9 ปี (14 -78 ปี) ผู้ป่วยส่วนใหญ่ (10 ใน 13 ราย) ไม่พบมีการบาดเจ็บต่อไขสันหลัง มี 2 ราย ได้รับการบาดเจ็บต่อไขสันหลังทุกส่วนชนิดถาวร และอีก 1 รายได้รับบาดเจ็บอย่างรุนแรงต่อสมองและต่อไขสันหลังชนิดบางส่วน เมื่อวิเคราะห์ตามลักษณะของกระดูกที่ได้รับบาดเจ็บ พบว่า 6 รายเป็นกระดูกหักและเคลื่อน (Fracture & dislocation), 4 รายเป็นกระดูกหักชนิด Burst Fracture, 2 รายเป็นชนิด Compression fracture และอีก 1 รายเป็นการบาดเจ็บชนิด Flexion / Distraction ผู้ป่วยทุกรายได้รับการผ่าตัดรายในระยะ 48 ชม. หลังบาดเจ็บระยะเวลาเฉลี่ยในการผ่าตัดประมาณ 3.5 ชม.(2 - 6 ชม.) และค่าเฉลี่ยการประมาณการเสียเลือด จำนวน 604 มิลลิลิตร (200 - 1000 มล.) ผู้ป่วยดังกล่าวมารับการตรวจติดตามเป็นระยะตั้งแต่ 2 สัปดาห์ ถึง 50 เดือน หลังผ่าตัด* (เฉลี่ย 9.2 เดือน) ความรุนแรงของกระดูกที่หักเมื่อแบ่งตาม Load-Sharing

classification พบว่าเฉลี่ย 6.5 คะแนน (3 -9 คะแนน) ผลการรักษาไม่พบว่ามีผู้ป่วยรายใดได้รับการบาดเจ็บต่อเส้นประสาทหรือไขสันหลังในระหว่างการผ่าตัดและไม่พบผู้ป่วยรายใดมีภาวะแทรกซ้อนอันเนื่องจากโลหะที่ใช้ยึด ไม่พบมีการติดเชื้อหลังผ่าตัดในผู้ป่วยรายใด จากการวิเคราะห์เอกซเรย์พบว่าในผู้ป่วยที่มารับการตรวจหลังผ่าตัดเมื่อ 6 เดือนขึ้นไป จะพบลักษณะการเชื่อมติดของกระดูกสันหลังบริเวณที่ผ่าตัดได้ในเอกซเรย์ ไม่พบว่ามีผู้ป่วยรายใดยังมีอาการปวดหลังรุนแรงจนต้องใช้ยาแก้ปวดชนิด Narcotic ค่าดัชนีการยุบตัวหรือค่อม (Sagittal Index of Kyphosis) วัดเมื่อก่อน, หลังผ่าตัดทันทีและล่าสุดที่มาตรวจติดตาม ได้ 20.6° (2-50), 14.2° (0 -27) และ 15.0° (3 -32) ตามลำดับ

สรุป : *การรักษากระดูกสันหลังช่วงอกตอนบนตั้งแต่ระดับ T9 ขึ้นไปหักและหรือเคลื่อนโดยวิธีการผ่าตัดยึดและเชื่อมกระดูกทางด้านหลังโดยใช้ Pedicle screw นับว่าเป็นวิธีที่ใหม่ที่ได้ผลดีและปลอดภัยอีกวิธีหนึ่ง โดยสามารถแก้ไขการผิดรูปหรือยุบตัวของกระดูกสันหลังและคงไว้ซึ่งรูปร่างหลังการแก้ไขจนกระทั่งกระดูกเชื่อมติด โดยไม่มีปัญหาหรือภาวะแทรกซ้อนแต่อย่างใด*

คำสำคัญ : *กระดูกสันหลังหัก, การผ่าตัดกระดูกสันหลัง, Pedicle screw*

A multicenter study of more than 1,000 spine fractures showed that thoracic fractures above T9 are rare. Sixteen percent of the fractures occurred between T1 and T10; 52 % between T11 and L1, and 32 % between L1 and L5 levels.[1] Since they are rare, relatively few studies have specifically reviewed the surgical treatment of upper thoracic spine fractures (at or above T9).

