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Posterior Lateral Mass Screw Fixation: Anatomic and Radiographic Considerations

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Abstract: During the last 10 years, posterior plating utilizing lateral mass screw fixation has become more popular for treating instability of the lower cervical spine. Injury to the spinal nerves associated with insertion of lateral mass screws is the main complication of this procedure. The purpose of this article is to briefly review the status of this procedure and to update the advances in anatomic and radiographic studies as to avoid or minimize spinal nerve injury.

Introduction

Posterior plating utilizing lateral mass screw fixation has been widely accepted for treating the unstable cervical spine caused by trauma, neoplasms, significant degenerative conditions, and failed anterior fusions [1–6]. Clinical studies have shown that posterior cervical plating results in a high rate of fusion [2–4,7]. The major advantage of this procedure is that it provides equal or greater biomechanical stability when compared to anterior plating or traditional interspinous wiring techniques [8–11]. It is also a superior method for patients who have had extensive, multiple-level laminectomies and for those whose spinous processes, laminae, and facets are injured or deficient. Injury to the adjacent nerve roots associated with lateral mass screw insertion and screw fixation failure is the main potential complication [7,12]. A solid anatomic and radiographic knowledge may avoid or minimize anatomic complications during lateral mass screw insertion. This article presents a brief review of the status of posterior lateral mass fixation, including anatomic and radiographic considerations, which will help to decrease the complications associated with this technique.

Current Status

Historical review

In 1964 in France, Roy-Camille [13] was the first to insert screws into the lateral mass of the cervical spine to stabilize the unstable spine. Those to follow included Louis [4] in France and Magerl [3] in Switzerland. The senior author [1] introduced the Roy-Camille technique in the United States for treating fractures and dislocations of the lower cervical spine.

Screw insertion techniques

Several techniques of lateral screw placement have been developed. Each has its unique entrance point for screw insertion and screw trajectory (Fig. 1). Roy-Camille [13] advocated that the entrance point for screw insertion should be located at the top of the lateral hill of the lateral mass, exactly at its midpoint. The entrance point is then drilled with a 2-mm bit, perpendicular to the vertebral plane and 10 degrees lateral to the sagittal plane. The drill hole is further tapped with a 3.5-mm tap, and a contoured Roy-Camille cervical plate of appropriate length is secured with cortical screws of 3.5-mm diameter. Louis [4] developed another technique in which the starting point for screw insertion is situated at the intersection of a vertical line 5 mm medial to the lateral margin of the inferior facet and a horizontal line 3 mm below the inferior margin of the inferior facet. The screw hole is drilled with a 2.8-mm bit, and the drill bit is directed strictly parallel to both sagittal and axial planes of the vertebra. The screw should not penetrate the ventral cortex, otherwise the nerve roots directly anterior to the superior facet may be at increased risk. Magerl [3] recommended that the screw entrance point be slightly medial and cranial to the posterior center of the lateral mass and the orientation of the screw be 20 to 30 degrees lateral and parallel to the adjacent facet. Anderson et al. [2] modified Magerl's technique. They recommended that the starting point for screw insertion be 1 mm medial to the center of the four boundaries of the lateral mass and screw direction be 30 to 40 degrees cephalad (parallel to the facet joint) and 10 degrees lateral. The screw hole tapping should be limited to the dorsal cortex to achieve sound bicortical bony purchase. An et al. [14] recommended that the ideal screw direction should be approximately 30 degrees lateral and 15 degrees cephalad starting 1 mm medial to the center of the lateral mass for C3–C6. For C7 special care should be taken during screw placement because the anteroposterior diameter of the lateral mass is thin.

Clinical efficacy

Several investigators have performed clinical studies, and a high fusion rate utilizing posterior cervical plating has

