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Original Investigation

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Is C1 Asymmetric Laminectomy Safer? A Cadaver Study

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ABSTRACT

AIM: To investigate the difference in the length of C1 laminectomy between the right and left sides and to determine the importance of considering the dominant vertebral artery in reducing complication risks.

MATERIAL and METHODS: Five caucasian male cadavers were studied. The distance of the C1 posterior tubercle to the vertebral groove (A), the length of the vertebral groove (B), and the diameter of the vertebral artery were measured and statistically investigated. Computed tomography scans were also obtained from all cadaver specimens.

RESULTS: The mean distance of the C1 posterior tubercle to the vertebral groove (A) on the right side was 20.20 ± 2.16 mm and on the left side was 16.40 ± 2.88 mm. The mean distance of the vertebral groove (B) on the right side was 13.80 ± 0.83 mm and on the left side was 17.60 ± 0.89 mm. The mean diameter of the vertebral artery on the right side was 3.58 ± 0.83 mm and on the left side was 3.70 ± 0.10 mm.

CONCLUSION: The vertebral groove was longer on the dominant artery side. Therefore, the dominant and nondominant sides have different lengths of safe C1 laminectomy areas. The length of the laminectomy area to be performed on the dominant artery side is shorter than that on the nondominant side. In cases in which the C1 posterior arcus must be removed for decompression, asymmetric decompression should be performed to reduce the risk of vertebral artery injury.

KEYWORDS: C1, Laminectomy, Vertebral groove, Vertebral artery, Injury

INTRODUCTION

C1 (axis) laminectomy is performed by removing the axis posterior arcus during surgery. The anatomy of the axis has a complex structure. For this reason, it differs from other laminae of the spinal region in laminectomy application. C1 laminectomy is usually indicated for spinal cord compressions such as spinal stenosis, trauma, congenital conditions (Chiari malformation, etc.), inflammatory diseases (rheumatoid arthritis, etc.), and infections (1). Insufficient decompression leads to continued pressure on the spinal cord and thus clinical symptoms. Excessive laminectomy increases the risk of complications. Previous studies have reported various complications associated with C1 laminectomy, including infection, bleeding, and nerve damage.

Few studies in the literature have addressed C1 laminectomy, and the length of decompression surgery has been rarely discussed (7). In general, the length of C1 laminectomy is performed symmetrically, like other levels of the spinal column. Despite the known risks of C1 laminectomy, there is limited research on the optimal length of the procedure to minimize complications.

In this study, we aimed to investigate the difference in length of C1 laminectomy between the right and left sides and to determine the importance of considering the dominant vertebral artery in reducing complication risks.

MATERIAL and METHODS

We studied five caucasian male cadavers. Ethical approval for the study was obtained from the local ethics committee

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(protocol No. 09.2021.1130). Dissection was performed on all cadavers through a midline skin incision extending from the occiput to the level of the C3 vertebra at the nuchal line. We performed bilateral dissection from the C1 posterior arch to to reveal the vertebral groove and transverse process. The artery was exposed from where the vertebral artery exits from the C1 transverse process to the vertebral groove and dura mater.

We measured and statistically investigated the distance of the C1 posterior tubercle to the vertebral groove (A) and the length of the vertebral groove (B) (Figure 1). For the statistical analysis, we conducted a paired *t* test using GraphPad Prism version 10.0.0 for Windows (GraphPad Software, Boston, MA, USA; www.graphpad.com).

Radiology

We obtained computed tomography (CT) scans from all cadaver specimens. CT imaging was performed on a 256-channel (2 x 128) or 128-channel multidetector CT scanner (Somatom Definition Flash or Somatom Definition AS+, respectively; Siemens Healthcare, Erlangen, Germany). Images were obtained in the axial plane with 0.6-mm collimation and 120 kVp (kilovolt peak). We adjusted the milliamperes per second for each patient via tube current modulation. The images were reconstructed with 1-mm thickness in all three planes. We determined the dominant and nondominant vertebral artery sides using CT scan measurements from the cadavers.

