Original Article

Different C2 screw placement techniques with mobilization of the vertebral artery in high-riding vertebral artery cases: Cadaver dissection

ABSTRACT

Objective: In neurosurgery, posterior approaches intended at the craniovertebral junction are frequently used. The most popular procedures for treating upper cervical instability are C1 lateral mass, C2 pedicle, and C1-C2 transarticular screw stabilization. Due to their proximity to neural structures and the presence of the high-riding vertebral artery (VA), these techniques are complicated. The risk of VA damage can be decreased by mobilizing the VA. Using cadaveric specimens in this study was aimed to demonstrate C2 pedicle and C1-C2 transarticular screw placement with VA mobilization and a novel C2 inferior corpus screw placement technique.

Methods: In this study, twelve adult cadaveric specimens and two adult dry cadaveric C2 bones were used with the permission and decision of the University Research Ethics Committee. Colored silicone was injected into the arteries and veins of these twelve cadaveric specimens. Then, muscle dissection was performed stepwise, and the C2 vertebrae of the cadavers were revealed with a surgical microscope. Each specimen and entire stages of the dissections were recorded photographically. After cadaver dissections, screw placement was performed with three different techniques. Finally, radiological imaging was done with fluoroscopy.

Results: After dissection, the lateral mass of the C2 vertebra was observed, and lateral to it, the transverse process and foramen were detected with the help of a hook. Next, the posterior wall of the VA groove was removed using a 1 mm thin plate Kerrison rongeur until the VA loop could partially be observed the VA. This enables us to find the top of the loop of the VA and mobilize it inferiorly using a dissector. Following this step, the C1-2 transarticular, C2 pedicle, and the novel C2 inferior corpus screw placement can be performed safely by directly visualizing the artery.

Conclusions: Due to the nearby neurologic and vascular structures, placing the C2 pedicle and C1-2 transarticular screw is a challenging procedure, especially in high-riding VA cases. However, it is possible to place the C2 pedicle, C1-2 transarticular, and novel C2 inferior corpus screw after the mobilization of the VA. This study aimed to show all of them together on a cadaver for the first time, to understand the anatomy of the C2 vertebra, and to use screw placement techniques to minimize the risk of complications.

Keywords: Axis anatomy, C2 anatomy, C2 screw placement, high-riding vertebral artery, mobilization of vertebral artery

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INTRODUCTION

Posterior approaches intended for the craniovertebral junction are frequently used in neurosurgery practice. Trauma, tumors, degenerative, congenital, rheumatological, iatrogenic, and infectious pathologies may reveal the necessity of surgery by causing instability in the craniovertebral junction, which requires upper cervical stabilization. Surgeries of the craniovertebral junction have been tried with many different techniques. C1 lateral mass, C2 pedicle, and C1-C2 transarticular screw stabilization are the most common techniques of upper cervical instability. These techniques are challenging in terms of their proximity to the neural structures and the presence of the vertebral artery (VA).[1] In addition to the complexity of the craniovertebral region, the atypical form of the C2 vertebrae and the high-riding VA make this region even more complex.

One of the most common techniques is the transarticular fixation technique, which was introduced in 1986 by Magerl and Seemann.[2] This technique has remained very popular due to its biomechanical superiority, relative convenience of surgical execution, and satisfactory long-term clinical results. In 1994, an atlantoaxial fixation technique, which involves the individual insertion of screws into the atlas lateral mass and the axis pedicle, was introduced by Goel.[3] The relative safety of the VA and the biomechanical durability of the technique have made it the most preferred atlantoaxial fixation technique. However, in high-riding VA cases, C2 pedicle and transarticular screw fixation are dangerous due to the high risk of injuring the VA. In this study, C2 pedicle and C1-C2 transarticular screw placement with VA mobilization and a novel technique for C2 screw placement was demonstrated in cadaveric specimens.

METHODS

This study was conducted with the permission and decision of the University Research Ethics Committee. In this study, twelve adult cadaveric specimens and two adult dry cadaveric C2 bones were used. Colored silicone was injected into the arteries and veins of these twelve cadaveric specimens. Then, muscle dissection was performed step by step, and the C2 vertebrae of the cadavers were revealed. Then, muscle dissection was performed stepwise, and the C2 vertebrae of the cadavers were revealed with a Zeiss OPMI Vario 700 Surgical Microscope. Each specimen and entire stages of the dissections were recorded photographically with a Canon 5D Mark II high-resolution digital camera (CanonCo. Tokyo, Japan). After cadaver dissections were completed and screw placement was performed with three different techniques, radiological imaging was done with C-arm fluoroscopy.

