Original Article

Posterior identification and exposure of the V3 segment of the vertebral artery

ABSTRACT

Objective: The purpose of this study was to define the anatomy of the V3 segment of the vertebral artery (VA) from the posterior approach.

Methods: Ten formalin-fixed cadavers were carefully dissected bilaterally using landmark features to identify and safely expose the VA from the posterior. Measurements regarding morphometric characteristics of landmark features and feasible resection quantifications were obtained and analyzed. The C2 pars was resected completely in all cadavers, averaging 15.03 ± 1.06 mm in thickness.

Results: The average diameter of the VA at the midline of C2 on the right side was 4.66 ± 0.51 mm compared to the left 5.2 ± 0.49 mm ($P = 0.002$). The distance of the VA from the midline increased from caudal to rostral. The distance between the VA to the lateral edge of the dura in the middle of the window of approach was 9.67 ± 0.81 mm. The rostral-caudal length of the window of approach was 21.94 ± 1.60 mm. The percentage of C2 body removal was 28.04% ± 6.09% through each side (249.55 ± 55.5/898.2 ± 146.17 mm^2). While carefully exposing the VA, a posterior approach can be feasible in cases of injury during C1–C2 instrumentation or during resection of tumors of the C2 pars with or without extension into the C2 body.

Discussion: The posterior approach for a C2 partial corpectomy can also be used as an adjunct to anterior approaches when necessary to widen the extent of bone resection.

Conclusion: Exposure of the V3 segment of the vertebral artery was defined as well as the extent of C2 corpectomy through the posterior approach.

Keywords: Axis, cervical spine, corpectomy, vertebral artery

INTRODUCTION

The V3 segment of the vertebral artery (VA) exits the transverse foramen of C2 and passes through the transverse foramen of C1. The artery then travels laterally on the superior edge of the C1 ring before entering the foramen magnum.[1] Failure to recognize anatomical variants of this segment might result in multiple complications. Conflicting demographic data exists regarding the incidence of such variabilities. An Asian-based study[2] showed 10% incidence of V3 anomalous course, compared to <1% in North American[3] and European studies.[1]

Multiple methods exist for C1–C2 fixation. The Magerl technique provides a more stable construct, as opposed to the Gallie and Brooks techniques, but the rate of VA injury (VAI) can be as high as 8%.[4,5] The Goel-Harms technique (C1 lateral mass and C2 pedicle screw construct) has a rate of 0%–5% for VAI. Most of the reported VA injuries in the literature occur during the initial exposure or screw insertion.[5,6] The incidence of VAI is much higher in posterior (0%–8%) compared to anterior cervical surgery (0.2%–0.5%).[7-13]

Among the treatment options for VAI (including repair and ligation), artery repair maintains arterial patency, so the injured VA can be exposed and controlled. In cases of

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iatrogenic injury to the VA, anterior approaches do not provide adequate exposure for control of the bleeding and possible repair or ligation of the artery. VA exposure is also necessary during tumor resections originating from, or extending to the C2 pars, with or without the involvement of the dens body. Tumors that are located dorsal to the V3 segment at C1–C2 are not amenable to anterior transoral or transnasal resection. We conducted a cadaveric study to identify and anatomically describe the VA at the C1–C2 interval, characterize its association with surrounding structures and quantify the feasibility of resecting the C2 pars and body from the posterior. To the best of our knowledge, a posterior approach to the V3 segment of the artery at the C1–C2 level, C2 pars resection, and evaluation of the extent of C2 corpectomy with this approach have not been reported in the literature.

METHODS

Ten formalin-fixed cadavers were dissected bilaterally at the C1–C2 level between January and March 2017. The occiput, cervical spine, and upper thoracic spine were intact in these cadavers. Before we started the posterior dissection, the mandible was split using a saw blade. The posterior wall of the pharynx was incised, and the anterior aspect of the ring of C1, the body of C2, C2–C3 disc, lateral edges of C2 body, and the transverse process of C2 was identified. Digital images of the anterior aspect of C2 were then obtained.

A midline incision was made using a #10 blade and deepened down to the spinous process. Subsequently, the lamina of C1–C3 were identified and followed to the lateral mass. The C2–C3 facet joint and the C2 nerve root were identified on both the right and left sides. All 10 cadavers were dissected bilaterally.

