POSTERIOR CERVICAL ARTHRODESIS AND STABILIZATION WITH A LATERAL MASS PLATE: A CLINICAL AND CT EVALUATION OF LATERAL MASS SCREW PLACEMENT AND ASSOCIATED COMPLICATIONS

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ABSTRACT:

Study Design: *This was a prospective computed tomographic analysis and clinical complications of the first twenty one consecutive patients treated with a plate and screw fixation system applied to the lateral masses of the cervical spine.*

Objectives: *We wished to determine the clinical safety of lateral mass screws by determining their anatomic location and clinical complications in a consecutive patient series.*

Summary of Background Data: *Lateral mass plating has been advocated for procedures in which wiring techniques cannot be used, especially in instances in which the posterior elements are deficient. Two cadaver studies have reported the procedure to be relatively safe with a low, but definable, rate of potential neurologic injury. No clinical series have been published correlating the CT anatomy with clinical outcome.*

Methods: *The first twenty-one consecutive patients who underwent posterior cervical arthrodesis and lateral mass plating with a single fixation system were reviewed prospectively. The surgeries were performed by two experienced spinal surgeons with the assistance of a spine surgery fellow. The Magerl technique was employed for screw placement. Postoperative CT scans were reviewed independently by an orthopaedic spinal surgeon and by a radiologist to evaluate screw tip position. An axial and sagittal zone system was used to precisely locate the screw tip within the lateral mass. Clinical and radiographic outcome was assessed at each postoperative visit.*

Results: *Ten of 164 (6.1%) lateral mass screws were malpositioned in six patients. Three symptomatic patients underwent 4 additional operative procedures to remove or replace the incriminating screws. One patient had a motor deficit which responded to screw removal. Two patients had sensory radiculopathies which incompletely resolved after screw removal. No patient had spinal cord or vertebral artery injury. All patients had radiographic union and no patient developed mechanical failure requiring removal of instrumentation.*

Conclusions: *Lateral mass plating was associated with no vertebral artery or spinal cord injury in this clinical series. There was a low per screw risk of neurologic injury (1.8%) which corresponded with published cadaver studies. The method was found to be clinically efficacious as there were no instances of radiographic nonunion or mechanical hardware failures leading to revision.*

Key Words: *CT evaluatin, Lateral Mass, Cervical, Arthrodesis, Plating*

PRECIS

A prospective CT analysis of the first twenty-one patients treated with a plate and screw fixation system applied to the lateral masses of the cervical spine was performed. An axial and sagittal zone system revealed a 6.1% incidence of screw malposition and a 1.8% per screw incidence of neurologic injury.

INTRODUCTION

Posterior cervical fusion utilizing lateral mass plating has been advocated for procedures in which wiring techniques cannot be used, especially in instances in which the posterior elements are missing. Several studies have shown it to be biomechanically sound and technically reproducible by spinal surgeons (1, 8, 10). Two cadaver studies examined the placement of screws into the lateral mass and their relationship to the neighboring anatomic structures. Both studies concluded that it was a relatively safe procedure, that the spinal cord and vertebral artery were unlikely to be injured, and that the nerve root was found to be at risk or injured at a per screw rate of 6.2% and 1.8%, respectively (1, 8). The purpose of this paper was to investigate the clinical safety of lateral mass screws by determining their anatomic location and clinical complications in a consecutive patient series beginning with the first patient in which the system was used.

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METHODS

Study Population

Twenty-one consecutive patients underwent posterior cervical arthrodesis and fixation with lateral mass plating using a single instrumentation system. The surgeries were performed by either of the two senior authors (CES, GLL) with the assistance of a spine surgery fellow. The patients had a variety of diagnoses: 17 with degenerative spondylosis, 2 with congenital stenosis, 1 trauma, and 1 with ossification of the posterior longitudinal ligament. The only inclusion criteria was that these patients represented the first 21 consecutive patients in which the AXIS™ Fixation System (Sofamor Danek, Memphis, TN) was used in the senior authors' clinical practice. This system has been approved by the FDA for use in long bones and the pelvis. All surgeries were performed by one of the senior authors with the assistance of a fellow trainee. The trainee performed half of the drilling, tapping, and screw placement in each case.