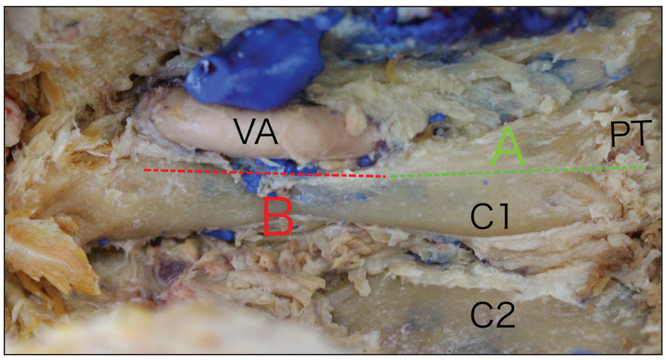

Figure 1: The distance of the C1 posterior tubercle to the vertebral groove (A-green line) and the length of the vertebral groove (B-red line) were measured in all cadavers. C1, first cervical vertebrae; C2, second cervical vertebrae; PT, posterior tubercule; VA, vertebral artery.

RESULTS

We performed dissections on all cadaver specimens. Anatomical distances were physically measured on the cadavers, in addition to the CT scan measurements of the identical specimens (Figure 1; Table I). CT scans were performed on the cadavers to demonstrate the relationship between the vertebral groove and laminectomy. The C1 lamina was measured from the right and left of the midline. The vertebral groove was measured separately on the right and left sides. We determined the dominant and nondominant sides of the vertebral artery in the cadaver tomography sections. According to the vertebral artery (VA) diameter measurements on the CT scans, we determined the left side of all cadavers as the dominant side (Figure 2A; Table II). In Figure 2A, the magenta-colored bar represents the left side of the VA diameter measured on the widest aspect of the artery in the coronal section of the CT image of cadaver 1. In Figure 2B, the magenta-colored bar represents the right-side VA diameter measured on the widest aspect of the artery in the coronal section of the CT image of cadaver 1. We attempted three-dimensional (3D) reconstruction to show the anatomical differences in the posterior–superior and posterior views of the vertebral groove. The 3D reconstructions of the CT images of the cadaver from a posterior–superior aspect of the cranium (Figure 2C). We digitally removed certain parts of the cranium to demonstrate the C1 anatomy. The magenta-colored shades represent the VA grooves on both sides (Figure 2C). The blue shade represents the left lamina, and the green shade represents the right lamina (Figure 2C). The 3D reconstructions of the CT images of the cadaver from a posterior aspect of the cranium (Figure 2D). We digitally removed certain parts of the cranium to demonstrate the C1 anatomy. The magenta-colored shades represent the VA grooves on both sides. The

Table I: Measurements Made on the Posterior Arcus, Vertebral Groove and Vertebral Artery in Cadavers

Cadaver	**C1 Length (mm)**				**VA**		
	A		**B**		**Diameter (mm)**		**Dominant Side**
	Right	**Left**	**Right**	**Left**	**Right**	**Left**	
1	19	15	13	17	3.5	3.6	L
2	21	18	14	17	3.6	3.7	L
3	22	19	14	17	3.6	3.8	L
4	17	12	13	18	3.5	3.6	L
5	22	18	15	19	3.7	3.8	L
Mean	20.20	16.40	13.80	17.60	3.580	3.70	
SD	2.168	2.881	0.8367	0.8944	0.08367	0.100	

