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Exposing vertebral artery from lateral to medial under the guide of peri-vertebral artery fat pad in far lateral approach

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Far lateral approach (FLA), together with its modified approaches, is a fundamental surgical approach for surgical resection of lesions located at the ventral or ventrolateral side of the foramen magnum.[1-5] The key procedure in FLA is exposing the vertebral artery (VA) especially the V3 segment.[1,5,6] When performing an FLA, most neurosurgeons choose to expose the suboccipital triangle (formed by the rectus capitis posterior major, the superior oblique, and the inferior oblique) as a key anatomical landmark initially and then expose the V3 segment.[1,2,5-7] However, on the one hand, this muscular anatomical landmarks-suboccipital triangle varies in depth, morphology, and location in different patients, which increases the risk of VA injury during surgery.[3] On the other hand, this procedure could lead to exposing difficulty due to the obstruction of overlying layers of muscles and the distribution of blood vessels, which could prolong the time for craniotomy fairly. The course of VA could vary, such as looping backward and bulge posteriorly between the lips of the suboccipital triangle, where it could be damaged if one expects it to be found in the depth of the suboccipital triangle.[3] Thus, neurosurgeons have the potential for VA injury and a rather prolonged time to successfully expose VA.

In this study, we proposed a novel surgical technique to identify and expose the V3 segment of VA from lateral to medial in FLA using the transverse process of atlas (C1) and peri-vertebral artery fat pad (PVAFP), obviating the need for exposing suboccipital triangle [Figure 1A]. Furthermore, we performed a retrospective statistical analysis on different ways to identify and expose VA to investigate the advantages of this novel manner (Group A) compared with suboccipital triangle manner (Group B) focusing on VA exposure duration, estimated blood loss (EBL), and VA injury. An institutional review board exemption and a waiver of the requirement of the written informed consent were submitted and approved by the Ethics Committee of West China Hospital of Sichuan University to perform this retrospective study (No.2021-1439).

From January 2014 to June 2020, patients who had a preoperative diagnosis of ventral lesions of the foramen magnum underwent surgery via FLA in our institute were retrospectively reviewed. The inclusion and exclusion criteria are provided in [Supplementary files (Part A, http://links.lww.com/CM9/A894)].

Patients were categorized into the following two groups. Group A: locating and exposing VA under the guidance of the transverse process of C1 and PVAFP from lateral to medial; Group B: locating and exposing VA through suboccipital triangle from medial to lateral.

We retrospectively reviewed the clinicopathological details, as well as VA exposure methods, VA exposure duration, EBL, VA injury, and outcomes. The VA exposure duration was termed as the time during skin incising and VA exposure. The EBL was evaluated as the total blood loss during that procedure. VA injury was recorded according to the operation notes. The definition of the extent of resection and follow-up protocol is provided in [Supplementary Materials (Part B, http://links.lww.com/CM9/A894)].

The Surgical procedures for Group A were as follows [Supplementary Video, http://links.lww.com/CM9/A897]. We usually use a supine position, with the head tilted to the healthy side 45 to 60° [Figure 1B]. If the lesion extends to the axis plane, we use lateral position instead, with head bent at 10 to 15° to the healthy side on the coronal plane, positioning the mastoid at the highest point. The head is fixed with Mayfield. We use a C-shaped incision in supine position patients and an inverse U-shaped incision in lateral position cases [Figure 1C].[4,5] After cutting and opening the skin flap, transecting the muscles horizontally along lineae nuchae superior and vertically along the extension line of the mastoid tip. Using unipolar electrosurgical unit to separate the whole layers of muscles

