Surgical and Radiologic Anatomy (2018) 40:581–586
https://doi.org/10.1007/s00276-017-1961-5

ORIGINAL ARTICLE

Surgical anatomy of neurovascular structures related to ventral C1–2 complex: an anatomical study

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Received: 21 June 2017 / Accepted: 18 December 2017 / Published online: 26 December 2017
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Abstract

Objective Transoral odontoidectomy and ventral C1–2 stabilization are important surgical procedures, performed to decompress ventral spinal cord, and to stabilize craniovertebral junction. These procedures require knowledge regarding surgical anatomy of neurovascular structures ventral to the C1–2 complex. The aim of this study is to evaluate the relationships between neurovascular structures and bony landmarks in ventral atlantoaxial complex.

Materials and methods This study was performed on six formaldehyde fixed cadaveric head and neck specimens. Relevant anatomical parameters, including distances from the midsagittal line to internal carotid arteries (ICA), vertebral arteries (VA), and hypoglossal nerves (HN), were measured using electronic calipers.

Results The mean distance between ICA and midsagittal line was observed as 26.13 mm at the level of axis and 24.67 mm at the level of the atlas. The mean distance between VA and midsagittal line was observed as 15.38 mm at the level of axis and 26.54 mm at the level of the atlas. The mean distance between HN and midsagittal line was observed as 33.27 and 33.58 mm at the level of the atlas and axis, respectively.

Conclusion This study confirmed that ICA and HN proceeded ventrally or laterally along the lateral aspect of the C1 lateral mass; therefore, the area located ventrally along the medial components of the C1 lateral mass was the safe zone for anterior surgical approach.

Keywords Surgical anatomy · Transoral odontoidectomy · Anterior cervical approaches · Atlantoaxial stabilization · Vertebral artery · Hypoglossal nerve · Internal carotid artery

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Introduction

C1–2 complex is located in the junction of cranium and spine. The ventral surgical approaches may be indicated in many conditions requiring ventral upper cervical spine decompression and instrumentation, particularly in basilar invagination [1, 2].

One of the most important ventral surgical procedures is odontoidectomy. Odontoidectomy has been performed for many years using transoral approach to decompress spinal cord [1, 3]. Recently, many surgeons started to perform minimally invasive odontoidectomy using endoscope via transnasal approach [4, 5].

On the other hand, ventral upper cervical approach may be used rarely to stabilize upper cervical spine. During both decompressive and stabilizing procedures, internal carotid artery (ICA), vertebral artery (VA), and hypoglossal nerve (HN) may be exposed to risk of surgical injury [6, 7]. Therefore, both ventral odontoidectomy and C1–2 stabilization

procedures require detailed topographic-anatomical information about neurovascular structures located ventrally to upper cervical spine.

The aim of this study is to investigate distances from midsagittal line to neurovascular structures and bony landmarks.

Materials and methods

This study was conducted at the Department of Anatomy, School of Medicine, Dokuz Eylul University. The official permission for this investigation was obtained from Dokuz Eylul University School of Medicine. In this study, six adult head–neck specimens, fixed in formaldehyde, were used. The arteries and veins were slowly filled manually with the coloured silicone.

The all measurements were taken with Mitotoyo digital caliper, accurate to within 0.01 mm. The statistical analysis was performed using SPSS 15.0 (SPSS Inc. Chicago, IL). Wilcoxon test was used to evaluate the data, and the significance was accepted at $p \leq 0.05$.

Results

The main cervical neurovascular structures (ICA, VA, and HN) were demonstrated using cadaveric dissections (Figs. 1, 2, 3). The distances of neurovascular structures (ICA, VA, and HN) to bony landmarks (midsagittal line, lateral border of the odontoid, and medial border of the C1 lateral mass) were measured (Fig. 4). The relevant paramaters regarding relationships of C1–2 complex to neurovascular structures (ICA, VA, and HN) in this study are shown in Table 1. The C1 lateral mass was ventrally zoned as follows: zone-1 (from median to medial border of the C1 lateral mass), zone-2 (medial half of C1 lateral mass), zone-3 (lateral half of the C1 lateral mass), and zone-4 (from lateral to lateral border of the C1 lateral mass) (Fig. 5). The positions and courses of ICA and HN with respect to the ventral aspect of C1 lateral mass zones were determined.

