CLINICAL ARTICLE

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# Comparison of Three Different Techniques in Cervical Transpedicular Screw Insertion

Young Jun Seo, M.D.,[1] Geun Sung Song, M.D.,[1] Won Ho Cho, M.D.,[1]
Byung Kwan Choi, M.D.,[1] Seung Heon Cha, M.D.,[1] Sun Yong Baek, M.D.[2]

*Departments of Neurosurgery,[1] Anatomy,[2] School of Medicine, Pusan National University, Busan, Korea*

**Objective :** This is a cadaver study to assess the accuracy of three cervical screw insertion techniques : the blind technique (Group I), the laminotomy technique (Group II), and the funnel technique (Group III).

**Methods :** Ten human cadavers embalmed with formaldehyde were prepared. After exposing the spinous processes, the laminas and the lateral masses, titanium alloy transpedicular screws were inserted from C3 to C7. A total of 100 pedicles were ramdomly assigned to one of three techniques (the blind technique : 31 screws, the laminotomy technique : 51 screws, the funnel technique: 18 screws). Axial computed tomography with 1-mm slices, and sagittal and coronal reformation were performed to identify the accuracy of the screw insertion and the anatomic relationships.

**Results :** In Group I, 9 screws (29%) were either contained within or penetrated less than 1mm, which were rated as successful. In Group II, 24 screws (47%) were successful. In Group III, 16 screws (89%) were successful. In the multiple comparison, there was a statistically significant difference between Groups I and III and between Groups II and III ($\chi^2$ test and Bonfenoni test).

**Conclusion :** The funnel technique can help a surgeon's understanding about the cervical pedicle more precisely than the other two techniques. The funnel technique is less dependent on lateral soft tissue retraction state.

**KEY WORDS : Cervical pedicle · Pedicle screw · Transpedicular fixation · Funnel technique.**

## Introduction

There have been several cervical fixation procedures, including anterior plating, posterior wiring, posterior lateral mass plating, and transpedicular screw fixation. Of these techniques, transpedicular screw fixation provides the greatest stability[9,13]. Transpedicular screw fixation is useful as a singlestage procedure of posterior cervical decompression and stabilization, and is efficient in patients undergoing posterior reconstruction after previous cervical laminectomy. It is also favorable in patients with osteoporosis and destruction of lateral mass, and in those undergoing correction of cervical kyphosis[3,5,9]. However, transpedicular screw fixation has been considered a potential risk of injury to adjacent vital structures such as the vertebral artery, the nerve root, and the spinal cord[1,4,5]. In this study, the author compared the accuracy of three transpedicular screw fixation techniques : the blind technique according to the anatomical guidelines, the laminotomy technique after determination of the pedicular direction by partial laminotomy, and the funnel technique after identifying the arch of the medial pedicle cortex with cancellous core by decortication.

## Materials and Methods

Ten human cadavers (eight male, two female) embalmed with formaldehyde were prepared. Each cadaver was placed in the prone position, and midline incision from the occipital protuberance to the T1 spinous process was performed. All of the soft tissues of the posterior aspect of the cervical spine were dissected and retracted laterally. After exposing the spinous processes, the laminas and the lateral masses, transpedicular screws were inserted from C3 to C7. Titanium alloy screws (Fig. 1) with 4.0mm diameter and 23mm length were inserted into each pedicle by one spine surgeon. A total of 100 pedicles were ramdomly assigned to one of three techniques (Fig. 2A).

In Group I (the blind technique), 31 screws were placed through the lateral mass using the modified Abumi technique[1,2],

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• Address for reprints : Geun Sung Song, M.D., Department of Neurosurgery, School of Medicine, Pusan National University, 1-10 Ami-dong, Seo-gu, Busan 602-739, Korea Tel : +82-51-240-7257, Fax : +82-51-244-0282, E-mail : gnsong@pusan.ac.kr