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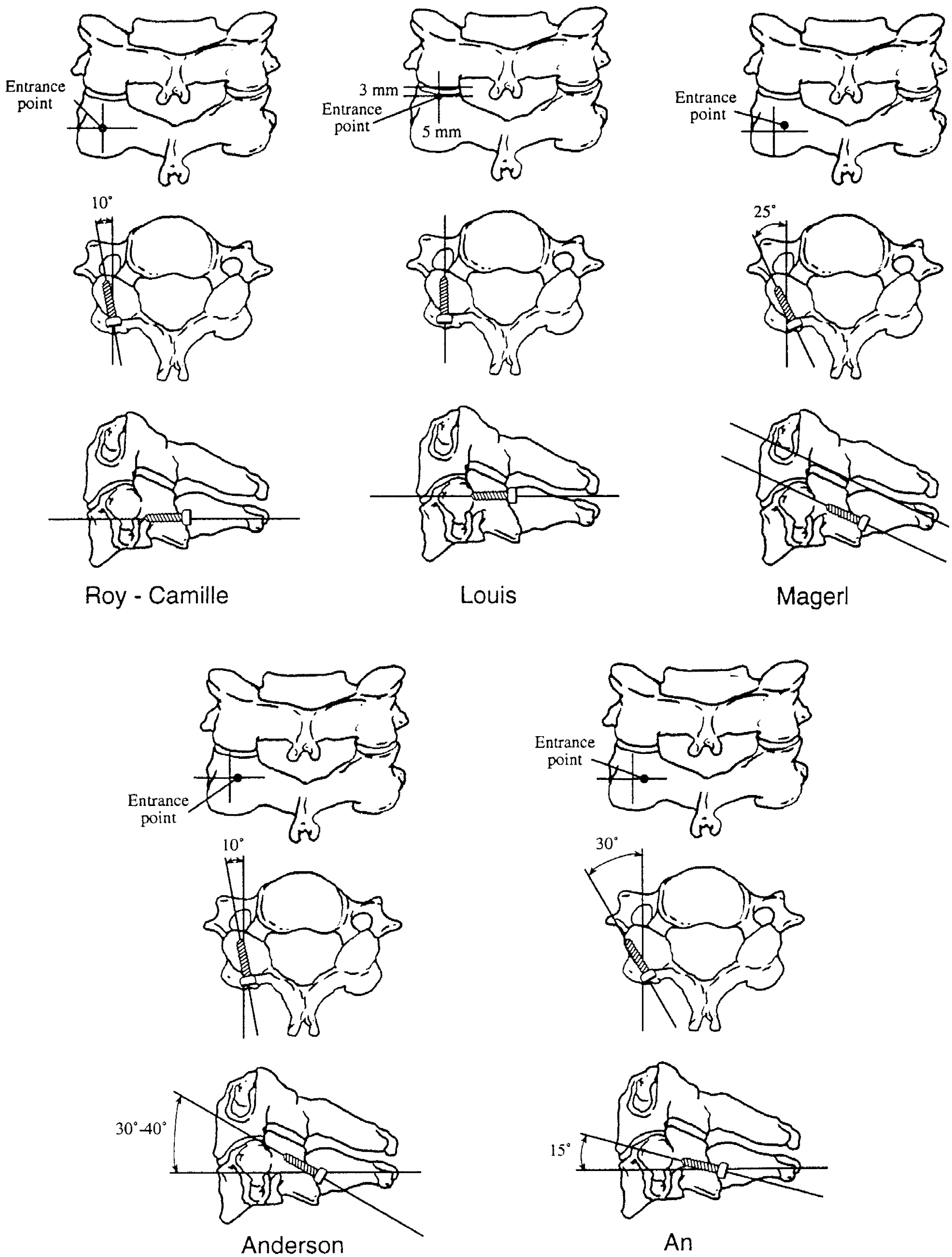

Fig. 1. Illustration of various screw insertion techniques.

been reported in the literature. A 100% fusion rate was documented by Nazarian and Louis [4], Jeanneret and Magerl [3], Anderson et al. [2] and Graham et al. [7] with a maximum follow-up of 54 months. A 95–99% fusion rate was reported by Heller et al. [12], Cooper et al. [15], Fehlings et al. [16], and Wellman et al. [17]. In their series, the mean follow-up ranged from 9 to 46 months. The largest series reported in the literature is from Roy-Camille et al. [5] who reported 197 cases treated with posterior lateral mass plating. They documented that 85% of the patients achieved posterior stabilization after lateral mass plating.