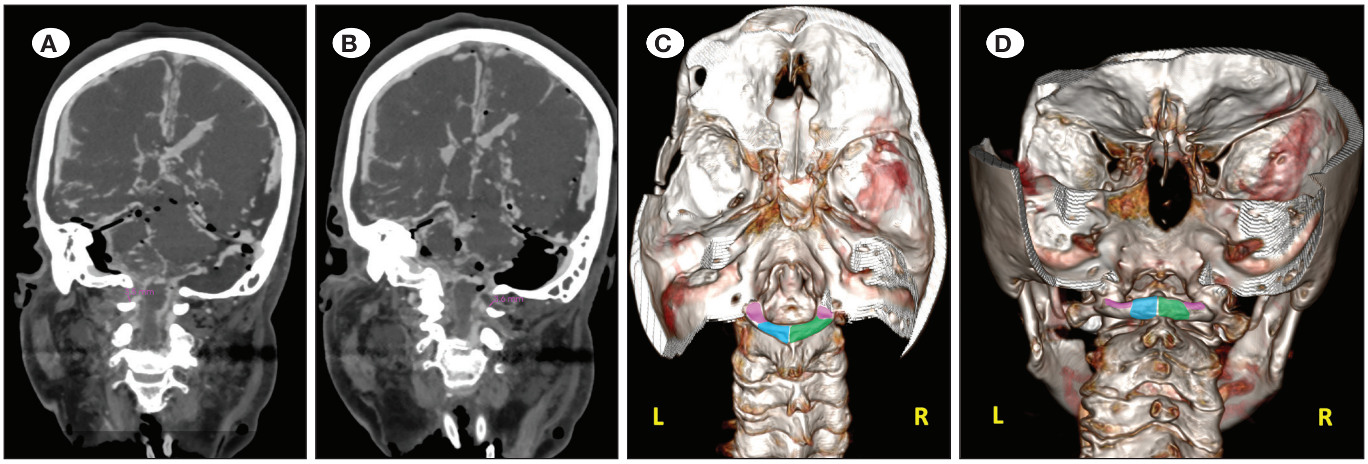

Figure 2: A) Coronal section of the CT image of cadaver 1. The magenta-colored bar represents the diameter of the left-side vertebral artery measured on the widest aspect of the artery. **B)** Coronal section of the CT image of cadaver 1. The magenta-colored bar represents the right-side vertebral artery diameter measured on the widest aspect of the artery. **C)** The 3D reconstructions of the CT images of cadaver 1 from the postero-superior aspect of the cranium. Certain parts of the cranium were digitally removed to demonstrate the C1 anatomy. Magenta shades represent the vertebral artery grooves on both sides. The blue shade represents the left lamina. The green shade represents the right lamina. **D)** The 3D reconstructions of CT images of cadaver 1 from the posterior aspect of the cranium. Certain parts of the cranium were digitally removed to demonstrate the C1 anatomy. Magenta shades represent the vertebral artery grooves on both sides. The blue shade represents the left lamina. The green shade represents the right lamina. L, left; R, right.

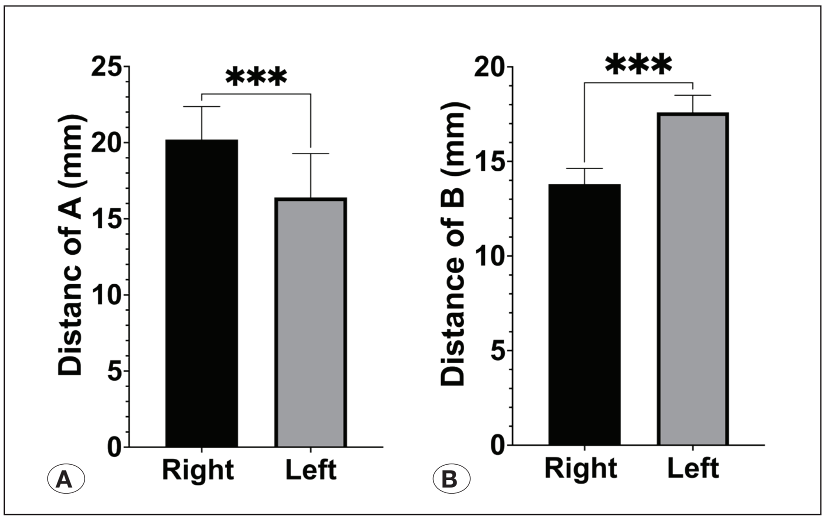

Figure 3: A) The comparison of the right and left posterior tubercle to vertebral groove (A) length measurement showed a significantly greater measurement on the right side (p<0.05). **B)** In comparing the length of the vertebral groove (B) on both sides, measurements of the left side were substantially greater (p<0.05).

blue-colored shade represents the left lamina, and the green-colored shade represents the right lamina (Figure 2D).

