Complications of Pedicle Screw Fixation in Reconstructive Surgery of the Cervical Spine

Kuniyoshi Abumi, MD, Yasuhito Shono, MD, Manabu Ito, MD, Hirosi Taneichi, MD, Yoshihisa Kotani, MD, and Kiyoshi Kaneda, MD

Pedicle screw fixation in the cervical spine has been considered too risky for the neurovascular structures, with the exception of the C2 and C7 vertebrae. Camille et al. stated that placement of screws in the C3–C6 pedicles would be associated with an unacceptable risk. In the upper cervical spine, there have been some reports of direct screw fixation of C2 pedicles in hangman's fracture. There have been several reports in the literature detailing the combined use of C2 or C7 pedicle screw fixation with C3–C6 lateral mass screw fixation. However, even the surgeons who insert screws into the C2 and C7 pedicles hesitate to place them in C3–C6 pedicles and recommend use of the lateral mass screw. According to previously reported studies, screw insertion into the lateral portion of the articular mass also exposes the spinal nerve or the vertebral artery to risk of injury. Kotani et al. have shown that of the many fixation devices used in the cervical spine, only the pedicle screw system and combined anterior plate and posterior wiring provided adequate stability in a circumferential discoligamentous cervical injury model. Bueff et al. demonstrated in an experimental study that C7 pedicle screw provided more rigid stability than C7 lateral mass screws in fixation of the cervicothoracic junction. The results of a recent comparative biomechanical study on the cervical spine by Jones et al. provided evidence of greater pullout strength of cervical pedicle screws than of lateral mass screws.

Abumi et al. first reported the results of pedicle screw fixation for traumatic lesion of the middle and lower cervical spine in 1994. Thereafter, they expanded indications for cervical pedicle screw fixation to lesions other than spinal trauma. Their clinical results showed that the cervical pedicle screw fixation procedure is one of the potential procedures for posterior reconstruction of the cervical spine in various kinds of disorders. This technique was particularly valuable for simultaneous posterior decompression and reconstruction in the cervical spine. In addition, they reported effectiveness of the cervical pedicle screw as an anchor for craniocervical fixation.

The greater pullout strength of pedicle screws enhances the capability for reduction of transitional deformity, for correction of cervical kyphosis and for reduction of flexion deformity at the craniocervical junction. Although, pedicle screw fixation provides many advantages in the reconstructive surgery of the cervical spine, the risks of damaging the neurovascular structures associated with screw placement into the cervical pedicle cannot be completely eliminated.

The objective of the current study was to clarify the complications associated with cervical pedicle screw fixation through the review of clinical and radiologic results.
of 180 patients with various cervical spinal disorders who had been treated by pedicle screw fixation. Based on the analysis of these results, the safety of the cervical pedicle screw fixation procedure is reported and the importance of preoperative planning and adequate surgical methods in reducing the risks associated with the procedure is emphasized.

Materials and Methods

From August 1990 through January 1997, 180 patients who needed cervical or occipitocervical reconstructive surgery were treated by pedicle screw fixation at the authors' hospital and affiliated hospitals. There were 106 males and 74 females. Average age at the time of the surgery was 51.8 years (range, 13-84 years). Cervical disorders included spinal injuries in 70 patients, occipitocervical or cervical lesions caused by rheumatoid arthritis in 35, cervical myelopathy due to spondylolisthesis or ossification of the posterior longitudinal ligament in 24, metastatic or primary vertebral tumor in 16, destructive spondyloarthropathy caused by long-term hemodialysis in 8, spinal cord tumor in 8, and other in 19. Occipitocervical fixation was performed in 28 patients. Cervical or cervicothoracic fixation was conducted in the remaining 152 patients. In 38 patients, the laminas were removed or laminoplasty was performed for staged decompression and reconstruction or the laminas had been removed by previous decompression surgery. A total of 712 screws were inserted into the cervical pedicles.

Implants. Pedicle Screws. Steffee variable screw placement (VSP) (AeroMed Inc., Cleveland, OH) screws made of stainless steel with 4.5-mm diameter were used in 34 patients in the early phase of this series. The newly designed cervical pedicle screw fixation system (CPS) (AeroMed Inc., Cleveland, OH), consisting of screws and plates made of titanium alloy or stainless steel, was used in the remaining patients in the recent phase of this series. The CPS screws provided were 3.5, 4.0, and 4.5 mm in diameter, and 20, 22, 24, and 28 mm in length.