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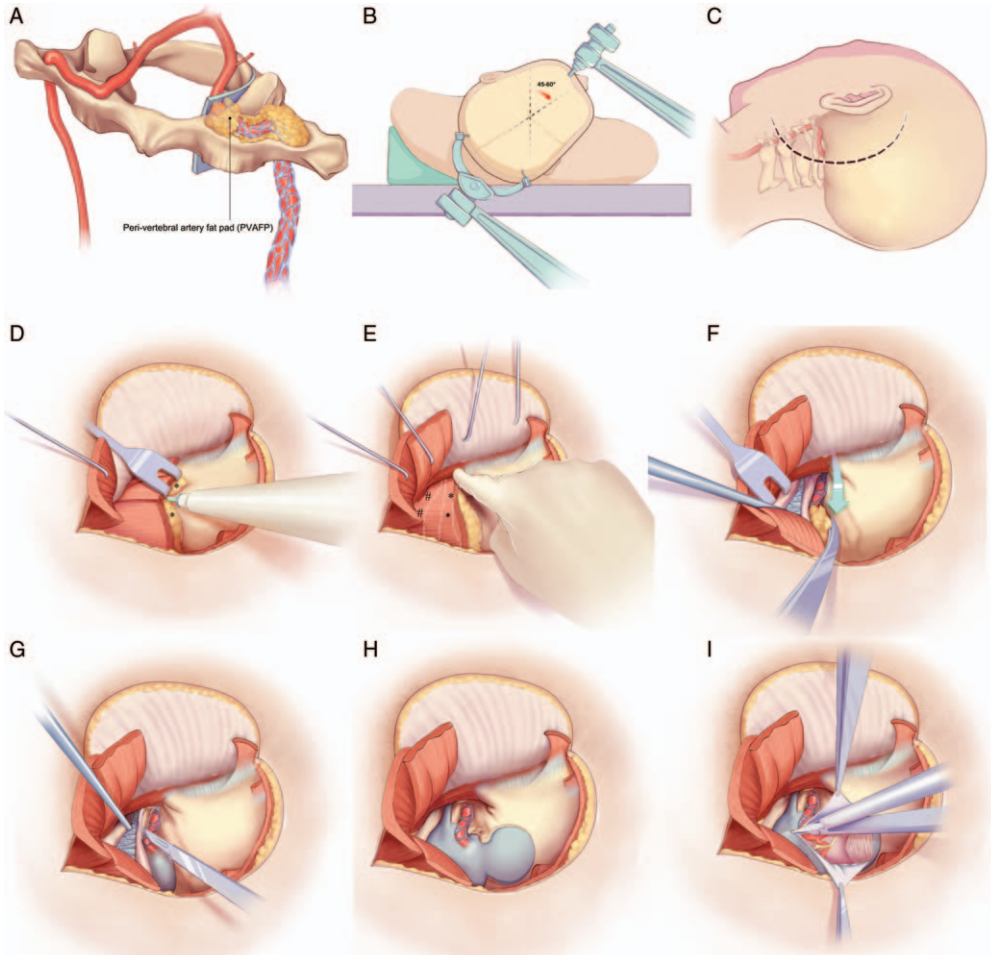

Figure 1: Illustration of PVAFP and main steps of exposing VA from lateral to medial via FLA (for Group A). (see Video, http://links.lww.com/CM9/A897). (A) The PVAFP surrounds the V3 segment of VA and its surrounding venous plexus, which could be considered as a significant anatomical landmark to locate and expose VA from lateral to medial via FLA. We usually use a supine position, with head tilted to the healthy side 45 to 60° (B) and a C-shaped skin incision (C). (D) The flap has been opened, and muscles have been transected. Then, separate the whole layers of muscles along the cranium to reveal the PVAFP*. (E) Palpate and locate the transverse process of atlas (C1) and confirm the course of V3 according to the distribution of PVAFP; cut the attachment point of a superior oblique muscle and inferior oblique muscle to atlas process (*projection of C1; #projection of C2). (F) Retract all layers of muscles as a whole, obviating the need for exposing suboccipital triangle; strip away PVAFP by meningeal scissors along the V3 from lateral to medial (arrow); coagulate the venous plexus with bipolar when necessary. (G) Cut the periosteum along the posterior side of lamina of the atlas and strip the VA in sub-periosteum space. (H) Remove the lamina of the atlas or further of the axis, form the bone flap, and drill the occipital condyle when necessary. (I) Open the dura, separate the VA dural cuff if necessary. FLA: Far lateral approach; PVAFP: Peri-vertebral artery fat pad; VA: Vertebral artery.

along the cranium to reveal the PVAFP [Figure 1D]. Palpate and locate the transverse process of atlas and confirm the course of V3 according to the distribution of PVAFP; cut the attachment point of superior oblique and inferior oblique muscle to atlas process [Figure 1E]. Performing curettage of the PVAFP by meningeal scissors along V3 from lateral to medial to skeletonize VA; coagulate the venous plexus with bipolar when venous hemorrhage occurs [Figure 1F]. Using a scalpel to cut the periosteum along the posterior side of the lamina of atlas and dissector to strip the VA in a subperiosteal manner from lateral to medial [Figure 1G]. We remove the lamina of the atlas or further of axis, form the bone flap, and drill the occipital condyle when necessary [Figure 1H]. We open the dura in a rectilinear fashion and mobilize the VA dural cuff if necessary [Figure 1I]. The surgical procedures of Group B are described in [Supplemental Materials (Part C, http://links.lww.com/CM9/A894)].

The key clinical features, treatment, and outcome are summarized in [Supplementary Table 1, http://links.lww.com/CM9/A895]. Of the 71 patients, the pathological diagnosis included meningioma, schwannoma, and vertebral aneurism (36, 4, and 1, respectively, in Group A and 26, 3, and 1, respectively, in Group B). No VA injury appeared during operation in Group A and two patients had VA injury in Group B. There was no surgery-related mortality in both Groups. After a mean follow-up of 38.3 ± 19.4 months (range 11–88 months), all patients were alive, recurrence was detected in two patients and both received gamma-knife radiosurgery.

