CLINICAL ARTICLE

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Clinical and Computed Tomography Evaluation of Plate and Screw on the Cervical Lateral Mass : A Modified Magerl's Technique

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Objective : To determine the clinical and radiological safety of 15 consecutive patients managed with plate and screw fixation systems applied to the cervical lateral mass.
Methods : 15 patients who underwent posterior cervical and T1 arthrodesis were reviewed from Jan 2002 to Dec 2004. Posterior cervical screw and plate fixation was applied on the lateral mass of the cervical spine. The authors have tried lateral mass screw fixation using a modified Magerl's technique (20° lateral and 20~30° rostral screw trajectory) under preliminary radiological study. The average patient age was 39.73° ± 11.00 years, and the average follow-up period was 9.73° ± 6.77 months. Computed tomography scans taken after surgery were reviewed to confirm the attempted screw trajectory correct and safety.
Results : Three of 93 lateral mass screws were malpositioned but clinical damage was not noted. Two of 8 pedicle screws on the T1 vertebrae were not placed on the correct pedicle area. Screw and plate loosening was observed in one case but was not subjected to an additional procedure because of maintained screw position observed during follow-up periods.
Conclusion : The results of this study indicate that lateral mass screw fixation using the Modified Magerl's technique on the cervical lateral mass may provide safe and effective application on the patients. In addition, the chance of incorrectly placed screws was higher in T1 pedicle screw fixation than in lateral mass screw fixation of the cervical area.

KEY WORDS : Lateral mass · Arthrodesis · Cervical spine · Magerl's technique.

Introduction

Spinal stabilization on the posterior cervical spine can be necessary in special situations, and posterior cervical fusion is considered as a proper measures in treating cervical fracture and dislocation involving posterior longitudinal ligament[9]. A number of internal fixation techniques have been developed for stabilization of the cervical spine. However, posterior stabilization of the cervical spine has posed significant clinical challenges. Cervical regions are difficult to apply the screw fixation technique because of anatomical characteristics, which include a narrow lateral mass, short pedicle, and potential injury to the spinal cord and vertebral artery. Lateral mass screw fixation in the cervical spine has been developed for the stabilization of a cervical spinal injury, but a special technique has been needed due to unique anatomical characteristics. Currently, the Roy-Camille and Magerl techniques on the lateral mass of the cervical spine are the leading techniques used for posterior plating and screw insertion on the cervical spine.

The Roy-Camille technique has a higher incidence of facet violation than the Magerl method. However, nerve root injury occurs more frequently in the Magerl method than the Roy-Camille method[10].

Recently, a new technique that compensates for the disadvantages of the Roy-Camille and Magerl techniques was reported by Anderson, An, and Yoon, et al[6]. Other available techniques of lateral mass screw placement, including the An and Anderson method, also have potential risk of nerve root violation[11]. The authors have developed and applied the Mo-

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Table 1. Profile of related screw fixations for 15 patients

No	sex	age	pathology	level	complication	Ant.fusion	Med. invasion	Lat. invasion	accident	laminectomy	neurology
1	F	42	C6-7 Fx-Dis	C6,7,T1	No	O	-	-	Motor	Yes	Complete
2	F	41	C6-7 Fx-Dis	C5,6,T1	No	O	O	-	Motor	Yes	Complete
3	M	42	C7 bursting Fx	C5,T1	Screw loosening	O	O	-	Motor	Yes	Complete
4	M	44	C4 spinal cord contusion	C3,4,5	No	-	-	O	Sliding	No	Incomplete
5	M	51	C6 spinal cord contusion	C5,6,7	No	-	-	-	Fall	Yes	Complete
6	M	40	C4-5 Fx-Dis	C3,4,5	No	O	-	O	Others	Yes	Complete
7	M	49	C6-7 Fx-Dis	C6,7,T1	No	-	-	-	Sliding	Yes	Incomplete
8	M	48	C4-5 Fx-Dis	C3,4,5,6	No	O	-	-	Motor	Yes	Complete
9	M	45	C5-6 Fx-Dis	C4,5,6,7	No	O	-	-	Fall	Yes	Incomplete
10	M	18	C5-6 Fx-Dis	C4,5,6	No	O	-	-	Fall	Yes	Complete
11	M	59	C4-5 Fx-Dis	C3,4,5	No	O	-	-	Fall	Yes	Complete
12	M	36	C6 lamina Fx	C5,6,7	No	-	-	-	Motor	No	Intact
13	M	28	C6 lamina Fx, HCD C6/7	C5,6T1	No	-	-	-	Motor	Yes	Complete
14	M	24	C5-6 Fx-Dis	C5,6,7T1	No	-	-	-	Motor	Yes	Complete
15	M	29	C4-5 Fx-Dis	C3,4,5,6	No	-	-	-	Motor	yes	Complete