The results of the studied parameters are presented in Table 1. The mean diameter of ICA at the level of C1 was found with 5.86 ± 0.30 mm. The mean distance between ICA and midsagittal line at the level of C2 was observed as 26.13 ± 3.48 mm, whereas the ICA was determined to be closer to the midsagittal line at the level of C1 with a mean distance of 24.67 ± 2.81 mm.

The VA passes through the transverse foramen, and C1–2 complex includes junction of part-2 and part-3 of VA. The mean distance between the VA and midsagittal line at the level of C2 (distal end of part 2 of VA) was observed as 15.38 ± 2.08 mm. While the VA ascends to the C1–2 junction, its part-3 proceeds sharply laterally. The mean distance between midsagittal line and VA at the level of C1 was observed as 26.54 ± 2.16 mm.

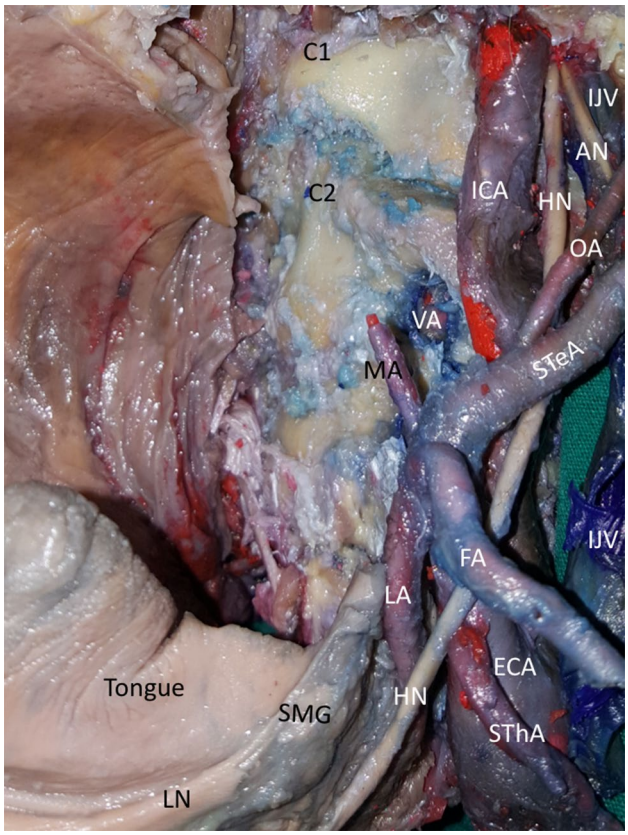


Fig. 1 Neurovascular structures on ventral aspect of cervical region. *ICA* internal carotid artery, *ECA* external carotid artery, *OA* occipital artery, *STeA* superficial temporal artery, *MA* maxillary artery, *LA* lingual artery, *FA* facial artery, *SThA* superior thyroid artery, *VA* vertebral artery, *IJV* internal jugular vein, *HN* hypoglossal nerve, *VN* vagal nerve, *LN* lingual nerve, *AN* accessory nerve, *SMG* submandibular gland

The HN proceeds straightly along the ventral aspect of C1–2 complex. The mean distances between midsagittal line and the HN at the level of C1 and C2 were determined as 33.27 ± 3.98 and 33.58 ± 4.55 mm, respectively.

The mean distances from medial border of the ICA to medial border of lateral mass (C1) and lateral border of the odontoid were observed as 15.91 ± 2.72 and 19.41 ± 2.74 mm, respectively.

