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Detailed Anatomy for the Transoral Approach to the Craniovertebral Junction: An Exposure and Safety Study

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Abstract

Objective The aim of this study was to demonstrate the anatomical structures of the transoral approach to the craniovertebral junction. We evaluated the necessary exposure field and the safety of this approach.

Methods Surgical operations with the transoral approach were performed on 36 cadaver specimens. The special anatomical structures were measured surrounding the exposure field with priorities given to measurements relating to the vertebral artery (VA). The anatomical relationships between the VA and nerves were observed.

Results The exposure field partly covered the vertebral basilar system confluent. The middle clivus to upper C3 vertebral body can be exposed by transoral approach. Cranial nerves and cervical nerves emerged from the caudal of vertebrobasilar artery and circumambulated anterolaterally, and some abnormalities were observed in the intracranial segment of vertebrobasilar artery. The safe field was in an inverted trapezoid shape, of which the widest point was 25.5 ± 4.5 mm to the midline at C1 transverse process level; the narrowest point was 11.2 ± 1.5 mm to the midline at the C2–3 level.

Conclusion Because the VA is the landmark of the safe field in this approach, surgeons should be very careful to avoid injuries of the VA and nerves while operating in the intracranial field or at the C2–3 level.

Keywords

- anatomy
- exposure
- safe
- transoral approach

Introduction

Commonly used for surgeries on the ventral and medial extradural lesions at the craniovertebral junction,[1] the transoral approach has developed rapidly in the last few years, especially with the invention of the transoral atlantoaxial plate internal fixation.[2,3] However, expanded use does not equate to no risks, and it is of great importance to get acquainted with the anatomical relationships of the cranial nerves and the vertebrobasilar complex to avoid life-threatening complications. Stulík et al reported on a case during this approach that was complicated with a VA injury that turned out to be extremely difficult to manage and eventually resulted in death.[4]

Therefore, a thorough understanding of the anatomy around the anterior upper cervical spine is indispensable for successful surgery and the avoidance of injuries to neurovascular structures. In this cadaveric study we measured the dimensions of the transoral approach with respect to the vertebral artery and the exiting craniocervical nerves so as to define a critical zone of safety and determine the limits of safe exposure.

Materials and Methods

Specimens

Two groups of specimens (20 fresh and 16 preserved with formalin) were used in this study. Fresh cadaveric specimens

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were used to measure the dimensions of the exposure zone, and the formalin-preserved specimens facilitated a better understanding of the vasculature because their blood vessels were injected with latex. The 20 fresh cadaveric craniocervical specimens (12 females and 8 males), which had taken almost 24 months to accumulate, were obtained from the Body Donation Acceptance Center of the Southern Medical University (Guangzhou, China). All these specimens were free from trauma, malignancy, or metabolic diseases as ascertained through clinical inspection and reviews of their medical histories. Anatomical observations were conducted immediately after the specimens were acquired. The 16 formalin-preserved specimens (10 females and 6 males), whose blood vessels were filled with latex emulsion, were offered by the Department of Anatomy, Southern Medical University (Guangzhou, China).

Anatomical Method

After the head and neck of the specimens were securely fixed on the operating table, the transoral approach to the craniovertebral junction was performed in the standard manner as described by Crockard.[5] The oral cavity was cleansed and retracted with a Codman oral retractor. The specimen was then dissected vertically in the midline of the pharyngeal wall, layer by layer until the bone was exposed, and then the thickness of the soft tissue was measured. The retractor blades were placed to maximize lateral retraction of the pharynx and craniocaudad retraction of the soft palate and tongue. Then the distance between the blades was measured as the lateral exposure width, and the distances from the C1 tubercle to both ends of the incision were also measured as the vertical exposure length in a fresh specimen.

A soft palate incision was also made from the posterior margin of the palatal bone to the superior margin of the uvula, curving inferiorly and gently to the right of this structure. The incision was extended to the capitular end, after the retractor was adjusted. The width and length of exposure were remeasured.

In all specimens the ramus of the mandible was cut off for further observation of the deep structures in the region. A Kerrison rongeur was used to remove the arch of C1, the odontoid, and the odontoid ligaments until the dura mater was exposed. Then the lower clivus and cerebral dura mater were resected so that the vertebrobasilar artery system was adequately exposed up to the confluence of the vertebral and basilar artery. After the retropharyngeal soft tissue was carefully resected, the vertebral arteries were exposed. The distances from different segments of the vertebrobasilar artery to the midline and the depths from the anterior border of paired vertebral arteries to the C1 tubercle were measured. Further anatomical exploration was performed to facilitate the observation of cranial nerves and cervical nerves as they exited the craniovertebral foramina.