To begin, a C2 unilateral laminectomy was performed [Figures 1a and 2]. The inferior articular process of C2 and subsequently the superior articular process of C3 were removed using Adson and Kerrison rongeurs. The third cervical nerve root was identified as the superior articular process of C3 was removed. The VA was then identified anterior to the C3 nerve root. The C3 nerve root was used as a landmark to prevent injury to the VA at this stage. Staying dorsal to the C3 nerve root, the remaining portion of the C2 pars was resected. The medial section of the C2 pedicle and the C2 transverse process laterally were identified. The posterior, medial, and lateral walls of the transverse foramen were removed, as well as the transverse process using a Kerrison rongeur. At this point, the VA was liberated from the transverse foramen of C2 [Figures 1b and 3]. To widen

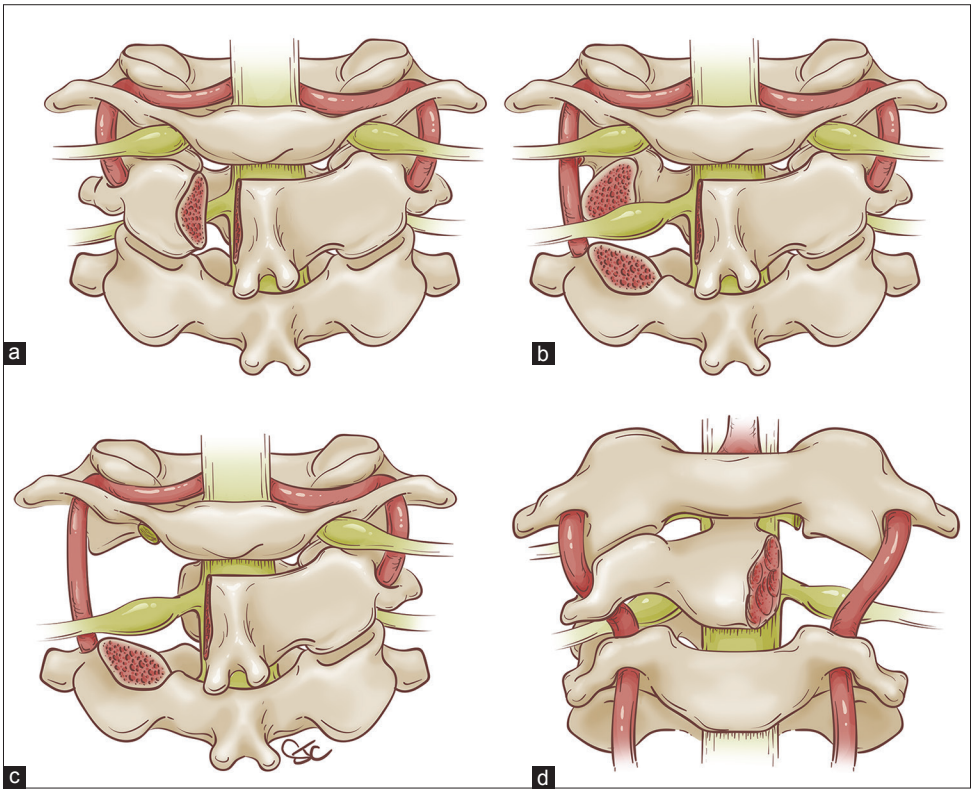

Figure 1: (a) C2 unilateral laminectomy (b) resection of the C2 pars, inferior articular process of C2, superior articular process of C3 and transverse process. The C3 nerve root was identified and used as a landmark to identify and safely liberate the vertebral artery. (c) Severance of the C2 nerve root, maximizing the window of approach. Resection of the C2 pedicle and partial corpectomy. (d) Anterior view showing the partial C2 corpectomy

