An anatomical study of the C-2 pedicle

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Object. The C-2 pedicle plays an important role regarding screw purchase for spinal fixation. The aim of this study was to measure the C-2 pedicle–related linear and angular parameters.

Methods. Seven parameters in 160 C-2 pedicles (80 dry vertebrae) were measured using a Vernier caliper (accurate to 0.1 mm) and goniometer. The Student t-test was used to determine statistical significance.

The authors found that the C-2 isthmus (pars interarticularis) and the C-2 pedicle are distinct structures. The C-2 isthmus covers the pedicle. The isthmus is present between the superior and inferior articular processes, and the pedicle is the structure beneath the C-2 isthmus. It connects the lateral mass–inferior articular process to the body of the axis. The heights of the right and the left C-2 pediculoisthmic components (PICs) were 10.3 ± 1.6 and 9.9 ± 1.5 mm, respectively. The posterior part of the superior aspect of the PIC was wider than the anterior portion. The widths of the posterosuperior aspect of the PIC were 11.1 ± 2 and 11 ± 1.7 mm on the right and left sides, whereas the widths of the anterosuperior aspect of the PIC were 7.9 ± 1.7 and 8.5 ± 1.6 mm, respectively. The inferior widths of this component were 6.0 ± 1.5 and 5.5 ± 1.3 mm on the right and left side, respectively. The lengths of the component were 28.8 ± 2.9 mm on the right and 28.8 ± 3.4 mm on the left side. The PIC exhibits a lateral-to-medial and an inferior-to-superior angle. Its axial angles were 28.4 ± 2.5 and 28.6 ± 2.2° on the right and left sides, respectively; its sagittal angles were 18.8 ± 2.1 and 18.8 ± 1.7°, respectively.

Conclusions. The C-2 pedicle can be seen in the inferior aspect of the vertebra, and it connects posterior vertebral elements (that is, the lateral mass and inferior articular process) to the axial body. The isthmus drapes the pedicle. The authors suggest that this be termed “the pediculoisthmic component.”

KEY WORDS • cervical spine • axis • isthmus • pedicle • axial

Results

Axial Pedicle and Isthmus

In this study the C-2 pedicle was defined as a portion of the axial lateral mass–inferior articular process complex connecting to the VB of the axis, seen in the inferior aspect of C-2; the isthmus, on the other hand, was described as a portion between the anterior and posterior articular processes seen in the superior aspect. Although the C-2 isthmus and pedicle are distinct structures, they are so integrated that it is more appropriate to call them PIC.

The heights of the right and the left C-2 PIC (in millimeters) were 10.3 ± 1.6 (range 7.3–15.9) and 9.9 ± 1.5 (range 6.3–14.6), respectively (p = 0.137 and p > 0.05) (Fig. 1 right). The posterior portion of the superior aspect of the PIC was wider than the anterior part (Fig. 1 left).
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The posterosuperior widths (in millimeters) of this component were 11.1 ± 2 (range 6.8–16.4) and 11 ± 1.7 (range 7.5–15.1) on the right and left side, respectively (p = 0.652 and p > 0.05). The anterosuperior widths of this component (in millimeters) were 7.9 ± 1.7 (range 4.2–11.7) and 8.5 ± 1.6 (range 4.7–13.6) on the right and left sides, respectively (p = 0.036 and p > 0.05) (Fig. 1 left). The inferior widths of this component (in millimeters) were 6 ± 1.5 (range 2.4–9.6) and 5.5 ± 1.3 (range 2.7–9.3) on the right and left sides, respectively (p = 0.038, p > 0.05) (Fig. 1 right). The length of the component (in millimeters) was 28.8 ± 2.9 (range 24–35) on the right and 28.8 ± 3.4 (range 24–36) on the left sides, respectively (p = 0.54 and p > 0.05) (Fig. 1 left). Axial angles (in degrees) were 28.4 ± 2.5 (range 24–33) and 28.6 ± 2.2 (range 26–32) on the right and left sides, respectively (p = 0.632 and p > 0.05) (Fig. 2). Sagittal angles (in degrees) were 18.8 ± 2.1 (range 16–22) and 18.8 ± 1.7 (range 16–21) on the right and left sides, respectively (p = 0.48 and p > 0.05) (Fig. 2 and Table 1).