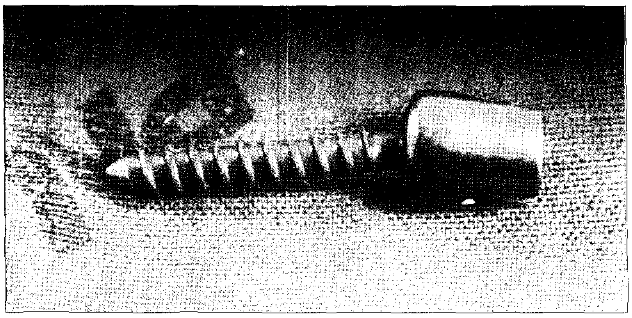

**Fig. 1.** Photograph of a titanium alloy screw with 4.0mm diameter and 23mm length (VERTEX®, Medtronic Sofamor Danek).

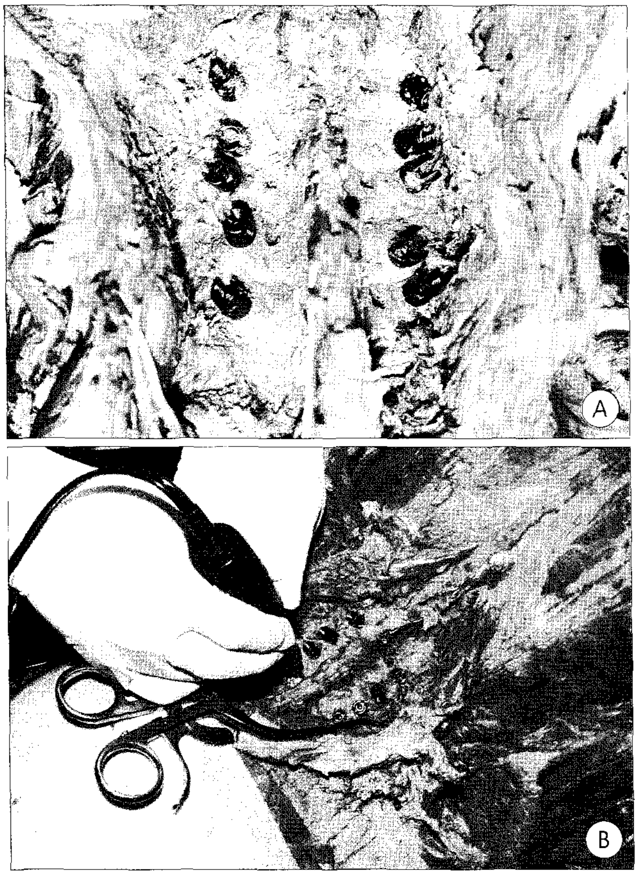


**Fig. 2.** Intraoperative photographs showing posterior aspect of the cervical spine after 10 screws insertion (A) and a partial laminotomy by drill (B).

in which a point of a superolateral quadrant of the lateral mass (2mm lateral and 2mm superior to the center of the lateral mass) was used as the starting point. Screws were inserted medially at about 45 degrees. A burr was used to decorticate the cortical bone at the starting point. Insertion trajectory was tapped with 2.5mm drill bit, and then a 3.0mm tapper was used to enlarge the screw hole through the pedicular cancellous bone. After probing the hole carefully to determine the penetration, the screw was placed into the drilled hole. No intraoperative fluoroscopy or radiographic control was used during the procedure.

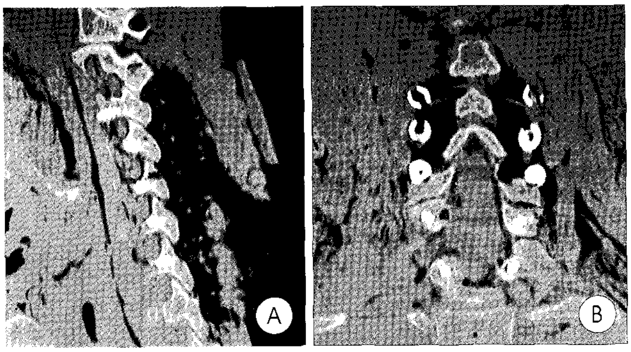


**Fig. 3.** *Computed tomography scans of the sagittal (A) and coronal* (B) reformation created with the raw scanning data. In the sagittal reformation (A), C3 screw perforate inferiorly and others are inserted properly within the cervical pedicle. In the coronal reformation (B), both C6 screws are inserted properly within the cervical pedicle.

In Group II (the laminotomy technique), 51 screws were placed into the cervical spine after a partial laminotomy in the upper part of the lamina (Fig. 2B). The starting point was guided by palpating the pedicle with a microdissector. Probing at the laminotomy site provides accurate information on structural and tactile cues of the pedicle dimension.