We did not find any significant differences between any parameters measured for each side (right and left). However, we determined that the ICA was mostly located along the ventral aspect of zone-3 (50%) and zone-4 (50%) and that the HN was mostly located along the ventral aspect of zone 4 (83.34%), at the level of C1 lateral mass (Table 2).

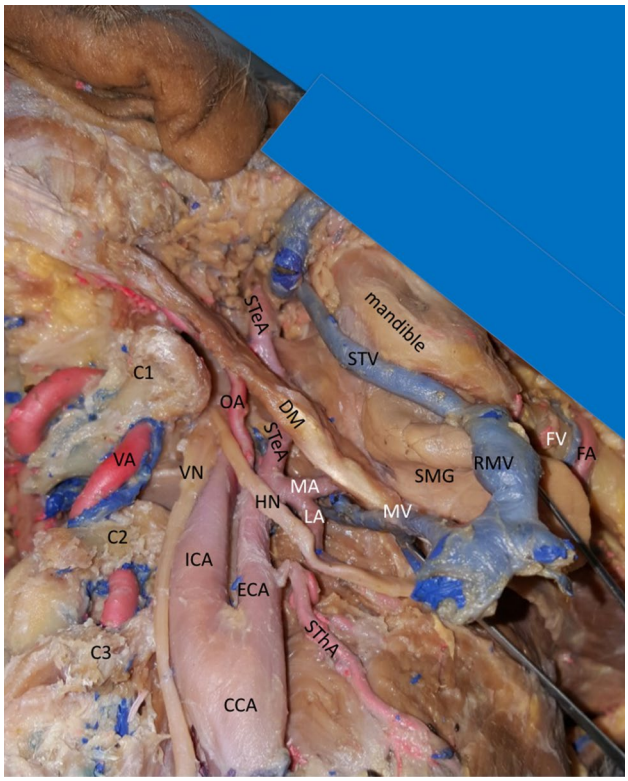


Fig. 2 Hypoglossal nerve and other neurovascular structures on posterolateral aspect of cervical region on the right side. *CCA* common carotid artery, *ICA* internal carotid artery, *ECA* external carotid artery, *OA* occipital artery, *STeA* superficial temporal artery, *MA* maxillary artery, *LA* lingual artery, *FA* facial artery, *STHA* superior thyroid artery, *STV* superficial temporal vein, *RMV* retromandibular vein, *MV* maxillary vein, *FV* facial vein, *VA* vertebral artery, *HN* hypoglossal nerve, *VN* vagal nerve, *SMG* submandibular gland, *DM* digastric muscle

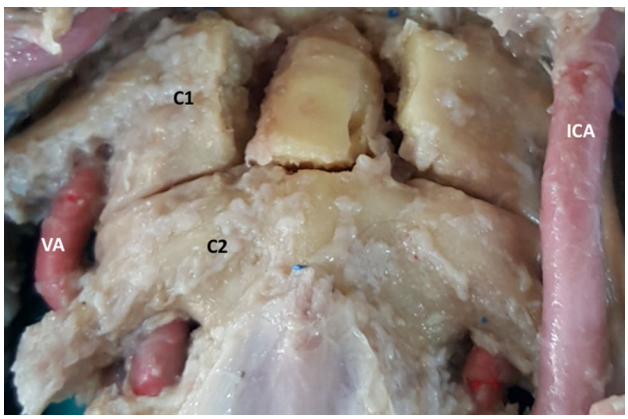


Fig. 3 Ventral aspect of C1–C2 complex, odontoid, internal carotid artery, and vertebral artery. *ICA* internal carotid artery *VA* vertebral artery