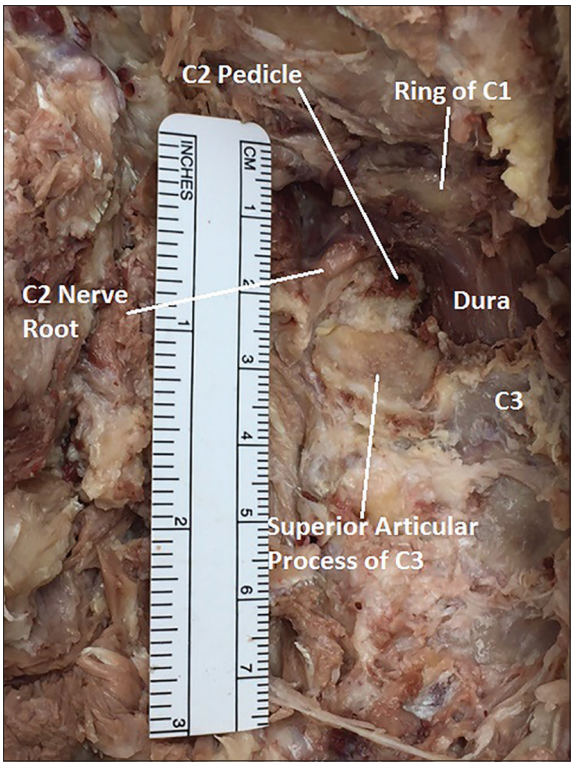

Figure 2: Sample photograph taken from the posterior after a C2 unilateral laminectomy and resection of the inferior articular process of C2

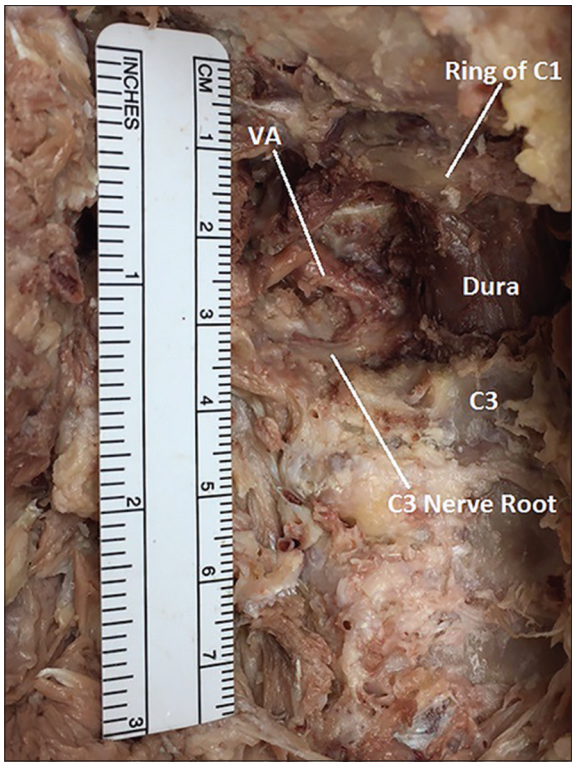

Figure 3: Sample photograph taken from the posterior after resection of the superior articular process of C3, pars of C2, and transverse process of C2. The C3 nerve root was used as a landmark to identify and liberate the vertebral artery

the window of approach, the C2 nerve root was incised sharply using a blade. If necessary, additional exposure of the VA can be obtained by removal of the posterior root of the transverse foramen of C2.

The boundaries of the "window of approach" to the C2 body were as follows the inferior edge of the posterior ring of C1 (superior border), the superior edge of the C3 nerve root (inferior border), and the lateral edge of the dura (lateral border) and medial edge of the VA (medial border), respectively. Next, the surgical window was widened by removal of the pedicle of C2, and the interval between the lateral body of C2 and anterior longitudinal ligament (ALL) was identified. Using the Kerrison rongeur, a C2 corpectomy under visualization was performed [Figures 1c, d and 4]. The cadaver was flipped back, and another anterior digital image of C2 was obtained to compare with the original intact C2 vertebrae. Measurements were obtained at the corresponding levels. Pictures were analyzed using the Image J Software (1.48 v, National Institutes of Health). The measurements were calibrated with an accuracy of 2 decimal digits according to the number of pixels per millimeter on the ruler image.