The upper thoracic spine (T1-T10) is relatively stiff, and the limited blood supply to the thoracic spinal cord remains a concern. Violent forces are commonly required to damage the thoracic spine. Therefore, fracture-dislocations (injuries with translation) associated with several bilateral rib fractures and aortic injury are common. The translational displacement, which commonly damages the aorta, can also cause severe spinal cord injury. Injuries with severe spinal cord injury are disproportionately common.

This study reports the results of surgical treatment of fractures and fracture-dislocations of upper thoracic spine by posterior spinal instrumentation and fusion, using pedicle screw-based instrumentation.

Material and Methods (Table. 1)

This is a retrospective study of medical records, operative notes, and radiographs of a series of 13 patients who had thoracic spine fractures and/or fracture-dislocations at T9 or above, who were instrumented with Isola pedicle screw-based instrumentations between January 1995 and May 2000. There were 8 males and 5 females with their average age of 30.9 years (14 -78 years).

Table 1. Data of the fracture upper thoracic spine patients.

Case No	Age (Y)	Gender	Cause	Preop	Diagnos	PSF	# of level fusion
1	26	M	Fall from a height	Complete SCI T6	Fx/ Dislo T5-T6	T1-T	8
2	30	M	Fall from a height	severe brain inj/IncSCI	Burst Fx T8	T5-T10	5
3	78	M	Fall from a height	None	Burst Fx T	T6-T10	4
4	20	F	MVA	None	Comp Fx T4-5-6	T3-T7	4
5	20	M	Bike Accident	None	Burst Fx T8	T7-T9	2
6	30	M	MVA	None	Fx/ Dislo T2-T3	T2-T5	3
7	18	M	MVA	None	Fx/ Dislo T4-T5	T2-T6	4
8	38	F	Fall from a height	None	Burst Fx T7	T6-T9	3
9	28	M	Undetermined	None	Comp T4-T7	T2-T8	6
10	23	F	MVA	complete SCI T4	Fx/ Dislo T4-T5	T1-T9	8
11	50	F	MVA	None	Flex/ Distraction T8	T6-T10	4
12	14	F	MVA	None	Fx/ Dislo T4-T5	T2-T6	6
13	27	M	MVA	None	Fx/ Dislo T8-T9	T5-T12	7
	30.9	8M , 5F					4,9

Table 1. Data of the fracture upper thoracic spine patients. (Cont.)

Case No.	Type of instrument	# of pedicle screws used	Bone graft	Op time (hr)	EBL(ml)	Preop kyphosis (sagittal index)
1	Prox Hooks/ Distal ped screws	6	local	6	750	
2	Isola pedicle screws	4	local	3	450	8
3	Isola pedicle screws	8	local	3	500	5
4	Isola pedicle screws + bed rest	4	local	2.5	1000	4
5	Isola pedicle screws	4	local	2.3	450	4
6	Isola pedicle screws	6	local	4	300	2
7	Isola pedicle screws	8	local	4	200	3
8	Isola pedicle screws	4	local	2	600	4
9	Isola pedicle screws	8	local	4	500	3
10	Prox Hooks/ Distal ped screws	6	local	4	700	6
11	Prox Hooks/ Distal ped screws	4	iliac crest	3.5	450	8
12	Isola pedicle screws	8	local	3	1000	4
13	Prox Hooks/ Distal ped screws	4	local	3.8	950	6
	Average	5.7		3.5	604	7

Table 1. Data of the fracture upper thoracic spine patients. (Cont.)

Case No.	Load sharing score	Postop kyphosis (ST)	Duration FU (month)	Kyphosis (SI) at latest fu
1	7	27	50	24
2	7	20	7	14
3	8	4	10	4
4	5	20	19	20
5	6	15	6	15
6	5	14	0.5	14
7	8	15	5	15
8	7	10	0.7	10
9	3	20	11	20
10	9	17	28	32
11	3	16	7	16
12	9	0	13	3
13	7	7	4	7
Average	6.5	14.2	12.4	15