In Group III (the funnel technique), 18 screws were placed into the cervical spine using the same technique described by Karaikovic et al.[12], which allows identification of the arch of the medial pedicle cortex and cancellous core by decorticating the lateral mass and laminae with a drill and curette. The funnel was built with a wide posterior base that converges into the cancellous core of the pedicle. In this technique, the medial cortex of the pedicle was used as a safe guide into the pedicle entrance.

After transpedicular screws fixation, axial computed tomography (CT, Simens Somatom Sensation 16 Cardiac, Siemens Medical Solutions USA) with 1-mm slices, and sagittal and coronal reformation (Fig. 3) that was created with the raw scanning data, were performed to identify the accuracy of the screw insertion and the anatomic relationship of the screw to the spinal cord, vertebral artery, and nerve root.

Perforation of the cervical pedicle cortex was classified as mild perforation (within 1mm), moderate perforation (1~ 3mm) or severe perforation (missed the pedicle, exceeded 3mm). If no perforation was detected with the scan, the screw was rated as "contained". The contained screw group and the mild perforation group were considered as "successful insertion". The moderate and severe perforation groups were considered as "unsuccessful insertion". The author compared the severity and the direction of the perforation with each insertion technique. Mediolateral penetration groups were also compared with superoinferior direction group.

Statistical analyses were performed using an $x^2$ test and a

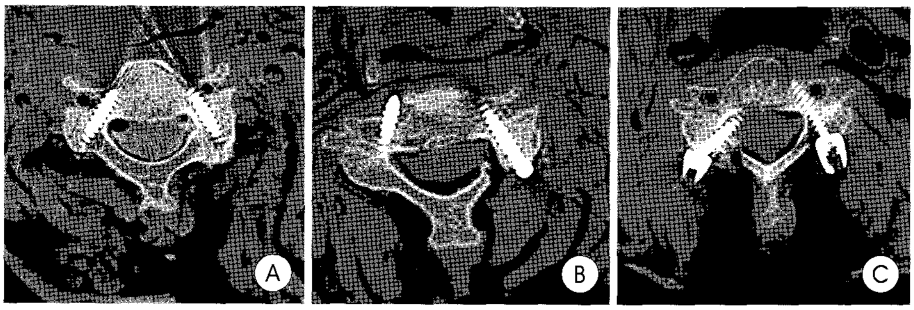


**Fig. 4.** Axial computed tomography scans. A : Both cervical pedicle screws are inserted properly within the cervical pedicle by the blind technique. B : The right cervical pedicle screw perforating the lateral pedicle toward the vertebral artery by the blind technique, and the left cervical pedicle screw perforating the lateral pedicle toward the vertebral artery by the laminotomy technique. C : The right cervical pedicle screw perforating the medial pedicle toward the spinal cord by laminotomy technique and the left cervical pedicle screw inserted properly within the cervical pedicle by the funnel technique.

Bonfenoni test in a multiple comparison study of each group and Fisher's exact test in comparison between mediolateral and superoinferior penetration groups.

## Results

A total of 100 screws were inserted by the three techniques. The results of screw insertion are shown in Table 1.

60 screws were inserted in upper cervical vertebrae(C3, C4, C5) and 40 screws in lower cervical vertebrae(C6, C7). In upper cervical vertebrae, there were 19 screws (61%) in Group I, 30 screws (58%) in Group II and 11 screws (61%) in Group III. In lower cervical vertebrae, there were 12 screws (39%) in Group I, 21 screws (42%) in group II and 7 screws (39%) in Group III (Table 6). Each technique showed no significant prevalence between upper and lower cervical vertebrae. (p=0.970, $x^2$ test). Mean perforation depth is shown in Table 7.

In Group I, 9 screws (29%) were either contained within or penetrated less than 1mm, both of which cases were rated as successful. In Group II, 24 screws (47%) were successful. In Group III, 16 screws (89%) were successful. Unsuccessfully inserted screws, which included moderate and severe perforation, were 22 in Group I (71%), 27 in Group II (53%), and 2 in Group III (11%). No severe perforation was recorded in the funnel technique group (Fig. 4). This would suggest that the funnel technique is significantly more successful than the laminotomy technique or the blind technique. In the multiple comparison, there was a statistically significant difference between Groups I and III ($p<0.001$, $x^2$ test and Bonfenoni test) and between Groups II and III (p=0.015, $x^2$ test and Bonfenoni test). Between Groups I and II, there was no statistically significant difference (p=0.501, $x^2$ test and Bonfenoni test).