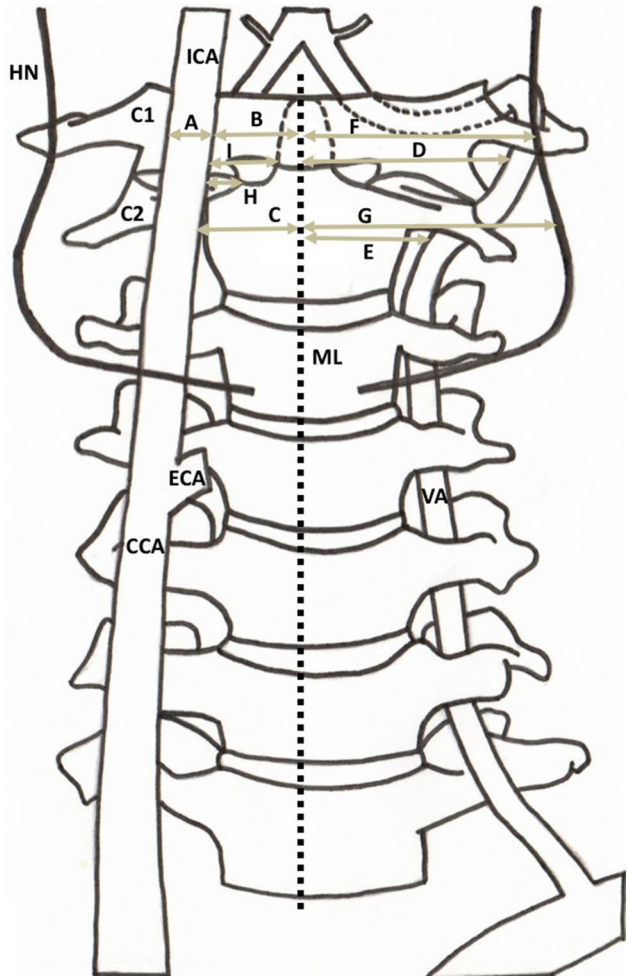


Fig. 4 Parameters. *CCA* common carotid artery, *ECA* external carotid artery, *ICA* internal carotid artery, *VA* vertebral artery, *HN* hypoglossal nerve, *ML* midsagittal line. Diameter of ICA at the level of C1 (**a**), distance between medial side of ICA and midsagittal line at the level of C1 (**b**), distance between medial side of ICA and midsagittal line at the level of C2 (**c**), distance between medial side of VA and midsagittal line at the level of C1 (**d**), distance between medial side of VA and midsagittal line at the level of C2 (**e**), distance between HN and midsagittal line at the level of C1 (**f**), distance between HN and midsagittal line at the level of C2 (**g**), distance between medial border of lateral mass and medial border of ICA (**h**), distance between lateral border of odontoid and medial border of ICA (**i**)

Discussion

This study confirmed that the ICA's converge and the VA's diverge as they ascend from C2 to C1, whereas the HN proceeds almost straightly as it descends from C1 to C2. The course of HN is parasagittal to midline at this level. The ICA converges medially at C1 level, and its course should be taken into consideration when performing anterior C1–2 surgeries. The VA proceeds more laterally at C1 level, and its course is also important when performing posterior screw fixation procedures at C1–2 level.

Table 1 Results of the measurements of internal carotid artery (ICA), vertebral artery (VA), and hypoglossal nerve (HN) at C1 and C2 levels

Parameters (mm)	Left mean ± SD (median)	Right mean ± SD (median)	Total mean ± SD	*p
ICA diameter at the C1 level	5.97 ± 0.13 (5.97)	5.74 ± 0.38 (5.71)	5.86 ± 0.30	0.192
Distance between midsagittal line and medial border of ICA at the level of C1	24.51 ± 3.56 (24.50)	24.73 ± 1.57 (25.54)	24.67 ± 2.81	0.258
Distance between midsagittal line and medial border of ICA at the level of C2	25.92 ± 3.58 (26.04)	26.32 ± 3.69 (26.84)	26.13 ± 3.48	0.852
Distance between midsagittal line and medial border of VA at the level of C1	26.69 ± 2.27 (27.01)	26.38 ± 2.24 (25.78)	26.54 ± 2.16	0.816
Distance between midsagittal line and medial border of VA at the level of C2	15.31 ± 2.52 (15.78)	15.44 ± 1.78 (15.33)	15.38 ± 2.08	0.923
Distance between midsagittal line and HN at the level of C1	32.76 ± 3.76 (32.42)	33.78 ± 4.48 (32.75)	33.27 ± 3.98	0.679
Distance between midsagittal line and HN at the level of C2	33.65 ± 2.41 (34.63)	33.51 ± 6.29 (34.18)	33.58 ± 4.55	0.962
Distance between medial border of lateral mass and medial border of ICA	14.96 ± 2.99 (15.07)	16.87 ± 2.28 (16.17)	15.91 ± 2.72	0.242
Distance between lateral border of odontoid and medial border of ICA	18.45 ± 3.46 (18.32)	20.36 ± 1.52 (19.55)	19.41 ± 2.74	0.245