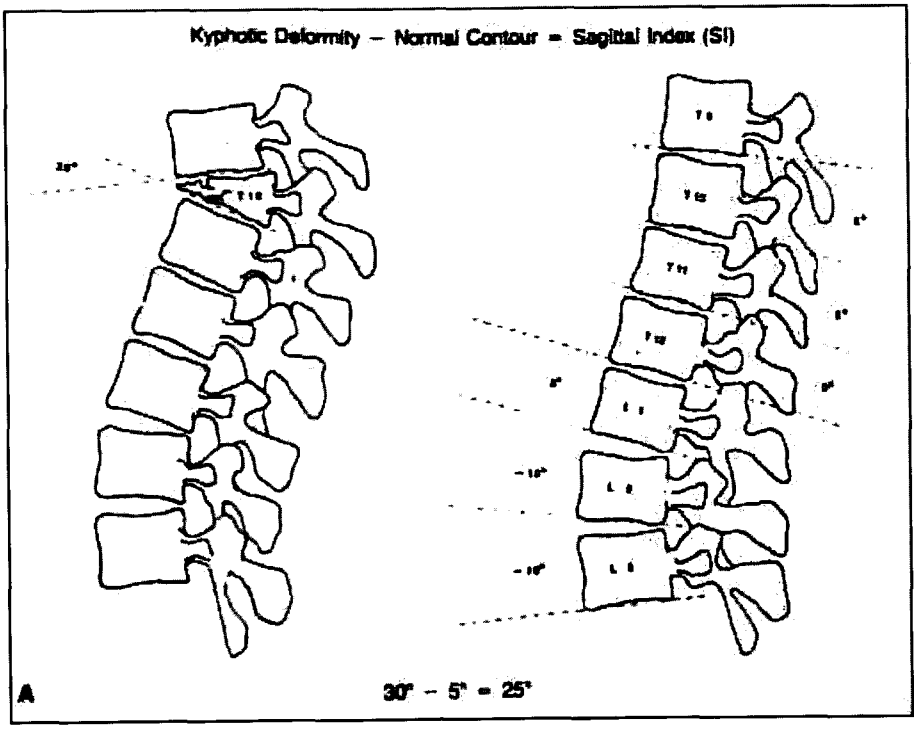

Figure 1. The Sagittal Index.

All surgeries were performed under the supervision of the senior author (RWG) at the Department of Orthopaedic Suegery, University of Missouri-Columbia. The patients' age at the injury, gender, cause of their injuries, preoperative neurological status, fracture type, severity of the fracture using the Load-sharing classification, [2] the levels of posterior spinal fusion, total number of pedicle screws used, type of bone graft used, operative time, estimated blood loss, complications, and findings at the latest follow-up were reviewed.

The radiographic measurement of kyphosis using" Sagittal Index (SI)" [3] preoperatively and immediate after the operation, and at the most recent follow-up were performed (Fig.1 SI measurement). (Sagittal Index is defined as the measurement of segmental kyphosis at a spinal motion segment adjusted for the baseline sagittal contour at that level in the normal spine). Radiographic fusion is determined by visualization of bridging callus on radiograph.

The Load-Sharing Classification of spinal fractures (Fig. 2) was used to classify the fractures.[2]

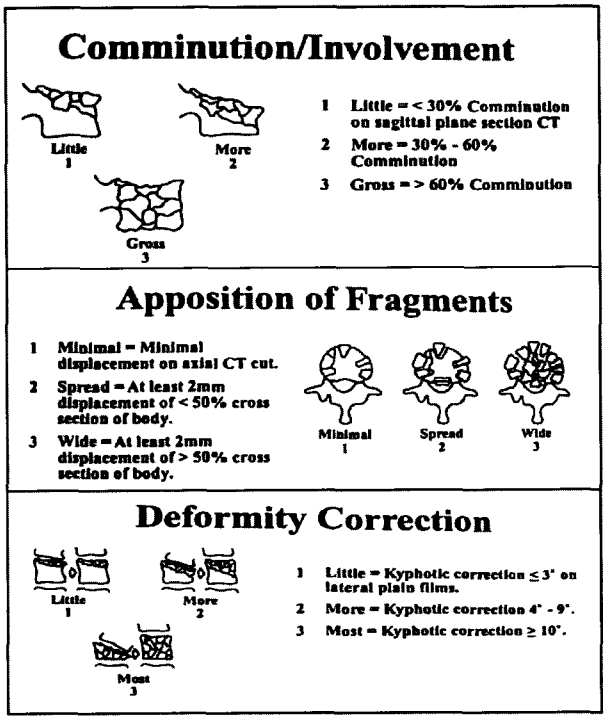

Figure 2. The load – sharing classification.