Statistical Analysis

Statistical analysis was performed using the SPSS v.11.0 software package by the Department of Medical Statistics, Southern Medical University (Guangzhou, China). A paired *t* test was used for statistical comparison of the data, with a p value < 0.05 considered statistically significant.

Results

Soft Tissue in the Retropharyngeal Wall

The soft tissue in the posterior pharyngeal wall was 3.7 ± 1.1 mm in thickness (range: 2.9–4.3 mm) at the C1 tubercle, 6.0 ± 2.0 mm (range: 5.2–7.1 mm) at the C1 lateral mass, and 5.8 ± 1.8 mm (range: 4.3–6.5 mm) at the central part of the C2 vertebral body. It could be dissected into five layers: the mucosa, muscularis mucosae, prevertebral fascia, prevertebral muscles, and anterior longitudinal fascia (►**Fig. 1A–E**). The irregular and convoluted space between the muscularis mucosae and the prevertebral fascia was labeled the retropharyngeal space, which contained loose connective tissues, pharyngeal veins, and pharyngeal branches of the ascending pharyngeal artery and palatine artery (►**Figs. 1B** and **2A**). The average diameter of veins was 0.83 mm with some unusually prominent veins observed in three specimens (older patients) (7.5%). Although some arteries were much more prominent in two specimens (young patients) (5.0%), the average arterial diameter was 0.49 mm. There were also some anterior vertebral vessels lying irregularly beneath the longus colli and the longus capitis muscles. The soft tissue on the roof of the nasopharynx, firmly attached to the ventral surface of the clivus, was composed of the nasopharyngeal mucosa, Sharpey fibers, and the attachment point of the longus capitis muscles (►**Fig. 2B**).

Exposure Zone in the Transoral Approach

The standard transoral approach exposed the retropharyngeal wall to a width of 39.4 ± 2.2 mm (range: 35.5–43.7 mm), as defined by the bilateral retractors, and to a length of 52.1 ± 3.5 mm (range: 44.3–62.0 mm) by the superoinferior retractors. The distance to the C1 tubercle was 13.6 ± 1.6 mm (range: 10.4–17.9 mm) from the tip of the incision, and it was 38.4 ± 2.9 mm (range: 32.3–46.2 mm) from the caudal end of the incision. The distance from the C1 tubercle to the tip of incision added 28.0 ± 3.1 mm (range: 24.1–33.6 mm) after the soft palate was split. Therefore, the incision of the soft palate increased the rostral length of exposure to 66.7 ± 3.9 mm (range: 58.3–77.6 mm) by an extra 14.6 mm. The exposure zone included a region from the lower third of the clivus to the upper of the C3 vertebral body. Exposure was facilitated by levering the handgrip of the Codman oral retractor onto the sternum. These observations were similar to those reported by Garfin and Bruce.[6] Any additional length of incision in this approach did not add to the width of the exposure zone.

The Vertebrobasilar Artery and the Cranial Nerves

The VA's course formed a diamond shape in the atlantoaxial segment, furthest away from the midline at the level of the lateral masses of C1, but closer to the midline at C2. The inner margin of vertebral arteries measured 11.2 ± 1.5 mm (range: 8.9–14.7 mm) from the midline at the level of C2/3, 20.2 ± 4.7 mm (range: 17.9–24.0 mm) at the transverse