*p values were given for the comparisons of right and left sides

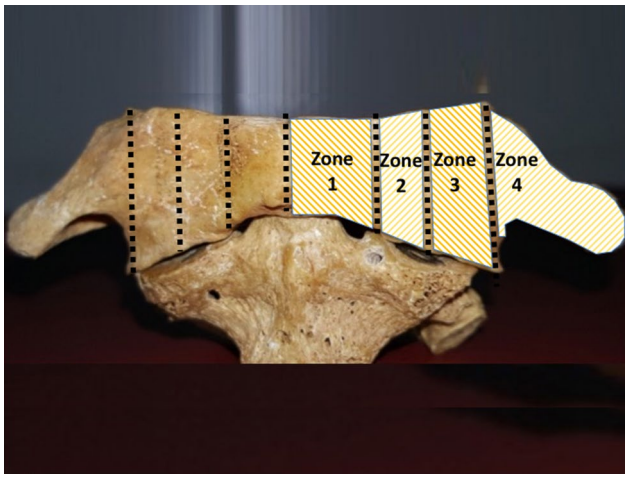


Fig. 5 Ventral aspect of C1–C2, position of ICA and HN with respect to C1 lateral mass (Zone 1 through 4)

Table 2 Locations of internal carotid artery and hypoglossal nerve at C1 level

	Zone 1	Zone 2	Zone 3 (%)	Zone 4 (%)
ICA in the right side	–	–	50	50
ICA in the left side	–	–	50	50
HN in the right side	–	–	16.66	83.34
HN in the left side	–	–	16.66	83.34

ICA internal carotid artery, *HN* hypoglossal nerve

Ebraheim et al. [8] studied 20 cervical spine specimens and observed that the HN actually takes place directly in front of the lateral portion of the C1 lateral mass (immediately medial to the C1 transverse process) and the C1–2 facet joint. Janfaza et al. [9] clarified that the HN emerges from the skull through the hypoglossal canal medial to the internal jugular vein and ICA then goes laterally and inferiorly on the posterior aspect of the vagus nerve. Hoh et al. [10] stated that the ICA originates from the carotid artery bifurcation and arises in the carotid triangle of the neck, and runs anteriorly to the atlas before entering the carotid canal at the skull base.

This study also confirmed that ICA and HN were not located along the ventral aspect of zone-1 and zone-2, whereas they were only located along the ventral aspect of zone-3 (50 and 16.6%, respectively) and zone-4 (50 and 83.3%, respectively) at the level of C1 lateral mass. Therefore, it may be defined that the safe zone for surgical procedures is an area between the midsagittal line and the midline of C1 lateral mass.

The ICA, VA, and HN are exposed to risk of surgical injury during posterior approach, whereas there is less risk of surgical injury during anterior approach. It should be noted that anterior surgical approach is not only used for transoral odontoidectomy, but also used for anterior decompression in skull base tumors and used for reconstructive surgery. Furthermore, the possibilities of altered anatomy and anatomical variations should be taken into consideration during the surgical procedures performed for basilar invagination, atlantoaxial dislocation, and atlas occipitalization.