Complications

The complications associated with lateral mass screw fixation consist of two categories: anatomical and biomechanical. Potential anatomic complications include injury to the spinal cord, vertebral artery, spinal nerves, and facet joints. Biomechanical complications involve screw loosening, screw pullout, or screw failure. Injury to the spinal nerve is the only reported complication with lateral mass screw insertion. The reported incidence of spinal nerve injury with lateral mass screw insertion varies greatly among individuals. Levine et al. [18] reported that 6 of 72 patients developed radicular symptoms following posterior lateral mass screw placement. In their series, Bassett and Zdeblick [19] found that one patient had C6 nerve root symptoms after surgery. Based on a review of 72 cases, Heller et al. [12] documented that the incidence of spinal nerve injury associated with posterior plating and lateral mass screw fixation was 0.6%. Graham et al. [7] reported a high incidence of nerve root complication with lateral mass screw insertion. They found that 10 (6.1%) of 164 lateral mass screws were malplaced in 21 consecutive patients. Nerve root compromise has been attributed to improper placement of excessively long screws.

Anatomic Consideration

Lateral mass and adjacent bony structures

The morphology of the cervical lateral or articular mass has been described by Roy-Camille et al. [13], Pait et al. [20], and Ebraheim et al. [1,21]. The lateral mass of the cervical vertebra consists of the superior and inferior facets. The area of the lateral mass is the part lateral to the lamina and between the inferior margins of the adjacent inferior facets (Fig. 2). The mean superoinferior diameters of the lateral mass range from 11 mm at C3 to 15 mm at C7, and the mean mediolateral diameters range from 12 to 13 mm at C3 through C7. The mean anteroposterior diameter of the lateral mass is smaller at the C6–C7 levels than at the levels above [22].

Anterior to the lateral mass are the pedicle, transverse foramen, and posterior ridge of the transverse process. The pedicle is a short tubular structure originating from the posterolateral corner of the vertebral body. It attaches to the anteromedial aspect of the lateral mass between the superior and inferior articular processes. The adjacent pedicles, the posterolateral wall of the vertebral body, and the anteromedial aspect of the superior articular process form the interpedicular foramen. The posterior ridge of the transverse process originates from the lateroinferior portion of the anterior aspect of the lateral mass just above the inferior articular facet. It develops laterally and inferiorly to accommodate the course of the ventral ramus of the spinal nerve. Anterolaterally just above the origin of the posterior ridge of the transverse process, there is a notch or groove for the dorsal ramus of the spinal nerve (Fig. 2). The transverse foramen, which contains the vertebral artery, is surrounded by the anterior ridge of the transverse process anteriorly, the vertebral body medially, the pedicle, anterior wall of the lateral mass, and the posterior ridge of the transverse process posteriorly. In the transverse plane, the transverse foramen lies anteromedial to the posterior center of the lateral mass at the levels of C3–C5. At the level of C6, it courses laterally and lies in front of the posterior center of the lateral mass [23].

The spinal nerve

The spinal nerve exiting the spinal canal passes through the interpedicular foramen. Laterally in the intertransverse foramen, it divides into a larger ventral ramus and a smaller

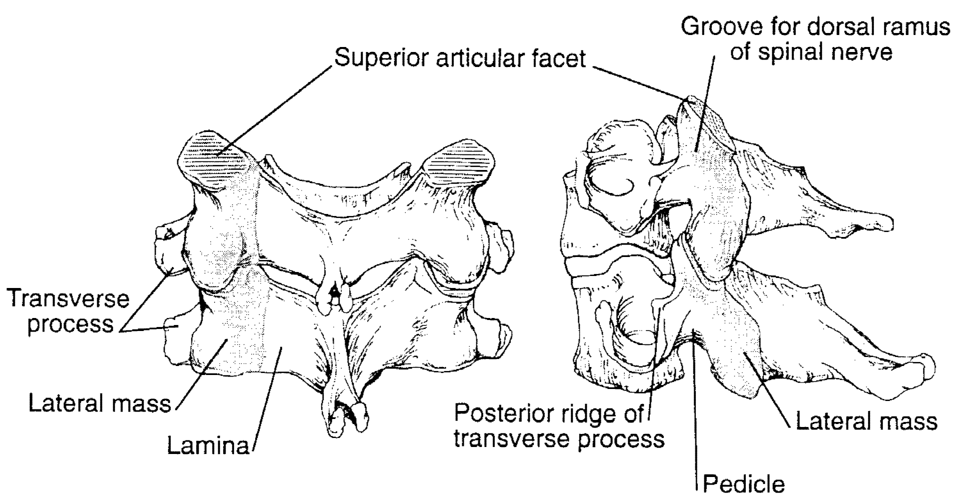

Fig. 2. Illustration of the lateral masses of the cervical vertebrae.

dorsal ramus (Fig. 3A). The ventral ramus of the cervical spinal nerve courses on the transverse process in the anterolateral direction to form the cervical and brachial plexus.