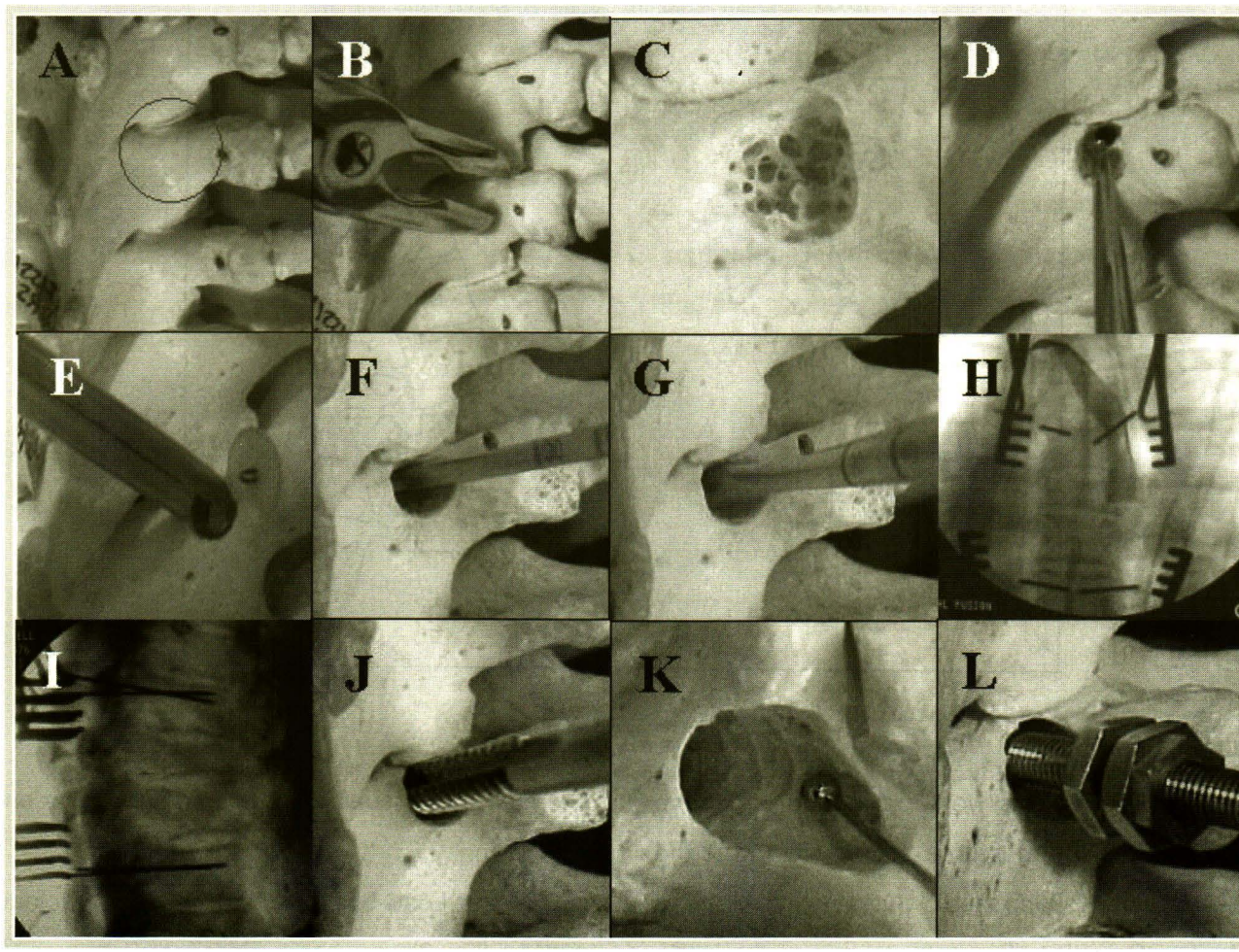

Figure 3. **Photographs illustrating the Funnel Technique. A:** The dorsal projection of the pedicle (black circle) is localized. **B:** A one-centimeter-diameter section of cortical bone is removed over the top of the pedicle with a burr or Lexcel rongeur. **C:** The cancellous bone within the pedicle is then visualized. **D:** The cancellous bone is removed with a curet until the cortical wall of the pedicle can be felt and visualized.This is followed by going deeper into the pedicle toward the isthmus. **E:** The Kerrison rongeur is used to remove the cortical bone peripherally so that the isthmus of the pedicle can be seen. **F:** Once the isthmus of the pedicle is directly palpated, a small two-millimeter pedicle probe is passed through the isthmus into the vertebral body. **G:** A larger (five-millimeter) probe then is used to enlarge the path through the isthmus of the pedicles. **H** and **I:** Small Steinmann pin segments (fifty-five millmeter in length) are place into probed pedicles as radiogrphic markers. (The anteroposterior [H] and lateral [I] c-arm images confirms the length of the screw to be used; the depth of each Steinmann pin is measured after it is removed.) **J:** Threads then are cut into the pedicle with progressively larger taps until firm cortical purchase is achieved. The feel achieved during the tapping process determies the screw diameter that is used. **K:** A ball-tip probe is used to feel the pedicle in all directions: the bottom of the pedicle (in the vertebral body) and the superior, inferior, medial and lateral inner walls of the pedicle. **L:** The screw then is inserted into the pedicle with the screwdriver. The purchase (insertional torque) must progressively increase until final seating.