Longitudinal Members. The VSP screws were connected by VSP plates or Isola rods (AeroMed) made of stainless steel in cervical or cervicothoracic fixation in the early stage of this series. The CPS screws were connected by CPS plates or Isola rods made of titanium alloy in the late stage of the series. For occipitocervical fixation, Cotrel-Dubousset (CD) occipitocervical rods (Sofamor Danek, Memphis, TN) made of stainless steel were used in eight patients in the early stage of this series, and the occipitocervical rods of Spine System (Aesculap AG & Co., Tuttingen, Germany) were used in 20 patients thereafter. For the CD system, two rods were connected by a horseshoe-shaped plate. In contrast, the rod of the Spine System was divided into two parts (right and left portion) and applied to the occipital bone independently. To connect the CPS screw with the rods, screw-rod connectors for the Isola system or newly designed CPS-rod connectors made by titanium alloy were used. Secure fixation of the rod or plate to the VSP or CPS screw was obtained by a constrained connecting mechanism.

Surgical Techniques. The patient was placed prone on a Relton-Hall frame, and the head was fixed using a horseshoe-type head rest or a Mayfield 3-pin skull fixation. The cervical spine was maintained in a neutral position, and the shoulders were pulled caudal by a heavy bandage to obtain clear intraoperative lateral radiographic image of the lower cervical spine. The numbers of the motion segments in which fixation procedures were performed ranged from zero to nine (average 2.6). Zero segments indicates osteosynthesis of the fractured vertebra in a hangman's fracture of the axis or separation fracture of the lateral mass.

The same techniques of screw insertion, bone grafting, and application of the longitudinal members described by Abumi et al.1-3 were used. After the screw insertion hole was created with a high-speed burr, a small pedicle probe was inserted into the pedicle with the help of a lateral image intensifier to confirm the direction and insertion depth. Tapping was performed before insertion of the screw. A drill bit was never used to penetrate the cortex of the lateral mass or to make a hole for screw advancement. In the cases in which it was difficult to insert the pedicle probe into the neurocentral junction, which is near the base of the pedicle in the vertebral body, the junction was perforated with a Kirschner wire to make the path for the pedicle probe into the vertebral body. Whenever possible, pedicle screw insertion was performed before laminectomy or laminoplasty.

For correction of middle or lower cervical kyphosis, rods or plates were contoured to form physiologic lordosis and attached to the pedicle screws. Correction of the kyphosis was performed segmentally by loading compression force between the inserted screws. The occipitocervical rods were contoured at the plate-rod junction to reduce hyperflexion alignment at the occipitocervical junction. Distraction force was applied with a spreader between the plate portion of each rod and the head of each screw inserted into the pedicle of C2 to reduce the upward migration of the odontoid process.

Radiologic Evaluation. Plain roentgenograms, computed tomography (CT) with a bone window, and magnetic resonance imaging were performed before surgery in all patients. Myelography and CT myelography were also performed in most of the patients. Bilateral oblique plain radiographs were obtained in all patients to evaluate the condition and size of the pedicles of each vertebra. The kyphosis angle in the midcervical spine was measured on lateral radiographs in the patients in a standing position. The angle between the lines drawn at the posterior margin of the most cephalad and caudal vertebral bodies forming the kyphosis was recorded as the kyphosis angle. Radiographic evaluations were performed 3, 6, 12, and 24 months after surgery and annually thereafter, to assess stability, deformity, and fusion. Solid union was assessed on the basis of the presence of a homogeneous fusion mass on lateral tomographs and segmental motion less than 2° on flexion-extension radiographs, as well as the absence of a clear zone around the pedicle screws. Postoperative CT scans were not obtained in four patients who died in the postoperative early stage, and seven patients refused to undergo postoperative CT examinations, mainly for economic reasons. In the remaining 169 patients, 669 screws inserted in the cervical pedicles were evaluated on CT scans and lateral and oblique radiographs independently by two radiologists. According to their report, if one or both of the two observers determined that the screw or screw thread penetrated the wall of the pedicle, the screw was judged to have "perforated," regardless of the clinical complications.

Postoperative Management. Postoperative immobilization varied according to the number of the spinal segments fixed, the patient's general condition, and the extent of osteoporosis. In
principle, to patients in whom short segmental fixation was performed a short, soft neck collar was applied after surgery for 2–3 weeks. A Philadelphia collar was applied for 2–3 months in patients with severe osteoporosis and in patients who had fixation of four or more motion segments. More rigid postoperative external supports including halo vest immobilization were not used. However, two patients who underwent occipitocervical fixation required halo vest immobilization for dislodgement of the occipital screws. Patients were allowed to ambulate or sit up in the bed the day after surgery if their general conditions permitted.