Surgical Technique

A posterior midline approach was performed and full exposure of the posterior elements was obtained to the lateral edges of the lateral mass/facet complex. The facet capsules and the interspinous ligaments above and below the limits of the desired fusion were preserved. The Magerl technique was attempted for placement of screws into the lateral masses of C-3 through C-6. The variable shape and size of the lateral mass of C-7 often required screws to be placed in a manner similar to that described by Roy-Camille. All drilling and tapping was done prior to application of the plate. Drilling was performed to allow bicortical screw purchase. Fluoroscopy was not used during the drilling or placement of the screws.

Decompressive procedures were performed as indicated. The arthrodesis was then completed by burring the exposed bone surface, curretting the facet joints, and placing bone graft into the facets and around the lateral masses. Care was taken to prevent excessive decortication on the dorsal surface of the lateral mass to allow optimum screw purchase in this location. Postoperatively, the patient's neck was protected with a soft foam collar while in bed and a semirigid collar (Philadelphia type) when ambulating for 6 weeks.

Clinical Evaluation

Routine neurologic exam was performed postoperatively and at each follow up interval (6 wks, 3mos, 6mos, and 1yr). All patient information was recorded prospectively on a computerized database for occurrence of clinical complications with special emphasis on neurological signs and symptoms.

A nerve root injury was defined as related to the instrumentation if the patient had a new motor or sensory radiculopathy after the posterior lateral mass procedure associated with a malpositioned screw.

CT Evaluation

Each patient received a postoperative CT scan with thin slices (2mm or 3mm) parallel to the vertebral end plates. The CT scans were reviewed independently and then jointly by an orthopaedic spinal surgeon and a radiologist to evaluate screw tip position. Neither of the senior authors (CES, GLL) participated in this evaluation. Two systems were used to describe screw tip position. We used Heller et al's method of dividing the cervical spine lateral masses into three zones in the sagittal plane (Fig. 1) (8). We complemented this with an axial zone system we devised to allow three dimensional localization of the screw tips (Fig. 2). Our axial plane zoning system identified the location of the screw tip in relation to the neurovascular structures at risk in the transverse plane. The number of screws in each zone was recorded.

Screws were defined as malpositioned if the tip was in the medial axial zone or if they overpenetrated the cortical margin of the lateral mass by 2mm or more in either the lateral or central axial zones.

Radiographic Evaluation

Routine AP and flexion/extension lateral radiographs were obtained at each clinical evaluation and examined for evidence of hardware failure including screw loosening, screw or plate breakage, or loss of fixation.

RESULTS

Clinical Outcome

Complete patient information is recorded in Table One. Of note is that this is a very heterogeneous population of patients with severe multilevel cervical disease. Four patients had 2 level surgery and the rest had 3 or more levels instrumented. Furthermore, 19 patients had concomitant anterior reconstructive procedures and the remaining 2 patients had only a posterior procedure.