Anterior surface area of C2 vertebral body from the inferior endplate to the base of the odontoid process and from the base of the C2 transverse process on either side was measured. The resected portion of the C2 body was measured by comparing the intact C2 image and postcorpectomy image. In addition, the following measurements were made:

- The thickness of the C3 lateral mass
- The interval between the middle of C2 and C3 lamina
- The distance between the superior edge of the C3 nerve root to the inferior edge of the C1 ring
- The distance between the edge of the dura and the VA after release from the C2 transverse foramen
- The thickness of the VA at three different locations within the window of approach
- The depth of the window of approach from the dorsal aspect of the dura to the anterior ALL after partial C2 corpectomy, and
- The distance from the top of the C3 nerve root to the inferior edge of the C2 nerve root.

The data were entered into SPSS 20 (SPSS, Inc., Chicago, IL, USA) and analyzed. We used ANOVA and Student's *t*-test to compare the means; a $P < 0.05$ was considered statistically significant.

RESULTS

Our cadavers were skeletally mature and consisted of 3 males and 7 females. Nine cadavers were Caucasian and one was

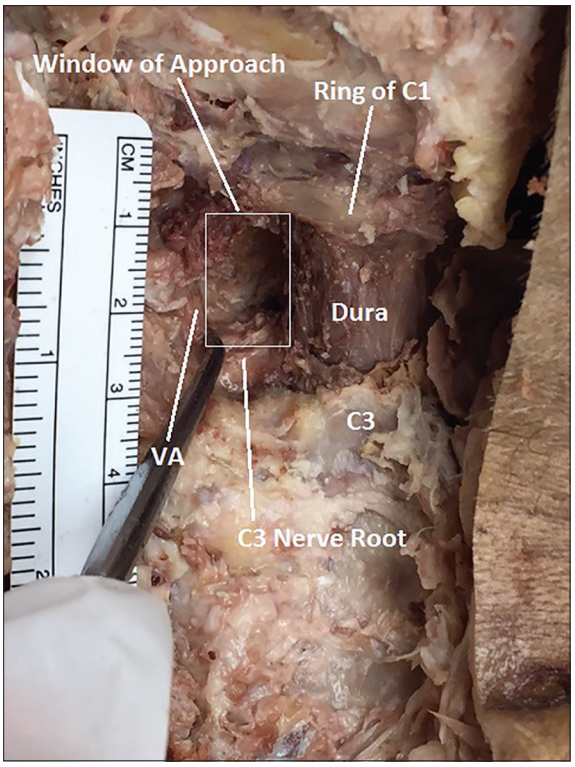

Figure 4: Sample photograph taken from the posterior after resection of the C2 pedicle, highlighting the window of approach

American Indian. None of the vertebral arteries were absent, redundant, or anomalous in location or course. The average thickness of the C2 pars, which was resected to identify the C3 nerve root, was 15.03 ± 1.06 mm. There was no difference between the distance of the VA to the midline at the level of the C3 nerve root and at the midpoint between the C3 nerve root and the lower edge of the C1 ring, however, there was almost 1 mm difference between the average distance of the VA from the midline at the lower edge of the ring of C1 between the right and left side 20.32 ± 1.45 versus 19.72 ± 0.99 mm, respectively ($P = 0.014$). The average diameter of the VA at the midline of C2 on the right side was 4.66 ± 0.51 mm compared to the left 5.2 ± 0.49 mm ($P = 0.002$). The distance of the VA from the midline increased from caudal to rostral. That distance was 14.48 ± 0.76 mm at C3 nerve root, 15.02 ± 1.06 mm at the midpoint between the C3 nerve root, and C1 lamina and 20.02 ± 1.25 mm at the C1 lamina ($P < 0.001$). There was no difference between the height and width of the window of approach for C2 body resection between right and left. The distance between the VA to the lateral edge of the dura in the middle of the window of approach was 9.67 ± 0.81 mm. The rostral-caudal length of the window of approach was 21.94 ± 1.60 mm. The average anterior-posterior depth of this window was 22.2 ± 2.78 mm after C2 partial corpectomy. The percentage of C2 body removal was 28.04 ± 6.09% through each side (249.55 ± 55.5/898.2 ± 146.17 mm^2).