RESULTS

Among the 12 cadavers, a high-riding VA was observed in only one specimen. The loop of the VA was located more superiorly and medially on the side of the high-riding VA, and it was indented to the pedicle of the C2 vertebra [Figure 1a]. In the case of the high-riding VA, decreased thickness of the isthmus is demonstrated with an Adson dissector [Figure 1b]. It is also shown in Figure 1b and c, and the ganglion of the C2 is observed sitting on the C1-C2 articular facet.

The lateral mass of the C2 vertebra was observed, and lateral to it, the transverse process and foramen were detected with the help of a hook. To mobilize the VA, with the help of a 1 mm thin plate Kerrison rongeur, the posterior wall of the VA groove was removed until the loop of the VA was observed partially [Figure 1c]. This allows us to use a dissector to find the top of the loop of the VA and mobilize it inferiorly [Figure 1d]. After removing the posterior wall of the C2 VA foramen, the VA was mobilized to the lateral and inferior by a dissector. Following this step, the C1-2 transarticular, C2 pedicle, and the C2 inferior corpus screw placement can be performed safely by directly visualizing the artery [Figure 2].

DISCUSSION

Magerl described C1-C2 transarticular screw placement. To our knowledge, no research has ever demonstrated the technique in a cadaver before. In Magerl's technique, the entry point of

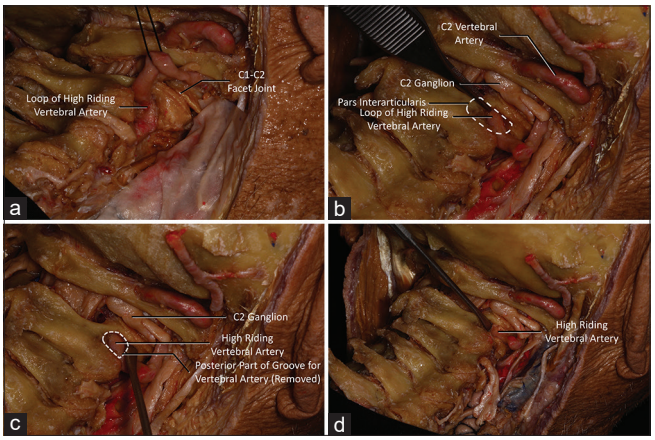

Figure 1: (a) The posterior part of the groove for the vertebral artery is removed, and the vertebral artery is elevated. High riding vertebral artery lies more medially and superiorly at the groove and decreases the space for the screw placement. (b) The area corresponding to the isthmus is shown in dotted lines. In the case of a high-riding vertebral artery, the safe zone for the screw placement is substantially decreased. (c) The posterior part of the groove for the vertebral artery is removed. A loop of the high-riding vertebral artery is demonstrated. (d) The tip of the groove for the vertebral artery is found with a dissector, and the vertebral artery could be mobilized inferiorly and laterally for safe screw placement

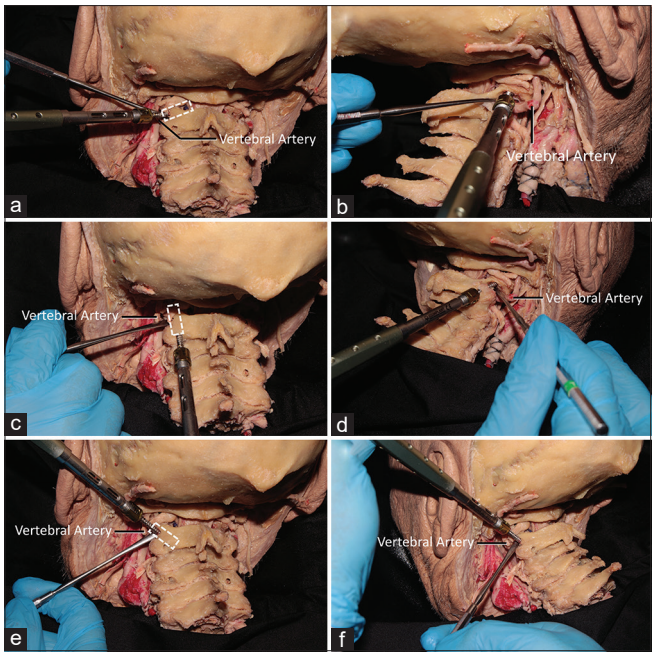

Figure 2: By removing the posterior part of the vertebral artery groove and mobilizing the vertebral artery to the inferior and lateral with the help of the dissector C2 pedicle screw placement (a and b), C2 screw placement with Magerl technique (c and d) novel C2 inferior corpus screw placement technique (e and f) are seen