All pedicle screws were placed using "Funnel Technique" [4-7] (Fig. 3). Seven out of 13 patients were injured in motor vehicle crashes; 4 fell from heights;one suffered a bike accident, and one an undetermined accident. The majority (10/13) were neurologically intact, while two had complete spinal cord injuries, and one had a severe brain injury with incomplete spinal cord injury. We recognized six fracture-dislocations (injuries with translational displacement), 4 burst fractures, 2 patients with compression fractures at adjacent levels, and one patient had a flexion/ distraction injury.

All patients were treated with posterior spinal fusion using pedicle screw-based instrumentations (12 Isola rods and one VSP plate) within 48 hours after injury. Eight patients had Isola rods and only pedicle screws; 4 patients had Isola rods with a combination of proximal hooks and distal pedicle screws; and one patient was instrumented with a VSP plate and pedicle screws. Of the total 12 Isola rods used, 10 were 6.25 mm. (1/4 inch) in diameter; the other 2 rods were 4.35 mm(3/16 inch) in diameter. The average length of the fusion was 4.9 (2-8) levels. The total number of pedicle screws used for all these 13 patients was 74 (an average of 5.7 screws per patient). A local autologous bone graft was used in twelve out of thirteen patients (resected laminae, spinous processes, and parts of the facet joints); an iliac crest bone graft was used for one patient. The average operative time was 3.5 hours (2-6 hours) and the average estimated blood loss was 604 milliliters (200 - 1000 ml). The period of follow-up ranged from 2 weeks to 50 months (average 9.2 months). The preoperative Load-Sharing Classification fracture score was 6.5 (3-9) points.

Results

The preoperative, immediate postoperative and latest follow-up kyphosis, measured by Sagittal Index (SI) were: 20.6 (2-50), 14.2 (0-27), and 15.0 (3-32) degrees, respectively (Fig. 4). No patients had