Results

Fourteen patients with metastatic vertebral tumors died between 2 and 23 months after surgery because of exacerbation of the primary disease. Two patients with severe spinal cord lesions died in the early postoperative stage for reasons unrelated to the surgery. The remaining 164 patients underwent more than 2 years’ follow-up. Excluding 16 patients with metastatic vertebral tumor who did not receive bone graft for fusion and two patients who died soon after surgery, the fusion rate was 99.4%. There were no patients with postoperative neurologic deterioration.

Complications Directly Attributable to Screw Insertion

There were three patients (1.7% of the patients; 0.4% of the inserted cervical pedicle screws) with neurovascular complications directly attributable to screw insertion into the cervical pedicles. Intraoperative injury of the vertebral artery during the taping of the fractured pedicle occurred in one patient with compressive extension injury at C6–C7. The bleeding was stopped by packing of bone wax into the insertion hole, and the fixation was performed by unilateral plating. No further neurologic complication or ischemia in the brain was observed, and solid fusion was completed (Figure 1). Radiculopathy caused by an inserted pedicle screw was identified the morning after surgery in two patients. A C6 nerve root lesion by superiorly perforated C6 screw threads resolved during the course of the follow-up without screw removal, and a C5 nerve root lesion caused by an inferiorly perforated C4 screw was associated with muscle weakness that recovered to normal strength after screw removal. Screw insertion into the lower adjacent disc occurred in one patient.

Complications Not Directly Attributable to Screw Insertion

Iatrogenic foraminal stenosis that caused C5 radiculopathy was observed in one patient with subaxial lesion caused by rheumatoid arthritis. The radiculopathy was due to reduction of the anterior translation of C4. The stenotic condition of the intervertebral foramen of C4–C5 was confirmed by the additional surgery consisting of foraminotomy without removing the screw and application of distraction force, and the C5 radiculopathy recovered completely.

Progressive degenerative change at the adjacent mobile segments was observed in three patients, and two patients who showed significant instability required extension of the fusion by pedicle screw fixation. One patient with atlantoaxial subluxation and subaxial lesion due to rheumatoid arthritis, who had C1–C2 fusion by Magerl procedure for atlantoaxial subluxation and combined C3–C7 posterior fusion using pedicle screw fixation and C4–C7 anterior fusion for subaxial lesion,
showed a degenerative change 3 years after the initial surgery at a nonfused C2-C3 segment with anterior translation of C2. Additional posterior fusion from the occiput to C7 was performed. In this surgery, the C1-C2 transarticular screws were removed and replaced with C2 pedicle screws. One patient with destructive spondyloarthropathy who had C2-C4 and C5-C7 pedicle screw fixation and anterior decompression and fusion that skipped C4-C5, showed postoperative degenerative change at the unfused C4-C5 segment. Twenty-six months after initial surgery, supplemental fixation was performed to connect previously fused portions using cervical pedicle screws and Isola rods (Figure 2).

Deep wound infection in two patients was successfully treated by continuous irrigation for 2 weeks without removal of the implants. Pseudarthrosis was observed in one patient and was managed by pedicle screw fixation with elongation of the fusion range. Leakage of cerebrospinal fluid occurred in eight patients after posterior decompression and was managed by lumbar subarachnoid drainage for 10-14 days without sequelae. Dislodgment of occipital screws occurred in two patients. In one patient with Down syndrome, the occipital screws and plate dislodged on the fifth postoperative day. Fixation of the rod to the cranium in this patient was performed by increasing the number of screws and altering the screw insertion points of the cranium. In this patient, a 3-month immobilization with a halo vest was necessary until a bony union formed. In another patient with rheumatoid arthritis, loosening of an occipital screw occurred without dislodgment of the plate and was treated by immobilization in the halo vest for 3 months without reoperation. One patient who previously had cervical spine surgery needed plastic surgery using vascularized myocutaneous flap for delayed wound healing after a salvage operation. Skin irritation by screw heads occurred in two thin women, and the implant was removed after solid union was achieved (Table 1).