Among the unsuccessful (moderate and severe perforations) screws inserted by the blind technique, lateral penetration (18 screws, 82%) was more frequent than medial penetration (3 screws, 14%). Inferior perforation was noted in only 1 screw (Table 3). Among unsuccessful laminotomy screws, medial penetration was noted in the cases of 16 screws (59%) and lateral perforation was noted in the cases of 9 screws (33%). Inferior perforation was noted in 1 screw, as was superior in 1 screw (Table 4). In the funnel technique, moderate perforation in the inferior direction was noted only in 2 screws (Table 5). Among the moderate and severe perforations (51 screws) of the three groups, lateral perforation was the most common (28 screws, 55%), followed by medial direction (19 screws, 37%). Most of the perforation were occurred mediolaterally in Group I (93%) and Group II (89%). There was a statistically significant difference between mediolateral and sup-

**Table 1.** Accuracy of transepedicular screw insertion

| | Successful | | Unsuccessful | | |
|---|---|---|---|---|---|
| | Contained | Mild perforation | Moderate perforation | Severe perforation | Total |
| Group I | 3(10%) | 6(19%) | 13(42%) | 9(29%) | 31 |
| Group II | 7(14%) | 17(33%) | 17(33%) | 10(20%) | 51 |
| Group III | 6(33%) | 10(56%) | 2(11%) | – | 18 |

**Table 2.** Direction of moderate and severe pedicle perforation

| | Mediolateral | | Superoinferior | | Total | p-value |
|---|---|---|---|---|---|---|
| | Medial | Lateral | Inferior | Superior | | |
| Group I | 3 | 18 | 1 | – | 22 | .038 |
| Group II | 16 | 9 | 1 | 1 | 27 | .035 |
| Group III | – | 1 | 1 | – | 2 | 1.0 |
| | 19(37%) | 28(55%) | 3(6%) | 1(2%) | 51 | |

**Table 3.** Accuracy and perforation rate in Group I (the blind technique)

| | Mild perforation | Moderate and Severe perforation | Total |
|---|---|---|---|
| Medial | 4(66%) | 3(14%) | 7 |
| Lateral | 1(17%) | 18(82%) | 19 |
| Inferior | 1(17%) | 1( 4%) | 2 |
| Superior | – | – | – |
| Total | 6 | 22 | 28 |

**Table 4.** Accuracy and perforation rate in Group II (the laminotomy technique)

| | Mild perforation | Moderate and Severe perforation | Total |
|---|---|---|---|
| Medial | 5(29%) | 16(59%) | 21 |
| Lateral | 9(53%) | 9(33%) | 18 |
| Inferior | 1( 6%) | 1( 4%) | 2 |
| Superior | 2(12%) | 1( 4%) | 3 |
| Total | 17 | 27 | 44 |

**Table 5.** Accuracy and perforation rate in Group III (the funnel technique)

| | Mild perforation | Moderate and Severe perforation | Total |
|---|---|---|---|
| Medial | 2(20%) | – | 2 |
| Lateral | 4(40%) | 1(50%) | 5 |
| Inferior | 2(20%) | 1(50%) | 3 |
| Superior | 2(20%) | – | 2 |
| Total | 10 | 2 | 12 |

**Table 6.** Anatomical distribution of screws according to insertion technique

| | C3, C4, C5 | C6, C7 | Total |
|---|---|---|---|
| Group I | 19(61%) | 12(39%) | 31 |
| Group II | 30(58%) | 21(42%) | 51 |
| Group III | 11(61%) | 7(39%) | 18 |
| | 60(60%) | 40(40%) | 100 |

**Table 7.** Mean perforation depth

| | Mean peforation length | SD |
|---|---|---|
| Group I | 2.06mm | ±1.21 |
| Group II | 2.01mm | ±1.57 |
| Group III | 0.89mm | ±0.96 |

eroinferior perforation in Group I (p=0.038, Fisher's exact test) and Group II (p=0.035, Fisher's exact test) (Table 2). In Group III, mediolateral perforation rate (58%) was much less than other two groups and the results showed no directional prevalence between superoinferior and mediolateral perforation.