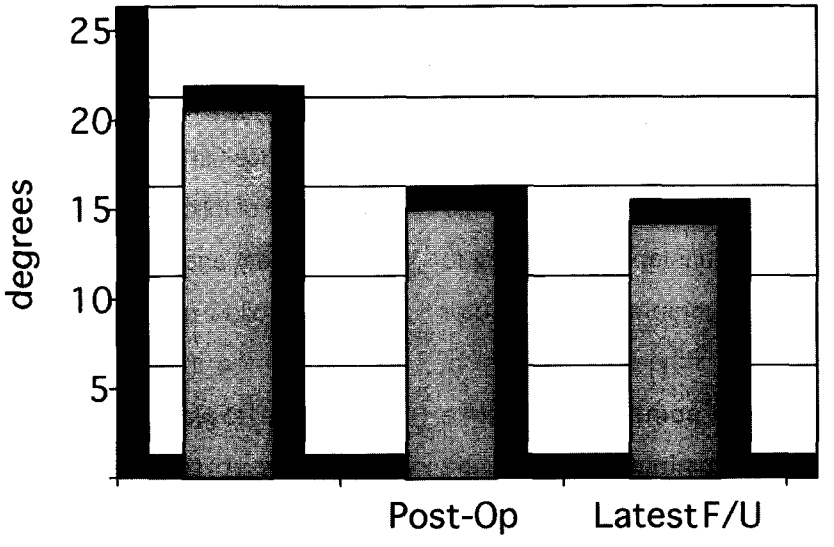

Figure 4. The Sagittal Index (SI) as a represent of kyphosis at pre-op, immediate post-operative, and Latest follow-up.

iatrogenic nerve root or spinal cord injuries and there were no hardware related complications (no screw misplaced/rod broken or hooks pulled out), or postoperative infections. All patients who were followed-up for more than 6 months achieved solid fusion on their radiographs with no loss of operative correction. No patients reported a back pain that required narcotic medication.

Only one patient had elective implant removal 4 years after surgery, due to proximal hardware-related symptoms (this patient was instrumented with a combination of proximal hook and distal pedicle screw fixation).

Discussion

The aims of surgical treatment of any spinal fracture, including the thoracic spine, are to reduce and stabilize the fracture deformity, to allow early mobilization of patients, to assist the improving neurological recovery in partial cord lesions, to reduce complication rates of prolonged bed rest and to prevent post-traumatic kyphosis. The relative stiffness and immobility of the thoracic spine makes mild high thoracic fractures stable and renders non-operative treatment effective.

Operative treatment is indicated when the thoracic spine fractures are unstable secondary to ligamentous injury, multisegmental injury, and/or translational displacement or if there is neurological deficit due to mechanical compression with a fragment, or if severe comminution makes the potentiality for collapse deformity high. Sublaminar wiring and hook-rod constructs were used in the past, but pedicle screw-based constructs give the surgeon the best opportunity for excellent fixation, particularly when the posterior elements of the vertebrae are fractured or missing. Pedicle screw fixation also allows shorter segment fusions than other techniques.

Although pedicle screw fixation has been proved the best method for spinal fixation by numerous biomechanical [8-11] and clinical studies,[12-14] some surgeons are concerned about the accurate placement of pedicle screws in the upper thoracic spine. Our experience suggests that the "Funnel Technique" for screw placement (after a careful preoperative radiographic (X-ray, CT-scan) evaluation of the dimensions of the pedicles) makes screw placement safe, even above T9.

Our review of this small series demonstrates that Isola pedicle screw-based spinal fixation systems can restore anatomic alignment and maintain correction of operated high thoracic spine fractures even when short segment instrumentation and fusion are performed for high point-total injuries. (Fig. 5 : A case example)

We used Sagittal Index (SI) to assess the degree of sagittal plane correction and the maintenance of correction. Our data showed that all patients had the sagittal plane alignment restored to normal. The degree of loss of correction was only 0.8 degree over the period of follow-up (the average SI had improved after surgery and changed only 0.8 degree over the period of follow-up).

Since 1995, we have used the "Funnel Technique" to place our pedicle screws. To evaluate the accuracy of screw placement in the thoracic spine using the "Funnel Technique", we compared the accuracy of screw placement for each of 3 surgeons (72 thoracic pedicles for each surgeon). Three fresh frozen cadavers were operated by each surgeon, 216