On the oblique sagittal images, the cervical nerve root is located in the lower part of the interpedicular foramen and occupies the major inferior part of the intertransverse foramen (Fig. 3B) [24,25]. On the posterior aspect of the lateral mass, the mean distance is about 5.6 mm from the posterior center of the lateral mass to the projections of the spinal nerves, superiorly and inferiorly, for all levels [26]. Pait et al. [20] divided the lateral mass into four quadrants and found that the superolateral quadrant is away from the spinal nerve. On the transverse section through the upper portion of the superior articular process, the spinal nerve either does not appear, or when it does, it is situated anteromedially to the anterior aspect of the superior facet (Fig. 4). On the transverse sections through the lower portion of the superior articular process, the contour of the spinal nerve is best delineated where it is still situated anteromedially or anteriorly to the anterior aspect of the superior facet and courses in the anterolateral direction. On the transverse section through the pedicle, the spinal nerve lies anterolateral to the lateral mass and is separated by the posterior ridge of the transverse process. The C7 spinal nerve is relatively larger and closer to the anterior aspect of the lateral mass due to its more posterior course in the transverse plane.

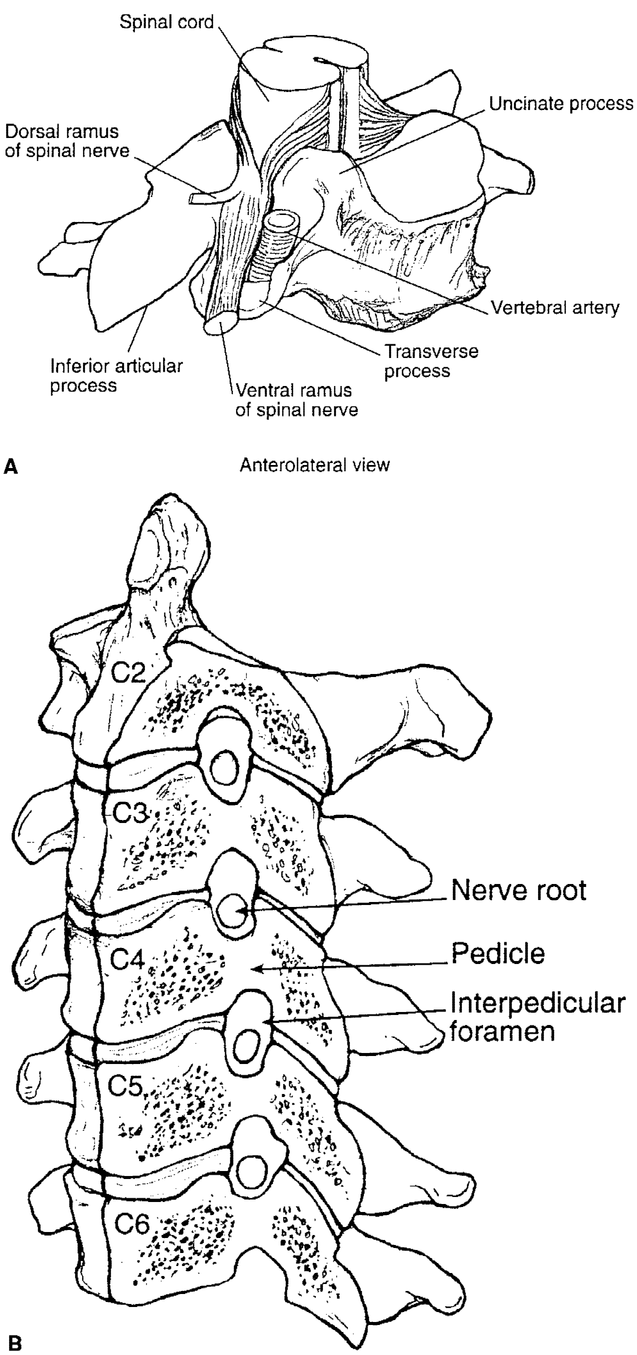

Fig. 3. Illustration of the spinal nerve. **A:** Oblique view. **B:** Oblique parasagittal section.