DISCUSSION

Molinari *et al*.[14] (two cases) and Yang *et al*.[15] (one case) reported cases of VAI in the C1–C2 level. An anonymous 10 question web-based survey among the members of the Cervical Spine Research Society showed that the incidence of VAI was 0.07% (111/163,324 cervical spine surgeries). The highest incidence of VAI was during posterior instrumentation of the upper cervical spine (32.4% of VA injuries), followed by anterior corpectomy (23.4%), and posterior exposure of the cervical spine (11.7%). Thirty-four percent of the injuries occurred during C1–2 posterior fusion. The injury resulted in permanent neurologic deficit in 5.5%, and death in 4.5% of the cases.

Patients with VAI had a variety of outcomes including no neurological complication, temporary or permanent neurologic deficit, cerebellar infarct, and death.[8] Possible compilations of VAI include cerebellar or brain stem infarct due to impaired posterior circulation, recurrent bleeding, excessive blood loss, and hypotension.[12,16-18] If VAI is treated with tamponade alone, late complications are more likely. These include pseudoaneurysms, arteriovenous malformations, and recurrent bleeding.[7,18,19] Intraoperative management strategies described in the literature include tamponade, vessel ligation, direct repair, and endovascular techniques (coiling or stenting).[7,16,20,21,22]

Genetic as well as hemodynamic factors influence the formation of the VA.[1] Several types of VA anomalies have been reported, including fenestration, hypoplasia, and medial migration at the intraforaminal or extraforaminal. These anomalies increase the risk of VAI during anterior cervical decompression and/or fusions.[6] In cases of the persistent first intersegmental artery, the VA passes inferior to the posterior arch of the atlas instead of superior to it.[1] The incidence of this anomaly was reported to be 3.2% in a magnetic resonance arteriogram study.[23] Fenestration is when the V3 segment of the VA splits into two branches after coming out of the transverse foramen of C2, which then rejoin again when entering the dura. In these situations, one branch is in the normal anatomical location of V3, and the other one enters the spinal canal in the C1 and C2 interval.[1,3]

Our approach to the C1–C2 interval entails resection of the C2–C3 facet joint to expose the C3 nerve root. The VA passes anterior to the C3 nerve root, and identification of this nerve is an important landmark for exposure of the artery. Subsequent dissection should be performed by staying posterior to the VA during resection of the C2 pars. The VA is

usually attached to the transverse foramen with fibrovascular tissue, making Kerrison rongeurs and currets a desirable option for dissection. After C2 pars resection, the pedicle of C2 can be identified medial to the transverse foramen of C2. The pedicle can be resected subsequently, which increases the interval for a partial C2 corpectomy. Kerrison rongeurs can be used to perform the corpectomy, using the interval between the ALL and anterior wall of the C2 vertebrae. The window of approach is limited by the VA laterally and the lateral edge of the dura medially. If necessary, the C2 nerve root can be severed to maximize the window of approach. The superior limit of the exposure was the inferior edge of the C1 lamina and the lateral mass and the superior edge of the C3 nerve root inferiorly.

The artery is tethered at the superior and inferior portions at the transverse foramens of C1 and C3, which limits the window of approach for a C2 corpectomy. This dissection can be used for exposure of the VA in cases of injury during C1–C2 instrumentation, or during resection of tumors of the C2 pars with or without extension into the C2 body.

One limitation of this study includes the use of formalin fixed cadavers as opposed to fresh cadavers. In fixed cadavers, the soft tissue may not be as easily mobilized or present in an exemplary manner. Another limitation is that this experiment does not address the variety of anomalies that can occur regarding the V3 segment of the VA. Anomalies can occur both in location and course but were absent in the cadavers of this study.

The anterior transoral or transnasal approaches cannot provide safe exposure of the artery for safe resection and control of the VA. The posterior approach for C2 partial corpectomy can be used as an adjunct to anterior approaches when necessary to widen the extent of bone resection. By using this approach, safe resection of the C2 vertebrae beyond the midline as well as the odontoid process can be difficult.

CONCLUSION

Exposure of the V3 segment of the vertebral artery was defined as well as the extent of C2 corpectomy through the posterior approach

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Conflicts of interest

There are no conflicts of interest.

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