*ant.=anterior, med.=medial, lat.=lateral, proc.=process, HCD=herniated cervical disc, Fx-Dis=fracture and dislocation

dified Magerl's technique (Yoon's technique) on the lateral mass.

The authors suggest new, more modified and safer technique for screw insertion and report their complications.

Materials and Methods

Patient population

This study was based on the charts and radiological records of 15 patients who were treated consecutively at Inha University Hospital for cervical instability. The patients were operated on by one surgeon between December 2004 and January 2005, and all patients were treated by posterior cervical fixation using a screw-rod or plate implant system according to the trajectory described by Yoon et al[11]. The patients had a variety of diagnoses : 2 (13.3%) had bursting fractures; 1 (6.7%) had lamina and spinous process fracture; 10 (66.7%) had fracture dislocation; and 2 (13.3%) had cord contusion. There were 2 women and 15 men (age range, 18 to 59; mean 39.61 years). All patients had varying degrees of normal cervical lordosis loss or cervical fracture dislocation. Patient characteristics are recorded in Table 1.

Operative procedure

Eleven (73.3%) of 15 patients previously underwent anterior approach for correction of a dislocated spine. Posterior decompression and stabilization were performed between one and seven days after admission for patients with acute injury. A posterior midline approach was performed, and full exposure of the posterior elements was obtained to the lateral edges of the lateral mass and facet joints at each level to be fused. After the decompressive procedure, posterior plating and screw insertion was performed as indicated. The authors used the technique of screw insertion trajectories described by Yoon et al., which is a modified Magerl's technique(Fig. 1A, B). The entry point was initiated at a point 1mm medial and 1mm superior to the midportion of the lateral mass, and preceded along a course 20~30° cephalic and about 20° lateral from C3 to C7[11]. There were 5 cases of screw insertion on the T1 vertebrae due to a C6-7 level injury. For thoracic spine fixation, the starting point for screw placement was 5mm medial to the lateral border of the superior facet and 5mm above the midpoint of the transverse process. The screw is angled medially 20~30° with 15~20° caudal angulations.

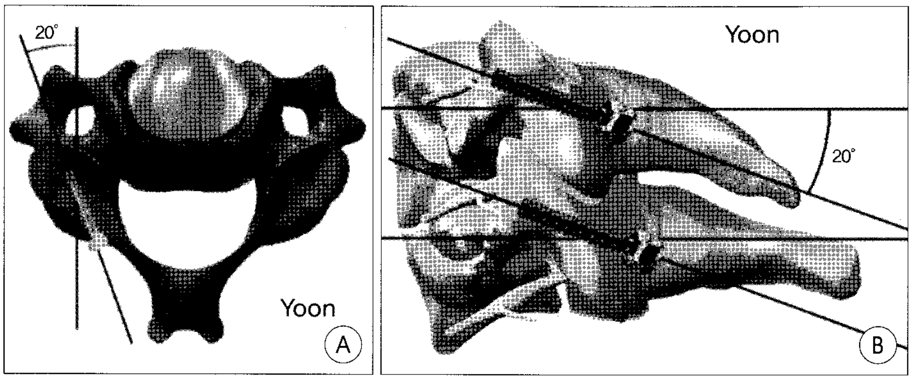

Fig. 1. A and B : The author's technique for posterior articualr mass plate fixation. Entry point is 1mm medial and 1mm superior to the mid portion of the lateral mass. Axial view depicting a 20° lateral screw trajectory. Lateral view depicting a 30° superior angulation.