Discussion

The location of the C-2 pedicle remains a subject of controversy. Although some authors have reported that the pedicle connects the VB to the superior articular process,2,3 others have defined the pedicle as the portion beneath and posterior to the superior facet.4,5,7,8,11–13 A pedicle is a portion of the spine connecting the ventral and dorsal elements. Although this is valid for all subaxial vertebrae, the C-2 pedicles are anatomically unique. Although the superior articular process is a posterior element of the vertebra (that is, posterior to VB in the axial plane) in all subaxial vertebrae, an inspection of C-2 reveals that its superior articular process is not anatomically posterior to the VB. In other words, the axial superior articular process may not be accepted as a posterior element of C-2. Therefore, we disagree with the belief that the C-2 pedicle is a portion connecting the VB to the superior articular process. The axial pedicle, in this study, was described as the aspect between the VB and inferior articular process–lateral mass complex (Fig. 3).

We also found that C-2 does not have an isolated pedicle, which can be observed in the subaxial vertebrae. There exists a complex containing the C-2 pedicle inferiorly and the isthmus superiorly (Fig. 3). Whereas the isthmus connects the superior and inferior articular process, the true pedicle connects the lateral mass–inferior articular process to the VB–odontoid process junction. The C-2 pedicle is covered by the facet joint and isthmus (Fig. 3). Therefore, it is more appropriate to term these two components as the PIC. An embryological study may provide insight into the process of ossification involving the PIC.

The PIC is posterolateral to the VB, medial to the transverse foramen, originates posterolaterally from the lateral mass–inferior articular process junction, and ends anteromedially at the VB–odontoid process junction. It is grooved laterally by the transverse foramen (Fig. 3).

The PIC exhibits a lateral-to-medial inclination and inferior-to-superior angulations (Fig. 2). The lateral-to-medial inclination of the pedicle was reported to be 35.2° by Howington, et al.,9 and 33° by Xu, et al.14,15 The projection point of the pedicle in both aforementioned studies was reported to be 5 mm inferior to the superior border of the lamina and 7 mm lateral to the lateral border of the spinal canal. Based on the same posterior projection point, this angle was found to be 28° in the present study; however, when penetration of the transverse foramen in some specimens is considered, a more (2–3°) medially oriented screw projection may be more adequate. The inferior-to-
superior angulations of the C-2 pedicle have been reported to be 38.8,9 20.2,14,15 and 18˚ in the present series.

It is clear that the main factors affecting the degree of the angles include the projection point of the pedicle axis and the position of the vertebra (that is, the intraoperative position of the axis in prone position).

Foley7 has reported that, whereas the mean pedicle screw axial and sagittal trajectories (in degrees) were 45 medial (range 24–56) and 41 cephalad (range 23–58), respectively, the mean values for the pars screws (in degrees) were 7.3 medial (10 lateral–21 medial) and 58.2 cephalad (range 49–68), respectively. These measurements differ from ours.

Knowledge of exact location of the C-2 pedicle is mandatory to understand its pedicle anatomy (that is, pedicle length, height, width, and angles). The different perceptions of the C-2 pedicular parameters affect the results reported in the literature.

The C-2 PIC Length

The measured length of the C-2 pedicle may differ depending on technique. Because the measured lengths vary, including pedicle axis length, lateral mass pedicle length, and anterior isoaxial length, Howington, et al.,9 examined 10 C-2 segments. They described the pedicle length as “the distance from the posterior surface of the inferior articular process to the junction of the pedicle with the body of axis,” which they reported to be 16.6 mm.

In an examination of 50 C-2 specimens, Xu, et al.,15 described pedicle length as “the distance between the anterior most point of the pedicle axis and the posterior point of pedicle axis projection,” which they recorded as 25.6 mm in males and 25.5 mm in females.

Karaikovic, et al.,10 reported the following axial measurements: pedicle axis length, 25.4 mm; lateral mass pedicle length, 16.7 mm; and pedicle length, 7.1 mm.