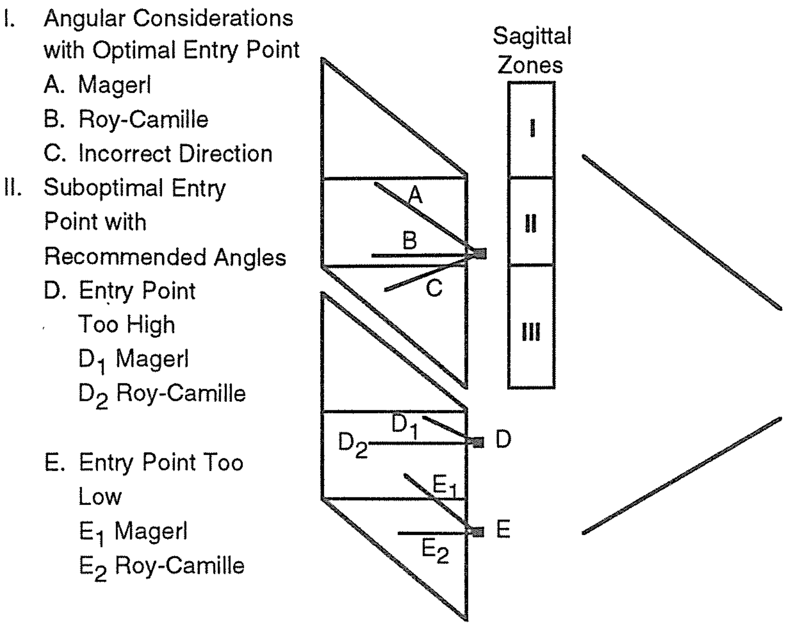

Figure 1. Screw placement in the sagittal zone, adapted from Heller et al

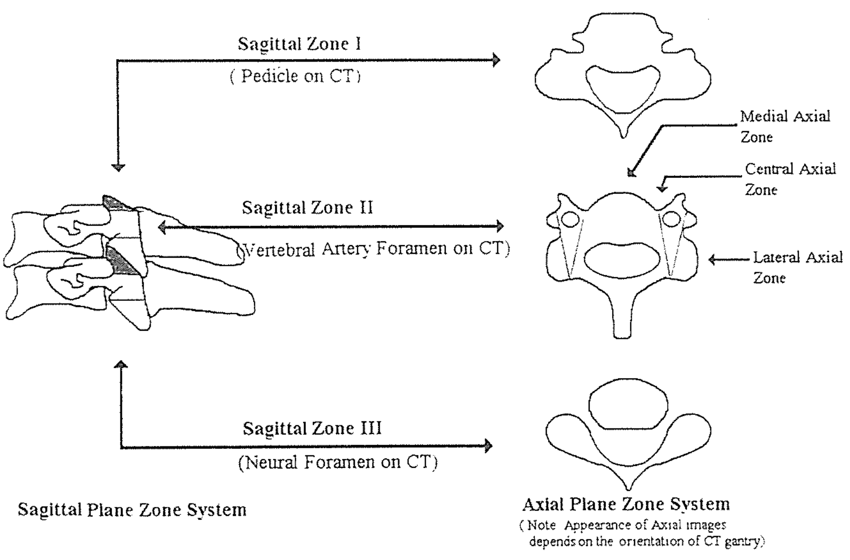

Figure 2. Comparison of sagittal and axial zone systems.

CT Outcome

A total of 176 screws were placed in the 21 patients. 135 screws were placed into the lateral masses of C-3 through C-6, 29 screws were placed into the lateral masses of C-7, two screws were placed into the vertebral body of C-2, and ten screws were placed into the vertebral body of T-1.

The majority of the screws were placed with their tips positioned in the lateral zone of the axial plane and in either zone I or II of the sagittal plane; these points correspond to the ideal screw placement when using the Magerly or Roy-Camille technique, respectively (Fig. 1). At levels C-3 through C-6 there were no screws placed in the medial axial zone, which would have placed the cord at risk (Table II). Twenty-nine screws were placed in the central axial zone; 5 of these were malpositioned placing the vertebral artery and the nerve root at risk. One hundred and six screws were placed in the lateral axial zone; 5 of these were overpenetrated in the cortical margin by 2mm or more, placing the nerve root at risk. Therefore, in this series, 10 (6.1%) of the 164 lateral mass screws were malpositioned.

The placement of screws into C-2, C-7, and T-1 were evaluated separately due to their unique morpology. The vertebral artery does not pass through the foramen transversarium of C-7, and the lateral mass is wider, but thinner, than the more cephalad cervical vertebrae (1). All screws were appropriately positioned on CT scan and there were no associated injuries of the nerve root, vertebral artery, or spinal cord involved with the placement of these screws.

Other findings on the postoperative CT scans included one patient (J.A.) with a fracture of the left lateral mass of C7 and another patient (S.S) with a screw cut out of the right C-3 lateral mass.

Table 1: Patient Data

Patient #	Patient	Sex	Age	Levels	Number of Levels	Anterior Surgery	Primary Diagnosis	Clinical Status
1	J.A.	Male	53	C3-C7	4	yes	Cervical Spondylosis	Unchanged
2	B.A.	Male	67	C3-C7	4	yes	Anterior Pseudoarthrosis	Improved
3	M.B.	Male	57	C3-C7	4	yes	Cervical Spondylosisş	Worse
4	J.B.	Male	62	C3-C7	4	yes	Cervical Spondylosis	Improved
5	F.B.	Female	46	C3-C7	4	yes	Cervical Spondylosis	Improved
6	R.D.	Male	75	C3-T1	5	yes	Anterior Pseudarthrosis	Improved
7	W.E.	Male	78	C3-C7	4	yes	Cervical Spondylosis	Improved
8	J.G.	Male	47	C5-C6	1	yes	Anterior Pseudarthrosis	Improved
9	F.J.	Male	28	C2-T1	6	yes	Trauma	Improved
10	F.L.	Male	34	C4-C7	3	yes	Cervical Spondylosis	Improved
11	W.M.	Male	41	C5-C6	1	yes	Anterior Pseudarthrosis	Improved
12	R.M.	Male	41	C4-C5	1	yes	Cervical Spondylosis	Improved
13	R.P.	Male	37	C3-C6	3	yes	Cervical Spondylosis	Improved
14	M.R.	Female	81	C3-C7	4	yes	Cervical Spondylosis	Improved
15	M.R.	Female	61	C3-T1	5	yes	Cervical Spondylosis	Improved
16	E.R.	Male	49	C3-C7	4	yes	Cervical Spondylosis	Improved
17	J.S.	Male	68	C2-T2	7	yes	Ossified Posterior Longitudinal Ligament	Worse
18	R.S.	Male	56	C3-T1	5	yes	Cervical Spondylosis	Improved
19	S.S.	Female	39	C3-C7	4	yes	Anterior Pseudarthrosis	Unchanged
20	D.S.	Male	41	C3-C7	4	yes	Cervical Spondylosis	Improved
21	J.T.	Male	40	C5-T1	3	no	Trauma	Improved
MEAN			50.6		3.81			