Table 1. Complications Related to Posterior Cervical Screw Fixation in Seven Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Present Study</th>
<th>Fehlings11</th>
<th>Graham12</th>
<th>Heller13</th>
<th>Levine18</th>
<th>Wellman25</th>
<th>Zlotolow27</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>180</td>
<td>44</td>
<td>21</td>
<td>78</td>
<td>24</td>
<td>43</td>
<td>87</td>
</tr>
<tr>
<td>No. of screws</td>
<td>712</td>
<td>210</td>
<td>164</td>
<td>654</td>
<td>281</td>
<td>556</td>
<td></td>
</tr>
<tr>
<td>Nerve root injury by screw</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Spinal cord injury by screw</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Vertebral artery injury by screw</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nerve root injury by foraminal stenosis</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Screw loosening or avulsion</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>7</td>
<td>2</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Loss of reduction</td>
<td>0</td>
<td>3</td>
<td>7</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pseudarthrosis</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Infection</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Screws were inserted into the pedicles in the present study, and into the lateral mass in the remaining six studies.
Table 2. Incidence of Screw Perforation From the Cervical Pedicle

<table>
<thead>
<tr>
<th>Vertebral Level</th>
<th>No. of Inserted Screws</th>
<th>No. of Perforated Screws</th>
<th>Incidence of Screw Perforation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2</td>
<td>74</td>
<td>3</td>
<td>4.1</td>
</tr>
<tr>
<td>C3</td>
<td>66</td>
<td>4</td>
<td>5.9</td>
</tr>
<tr>
<td>C4</td>
<td>123</td>
<td>13</td>
<td>10.6</td>
</tr>
<tr>
<td>C5</td>
<td>145</td>
<td>10</td>
<td>6.9</td>
</tr>
<tr>
<td>C6</td>
<td>167</td>
<td>7</td>
<td>4.2</td>
</tr>
<tr>
<td>C7</td>
<td>92</td>
<td>8</td>
<td>8.7</td>
</tr>
<tr>
<td>Total</td>
<td>669</td>
<td>45</td>
<td>6.7</td>
</tr>
</tbody>
</table>

Radiologic Evaluation

Forty-five of 669 screws (6.7%) showed perforation of the screw from the pedicle wall to various extents. Two of these 45 screws caused radiculopathy. The portion of the pedicle perforated by the screw was the medial wall in 21 screws, inferior in 10, lateral in 10, and superior in 4. There was no statistical difference between the inserted sides: right (21 screws) or left (24 screws). Table 2 shows the number and incidence of perforated screws in each vertebral level. The incidence of screw perforation was the highest in C4 followed by C7 (Table 2). Excluding the patients with fresh spinal injury and the patients with metastatic vertebral tumors, there were 31 patients with cervical kyphosis of more than 15°. In these patients, averaged preoperative kyphosis of 29.5° (range, 15–52°) improved to 2.8° (range, −8–28°) at the final follow-up.

Discussion

Although cervical pedicle screw fixation is the most rigid fixation method of the cervical spine\(^8,14,17\) and has many biomechanical advantages in reconstruction of the cervical spine, this procedure has been criticized for the risks to the neurovascular structures. Karaikovic et al\(^16\) showed anatomic limitations of the pedicle screw in the cervical spine. According to their report, the pedicles in some patients are too small in diameter to allow screw insertion. Therefore, preoperative plain radiographs (bilateral oblique views) and CT evaluations (adjusted to the bony windows) are essential for assessment of the pedicle condition and determination of the pedicle size that also allow surgeons to decide appropriate pedicle screw diameter and length. Ebraheim et al\(^10\) stated that considering the amount of anatomic variations of the cervical pedicles between patients and levels, combined use of CT scan and conventional radiographs might en-

Figure 3. A, A 58-year-old woman with subaxial lesion caused by rheumatoid arthritis. B, One-stage posterior decompression of the spinal cord and reduction and fusion using cervical pedicle screw fixation was performed. C, A postoperative computed tomographic scan demonstrated C4 pedicle screws perforating the lateral pedicle wall toward the vertebral artery. D and E, Postoperative angiographs of the vertebral artery showed normal flow of the arteries without obstruction or rupture.
Complications of Cervical Pedicle Screw Fixation

Abumi et al. 967

Figure 4. A, A 48-year-old man with an old C3-C4 distractive extension injury associated with severe myelopathy. B, C, One-stage posterior decompression by laminoplasty and fusion using pedicle screw fixation was performed. D and E, Postoperative computed tomography showed proper insertion of the C3 pedicle screws and C4 screws with medial perforation of the pedicle wall. No postoperative spinal cord lesion caused by C4 screws was observed.

hance the safety of pedicle screw fixation in the lower cervical spine.