## Discussion

In cases with cervical decompression, traumatic injury, neoplastic and spondylolitic conditions, multilevel instability, and postlaminectomy kyphotic reconstructions, the transpedicular screw can be utilized as a useful supplementary measure[15]. Bueff et al.[7], in an experimental study, found that C7 pedicle screws provided more rigid stability than C7 lateral mass screws in fixation. The evidence that transpedicular screws have greater pull-out strength than lateral mass screws was presented by Jones et al.[9]. The comparative biomechanical performance of transpedicular screw fixation was examined by Kotani et al.[13]. Transpedicular screw fixation was demonstrated to offer increased stability over conventional posterior cervical instrumentation methods when treating multicolumn injuries and multilevel instability pattern in a calf spine model.

For successful insertion of pedicle screws, anatomic studies of the cervical spine have yielded important information. Panjabi et al.[17] and Jeanneret et al.[8] described anatomical landmark and angulation for screw placement. They indicated that a computed tomography(CT) scan was required as a preoperative examination to determine the appropriate screw angle.

The results on lower cervical levels (C6, C7) showed greater accuracy due to the morphometry of the pedicle. The caudal subaxial vertebrae (C6, C7) have larger pedicle diameters and thus have fewer critical perforation[16]. In the current study, we chose insertion method randomly regardless of vertebral level. Fortunately, it doesn't show significant prevalence between upper and lower cervical vertebrae at each group. In the funnel technique, the rate of the screw in upper cervical vertebrae was more than that of upper levels.

Fifty-eight cases were reported by Abumi et al.[1,2] to manage subaxial traumatic and nontraumatic cervical injuries. Three cortical perforations was noted on postoperative CT scan. There were no neurologic or vascular complications. This investigation was the first report of a method describing the starting point of screw insertion in the posterior aspect of the lateral mass using a surface landmark. The starting point of the cervical screw was proposed as 1mm inferior to the caudal edge of the facet joint in the midline of the lateral mass. Twenty-one patients with transpedicular screw insertion were reported by Albert et al.[6]. After a laminoforaminotomy was performed at C7, all transpedicular screws were inserted. There were no neurologic complication concerning the screw insertions.

When performing transpedicular screw fixation, it is advantageous to choose a method that provides the best margin of safety. Kramer et al.[15] studied the human cadaveric cervical spine from C3 to C7 by three techniques : using topographic guidelines, performing laminoforaminotomy, and using a computer-assisted image-guidance system. They demonstrated that the computer-assisted image-guidance system has the greatest potential for improving surgeons' understanding, compared with the two previous methods. Critical perforations of the pedicle cortex were noted in 66% of the cases using topographic guidelines and in 40% of cases using the laminoforaminotomy, but in only 11% of the cases using the computer-assisted image-guidance system.

The rate of pedicle wall perforation in our three techniques was higher than those reported clinically by Abumi et al.[2,3]. The preoperative computed tomography and fluoroscopic guidance might have provided information about the pedicular dimension and trajectory of the screw placement. However, neither intraoperative fluoroscopy nor preoperative computed tomography were used during the procedure.

Most of the perforations were encountered laterally. This was explained by a thinner pedicle lateral cortex[10,18]. However, in Group II, the rate of medial perforation was more than that of lateral perforation, which was different from the results of previous reports[15]. The reason for this occurrence in the current study is most likely the awareness of the pedicle characteristics. It was thought that the operator went too far to the medial side of the cervical pedicle after identifying the medial wall by laminotomy. The tendency of perforation on mediolateral side of the pedicle also can be explained by the fact that cervical pedicle height, as measured from the superior to the inferior border of the pedicle, is significantly greater than the pedicle width as measured from the medial to lateral border of the pedicle[17].

The laminotomy technique is a fairly simple procedure and provides access to the medial wall of the pedicle. A probing from the superior to the inferior border on the medial side of the pedicle yields visual and tactile information as well as sense of the overall sagittal diameter and orientation[15]. But there are several risks in the laminotomy technique. Epidural hematoma after operation and a hazard of dura or spinal cord injury as a consequence of dural exposure by partial laminectomy should be considered. In the funnel technique, there is no danger because dura is not exposed.

According to the present study, the funnel technique was more accurate than other techniques. The author could identify the starting point of the cervical pedicle with the naked eye. The pedicle was a funnel shape with a wide posterior base, which narrowes toward the pedicle and the isthmus. The pedicle screw was directly inserted through the funnel and led into the pedicle isthmus and vertebral body in Group III. However, in the other two techniques, the transpedicular screw was inserted into the pedicle by supposition because the screw was passed through the lateral mass. In the funnel technique, although these funnel shape pedicle provided more accurate screw insertion, excessive decortication of the lateral mass makes the screw purchase shorter, which might decrease the pull-out strength of pedicle or leads to failure of the screw insertion. However, Kowalski et al.[14] reported that there is no loss in pull-out strength of cervical pedicle screws when the cancellous bone of the lateral mass is removed.