the transarticular screw is located 3 mm superior to the inferior articular facet and as medial as possible without penetrating the lateral wall of the spinal canal at C2 [Figures 3a and 4a]. After defining the entry point, the screw is oriented to the middle part of the C1 anterior tubercle [Figure 3b]. While the screw is being placed, it passes through the pars of the C2, facet of the C1-C2, and terminates at the lateral mass of the C1. The aim is to place the screw through the lateral mass of the C2, the articular facet of the C1-C2, and the end at the lateral mass of the C1 vertebra. Although the C1-C2 transarticular screw placement technique is biomechanically strong, the most crucial disadvantage is the increased risk of VA injury in high-riding VA cases.[4,5] In the literature, up to 18% and 23% of VA injury has been reported in screw placement with the Magerl technique.[6,7] As described in the results section, after the mobilization of the VA, C1-2 transarticular screw can be placed safely by direct visualization of the VA groove, which can decrease the risk of injury, especially in high-riding VA cases [Figures 2c,d and 3a]. Goel *et al.* performed this technique in clinical cases.[8] It was shown for the first time on a cadaver in this study. In cases where C2 corpus is involved, and pedicle screw placement is not possible, such as tumor and infection, VA mobilization and C1-C2 transarticular screw placement technique can provide strong stabilization.

The Classical Pedicle entry point of C2 screw placement is the intersection between the superior edge of the C2 lamina

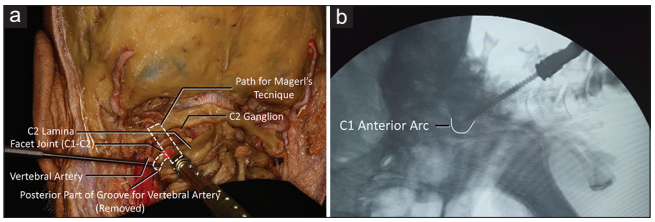

Figure 3: (a) After the mobilization of the vertebral artery with a dissector, C1-2 transarticular screw was placed safely. The trace of the C1-2 transarticular screw can be seen with white dotted lines. In the case of a high-riding vertebral artery, screw placement with Magerl's technique can be dangerous, as its trajectory passes from the region corresponding to a loop of vertebral artery (demonstrated in the red area, with a red dotted line). (b) Placement of the 38 mm screw with Magerl's technique on lateral fluoroscopy. The anterior tubercle of C1 is targeted in this screw placement

and the midpoint of the C2 pars interarticularis [Figure 4a]. Usually, 20°–30° medial and cranial directions are accepted. The classical C2 pedicle screw technique was modified by Goel *et al*. to avoid injury to the VA.[2] In their modified technique, the starting point for screw placement is located more medial and 2 mm inferior to the C1-C2 facet joint [Figure 4a]. With this technique, safer placement of the screw is possible by identifying the projection of the pedicle of the C2 vertebra with a hook or dissector. This is an advantage compared to the classical technique since it allows the visualization of the pedicle. However, the high-riding VA increases the risk of injury while placing the C2 pedicle screw. This risk can be decreased, and safe placement of a screw into the pedicle can be performed by mobilization of the VA[8,9] [Figures 1 and 2a and b]. Before placement of the screw, the posterior wall of the VA Groove should be drilled or removed by a Kerrison rongeur about 5 mm from lateral to medial. This allows us to use a dissector to find the top of the loop of the VA and move it to the lateral and inferior [Figure 1d]. After removing the loop through the lateral and inferior, the C2 pedicle screw can be placed more safely since the probability of the loop's occurrence in the screw trajectory is decreased. Goel *et al*. described a similar method where they directly used a diamond burr to the posterior wall of the VA groove to visualize the VA.[8,9] In our method, we started by removing the posterior wall from the lateral transverse foramen.