The comparison and statistical analysis between Group A and Group B were summarized in [Supplementary Table 2, http://links.lww.com/CM9/A896]. No patient of the two groups had the need to transpose VA. There was no surgery-related mortality. The mean VA exposure duration was 25.6 ± 3.1 min (range 20–31 min) in Group A and 55.2 ± 6.2 min (range 44–68 min) in Group B. The mean EBL was 50.6 ± 18.7 mL (range 20–90 mL) in Group A and 248.3 ± 217.5 mL (range 150–1200 mL) in Group B. No significant difference was found regarding age, gender,

and lesion size between Group A and Group B. Student's *t* tests revealed that Group A had significantly shorter VA exposure duration and less EBL compared with Group B ($P < 0.001$) [Supplementary Figure 1A and 1B, http://links.lww.com/CM9/A893]. Group A had a lower rate of VA injury compared with Group B (0 *vs.* 6.7%) but did not reach statistical significance ($P = 0.060$). Supplementary Figure 1C, http://links.lww.com/CM9/A893 shows the penetrance of the two groups (separated on the y-axis) performed over time (x-axis) for a one-single surgeon.

FLA is a vital surgical approach to access the lesion located at the ventral or ventrolateral side of the foramen magnum, which should be mastered by each neurosurgeon. However, this approach could be challenging, especially for beginners mainly because of the difficulty of VA exposure. In classical surgical techniques, VA is usually located by the suboccipital triangle.[7] Locating and searching the suboccipital triangle is difficult and time-consuming because it may vary in depth, morphology, and location and sometimes it is hard to be recognized because of the obstruction of thick layers of muscles.[1,2] Thus, VA is vulnerable to injury as it is hard to be located and recognized, especially when VA is elongated and tortuous.[3] PVAFP is a loose sheath, with 2 to 3 mm thickness, encasing the VA for the whole course.[2,8] The existence of a fat pad covering the VA had been described in previous studies and some investigators treat it as guidance of VA separation from medial to lateral in FLA.[2,3,7] However, identifying and exposing VA from medial to lateral through PVAFP may not be smoothly performed, because PVAFP is thin and hard to be recognized when dissecting from medial to lateral. Besides, no study proposed the separation of VA from lateral to medial to our knowledge. In this study, we emphasize the anatomical significance of the transverse process of C1 and PVAFP in FLA and present a novel VA exposure and skeletonization technique from lateral to medial.

When dissecting the suboccipital muscles, we cut off all the layers of muscles together from the occipital attachment point, including inferior oblique and rectus capitis posterior major muscles, obviating the need for exposing the suboccipital triangle. While separating the whole layers of muscles, the fat pad sheath (PVAFP) is the first exposing structure that surrounds the venous plexus. After PVAFP is exposed, we use meningeal scissors to strip it away along the VA from lateral to medial, simultaneously we coagulate the venous plexus surrounding VA when necessary (e.g., bleeding occurs). Thus, there are two vital structures between suboccipital muscles and VA: PVAFP and venous plexus [Figure 1A]. PVAFP is easy to be recognized and stripped away, almost without a blood supply, which is an ideal anatomical gap for separating and exposing VA. Besides, we hold that the transverse process of C1 is the optimal bony anatomical landmark to locate the V3 segment. When accessing PVAFP, neurosurgeons could easily strip it away from the dorsal part of the transverse process of C1 where superior and inferior oblique attach, with a direction from lateral to medial. This surgical technique allows neurosurgeons to expose the V3 segment in a non-bleeding and fast way. Compared with classical exposure of the suboccipital triangle and then separating the VA from medial to lateral, our procedure has the advantageslisted in Supplementary material Part C, http://links.lww.com/CM9/A894.

Besides, VA exposure is also a key procedure in many other surgical procedures involving opening the posterior side of the craniocervical junction, such as C1–C2 hemilaminectomy, posterior cervical fusion, occipitocervical fusion, and VA cessation.[1] Thus, our surgical technique to expose VA from lateral to medial under the guide of the transverse process of C1 and PVAFP could also be used in these conditions, which requires VA exposure and transposition.[2] The limitations of our study are provided in [Supplementary Materials (Part D, http://links.lww.com/CM9/A894)].

In conclusion, using the transverse process of C1 and PVAFP as anatomical landmarks, and separating and exposing VA with a direction from lateral to medial is a clear, safe, fast, and non-bleeding technique in FLA.

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Conflicts of interest

None.

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