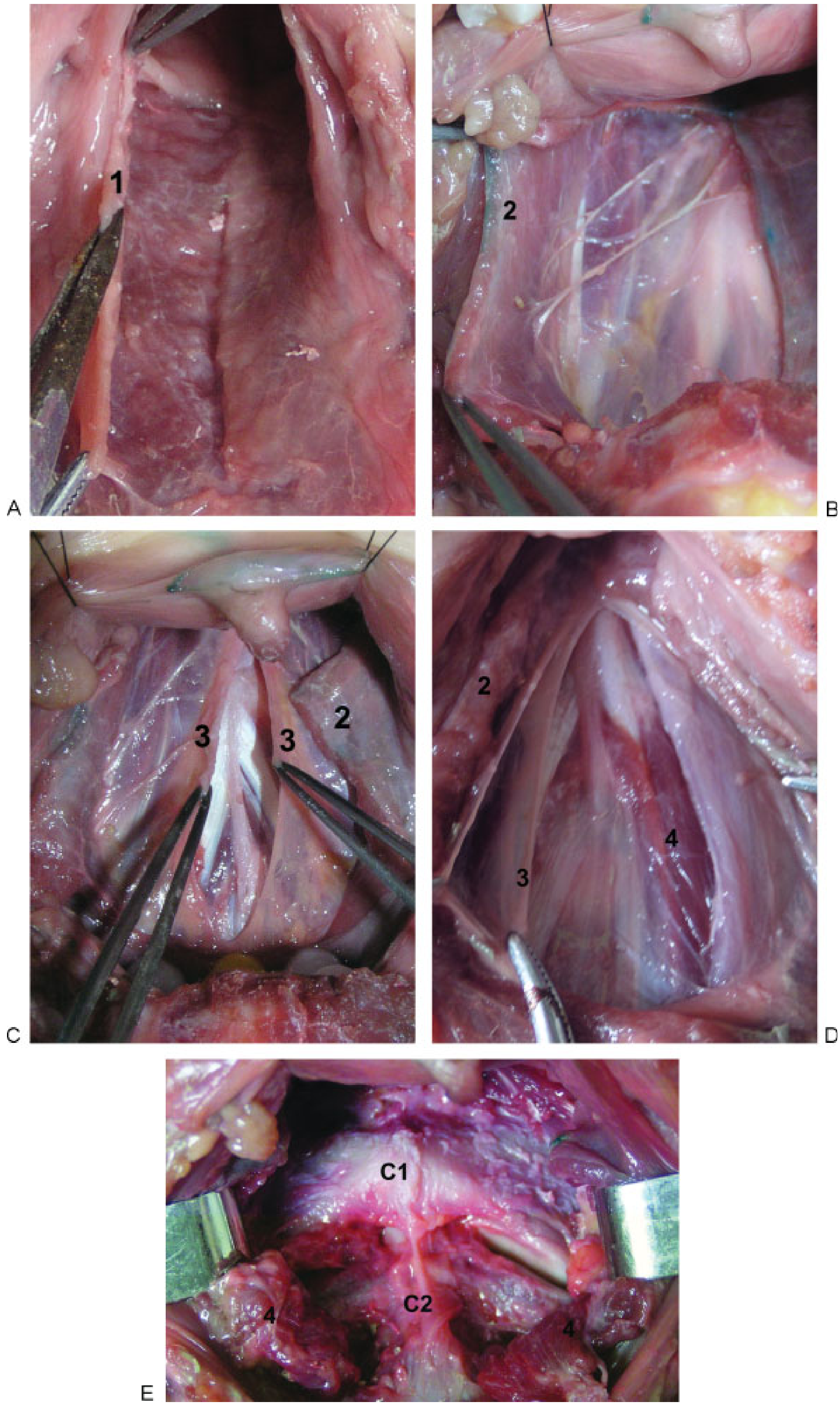

Fig. 1 (A) The mucosa was incised to show the muscularis mucosae. (B) The mucosa and the muscularis mucosae were incised to show the retropharyngeal space where some small vessels were located. (C) The prevertebral fascia was incised to show the prevertebral muscles. (D) The prevertebral space. (E) Bone structure revealed after the soft tissue was incised and retracted. 1, The mucosa; 2, the muscularis mucosae; 3, the prevertebral fascia; 4, the prevertebral muscles.