As another determining factor for perforations, pedicle diameter and inclination might be considered. Sharp angulation of the cervical pedicle makes transpedicular screw insertion more difficult than thoracic or lumbar pedicle insertion. A surgeon's previous experience in placement of lumbar and thoracic pedicle screws also can cause difficulty in transpedicular screw insertion[11]. In cadaver, the soft tissue was very rigid and it was extremely difficult to get lateral angulation of insertion, which means they are significantly influenced by the retraction status of the soft tissue. Because operator couldn't get enough lateral retraction the starting point has to be moved medially, thus leading to more mediolateral perforation. Group I, II showed more perforation in mediolateral direction than Group III, which means funnel technique is less likely to be influenced by the lateral retraction state. Moreover, the size of the screw can be thought to cause perforation. Panjabi et al.[18] demonstrated that the width and height of the cervical pedicles are the largest at C2 and the smallest at C3, with gradual increases to C7. The inner mediolateral diameter of the cervical pedicle represents the greatest diameter of the screw. The optimal diameter of the screw is smaller than the inner mediolateral diameter of the cervical pedicle. Several investigations have reported screw diameters of 4.0mm[8], 4.5mm[1], and 5.5mm[13].

In this study, it was the operator's observation that the blind technique was impossible to find proper trajectory because the lateral mass was not uniform in shape. The center of lateral mass could be very variable depending on surgeon's experience. With laminotomy technique, the medial border of the pedicle were clearly visible but we could not sure whether the screw was exact in trajectory as we wanted. The funnel technique gives confidence to the surgeon that the screw is within the pedicle and it passes right direction in most cases.

## Conclusion

In this study, the author compared the accuracy of three transpedicular screw insertion techniques. In the funnel technique, the author could locate the starting point more accurately and this technique was less dependent on retraction state than other insertion techniques. This technique can help a surgeon's understanding about the cervical pedicle more precisely than the other two techniques.

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## Commentary

I read with a great interest "Comparison of Three Different Techniques in Cervical Transpedicular Screw Insertion." I would like to congratulate the author(s) on their very informative and well organized anatomic study. I generally agree with the authors' view of cervical pedicle screw insertion including funnel technique.

The present author(s) concluded that the funnel technique could help a surgeon's understanding about the cervical pedicle more precisely than the other two techniques, that is, the blind technique and the laminotomy technique. The small diameter, steep medial angulation, and thin cervical pedicle cortex toward the vertebral artery create placement challenges not encountered in the thoracic or lumbar spine. Karaikovic et al.[3] originally considered every pedicle to be built as a funnel with a wide posterior base, which narrows towards the isthmus. A distinct characteristic of the cervical pedicles is that the lateral pedicle wall is always the thinnest cortex[2,7]. Therefore, the medial pedicle cortex was used as a safe guide into the pedicle isthmus, then through it and then into the vertebral body. The arch of the medial pedicle wall, under which advancement into the pedicle proceeded, was always identified. These findings have great importance for a practicing spine surgeon because both pedicle parameters (the outer mediolateral diameter/width, and the lateral wall thickness) can be measured easily on routine axial computed tomography scans of the cervical spine[2,3,4]. A surgeon not familiar with cervical pedicle anatomy can easily perforate a pedicle regardless of its diameter. Although the pedicles in the upper cervical spine are more ellipsoid, the pedicles in the lower cervical spine more round, Karaikovic consisted that the outer pedicle width remains the critical parameter in most cases[1]. With this point in mind, I wonder if there was no difference of pedicle perforation between upper and lower cervical pedicles in the present authors' series.

I would like to mention that most surgeon prefer using the fluoroscope when they insert cervical pedicle screws. I believe the unusually low success rate of Group I (modified Abumi technique) in the present study hardly happen during the actual pedicle screw insertion during surgery on the cervical spine under the fluoroscopic guidance with decancellation of the entire lateral mass with a drill as adopted by Kowalski et al.[6]. Also if a computer-assisted-navigation system is equipped, we could increase the accuracy of screw placement, meanwhile decrease complication rates[5].

Eun-Sang Kim, M.D., Ph.D.
Department of Neurosurgery, Samsung Medical Center

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