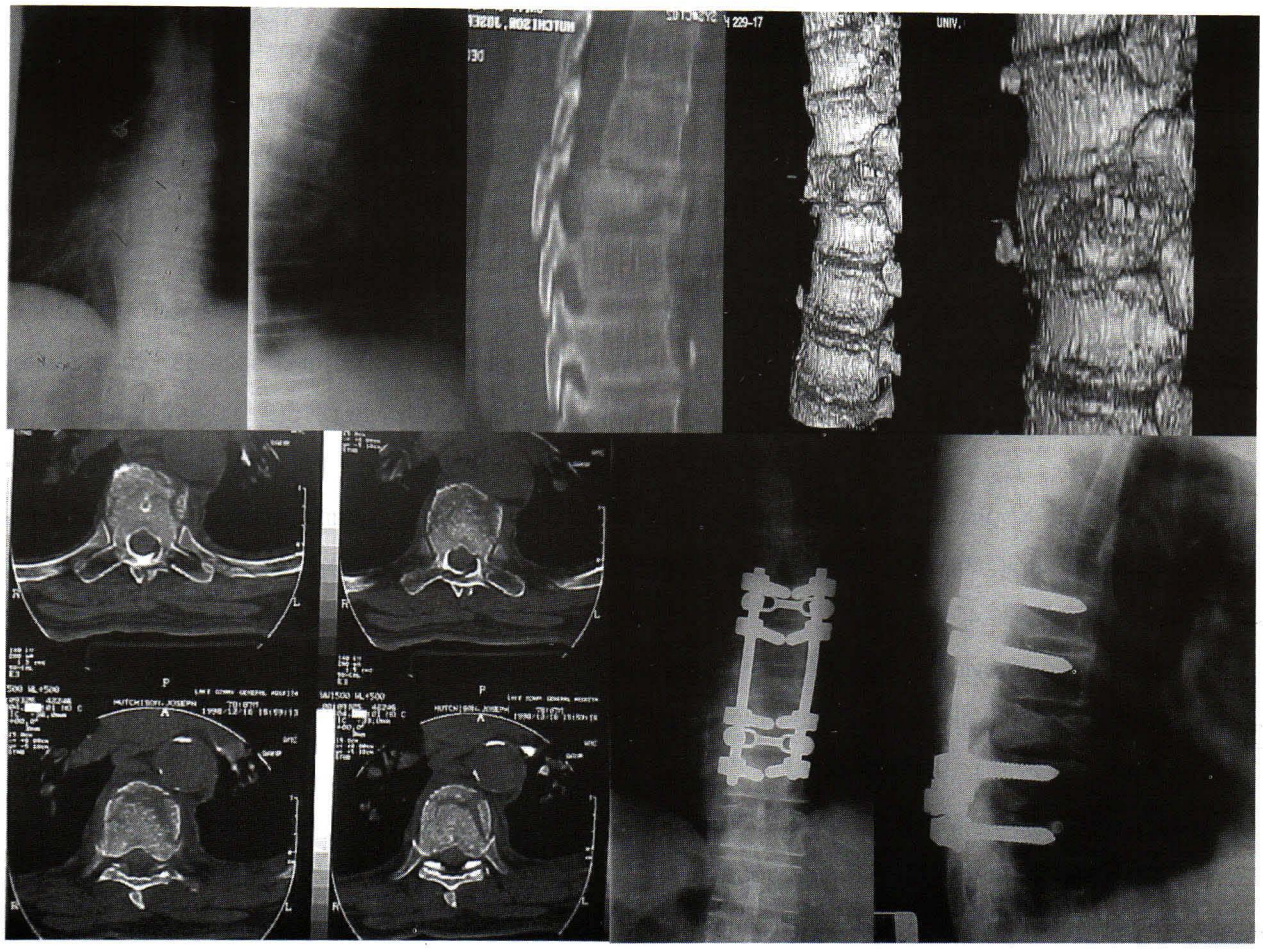

Figure 5. A 28 y/o male with automobile accident.

thoracic pedicles were probed. The accuracy of screw placement using the "Funnel Technique" was evaluated by direct inspection of the screw path.

Based on this cadaveric study[7] using the "Funnel Technique" without any radiographic guidance, the non-critical misplacement rate (a perforation of a pedicle wall without contact with a nerve root nor the dura around the spinal cord) was only 6 % (ranged from 1.4-12.5% among 3 different surgeons. There was only one critical perforation (screw touching the dura or a nerve root). This study demonstrated that the "Funnel Technique" is a safe and cost-effective alternative to other current techniques for pedicle screw placement, particularly in the thoracic spine. Our clinical results[6] also supported the accuracy of screw placement using the "Funnel Technique".

Conclusion

These Pedicle screw-based constructs provided strong and stiff internal fixation for posterior spinal instrumentation for this series of instrumented high thoracic injuries, allowing short fusions of the upper thoracic spine. Correction to normal alignment and retention of all achieved correction regularly occurred without implant problems.

Although pedicle screw based implants are not the only available implant of choice, they should be an available option in the surgeon's armamentarium for posterior spinal instrumentation.

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