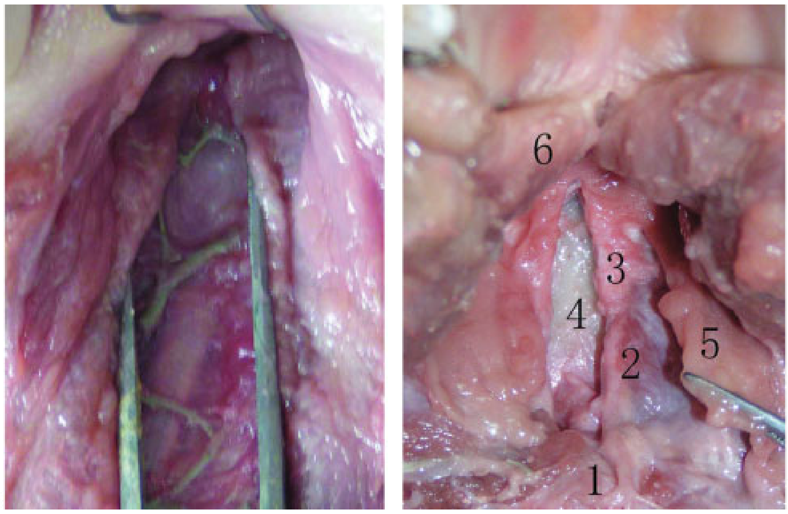

Fig. 2 (A) Vessels in the retropharyngeal space. (B) Soft tissue on the roof of the nasopharynx. 1, the C1 tubercle; 2, attachment point of the longus capitis muscles; 3, Sharpey fibers; 4, clivus; 5, the mucosa; 6, the soft palate.

foramen of C2, 19.7 ± 2.7 mm (range: 13.8–27.4 mm) at the level of C1/2, and 25.5 ± 4.5 mm (range: 21.9–26.7 mm) at the transverse foramen of C1. The depth from the anterior border of vertebral arteries to the C1 tubercle registered 9.8 ± 1.5 mm (range: 5.5–14.3 mm) at the level of C2/3, and 9.2 ± 1.3 mm (range, 6.1–12.8 mm) at the level of C1/2. Because there was no difference between bilateral vertebral arteries in the data obtained ($p < 0.05$), the values were incorporated (►**Table 1**).

Previous studies reported that both sides of the vertebral arteries join together and form the basilar artery (described as similar to the Greek symbol "Λ"). However, this confluence was not always symmetrical because we observed a symmetrical arrangement (►**Figs. 3** and **4**) in 19 cases (52.7%) and unsymmetrical shapes in 17 (47.3%). When the junction point was located on the right side, the data were recorded as positive values; otherwise they were recorded as negative values. The width from the junction point to the midline was 0.2 ± 2.0 mm (range: −3.8 to 2.5 mm) ($p > 0.05$), and the height to the foramen magnum level was 23.2 ± 5.3 mm (range: 14.9–31.8 mm). The width from the inner margins of bilateral VA to the midline was measured, respectively, at the level of 10 mm above the C1 tubercle with data recorded as negative if the VA extended beyond the midline to the opposite side. Results showed that there was 2.9 ± 2.5 (range: −2.2 to 6.2 mm) at the left VA, and 2.5 ± 2.6 (range: −1.6 to 8.0 mm) at the right artery ($p > 0.05$). Nevertheless, the distances measured from the paired vertebral arteries to the midline at the clivus segments displayed a significant difference between the left artery and the right (►**Table 2**), usually indicating an unsymmetrical course of the intracranial vertebrobasilar artery. Therefore, this finding that the junction point of the vertebrobasilar arteries always deviates from the midline contradicts the common assumption that the vertebrobasilar confluence manifests a symmetrical arrangement.

The depth from the incisor tooth to the anterior surface of the vertebrobasilar was 91.4 ± 4.6 mm (range: 87.3–98.1 mm) at the C1–2 segment, 94.9 ± 4.8 mm (range: 89.7–103.4 mm) at the C2–3 segment, and 97.7 ± 5.3 mm (range: 81.5–108.2 mm) at the junction point.

The lower 10 cranial nerves(III–XII) emerge from the brainstem, then flank the vertebrobasilar artery, and finally enter the basicranial pores, passing through the superior

Table 1 Parameter of the vertebral artery between the occipital condyle and the C3 body

	Mean, mm	Range, mm
WVM at the level of C2–3	11.2 ± 1.5	8.9–14.7
WVM at the TF of C2	20.2 ± 4.7	17.9–24.0
WVM at the level of C1–2	19.7 ± 2.7	13.8–27.4
WVM at the TF of C1	25.5 ± 4.	21.9–26.7
DVA at the level of C2–3	9.8 ± 1.5	5.5–14.3
DVA at the level of C1–2	9.2 ± 1.3	6.1–12.8

Abbreviations: DVA, depth from the vertebral artery to the atlas tubercle; TF, transverse foramen; WVM, distance from the vertebral artery to the midline.