Table 2. Screw Position LIn Lateral Masses of C3 - C6

		SAGITTAL ZONES		
		ZONE I	ZONE II	ZONE III
	MEDIAL	0	0	0
AXIAL ZONES	CENTRAL	22	2	5
	LATERAL	47	50	9

Malpositioned Screws

The 10 malpositioned screws were placed in 6 patients (Table 3). Three patients (14%) had radiculopathies and underwent 4 additional operative procedures to remove or replace the incriminating screw(s). Two of these three patients had a sensory radiculopathy and one patient had a motor and sensory radiclopathy which corresponded to the level of screw placement. The three other patients had symptoms which could not be directly attributed to the malpositioned screw and were treated nonoperatively.

Since the study's completion, the senior author's have placed an additional 210 lateral mass screws in 37 patients with a minimum 6 week follow-up. Three (1.4%) of these screws in 2 (5.4%) patients have been removed for malposition associated with clinical symptoms. No patient had a spinal cord or vertebral artery injury.

Case Report

R.D. (patient #6) had a diagnosis of Charcot-Marie-Tooth and cervical spondylosis with neck pain and radiculopathy. He had a combined anterior and

Table 3. Malpositioned Screws: Location, Symptoms, and Intervention

Patient	Patient#	Cervical Level	Sagittal Zone	Axial Zone	Symptoms	Operative Intervention
R.D.	6	R- C5	I	Lateral	R-C5 Motor and Sensory Deficit	Removal C5 Screw
		R- C3	I	Central	none	none
E.R.	16	R- C4	II	Lateral	none	none
		R- C7	III	Central	R- C6/C7 Sensory Deficit	Exchange C6 and C7 Screws
F.J.	9	R- C6	I	Lateral	R- C5/C6 Sensory Radiculopathy	Removal C6 Screw
		L- C6	I	Central	L- C5/C6 Sensory Radiculopathy	none
R.S.	18	R- C6	I	Central	Intermittent R- C6/C7 Radiculopathy	none
		L- C6	II	Lateral	Intermittent L- C5 Radiculopathy	none
J.T.	21	L- C6	III	Central	L- C5/C6 Motor and Sensory Radiculopathy	none (deficit present preoperatively from trauma)
R.P.	13	R- C6	I	Lateral	Intermittent Hand Numbness	none (nondermatomal symptoms)
Totals	6 patients	10 screws	malpositioned			4 screws removed

posterior decompression and reconstruction. The posterior procedure included a laminectomy of C4, C5, and C6 and posterior cervical fusion with lateral mass plating. Postoperatively, a right C5 motor deficit was present with 0/5 deltoid function and 3/5 biceps function. The CT scan revealed malpositioned screws within the right C3 and C5 lateral masses. Intravenous steroids resulted in partial recovery of the deficit, however, upon tapering of the steroids the deficit returned. Ten days postoperatively, he was taken back to surgery for removal of the right C5 screw. Twenty-two months postoperitively, the patient had 5-/5 biceps and deltoid strength.