All drilling and tapping was done with a hand drill. The drill hole was prepared and hole dilatation was performed with a hand dilator. We had intended to insert deeper screw insertion, if possible and did not always attempt to achieve bicortical screw purchase in all patients; generally, 12~16mm screws were used depending on patient size). Screws were inserted into prepared holes on the lateral mass. After screw insertion, a plate (Peak; DePuy Acromed Inc, Raynham. MC) or rod (Vertex; Sofamor/Danek Inc, Memphis, TN) was connected between the screws. Arthrodesis was completed by burring the exposed bone surfaces and placing bone graft, donated from the iliac bone, into and around the lateral mass. After surgery, the patient's neck was protected with a Philadelphia collar for 6 or 8 weeks.

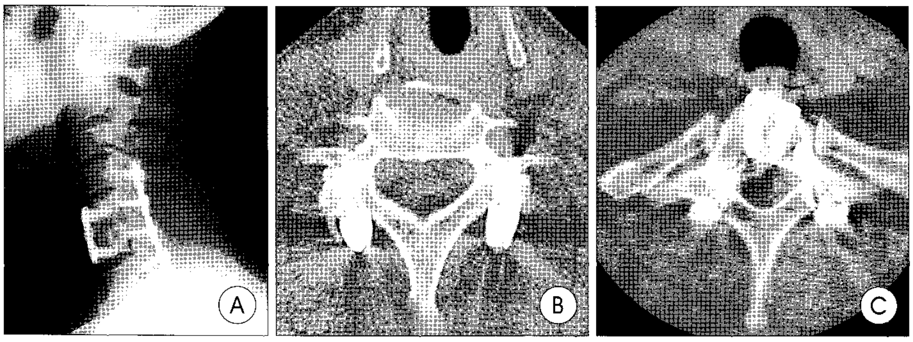

Fig. 2. A : Lateral roentgenogram of the cervical spine taken after placement of plates and screws from C3 to C7 shows excellent alignment. B : computed tomography(CT) scan in the transaxial plane at the C6 level. Screws are directed lateral to the transverse foramen C : CT scan of T1 level shows spinal canal invasion by the right pedicle screw.

Clinical evaluation

Routine neurological examination was performed after surgery and at each routine follow-up interval. Data of all patients were recorded with occurrence of clinical neurological signs and symptoms related to lateral mass screw fixation.

Radiological evaluation

After surgery, routine anteroposterior and flexion-extension lateral radiographs were obtained at each clinical evaluation, and were examined for lateral mass screw sagittal angle on both sides, evidence of screw loosening, and screw breakage.

A thin section computed tomographic scan focused on the lateral mass fixation area during routine follow-up periods, and recorded the lateral angle of the lateral mass screws on both sides and the position of the screw tip in relation to the vertebral foramen. For example, the screws were defined as 'malpositioned' if the tip penetrated into the vertebral foramen (foraminal invasion) or into the spinal canal (cord invasion).

Table 2. Average sagittal and lateral angle of inserted screws

level/angle	R	L
C3 lateral	19.4 ±7.28	12.9 ±4.92
C3 upward	20.16±8.49	15.62±6.78
C4 lateral	20.1 ±5.61	21.39±4.57
C4 upward	18.29±5.71	15.43±7.27
C5 lateral	20.26±6.77	18.05.49
C5 upward	14.89±4.99	17.02±6.56
C6 lateral	16.85±6.99	19.75±4.80
C6 upward	16.25±6.44	18.41±5.70
C7 lateral	16.28±6.57	15.16±7.31
C7 upward	8.75±5.76	7.633±5.60
T1 medial	25.16±9.90	19.75±5.61
T1 downward	11.0 ±9.0	13.07±6.47

Table 3. Differences between true screw angle and hypothetical ideal angle

Level	Angle position	True angle	Ideal angle
C3–C7	Lateral	18.11±1.87°	20°
	Cephalic	15.23±3.98°	20~30°
C7–T1	Medial	23.09±0.93°	30°
	Caudal	18.84±9.63°	15~20°

Results

Clinical data

The patients in this study ranged in age from 18 to 59 years with an average age of 39.7 years. Eight patients were involved in motor vehicle accidents, 4 by fall, 2 by sliding, and one patient was hit on his head by a rope while working on a ship. The duration of follow-up was 10±6.95 months on average (range 1~22 months). One patient was neurologically intact and 14 patients had spinal cord injury, 11 patients of which were complete and 3 patients were incomplete. On follow-up examination, no patient's neurological status had deteriorated subsequent to surgery. Fracture types were variable. One patient had a burst fracture, 10 had fracture dislocation, 2 had lamina fracture, and 2 had cord contusion (Table 1).