In our PIC series length was 28.8 mm (Fig. 1 and Table 1).

The C-2 PIC Width

The use of different terminology causes confusion when attempting to determine width of the pedicle and the isthmus. Howington, et al.,9 reported the width of the C-2 pedicle (that is, inferior aspect of the PIC) to be 8.6 and 7.9 mm in males and females, respectively, whereas Xu and Ebraheim14 reported the mean width to be 7.9 mm.

Karaikovic, et al.,10 reported the width of the axial isthmus (that is, superior aspect of the PIC) to be 6.9 mm, whereas we found this measurement to be 11.1 mm.

In an examination of 40 C-2 specimens, Ebraheim, et al.,6 evaluated the pedicle and transverse foramen. They measured the superior and inferior portions of the pedicle separately and reported that the pedicle was grooved deeply by the transverse foramen anterolaterally, which caused a dimensional difference between the superior aspect of the C-2 “pedicle” (that is, isthmus) and inferior aspect of the C-2 pedicle (true pedicle). They indicated that the superior dimension of the C-2 pedicle was approximately 3 mm greater than its inferior diameter.

The results obtained in the present study are in line with those reported by Ebraheim, et al.6 According to our findings, the superior aspect of the C-2 PIC is wider than its inferior aspect (11 and 6 mm, respectively). On the other hand, the posterior part of the superior aspect of the PIC is also wider than its anterior part (11 and 8 mm, respectively). The variable diameters of its different portions should be taken into consideration during C-2 pedicle screw fixation.

The C-2 PIC Height

We determined the PIC to be 10.3 and 9.9 mm in height on the right and the left sides, respectively (Table 1 and Fig. 2). These values are not different from the other reported heights. The heights of the C-2 pedicle were reported to be 7.7 and 6.9 mm in males and females, respectively, by Xu, et al.,14 7.2 and 6.1 mm, respectively, by Karaikovic, et al.,10 and 10.5 and 9.1 mm, respectively, by Howington, et al.9

Surgery-Related Considerations

In this original study we focused on the C-2 PIC anatomy in a large number of specimens. Our goal was to address the confusion regarding the terminology of this structure. Typically, confusion in terminology arises from
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TABLE 1
Summary of C-2 PIC measurements

<table>
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<tr>
<th>PIC Aspect</th>
<th>Mean</th>
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* SD = standard deviation.

the anatomical confusion. Such confusion may lead to inaccurate surgical technique.

The definition of the C-2 pedicle and isthmus provides the surgeon with a better understanding of the anatomy for safer axial screw fixation. Because of the close relationship between the C-2 pedicle and isthmus, the term transpediculoisthmic fixation is more appropriate than transpedicular fixation.

Xu and Ebraheim14 reported that the safest angles for transpediculoisthmic screw placement were 35° medially and 20° rostrally. Using the same posterior screw entry points as Xu and Ebraheim, we tested 28° axial and 18° sagittal orientations for the safe placement of transpediculoisthmic screws; we found that a more axially oriented screw trajectory may be more appropriate for safe screw placement. After using approximately the same posterior screw entry points, Abumi1 recommended placement of screws parallel or slightly cephalad to the C2–3 disc in the sagittal plane.

The height of the C-2 PIC is great enough to accommodate a 3.5-mm screw safely. The superior width of the PIC is almost 2 to 5 mm larger than the inferior width of the PIC. This difference should be kept in mind during C-2 pedicle screw fixation.

Ebraheim, et al.,6 have reported that the lateral wall of the C-2 pedicle is thinner than the medial wall and may be vulnerable to injury during the pedicle screw placement. This point also requires consideration during C-2 pedicle screw placement.

Conclusions

The axial pedicle and the isthmus are distinct structures. Unlike the pedicles of the subaxial vertebrae, the C-2 pedicle is visible on the vertebra’s inferior aspect. It connects the posterior vertebral elements (lateral mass and inferior articular process) to the axial VB. The pedicle is covered by and integrated with the isthmus. Therefore, we suggest the term PIC better defines this structure than the C-2 pedicle (Fig. 3).

References


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