Table I shows the results of the anatomical properties of the C1, C2, and VA measurements of all cadavers. We calculated the means and standard deviations for the parameters based on the left and right measurements, respectively (Table I). The comparison of the right and left posterior tubercle to vertebral groove (A) length measurement showed that the measurement was significantly greater on the right side (p<0.05) (Figure 3A). In addition, when comparing the vertebral groove length (B) on both sides, the measurements of the left side were substantially greater (p<0.05) (Figure 3B).

In the first cadaver specimen, the distance of the C1 posterior tubercle to the vertebral groove (A) on the right side was 19 mm, whereas the distance on the left side was 15 mm. In the second cadaver specimen, the exact distance (A) was 21 mm on the right side and 18 mm on the left side. The measurements of A in the third cadaver specimen were 22 mm and 19 mm on the right and left sides, respectively. The fourth cadaver specimen had measurements of 17 mm and 12 mm on the left and right sides, respectively, for the same distance (A). Finally, in the fifth cadaver, the distance of A was 22 mm on the right side and 18 mm on the left side. The mean distance of the C1 posterior tubercle to the vertebral groove (A) on the right side was 20.20 ± 2.16 mm whereas it was 16.40 ± 2.88 mm on the left side.

In the first cadaver specimen, the distance of the vertebral groove (B) on the right side was 13 mm and on the left side was 17 mm. In the second cadaver specimen, the exact distance was 14 mm and 17 mm on the right and left sides, respectively. Measurements for the distance of B obtained in the third cadaver specimen were 14 mm and 17 mm on the right and left sides, respectively. In the fourth cadaver, the distance for B was 13 mm on the right and 18 mm on the left. The fifth cadaver specimen demonstrated measurements of 15 mm on the right and 19 mm on the left for the same measurement (B). The mean distance of the vertebral groove (B) on the right side was 13.80 ± 0.83 mm and on the left was 17.60 ± 0.89 mm.

The mean diameter of the VA was 3.58 ± 0.83 mm on the right side and 3.70 ± 0.10 mm on the left side. We accepted the left VA as the dominant artery in all cadavers.

DISCUSSION

C1 laminectomy without fusion is indicated in some cases, especially in patients who have no instability (3). C1 laminectomy is frequently performed as a surgical intervention for Arnold–Chiari malformation, spinal intracanal tumor, craniovertebral junction stenosis, trauma, and infections. In this study, our aim was to investigate the difference in C1 laminectomy length between the right and left sides and to determine the importance of considering the dominant VA in reducing the risk of complications.

C1 laminectomy is a well-known surgical procedure. However, it is important to be aware that complications may occur during surgery, and to avoid such complications, careful consideration of the anatomy of the VA is required. According to previous studies, the incidence of VA injury is 5.4% during laminectomy and ranges from 8% to 32.4% during C1–2 fixation (4,5,8). There is also a high risk of VA injury during craniocervical surgical procedures. Complications that occur during C1 laminectomy include VA injury and spinal cord injury. Among these, injury to the VA is a life-threatening complication. Complications of VA injury include bleeding, infection, blood clots in the legs or lungs, spinal cord or nerve root injury, and cerebral infarcts. Studies have demonstrated a risk of VA injury, especially during laminectomy. The C1 anatomy must be well identified to prevent catastrophic complications after VA injury.

The vertebral groove widens anteriorly as it progresses on the posterior arch. From the information we obtained in our previous studies, we noted differences between the measurements of the vertebral groove from the superior–anterior to the posterior regions (2,6). In the current study, we obtained measurements from the posterior region; thus, our surgical view was also posterior. The length of the vertebral groove from the posterior region was shorter than that of the superior region (2). Our study results show that the vertebral groove has a specific anatomical shape. It is understood that the course of the VA continues a few millimeters anteriorly and medially at the superior surface of the C1 arcus, and the length of this part is longer than the length of the vertebral groove of the posterior view. Because of these anatomical differences, it should be kept in mind that the risk of arterial injury is high