Radiological data

Eight patients were stabilized with screws and plates and 7 patients with screws and rods. A total of 93 screws, 16 plates, and 14 rods were implanted in 15 patients. Fixation was carried out from C2 to T1. The system was successfully implanted in all patients despite the presence of coronal and sagittal plane deformities and lateral mass abnormalities due to fracture and dislocation. Fig. 2A, B show post-operative X-ray and computed tomographic scan of a patient who is 45-year-old man with C5-6 fracture-dislocation. The length of follow-up was 10±6.9 months (range 1~22months). We compared the average upward and lateral angle of the inserted screws between right and left side at each level to prove technical repetition

(Table 2). Table 2 shows the average angle of the each screw level. We also compared the mean data between the imaginary ideal angle and the patients' real measurement (Table 3). Generally the sagittal angle was in the range of 15~22 degrees and the average was 18.72°, which is lower than the initially planned 20~30°. Also, the lateral angulations (range 15~21°, average 18.51°) were less than originally planned 20°. However, the differences between the planned and measured angles were not larger. The vertebral foramen and spinal canal invasion by screws may have resulted from these insufficient angulations. Complications include two categories, neurovascular complications resulting from screw insertion and others such as postoperative pain and wound infection. In this series, there was 1 screw of medial (T1 level) and 3 screws of lateral invasion (C2, C5, and C6 level) associated with the insertion of lateral mass screws. Medial invasion occurred in a T1 screw (Fig. 2C).

No patient experienced symptoms or signs associated with vertebral artery or nerve root injury, nor neurological deterioration as a result of operation. There were no cases of postoperative wound infection. One screw in this series, at the C5 level, was extruded on the 228th postoperative day, which was observed in a plain cervical x-ray.

There were no other instances of screw loosening in the lateral mass. No patient required a second procedure to remove or replace malpositioned screws. 12mm length screws were used in 7 patient (46.7%), 14mm screws in 7 patients, and 16mm screws in 1 (6.7%) patient. Two-level posterior plating was performed in 1 patient (6.7%), three-level in 10 patients (66.7%), and four-level in 4 patients (26.7%). There was spinal canal invasion in 1 (1.06%) screws and vertebral foramen invasion in 3 (3.19%) screws. All other patients remained stable, with screws and plates in good position during the follow-up period.

Discussion

Posterior stabilization of the cervical spine using plates and screws was pioneered by Roy-Camille et al. in 1979[5]. A 95% fusion rate was reported by Cooper and coworkers[1,3]. Recently, several clinical reports have been published on this technique[7,12]. Magerl and Seemann, developed hardware that differs from the Roy-Camille technique, and they recommended different drill trajectories for screw insertion[8]. Roy-Camille have advocated screw placement at the center of the lateral mass, proceeding in a direction 10° lateral and 0° cephalic[3,5]. The Magerl technique involves drilling from a point 1~2mm medial and rostral to the center of the lateral mass along a trajectory 25° lateral and 40~60° cephalic[4]. The sagittal angulation is intended to orient the screw parallel to the facet joint. Anderson et al. suggested another trajectory in which the screw has a 30~40° cephalic and 10° lateral direction. An et al. described their own technique in a cadaver that precedes 15° cephalic and 30° in the lateral direction[2]. The purpose of the lateral angling is to avoid nerve root injury.

Based on our experiences and studies with the plate-screw technique in the cervical spine, we believe Magerl's technique, with some modifications, could be rewarding.