Internal carotid artery

The most of the anatomical and radiological studies evaluating the relationship between C1–2 and ICA focused on risk of penetration of ICA with C1–2 posterior screws. These

studies examined the distances between ICA landmarks including and, the distances between ICA and landmarks involving anterior C1 cortex, including anterior tubercle, lateral mass, and transverse process of C1 [10–15].

In some studies, the mean distance between ICA and C1 anterior cortex was reported as 3.70, 2.88, and 4.89 mm [12, 13, 15]; however, this parameter is not applicable for ventral craniovertebral surgery.

The distance between the midsagittal line and medial wall of ICA was reported as 21.7 mm [14]. In our study, it was observed as 26.13 ± 3.48 and 24.67 ± 2.81 mm at the level of C2 and C1, respectively. Our results revealed that ICA converges minimally as it ascends from C2 to C1.

In their study, Hoh et al. [10] reported the mean diameter of the ICA as 5.5 ± 1.2 and 5.5 ± 1.2 mm at the left and right sides, respectively. In the present study, we obtained the mean diameter of ICA as 5.97 ± 0.13 and 5.74 ± 0.38 mm at left and right sides, respectively.

Some authors studied location of ICA with respect to lateral mass of C1. They divided the lateral mass into three portions. According to most of the studies, the ICA was located mostly along the ventral aspect of lateral 1/3, whereas it was located rarely along the ventral aspect of middle 1/3 of lateral mass of C1 [10, 13, 14]. The ICA was reported to be located on the medial 1/3 of lateral mass in only one case [10]. Our results were similar to the results of the aforementioned studies. We observed that the ICA was located either along (50% of cases) or outer side of (50% of cases) the ventral aspect of the lateral mass of C1. We also found that the ICA did not pass ventrally along the medial half of the lateral mass; therefore, the medial half of the ventral aspect of lateral mass is determined as the safe zone for anterior surgical approach. This anatomical finding is particularly significant for both dissection and retraction of retropharyngeal mucosa during transoral odontoidectomy procedure.

Hypoglossal nerve

The HN emerges from occipital condyle and passes downward between ICA and jugular vein. Ebraheim et al. [8] determined that the HN usually travels behind the ICA and lies approximately 2–3 mm lateral to the middle of the ventral aspect of the lateral mass of C1. Although dysphagia is a common complication of anterior cervical spine surgery, the post-surgical HN damage leading to dysphagia is quite rare, and it is frequently associated with excessive retraction of esophagus during surgery [6, 16–18]. Hong et al. [19] reported the first case of HN injury after fixation of the lateral mass of C1.

In our study, the distance between the midsagittal line and the HN was observed as 33.27 ± 3.98 and 33.58 ± 4.55 mm at the level of C1 and C2 vertebrae, respectively. We found that the HN was located either along the lateral half of (16.66% of cases) or outer side of (83.34% of cases) the ventral aspect of the C1 lateral mass. These results confirm that HN is located lateral to the ICA, and it is rarely exposed to risk of surgical injury during ventral craniovertebral junction procedures.

Vertebral artery

Although the incidences of VA injury during the anterior subaxial cervical spine and the posterior craniovertebral junction surgery are reported as 0.3–0.5 and 4.1%, respectively, the VA is not frequently exposed to great risk of injury during anterior C1–2 procedures for the reason that it passes through the transverse foramen and far from the midsagittal line [20, 21]. Nevertheless, there were a few cases of VA injury during transoral odontoidectomy reported in the literature. In 1986, Crockard et al. [22] reported results of the transoral odontoidectomy in 14 patients with rheumatoid atlantoaxial subluxation. In their study, there was one (7.1%) case with VA injury due to the drilling [22]. Similarly, Dickman et al. [23] reported one case (0.68%) of brainstem stroke following odontoidectomy procedure for bilateral VA occlusion. However, the cases of VA injury did not result from direct injury to the VA during surgery. According to these authors, VA injuries resulted from iatrogenic delayed vertical occipitoatlantal subluxation [20–23].