Karaikovic et al.16 showed that the cortex of the cervical pedicles is always thinnest laterally toward the vertebral artery, and they admonished that surgeons should keep this in mind during probing and tapping of the pedicle and while placing the screws. In contrast, screw insertion into the C2 pedicle, which has a larger pedicle diameter compared with those of C3-C7, can be conducted by direct visualization and confirmation of the superomedial surface of the pedicle without performing laminectomy. Presumably, a C2 pedicle screw procedure would be safer than insertion into the pedicles of C3-C7. Actually, postoperative radiologic assessment of the inserted screws in this study showed that incidence of screw perforation from the pedicle was the lowest in C2, the highest in C4, and the next highest in C7 (Table 2). The highest incidence of screw perforation in C4 may be attributed to the fact that the pedicle diameter is the smallest in C4. In the C7 screw insertion procedure, the shoulder girdles frequently obstruct a clear intraoperative lateral radiographic image of the pedicles. This problem may contribute to a high incidence of C7 pedicle screw perforation.

In this series, there were nine screws that perforated laterally. However, no vertebral artery injuries were observed. The vertebral artery does not occupy the whole area of the foramen transversarium. Therefore, the chance of vertebral artery injury by laterally perforating pedicle screws may not be so high (Figure 3).

According to the published anatomic studies, the cervical nerve root run approximately 45° anterolaterally in relation to the coronal plane and 10° downward in relation to the transverse plane.9,20 Within the foramen, they are located at the disc level and below it—i.e., in the inferior half of the neural foramen.20 Thus, there is some room between the neural elements and surface of the medial and inferior pedicle walls. Therefore, slight
perforation of pedicle wall by screw threads in the medial or inferior direction is relatively safe for the spinal cord and nerve root in the cervical spine (Figure 4).

Selection of the proper screw insertion point and confirmation of insertion of a pedicle probe into the vertebral body are especially important in cervical pedicle screw fixation. Direct exposure of the pedicle cavity by creating a hole with a burr and a small curette and pedicle probing guided by lateral radiographic imaging augment the safety of cervical pedicle screw placement. The results of this series show that if proper screw insertion is performed and adequate screw diameter is determined, the incidence of pedicle screw perforation laterally toward the vertebral artery can be minimized. In this series, injury of the vertebral artery during tapping of a fractured pedicle occurred in one patient. Screw insertion into the fractured pedicle must be performed with great care. The authors observed one case of nerve root lesion that was unrelated to pedicle screw insertion. Foraminal stenosis due to excessive reduction of the anterior translational deformity was the cause of nerve root lesion as described by Heller et al. Application of distraction force to open the narrowed foramens during a reduction maneuver can effectively prevent this type of complication.

In studies regarding lateral mass screw procedures, investigators have described several cases of nerve root complications and screw loosening with pseudarthrosis and/or loss of kyphosis correction. The incidence of neurovascular complications was low. The risks to neurovascular structures cannot be completely eliminated. Thorough knowledge of local anatomy, careful preoperative planning, and intraoperative imaging are essential in this procedure. Furthermore, navigational computer assistance may increase the safety of screw insertion into the cervical pedicle. With advent of this technology, cervical pedicle screw fixation may become a more popular reconstructive procedure for cervical spine disorders.

**Conclusions**

The incidence of clinically significant complications of screw insertion into the cervical pedicle was low. The rates of neurovascular complications were 1.7% of the patients and 0.4% of the inserted pedicle screws. Complications associated with cervical pedicle screw insertion can be minimized by sufficient preoperative imaging studies of the pedicles and strict screw insertion technique using a lateral radiographic image and pedicle probe. Pedicle screw fixation is a useful procedure for reconstruction of the cervical spine with various kinds of disorders and can be performed safely.

**Key Points**

- The complications of the cervical pedicle screw fixation in 180 patients were analyzed.
- Injury of the vertebral artery in one patient and radiculopathy in two were caused by screw insertion.
- The incidence of neurovascular complications caused by cervical pedicle screws was low.
- Neurovascular complication by cervical pedicle screw can be minimized by sufficient preoperative evaluation of the pedicles and strict screw insertion technique.

**References**

Complications of Cervical Pedicle Screw Fixation


Address reprint requests to
Kuniyoshi Abumi, MD
Department of Orthopaedic Surgery
Hokkaido University School of Medicine
N-15 W-7, Kita-Ku
Sapporo 060-8638, Japan
E-mail: abumi@med.hokudai.ac.jp