F.J. (patient #9) had a diagnosis of congenital stenosis that was associated with an episode of transient quadriplegia immediately following a football injury. He had laminectomies performed from C3 through C7 eight years prior to this procedure. He subsequently developed loss of cervical lordosis, spondylosis, and upon reinjury developed cord contusion with myeloradiculopathy. A combined anterior and posterior decompression and reconstruction was performed. The posterior procedure involved levels C2 through T1. Postoperatively, he complained of mild left shoulder and radial forearm pain. The CT scan revealed the ipsilateral screw within the lateral mass of C6 to be 2mm outside the cortical margin. The patient's symptoms worsened over several weeks and a right C6 nerve root block was performed resulting in significant relief of the pain. The right C6 screw was removed but provided incomplete resolution of symptoms. Thirteen months after his initial surgery, the hardware was removed from the anterior and posterior cervical spine. A solid fusion was noted intraoperatively. Twenty-four months postoperatively, the patient had partial resolution of his radicular symptoms and has a normal motor and sensory exam.

E.R. (patient #16) had a diagnosis of cervical spondylosis with acquired spinal stenosis. He underwent a combined anterior and posterior decompression and reconstruction. Posteriorly, laminectomies of C3 through C7 were performed and the lateral masses of C3 through C7 were plated. Immediately after surgery, the patient reported severe pain and hyperaesthesia of the right thumb and index finger without motor deficit. The CT scan revealed malpositioned screws within the right C6 and C7 lateral masses. A selective local anesthetic block of the right C6 nerve root provided significant relief of the patient's symptoms. He was returned to the operating room five days after the posterior plating and the right C6 nerve root provided significant relief of the patient's symptoms. He was returned to the operating room five days after the posterior plating and the right C6 and C7 screws were exchanged. Six months postoperatively, the patient had persistent C6 distribution sensory symptoms without motor weakness. The patient died of causes unrelated to his surgery 10 months postoperatively.

DISCUSSION

Posterior cervical fusion using screws and plates secured to the lateral mass has several advantages over wiring techniques. Specifically, fixation may be performed in the absence of the posterior elements, the spinal canal is not entered, and lateral mass instrumentation has been shown to be biomechanically sound in numerous planes of motion (2, 4, 6, 14, 18, 19). Because of these reasons, and the ability to manage patients postoperatively without the need for supplemental halo fixation, there has been an increase in the number of patients who have received lateral mass fixation with a variety of implant systems. There are several reports suggesting that the method is effective and safe. The cadaver studies by An and Heller suggest that screw placement is reproducible and the learning curve relatively short for those surgeons already familiar with cervical spine surgery (1, 8). However, very little information is published regarding the placement of these screws in a clinical setting. The purpose of this study was to review the anatomic location, clinical safety, and efficacy of lateral mass screw placement with a single instrumentation system used by experienced orthopaedic spinal surgeons familiar with various posterior plating methods. However, this series represents the learning curve with this system in that these are the first 21 patients in which the system was used and the fellow trainee performed half of the drilling, tapping, and placement of screws. In the subsequent 37 patients the risk per screw placed was reduced to 1.4% and the risk per patient was reduced to 5.4%.

The instrumentation used in this study (AXIS^{TM} Fixation System, Sofamor-Danek, Memphis, TN.) allows for flexibility in screw placement to accomodate the variable anatomy of the lateral masses. This allows the surgeon to plan screw placement at each level to maximize bone purchase without the need to drill through the implant and potentially compromise either fixation or neurovascular structures.

Jonsson, Rauschning and others have examined the anatomy of the cervical spine's articular pillar (5, 11, 12, 16, 17). The vertebral artery, nerve root, and superior articular process lie in extreme proximity to one another. Jonsson and rauschning have observed that the anterior surface of the superior articular process has an oblique laterally sloping sulcus that accommodates the nerve root an ganglia. In the degenerative spine this sulcus may be quite deep, limiting excursion of the root. The vertebral artery lies anterior, and in immediate contact with, the nerve root and its ganglia flattening both against the pillar of the lateral mass. The shape of the space occupied by these structures defines an irregular funnel with the apex of the funnel being the neuroforamen medially. As the nerve root travels laterally, the volume of the neuroforamen increases, providing greater ability for the nerve root to accommodate a prominent screw tip.