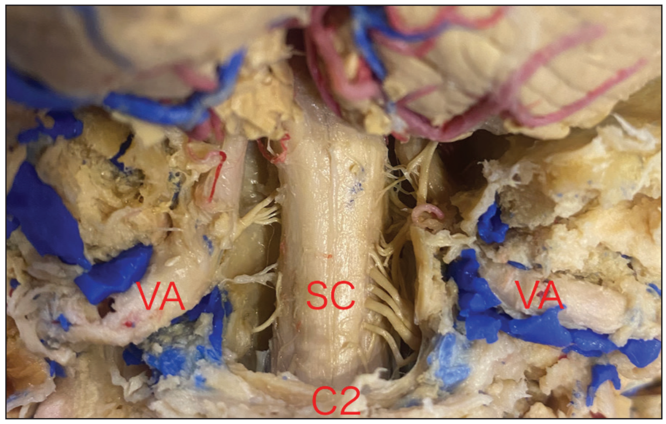

Figure 4: The spinal cord and VA are seen after removal of the C1 posterior arcus, posterior part of the foramen magnum, and part of the occipital bone. The medial border of the vertebral groove is located at the point where the VA artery turns from posterior to anterior. It can be seen in the figure that there is a free distance between the VA and the dura, although the lack of CSF is also taken into account. C2, second cervical vertebrae; SC, spinal cord; VA, vertebral artery.

where the medial border of the vertebral groove begins. It is essential to stop at the medial edge of the vertebral groove, where it is observed from the posterior. As shown in this study, laminectomy should be completed when the medial border of the vertebral groove is reached. Figure 4 shows the free space between the lateral border of the spinal cord and the vertebral groove. As seen in the figure, the spinal cord is covered with the dura in a fixed cadaver. Because there is no cerebrospinal fluid (CSF), the distance between the VA and the dura is greater in cadavers than expected in living tissue. Even when CSF is present, there is a free distance between the dura and VA due to the unique feature of the C1 lateral mass. Decompression at the border of the vertebral groove is known to be sufficient. Extending beyond the medial border of the vertebral groove and reaching more laterally is unnecessary for spinal cord decompression (Figure 4). The thickness of the vertebral groove has been studied in the literature, but studies on its length are limited. The length and diameter measurements we obtained for the vertebral groove of the VA are compatible with those reported in the literature (1,6).

This study shows that the length of C1 laminectomy on the dominant side is significantly different from that on the nondominant side. To reduce complication risks, the decision regarding the extent of laminectomy should be based on the dominant VA. This study addresses the difference in laminectomy areas on the right and left sides of the axis posterior arcus. C1 laminectomy is a commonly performed surgical procedure, and in general, the decision regarding the extent of laminectomy is assumed to be similar on both sides. According to our results, the extent of laminectomy should be asymmetric, because VA damage can significantly affect the outcome of the surgery and the patient's recovery. The data in our study showed that the C1 posterior arch and vertebral groove were different in each cadaver. In addition, in our research, we observed that the VA measurements were different in each cadaver. We also noted that the lengths of the vertebral groove on the dominant and nondominant sides were different in each cadaver. The data obtained in this research guide us in clinical studies. It should be known that the length of the dominant artery differs among patients; therefore, the lengths of the vertebral grooves are also different. Thus, it is useful to evaluate the vertebral groove using preoperative CT in patients planning to undergo C1 laminectomy.

This study has significant implications for surgical planning and decision-making in C1 laminectomy procedures. The findings of our study can be applied to improve the outcomes of C1 laminectomy procedures and reduce the risk of complications during surgery. Our study provides new insights into the importance of considering the dominant VA when determining the length of C1 laminectomy. To ensure the best outcomes for patients, preventing complications during C1 laminectomy is vital. Because the C1 anatomy is complex, laminectomy procedures require careful planning and execution to minimize the risk of complications.

In our previous C1–2 anatomy study, we found that the C1–2 CT measurements and dissection measurements were similar to each other (2). In the current study, we performed CT scans on cadavers to demonstrate the relationship between the vertebral groove and laminectomy. Therefore, we advocate taking preoperative CT studies into consideration. Because there is a possibility of not entering the section during the CT scanning procedure in the vertebral groove, the scans should be performed with thin (1-mm) sections. Radiologic examinations should be carefully examined preoperatively, the course of the VA should be evaluated, and the length of the laminectomy on the right and left sides should be calculated preoperatively. This cadaver study emphasizes the importance of measuring the C1 posterior arch and vertebral groove by performing preoperative CT in clinical cases where the C1 posterior arch must be removed.