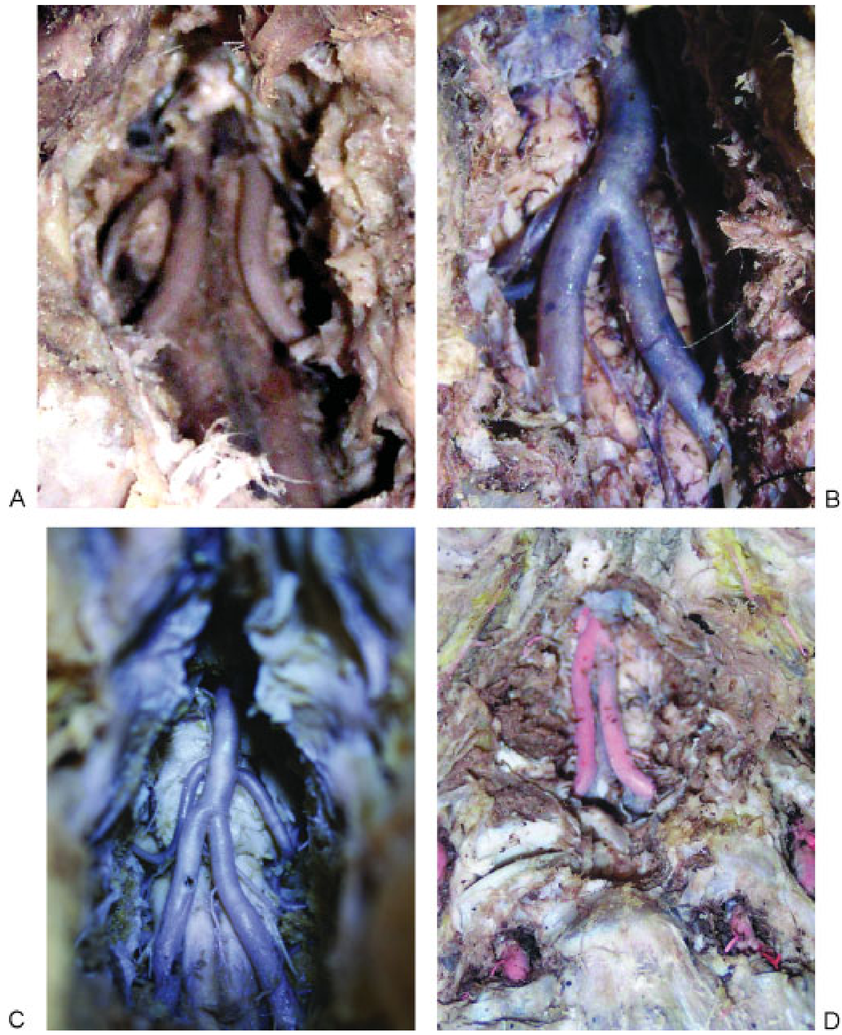

Fig. 3 (A–D) Polymorphic and unsymmetrical shapes of the intracranial vertebrobasilar artery.

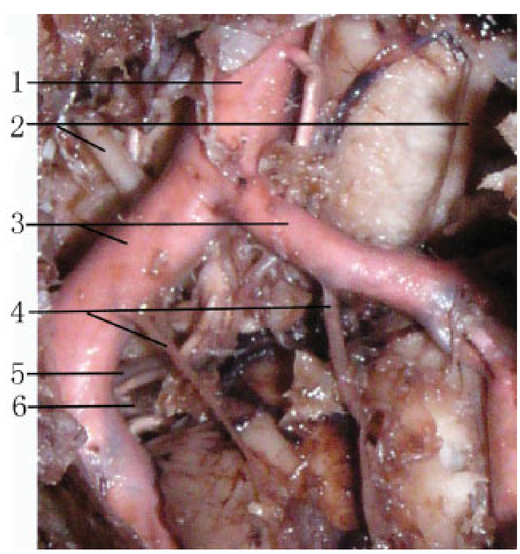

Fig. 4 The spatial relation between the intracranial vertebrobasilar artery and the cranial nerves. 1, basilar artery; 2, abducens nerve; 3, vertebral arteries; 4, anterior spinal artery; 5, vestibulocochlear nerve; 6, the facial nerve.

orbital fissure, the foramen rotundum, the foramen ovale, the internal acoustic pore, the jugular foramen, and the hypoglossal canal. The course of the cranial nerves stepped over the dorsal surface of the vertebrobasilar artery and extended along the anterior lateral direction (►**Fig. 4**). Because no variation of this anatomical relationship was observed in all studied specimens, we considered it relatively safe to confine the operation to between the inner margins of the bilateral vertebral arteries.