In this study, we described the alternative C2 screw placement technique instead of the classical C2 pedicle screw. In classic C2 pedicle stabilization, the natural orientation of the pedicle is directed to screws into the medial and superior part of the corpus [Figures 2a, b and 4c, d]. The entry point and lateral fluoroscopic view of the novel C2 inferior corpus screw placement are also shown [Figure 4b, f]. In this technique, the lateral pedicle wall is directly visualized after the mobilization of the VA. At this

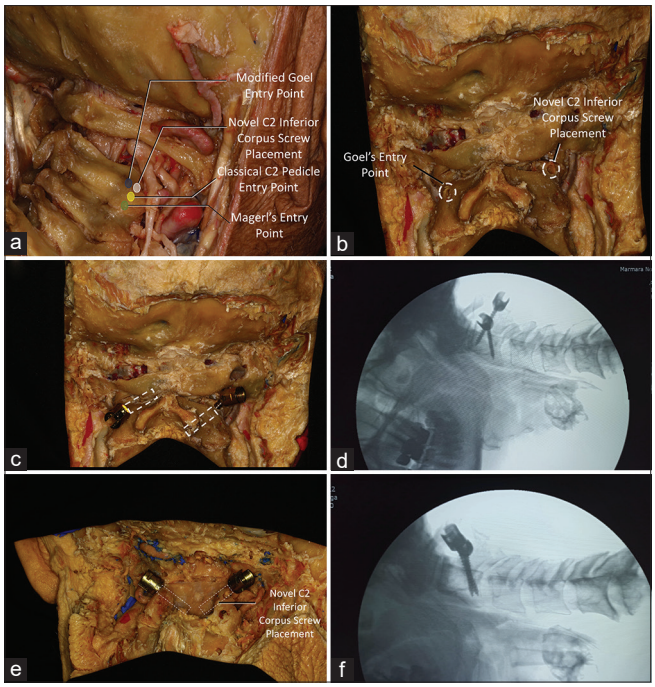

Figure 4: (a) Different C2 entry points are demonstrated through the colored circle. The Classical C2 pedicle screw entry point (yellow circle), modified Goel's C2 pedicle screw entry point (blue circle), the novel C2 inferior corpus screw placement technique (white circle), and C1-2 Magerl's transarticular screw entry point (green circle) is indicated. (b) Comparison of entry points. The right-sided dotted circle demonstrated the entry point of the novel C2 inferior corpus screw placement technique. Goel's entry point is demonstrated on the left. (c) Goel's technique is seen on the left side. This screw is placed through the superior articular facet to the pedicle. On the right, the novel C2 inferior corpus screw placement technique is seen. With this technique, a screw is placed starting from the superior articular facet and directed to the inferomedial part of the corpus. In this technique, the screw courses from the superior part of the corpus to the inferior medial part. (d) Goel's and novel C2 inferior corpus screw placement techniques are demonstrated on lateral fluoroscopic view. (e) Lamina of the C2 is removed. Screw placement traces in the novel C2 inferior corpus screw placement technique are shown bilaterally. (f) In the novel C2 inferior corpus screw placement technique, pedicle screw placement starts from the superior articular facet, and the tip of the screw is directed toward the median part of the inferior corpus. A screw is oriented inferiorly and medially at its last position. Lateral fluoroscopic view demonstrating bilateral screw placement

point, the screw may be placed from the superolateral part of the superior articular facet; then, it will be oriented into the inferior medial part of the corpus, which is angulated 20°–25° medially and 30°–40°caudally [Figure 4]. This technique is similar to Patkar's subfacetal axis screw placement.[10] In Patkar's method, the screw is oriented 15°–20° medially and downward from the entry point. However, in our technique, after the mobilization of the VA, the more caudally oriented C2 screw placement is possible than Patkar's technique which may allow longer screw placement and much more durability in biomechanics.

To demonstrate the technique clearly in the cadaver, the lamina of the C2 vertebra was removed bilaterally, and the C2 corpus, bilateral pedicles, and groove of the VA were exposed [Figure 4e]. Due to the inferior part of the C2 corpus being wider and longer than the superior part of the C2 corpus, the caudally oriented screws will be longer than classic superior-oriented screws. Although not proven by biomechanical and clinical studies, inferior-oriented screws may provide better biomechanical strength while allowing safe screw placement.

CONCLUSIONS

C2 pedicle and C1-2 transarticular screw placement is a challenging technique due to the adjacent neurologic and vascular structures. This study aimed to show the Goel and Magerl techniques on a cadaver for the first time, to understand the anatomy of the C2 vertebra, and to use screw placement techniques to minimize the risk of complications. After the mobilization of the VA, the C2 pedicle, C1-2 transarticular, and novel C2 inferior corpus screw placement may decrease the risk of neurological and vascular injury, especially in high-riding VA cases. However, further clinical, anatomical, and biomechanical studies are needed to understand the biomechanical strength of these techniques.

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Conflicts of interest
There are no conflicts of interest.

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