The dorsal ramus branching off the spinal nerve in the intertransverse foramen runs posteriorly against the anterolateral corner of the base of the superior articular process just above the origin of the posterior ridge of the transverse process. It supplies the facet joint, ligaments, deep muscles, and skin of the posterior aspect of the neck. The dorsal rami of C3–C5 have a larger diameter (1.6–2.2 mm), whereas the dorsal rami of C6–7 have a smaller diameter (1.2 mm). The distance between the dorsal ramus and the tip of the superior articular facet is smallest at the level of C7 (5.5 mm) in the cervical region [27].

The vertebral artery

The vertebral artery originates from the subclavian artery, enters the transverse foramen of the sixth cervical vertebra, and courses upward through the foramina above. On the transverse plane, the vertebral artery lies in front of the lateral mass, but is separated by the spinal nerve. The vertebral artery is not at risk of injury as long as the screw is directed lateral to the sagittal plane.

Anatomic relationships between screw trajectories and vital structures

Among the previously mentioned techniques, the Roy-Camille and Magerl techniques are perhaps the leading techniques of posterior plating of the cervical spine. The ideal exit point with bicortical purchase for the Magerl screw is located at the anterolateral corner of the superior articular process, and for the Roy-Camille screw it is just lateral to the origin of the posterior ridge of the transverse process. Due to the close anatomic relationship of the screw exit point to the courses of the spinal nerve and its dorsal ramus, the Magerl screw may have a higher incidence of nerve injury than the Roy-Camille screw [28,29] although the former provides more rigid fixation than the latter [30,31]. If the Magerl technique is to be used, the screw should be directed as lateral and as superior as possible, passing through the upper portion of the superior articular process to avoid injury to the spinal nerve and its dorsal ramus (Fig. 5) [29]. The exit point for the Roy-Camille screw seems safe because it lies inferior to the dorsal ramus and is separated from the ventral ramus by the posterior ridge of the transverse process. However, an excessively

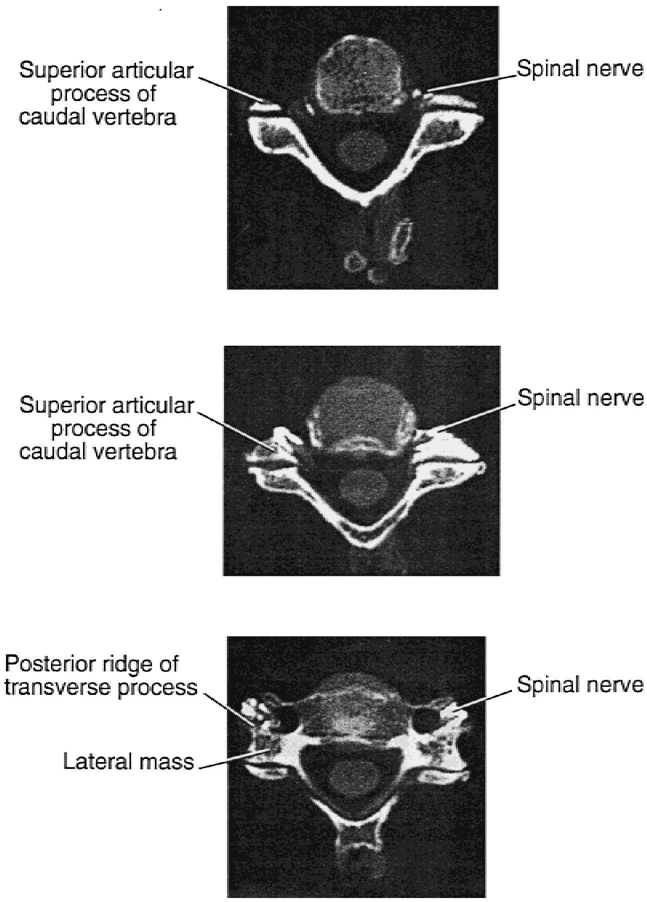

Fig. 4. Axial CT scans of the lateral mass. **Top:** Scan through the upper portion of the superior facet. **Middle:** Scan through the lower portion of the superior facet. **Bottom:** Scan through the pedicle.

long Roy-Camille screw should be avoided because the ventral ramus of the spinal nerve lies in front of the screw trajectory.