Scalici et al. [24] reported a case of VA injury after transoral odontoidectomy and posterior stabilization procedure. The reason of VA injury was unclear, whereas it was attributed to the delayed VA dissection due to bone fragments [24].

VA injury rarely occurs during ventral upper cervical spine surgery; however, the risk of VA injury should be taken into consideration in the presence of anatomic variations. While the VA is ascending along the atlantoaxial joints to occipital slope, radiologic examination of VA with 3D CT angiography may display whether or not third and fourth parts of VA has some curves or loops and variations. These radiographic imaging findings play an important role in the diagnosis and surgery of VA diseases [25].

Sardhara et al. [21] determined that VA may be deviated more medially in cases of atlantoaxial dislocation (AAD) with an occipitalized atlas; therefore, there may be at higher risk for VA injury in these cases. In their study, the distance between odontoid and VA was reported as 8.35, 12.0, and 16.2 mm in cases of AAD with an occipitalized atlas, in cases of AAD without an occipitalized atlas and in normal cases, respectively [21].

Ai et al. [26] found that the distances between VA and midsagittal line were 18.4 ± 2.3 and 25.1 ± 2.4 mm at the level of C2 and C1, respectively. Hu et al. [27] also declared that these distances were 19.3 ± 3.4 and 25.6 ± 3.8 mm at the level of C2 and C1, respectively.

Lu et al. [28] reported the distances between VA and midsagittal line at the level of C1 and C2 as 25.6 ± 3.0 and 18.8 ± 2.5 mm, respectively. In our study, these distances were observed as 26.54 ± 2.16 and 15.38 ± 2.08 mm at the level of C1 and C2, respectively.

Conclusion

The main neurovascular structures may be at significant risk of injury during ventral upper cervical spine surgery. This study confirms that the risk of surgical injury for VA and HN is less than ICA, and the part of ICA located ventrally along the lateral half of the lateral mass of C1 may be at higher risk of surgical injury than the other part located ventrally along the medial half of the lateral mass of C1. It is concluded that the medial half of the lateral mass of C1 appears to be safe zone for ICA during ventral surgical procedures.