Discussion

Clinical Significance

Due to the advantages of direct decompression and the improvement of technique, the transoral operation has developed rapidly in recent years, further facilitated by modifications of the transoral approach and the concomitant invention of newer specific internal fixation systems.[2,3,7,8] It is therefore necessary for surgeons to identify the limits of exposure and the zone of safety of particular relevance to the vertebral artery and its confluence. This applied anatomical study provides a reliable basis on which further

Table 2 Parameter of the intracranial vertebral artery

	Mean, mm	Range, mm
H	23.2 ± 5.3	14.9–31.8
W1	0.2 ± 2.0	−3.8 to 2.5
W2[a]	2.9 ± 2.5	−2.2 to 6.2
W3	2.5 ± 2.6	−1.6 to 8.0

Abbreviations: H, height from the junction point of the vertebrobasilar artery to the foramen magnum level; W1, width from the junction point to the midline; W2, width from the left vertebral artery to the midline at the level of 10 mm above the C1 tubercle; W3, width from the right vertebral artery to the midline at the level of 10 mm above the C1 tubercle.
[a]There was a significant difference between W2 and W3.

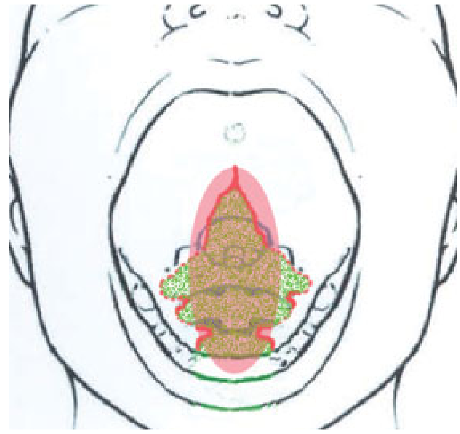

Fig. 5 The sagittal exposure zone and the safe zone. The red line represents the course of the vertebrobasilar artery, the red zone represents the exposure zone, and the green zone represents the safe zone.

surgical procedures, exposures, and implant designs could be planted.

Technique in Soft Tissue Treatment

Local infection in the transoral operation, mainly induced by clean-contaminated oral circumstances, can be aggravated with the presence of foreign and/or devitalized materials such as fixation plate and autologous bone graft. Soft tissue dissection should be done in line with the anatomical planes. Precise hemostasis is necessary when incising the retropharyngeal space and the surface of the vertebral body, where some small vessels and nutrient arteries are located sporadically. At the time of closure, all devitalized tissues must be removed and the posterior wall of the pharynx should be sutured in two layers to enclose the retropharyngeal space and the prevertebral space. We also suggest that the prevertebral muscles be stitched with synthetic absorbable braided suture in a method called a figure-of-eight suture, and the mucosa and the muscularis mucosae be intermittently stitched by monofilament suture. Because some tenacious soft tissues such as the Sharpey fibers and the attachment point of longus capitis muscles exist in the roof of the nasopharynx and attach firmly to the clival sclerotin, transversal exposure would be limited. The incision and suturation of this layer must therefore be done with extreme care to ensure good postoperative wound healing.[9]

Zone of Exposure and Safety

The exposure length ranged from the inferior border of the clivus to the superior border of C3. The upper boundary can reach to the middle of the clivus, which measures 28.0 ± 3.1 mm above the C1 tubercle, after the soft palate is incised. This boundary is high enough to expose the junction point of the vertebrobasilar artery that is 23.2 ± 5.3 mm above the C1 tubercle. To avoid the iatrogenic injury of the abducens nerve (VI) and the upper nerves (I–V), we suggest the exposure be confined to a 20-mm height over the C1 tubercle or no higher than the junction point. Otherwise, potential damage to these two cranial nerves would increase significantly.

Transversal exposure can reach 39.4 ± 2.2 mm in a fresh specimen. Although Kandziora et al described the safe zone for anterior C1–C2 screw placement through the transoral approach by measuring 32 linear and 4 angular parameters with 50 human dry C1 and C2 vertebrae,[10] the detailed and complete safe boundary in transoral operation has not been delineated. It has been demonstrated that bilateral safe borders should mainly refer to the course of VA because all constraints to further lateral dissection are imposed by the VA. Nevertheless, the course unveiled is circuitous and overlaps partly with the exposure borders(►**Fig. 5**).