C7 anatomic features pose special challenges for lateral mass screw insertion. Use of an excessively long screw may place the spinal nerve at great risk, and a short screw may result in fixation failure. The best approach for C7 lateral mass fixation would be a screw placed more inferiorly and directed more superiorly toward the anterolateral corner of the superior facet in order to obtain longer length of the screw. Alternatively, the C7 pedicle may be utilized [14].

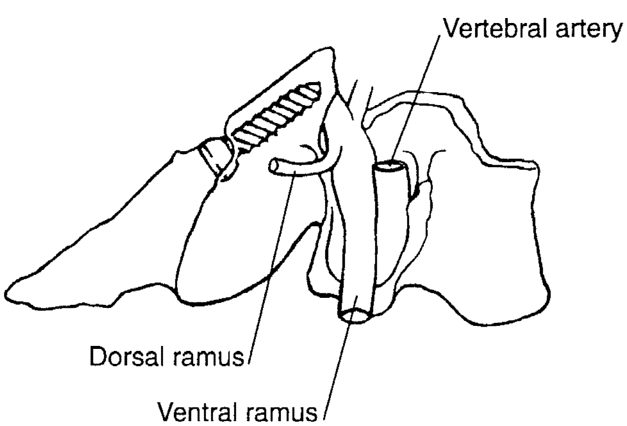

Fig. 5. Illustration of the modified Magerl technique.

Radiologic Consideration

Plain radiographs

Plain radiographs are the most commonly used radiographic modality in the evaluation of screw position intraoperatively and postoperatively. The anteroposterior and lateral views show the general configuration of the instrumentation and corresponding alignment of the fixed segments. The lateral projection may show the relationship of the screw to the facet joint. Screw loosening, pullout, or breakage can also be detected by this view. During surgery, the lateral projection of fluoroscopy is commonly used to direct screw insertion in the sagittal plane or to check the screw position after insertion. Because spinal nerve injury associated with lateral mass fixation results most likely from excessively long screws, the value of the lateral radiograph in determining proper screw length needs to be studied. Ebraheim et al. [32] experimentally placed screws into the lateral masses in four stages in cadaveric specimens. The stages included placement of the screw tip staying within the ventral cortex and 2-mm, 4-mm, and 6-mm overpenetration of the ventral cortex using the Roy-Camille and Magerl techniques separately. They found that 78% of the Roy-Camille screws and 44% of the Magerl screws without perforating the ventral cortex were projected on the posterior fourth of the vertebral body and just posterior to the

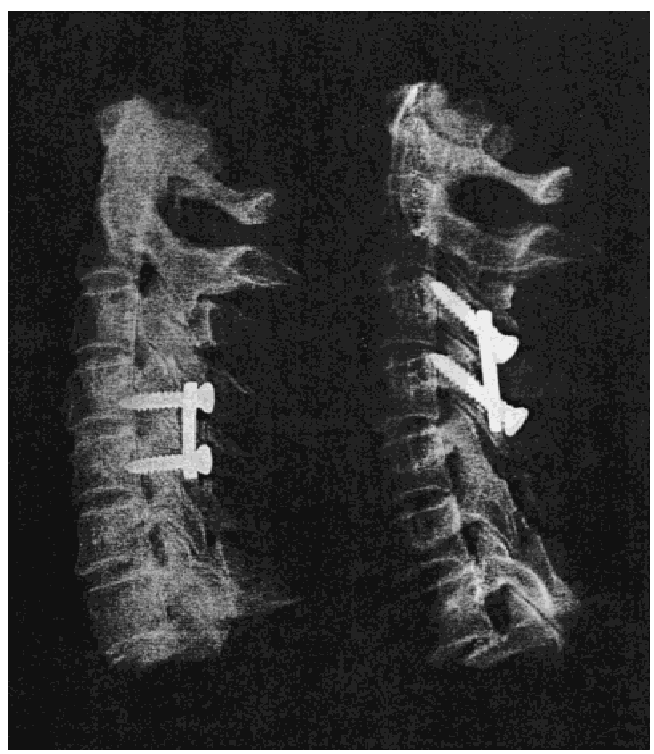

Fig. 6. The ideal screw tip position for the Roy-Camille **(left)** and Magerl **(right)** technique on the lateral radiograph.

posterior cortex of the vertebral body on the lateral radiographs, respectively (Fig. 6).