The artery was filled with silicone in this study; however, the diameters of the vertebral arteries vary in clinical practice. In addition, to reveal the existence of anatomical variations, large-series clinical studies are needed as well as clinical studies that include patients who have undergone surgery and studies that involve CT scans.

CONCLUSION

In this study, we observed that the C1 posterior arcus had different characteristics in each cadaver sample. Our findings contradict the common belief that the length of C1 laminectomy should be the same on both sides. Our study provides supporting data for the importance of considering the dominant VA in determining the extent of C1 laminectomy. The vertebral groove was longer on the dominant artery side and shorter on the nondominant artery side. Thus, the dominant and nondominant sides have different lengths of safe C1 laminectomy areas. The extent of the length of the laminectomy area to be performed on the dominant artery side was shorter than that on the nondominant side. In cases in which the C1 posterior arcus must be removed for decompression, asymmetric decompression should be performed to reduce the risk of VA injury.

Declarations

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Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author by reasonable request.

Disclosure: The authors declare no competing interests.

AUTHORSHIP CONTRIBUTION

Study conception and design: YG, UV
Data collection: YG,UV
Analysis and interpretation of results: UV, YG
Draft manuscript preparation: YG, UV
Critical revision of the article: YG,UV
Other (study supervision, fundings, materials, etc...): UV, YG
All authors (YG, UV) reviewed the results and approved the final version of the manuscript.

REFERENCES

1. Ebraheim NA, Xu R, Ahmad M, Heck B: The quantitative anatomy of the vertebral artery groove of the atlas and its relation to the posterior atlantoaxial approach. Spine (Phila Pa 1976) 23:320-323, 1998. https://doi: 10.1097/00007632-199802010-00007.
2. Guvenc Y, Topal B, Verimli U, Biyikli E, Akdeniz E, Ziyal İ: Posterolateral paramass approach to lesions located at the anterior C1-2 level: A cadaver study. World Neurosurg 186:e566-e576, 2024. https://doi: 10.1016/j.wneu.2024.03.176.
3. Kakutani K, Doita M, Yoshikawa M, Okamoto K, Maeno K, Yurube T, Sha N, Kurosaka M, Nishida K: C1 laminectomy for retro-odontoid pseudotumor without atlantoaxial subluxation: Review of seven consecutive cases. Eur Spine J 22:1119-1126, 2013. https://doi: 10.1007/s00586-013-2681-0.
4. Khan S, Cloud GC, Kerry S, Markus HS: Imaging of vertebral artery stenosis: A systematic review. J Neurol Neurosurg Psychiatry 78:1218-1225, 2007. https://doi: 10.1136/jnnp.2006.111716.
5. Lunardini DJ, Eskander MS, Even JL, Dunlap JT, Chen AF, Lee JY, Ward TW, Kang JD, Donaldson WF: Vertebral artery injuries in cervical spine surgery. Spine J 14:1520-1525, 2014. https:// doi: 10.1016/j.spinee.2013.09.016.
6. Omotoso BR, Harrichandparsad R, Satyapal KS, Moodley IG, Lazarus L: Radiological anatomy of the intracranial vertebral artery in a select South African cohort of patients. Sci Rep 11:12138, 2021. https://doi.org/10.1038/s41598-021-91744-9
7. Takemoto M, Neo M, Fujibayashi S, Sakamoto T, Ota M, Otsuki B, Kaneko H, Umebayashi T: Clinical and radiographic outcomes of C1 laminectomy without fusion in patients with cervical myelopathy that is associated with a retro-odontoid pseudotumor. Clin Spine Surg 29:E514-E521, 2016. https://doi: 10.1097/BSD.0b013e31829eb7e6.
8. Yamaguchi S, Eguchi K, Kiura Y, Takeda M, Kurisu K: Posterolateral protrusion of the vertebral artery over the posterior arch of the atlas: Quantitative anatomical study using three-dimensional computed tomography angiography. J Neurosurg Spine 9:167-174, 2008. https://doi: 10.3171/SPI/2008/9/8/167.