References

1. Beech TJ, McDermott AL, Kay AD et al (2012) Endoscopic endonasal resection of the odontoid peg—case report and literatüre review. Childs Nerv Syst 28:1795–1799
2. Wang C, Yan M, Zhou HT et al (2003) Treatment of irreducible atlantoaxial dislocation with surgical lysis through transoral approach and internal fixation by means of posterior approach (Chin). Zhongguo Ji Zhu Ji Sui Za Zhi 13:583–586
3. Kandziora F, Pflugmacher R, Ludwig K et al (2002) Biomechanical comparison of four anterior atlantoaxial plate systems. J Neurosurg 96(3):313–320
4. Qiuhang Z, Feng K, Bo Y et al (2013) Transoral endoscopic odontoidectomy to decompress the cervicomedullary junction. Spine (Phila Pa 1976) 38:901–906
5. Tubbs R, Shane et al (2016) Complications of transoral and transnasal odontoidectomy: a comprehensive review. Child's Nerv Syst 32:55–59
6. Kalb S, Reis MT, Cowperthwaite MC et al (2012) Dysphagia after anterior cervical spine surgery: incidence and risk factors. World Neurosurg 77(1):183–187
7. Stulík J, Vyskocil T, Sebesta P et al (2005) Harms technique of C1-C2 fixation with polyaxial screws and rods. [in Czech]. Acta Chir Orthop Traumatol Cech 72(1):22–27
8. Ebraheim NA, Misson JR, Xu R, Yeasting RA (2000) The optimal transarticular c1–2 screw length and the location of the hypoglossal nerve. Surg Neurol 53(3):208–210
9. Janfaza P, Nadol JB, Galla RJ et al (2001) Surgical anatomy of the head and neck. Lippincott, Williams and Wilkins, Philadelphia, p 575
10. Hoh DJ, Maya M, Jung A et al (2008) Anatomical relationship of the internal carotid artery to C-1: clinical implications for screw fixation of the atlas. J Neurosurg Spine 8:335–340
11. Currier BL, Todd LT, Maus TP et al (2003) Anatomic relationship of the internal carotid artery to the C1 vertebra: a case report of cervical reconstruction for chordoma and pilot study to assess the risk of screw fixation of the atlas. Spine 28(22):461–467
12. Currier BL, Maus TP, Eck JC et al (2008) Relationship of the internal carotid artery to the anterior aspect of the C1 vertebra implications for C1–C2 transarticular and C1 lateral mass fixation. Spine 33(6):635–639
13. Estillore RP, Buchowski JM, Minh DV et al (2011) Risk of internal carotid artery injury during C1 screw placement: analysis of 160 computed tomography angiograms. Spine J 11:316–323
14. Murakami S, Mizutani J, Fukuoka M et al (2008) Relationship between screw trajectory of C1 lateral mass screw and internal carotid artery. Spine 33(24):2581–2585
15. Şimşek S, Yiğitkanlı K, Turba UC et al (2009) Safe zone For C1 lateral mass screw: anatomic and radiological study. Neurosurgery 65:1154–1160
16. Cho SK, Lu Y, Lee DH (2013) Dysphagia following anterior cervical spinal surgery: a systematic review. Bone Joint J 95-B (7):868–873
17. Lee MJ, Bazaz R, Furey CG et al (2007) Risk factors for dysphagia after anterior cervical spine surgery: a two-year prospective cohort study. Spine J 7:141–147
18. Rihn JA, Kane J, Albert TJ et al (2011) What is the incidence and severity of dysphagia after anterior cervical surgery? Clin Orthop Relat Res 469:658–665
19. Hong JT, Lee SW, Son BC et al (2006) Hypoglossal nerve palsy after posterior screw placement on the C-1 lateral mass. J Neurosurg Spine 5:83–85
20. Peng CW, Chou BT, Bendo JA, Spivak JM (2009) Vertebral artery injury in cervical spine surgery: anatomical considerations, management, and preventive measures. Spine J 9:70–76
21. Sardhara J, Behari S, Mohan BM et al (2015) Risk stratification of vertebral artery vulnerability during surgery for congenital atlanto-axial dislocation with or without an occipitalized atlas. Neurol India 63(3):382–391
22. Crockard HA, Pozo JL, Ransford AO et al (1986) Transoral decompression and posterior fusion for rheumatoid atlanto-axial subluxation. J Bone Joint Surg 68B(3):350–356
23. Dickman CA, Spetzler RF, Sonntag VKH, Apostolides PJ (2013) Transoral approach to the craniovertebral junction. In: Dickman CA, Spetzler RF, Sonntag VKH (eds) Surgery of the craniovertebral junction. Thieme, New York, pp 277–290
24. Scalici E, Indorato F, Portelli F et al (2014) A fatal iatrogenic right vertebral injury after transoral odontoidectomy and posterior cervical stabilization for a type II odontoid fracture. J Forensic Leg Med 22:41–44
25. Duan S, He H, Lv S, Chen L (2010) Three-dimensional CT study on the anatomy of vertebral artery at atlantoaxial and intracranial segment. Surg Radiol Anat 32(1):39–44
26. Ai F, Yin Q, Wang Z, Xia H et al (2006) Applied anatomy of transoral atlantoaxial reduction plate internal fixation. Spine 31(2):128–132
27. Hu Y, Yang S, Xie H et al (2008) The anatomic study on replacement of artificial atlanto-odontoid joint through transoral approach. J Huazhong Univ Sci Technol Med Sci 28(3):327–332
28. Lu B, He XJ, Zhao CG et al (2009) Artificial atlanto-odontoid joint replacement through a transoral approach. Eur Spine J 18(1):109–117