Another useful projection of plain radiographs is the oblique view. This projection best delineates the ventral aspect of the superior articular process, posterolateral corner of the vertebral body, pedicle, and intervertebral foramen. Also, the anatomic relationship between a lateral mass screw and the intervertebral foramen can be evaluated by the oblique view. An excessively long screw invading the intervertebral foramen can be detected by this view. Xu et al. [33] and Ebraheim et al. [34] found that the spinal nerve is most likely at high risk of violation if the screw tip crosses the line connecting the posterior borders of the intervertebral foramina and is located on the lower portion of the intervertebral foramen or pedicle in the oblique radiograph (Fig. 7).

Computed tomography (CT)

CT scans delineate detailed anatomy of the cervical spine by providing multiplanar images. Preoperatively, axial CT scans should be routinely obtained. Careful evaluation includes bony pathology of the cervical spine, the internal structures, and the anteroposterior diameter of the lateral masses to be instrumented. Axial CT may also be used in evaluation of the patients who complain of neck pain or who develop radicular symptoms after lateral mass screw fixation. A screw perforating the ventral cortex of the lateral mass can be clearly detected by axial CT scans. However, it is very difficult to determine whether or not the screw compresses or penetrates the nerve root [34]. An oblique radiograph will show the location of the extracortical screw in the intervertebral foramen. A reconstructive CT or an oblique magnetic resonance image (MRI) may display the relationship of the screw tip to the nerve root.

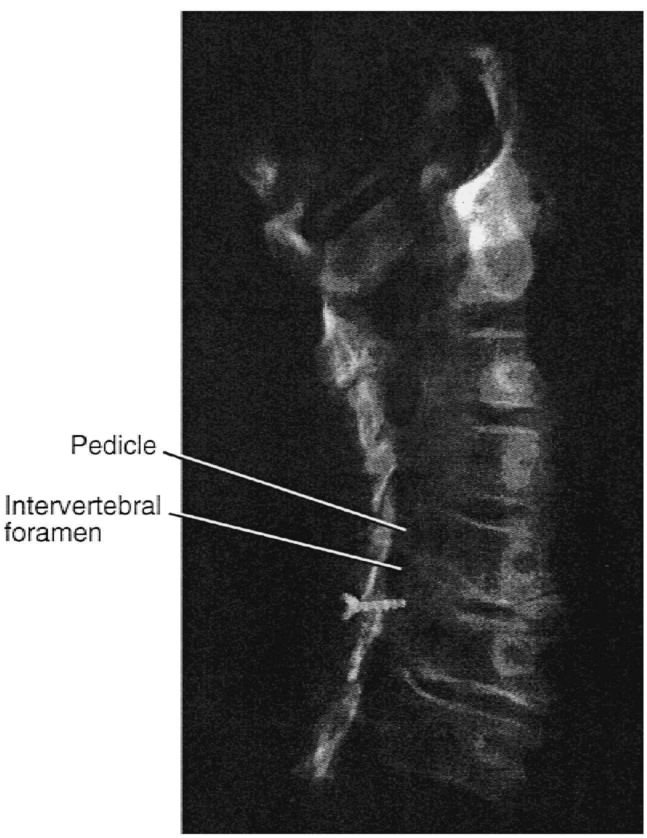

Fig. 7. Oblique radiograph of the cervical spine showing that the screw is located in the lower portion of the intervertebral foramen.

Summary

Posterior cervical plating, regardless of the technique, has potential anatomic risk of injury to the adjacent spinal nerves. The cervical spinal nerve and its dorsal ramus have a close relationship to the lateral mass. C7 is distinguished from the levels above by having a larger spinal nerve and thinner lateral mass. Oblique radiographs are valuable for detecting screw invasion of the intervertebral foramen. Axial CT scans allow detection of screw penetration of the ventral cortex of the lateral mass, but fail to determine if an overpenetrated screw violates the nerve root or not. Surgeons should be thoroughly familiar with the three-dimensional anatomy of the cervical spine. Preoperative radiographs and axial CT scans should be routinely obtained due to the anatomic variation between individuals. Meticulous surgical technique is required for exposing the posterior aspect of the cervical spine and placing the screw into the lateral mass to achieve sound bony purchase. Oblique radiographs prior to completion of the surgical procedure should also be routinely taken to avoid or minimize the incidence of postoperative neurologic complications.

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