The VA between C0 and C1 runs deep into the groove for VA, which is located at the dorsal massa lateralis atlantis. Surgery in this zone would be safe because generally the location is rarely accessed in the anterior approach. The VA between the transverse foramens of C1 and of C2 travels outside the exposed boundary. According to our research, manipulation in the transoral approach is relatively safe between the occipital condyle and the transverse process of C2, especially in the C0–C1 segment. However, even though the VA in C1–C2 exceeds the exposed zone, it is suggested that the lateral dissection be confined within the interior two-thirds of the atlantoaxial lateral mass joint, in consideration of maximum safety.

The VA in the segment of the clivus and C2–C3, in contrast, is inside the exposed zone. Manipulation in these two regions would entail relatively more risks. It is recommended that the safe surgical region in the C2–C3 segment be restricted to no more than 10 mm from the midline in width and no more than 8 mm from the C1 tubercle in depth. It is also feasible to take transverse foramens of C1 and C2 as references. Regarding operations at the clivus, concrete statistics for the safe zone could not be provided on account of the volatile course of the VA. Because observing the course of the arteries is essential for avoiding iatrogenic trauma of nerves or vessels, CT angiography would be helpful for preoperative or detailed surgical dissection.

Conclusions

Because there are no important blood vessels or nerves lying in the sagittal plane and within the center of the exposure, transoral surgery proves relatively safe as the exposure zone is wide enough to allow placements of plates and screws, and the retropharyngeal soft tissue has a bulk that can serve to cover a 2-mm-thick plate. Our study divided the exposure zone into four regions: the clivus segment, the C0–C1 segment, the C1–C2 segment, and the C2–C3 segment. The C0–C1 segment was revealed as the safest region for surgery followed by the C1–C2 segment and the C2–C3 segment. The clivus segment was the most hazardous.

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References

1 Tun K, Kaptanoglu E, Cemil B, Karahan ST, Esmer AF, Elhan A. A neurosurgical view of anatomical evaluation of anterior C1-C2 for safer transoral odontoidectomy. Eur Spine J 2008;17(6):853–856
2 Kandziora F, Pflugmacher R, Ludwig K, Duda G, Mittlmeier T, Haas NP. Biomechanical comparison of four anterior atlantoaxial plate systems. J Neurosurg 2002;96)3, Suppl):313–320
3 Yin Q, Ai F, Zhang K, et al. Irreducible anterior atlantoaxial dislocation: one-stage treatment with a transoral atlantoaxial reduction plate fixation and fusion. Report of 5 cases and review of the literature. Spine (Phila Pa 1976) 2005;30(13):E375–381
4 Stulík J, Vyskocil T, Sebesta P, Kryl J. Harms technique of C1-C2 fixation with polyaxial screws and rods. [in Czech]. Acta Chir Orthop Traumatol Cech 2005;72(1):22–27
5 Crockard HA. Transoral approach to intra/extradural tumors. In: Sekhar LN, Janecka IP, eds. Surgery of Cranial Base Tumors. New York, NY: Raven Press; 1993:225–234
6 Garfin SR, Bruce E. Surgery for Spinal Cord Injuries. New York NY: Northrup Raven Press; 1993
7 Youssef AS, Guiot B, Black K, Sloan AE. Modifications of the transoral approach to the craniovertebral junction: anatomic study and clinical correlations. Neurosurgery 2008;62(3, Suppl 1):145–154; discussion 154–155
8 Liu JK, Couldwell WT, Apfelbaum RI. Transoral approach and extended modifications for lesions of the ventral foramen magnum and craniovertebral junction. Skull Base 2008;18(3):151–166
9 Resch KD. Minimally invasive techniques in neurosurgery: the transoral transpharyngeal approach to the brain. Neurosurg Rev 1999;22(1):2–25; discussion 26–27
10 Kandziora F, Schulze-Stahl N, Khodadadyan-Klostermann C, Schröder R, Mittlmeier T. Screw placement in transoral atlantoaxial plate systems: an anatomical study. J Neurosurg 2001;95(1, Suppl):80–87