Several recommendations have been made for the ideal starting point and placement angle of the lateral mass screw (1, 3, 7, 15, 20, 21). All strive to achieve maximum safety, and optimize biomechanical effectiveness. Most are variations from the two earliest methods taught by Magerl andRoy-Camille. The Magerl technique dictates a screw trajectory of 45 degrees cephalad in the sagittal plane (relative to the vertebral body's end plate) and 25 degrees lateral in the axial plane. According to An and Heller, directing the screw tip to the most superior portion of the lateral mass, places the root at greater risk, but improves fixation by increasing the excursion of the screw in bone (1, 8, 13). The Roy-Camille technique prescribes a screw trajectory of 0 degrees in the sagittal plane and 10 degrees laterally in the axial plane. The theoretical advantage of the Roy-Camille technique is less risk to the nerve root (1, 8, 13). Both techniques dictate lateral angulation of the screw thereby lessening the risk of nerve root and vertebral artery injury. The caudal facet is at less risk with the Magerl technique because of the cephalad orientation of the screw (1, 8). In Fig. 1, screw placements B, C, and E2 (Roy-Camille) have the greatest likelihood of penetrating the caudal facet joint.

An et al, recommended a screw placement that was a compromise of the two classic techniques. By directing the drill 17 degrees cephalad and 33 degrees laterally, the risk to the nerve root and vertebral artery is theoretically lessened, and the fixation in bone improved (1). Ideally, if a screw could be directed to the anterolateral corner of the lateral mass from C-3 to C-6, safe bicortical purchase could be obtained.

Reproducing screw trajectory in the operating room is diffecult because of the variability of each patient's anatomy and the difficulty of measuring the angle of insertion accurately. Furthermore, the optimal starting point in the lateral mass may not be utilized if the plate configuration and hole spacing restrict its access. In this clinical series the Magerl technique was used. Despite this choice of technique the postoperative CT scans documented 50 (37%) screws in the lateral masses of C-3, C-4, C-5 and C-6 that were located in zone 2 of the sagittal plane; corresponding to the Roy-Camille technique. Heller suggested that intraoperative imaging be used to direct each screw. Cephalad screw trajectory could be monitored this way and could improve the consistency of the surgeon to obtain a particular angle of screw insertion in the sagittal plane. However, excessive and potentially unnecessary radiation exposure may occur.

Although the cephalad trajectory was variable, the lateral angulation was consistently reproduced throughout the series. All screws avoided the medial axial zone (spinal canal). However, 29 (17%) of the screws were within the central axial zone. Five of these (17% of 29, 3% of 174) penetrated the cortical margins by 2mm or more. Screws placed in this region place the nerve root and vertebral artery at risk when overpenetration of the drill, depth gauge, tap, or screw occurred. Despite this number in the central axial zone there were no vertebral artery injuries.

Ten of the 164 screws (6.1%) placed in the lateral masses o C-3 through C-6 over penetrated the cortical margins. These 10 screws involved 6 patiets. Of these 6 patinets, 4 patients had significant radicular complaints. All three had screws that were in a position which corresponded appropriately with their associated nerve root injury. In this series, bicortical screw purchase was attempted for all screws. This method puts the nerve and vertebral artery at risk from the drill, the tap, the depth gauge, and an inappropriately measured screw. The advantage of bicortical purchase is that it increases pull-out strength compared to unicortical purchase. However, clinically we do not know if this results in fewer hardware failures. Since all patients in this series had bicortical purchase and there were no hardware failures requiring revision, we can only state that this method is clinically efficacious. The disadvantage of bicortical purchase and the Magerl technique is a theoretical increased rate of nerve root injury (1, 8, 13). All three nerve root injuries that occured in this series can be considered a direct result of performing bicortical screw purchase. Clinical studies comparing the safety and efficacy of unicortical compared to bicortical screw purchase need to be performed befor any final recommendations may be made.

CONCLUSION

Posterior cervical fusion utilizing lateral mass plating has several advantages over posterior wiring techniques. Fixation in the absence of midline posterior elements, avoidance of the spinal canal, increased biomechanical stability, and obviating the need for rigid external immoblization make this technique appealing. Furthermore, previous clinical series have reported few complications. Cadaver studies reported a per screw injury rate of 1.6% with bicortical screw purchase. In this series, also with bicortical screw purchase, we noted a lateral mass screw nerve root injury rate of 1.8%, involving 3 (14%) of the 21 patients. Our experience suggests that this method can be performed with negligible risk to the cord and vertebral artery, and a low risk to each nerve root, when utilized by experienced spinal surgeons. The method is clinically efficacious since there were no clinical failures of fusion or hardware failures leading to revision. Whether unicortical purchase, which in this series would have reduced the neurologic injuries to zero, provides adequate fixation without hardware failures cannot be known at this time.

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