Principle of the authors technique was deeper insertion of screw while to maintain safety without cord or root violation. And lateral screw insertion of about 20° should be able to insert more deep screw than other technique, however, safey is more important than biomechanical stability. Potential problems associated with posterior plating of the cervical spine include injury of the vertebral artery, spinal cord and nerve roots, as well as violation of the facet joints. The risk of direct trauma to neurovascular structures is most significant while drilling the articular masses and inserting lateral mass screws. The ideal screw trajectory should be away from the nerve root. Fehlings et al. reported the incidence of screw loosening in the Roy-Camille method as 3.8%[8]. In the authors' method, loosening occurred in one out of 93 screws (1.08%). However, there were no associated symptoms with the screw loosening and no stability problems because solid fusion was attained at that level, which was confirmed by plain x-ray. Heller et al. reported that the incidence of nerve root injury was 0.8% in the Roy-Camille method, and 7.3% in the Magerl method[7]. They also reported that, facet joint violation occurred in 22.5% of Roy-Camille screws, and in 2.4% of Magerl screws in the treatment of lower cervical spine injury (C3-C7)[4,7]. Xu et al. compared Magerl, Anderson, and An techniques for neurovascular complication, especially nerve root violation in their cadeveric study[12]. They intentionally overpenetrated the ventral cortex of the lateral mass to observe the anatomic relationship of the screw tip to the adjacent nerve root and subdivided nerve root injury rating into grades 1-3, (Grade 1 : screw touching the ventral or dorsal ramus, Grade 2 : screw penetrating the ramus, Grade 3 : screw touching or penetrating the ventral or doral rami at their bifurcation). Therefore, their overall percentage of nerve root violation was higher than other series. This anatomic study indicated that the potential risk of nerve root injury is higher with the Magerl (95%) and Anderson (90%) techniques than with the An technique (60%)[12]. In our study, vertebral foramen invasion and spinal canal invasion occurred in 2 screws (2.15%) between C3-C7 level. These findings were observed not by anatomical study, but by postoperative cervical computed tomographic scan. It seems that the rate of malpositioned screw in Yoon's method is about similar or lower than those of other methods, but the rate of other methods is the result of cadaveric study. But, because the clinical application of a surgical technique has more variables than cadaveric study. The simple comparison between these results does not make sense and is more confounding, Considering that the trend of worse result of clinical study, the authors' method is about same or safer than others. We could determined that in root injury our relative safety rate in comparison with other study should be guess due to cephalad angle of our screw insertion. Because normal root course located transversely straight and original Magerl's method to have too cephalad angle possible hurt upper level root more than our methods. And the randomized controlled study is required for exact comparison.

In C6-7 fracture and dislocation, T1 level screw insertion is needed but there are many screw malpositioning because of its technical difficulties. There was one spinal canal invasion at T1 screw(Fig. 2C), but the result of screw malpositioning at this level was not compared to other lateral mass screw malposition and not included in statistical analysis of this series.

Although, postoperative cervical CT scan revealed vertebral foramen invasion by 2 screws at the level of C5 and C6 each, there was no arterial bleeding associated vertebral artery injury during screw insertion, and no postoperative neurological deterioration or symptomatic aggravation in our study. Therefore, the vertebral or spinal canal involvement by screws was not clinically significant, i.e., the screws may not penetrate the vertebral artery or nerve root, but just touches them. There were several anatomic studies comparing the potential risk among these techniques, but clinical results regarding complications after screw insertion have not been reported. And the result revealed no clinical deterioration after surgery, but the two patients of malpostioned screws had complete spinal cord injury, therefore the clinical symptoms from these screw malposition could be masked by the sensory impairment. In this study, the insertion angle was somewhat insufficient in the sagittal plane and was further reduced laterally. A more correct insertion of these screws may lower the complication rate.

Conclusion

There have been several techniques developed for posterior cervical pate and screw fixation, but the surgical complications associated with the each screw insertion method issued also. The results of this study indicate that lateral mass screw fixation using the Modified Magerl's technique on the cervical lateral mass may provide safe and effective application on the patients.

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Commentary

This analysis of 15 cases of lateral mass screw fixation using 93 screws from C1 to T1 levelshows a new trajectory for lateral mass screw fixation to prevent serious complications such as vertebral artery injury, neural injury and hardward failure. Especially the author emphasized on the depth of screw and recommended the deeper screw to maintain safety without cord or root violation compared to other techniques.

This modified technique can be more stable compared to other techniques by deeper screw but the technique shows more medial directionandless cephalic direction than original Magerl's technique without significant difference. So I don't think this is a new technique for lateral mass screwing except deep insertion. It should be confirmed the safety, difference and accuracy with anatomical study using cadaver.

In my opinion there is no lateral mass in T1 spine and not sufficient for fixation in C7 level. So it should be considered in statistical analysis. With this technique, surgical results have been satisfactory with rare complications. In summary, I would like to thank the author for reminding us the complications of lateral mass screwing and the way to avoidthese problems by showing the author's technique. I think further follow up in clinical and anatomical basis is recommended.

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