

## Main Article

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# Microsurgical anatomy of the internal carotid artery at the skull base

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## Abstract

**Background.** The aetiology and significance of internal carotid artery variations at the skull base remain controversial after decades, with limited available literature. Approximately 10–40 per cent of the general population has parapharyngeal internal carotid artery variations.

**Method.** A prospective observational study was conducted on internal carotid artery variations in 36 cadavers, in a tertiary care hospital, between March 2019 to March 2020.

**Results.** The most common internal carotid artery variation observed in the specimens was tortuosity, in 30 per cent, followed by kinking in 18 per cent and coiling in 10 per cent. Thirty per cent of specimens had variations present bilaterally. A loop pattern of the internal carotid artery was identified. Coiling of the internal carotid artery may present as a node; hence, meticulous dissection is advocated near the skull base to avoid complications. These variations hold utmost importance for otorhinolaryngologists performing pharyngeal and nasopharyngeal surgical procedures.

**Conclusion.** A detailed knowledge of anatomy, along with its variations, and surgical expertise, will help reduce the incidence of surgical complications.

## Introduction

The aetiology and significance of internal carotid artery (ICA) variations at the skull base remain controversial after decades, with limited literature available. These variations have been associated with embryological development, arteriosclerosis or fibromuscular dysplasia.<sup>1</sup> However, ICA aberrations in the parapharyngeal space are not rare.

Anatomical descriptions of the cervical ICA typically state that normally the artery runs straight to the skull base without branching.<sup>2</sup> The regular anatomical course of the ICA is posterolateral to the pharyngeal wall, with an age-dependent distance from the tonsillar fossa, approaching 2.5 cm in an adult.

Approximately 10–40 per cent of the general population has parapharyngeal ICA variations. Such variations have also been observed to occur bilaterally. These variations may place the vessel into a close relationship with the pharyngeal wall, thereby increasing the risk of injury during various pharyngeal procedures. Weibel and Fields introduced an anatomical classification system that is still valid today, distinguishing tortuosity, kinking and coiling of the vessel.<sup>3</sup>

From our experience, these variations may present differently during operations; hence, a thorough knowledge about the anatomy and variations of the ICA is needed. The provided data intend to highlight the clinical significance and variations of the ICA encountered at the skull base via cadaveric dissection.

## Objectives

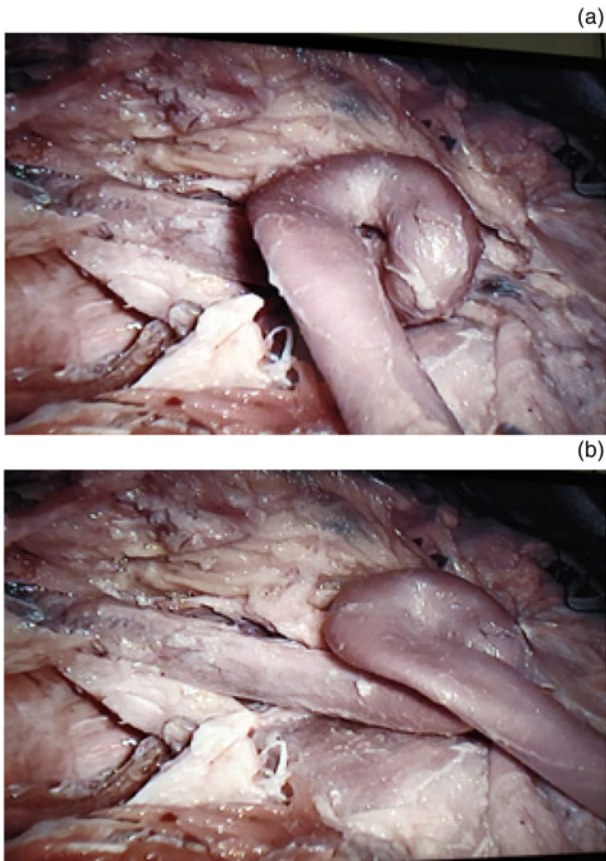
The study aims were: (1) to explore the clinical significance of the ICA at the skull base; and (2) to document ICA variations at the skull base.

## Materials and methods

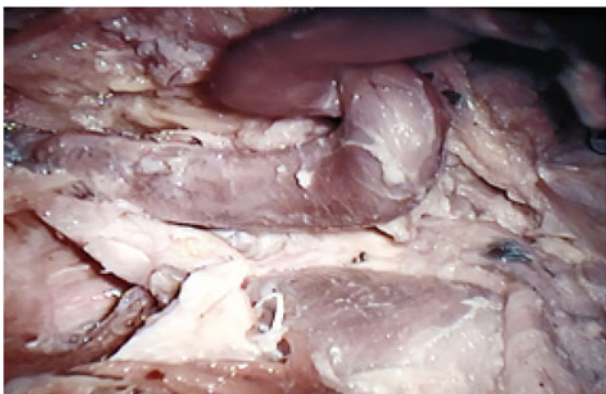
This prospective, observational study was conducted in a tertiary hospital in a rural area between March 2019 and March 2020, in which 36 cadavers were dissected.

In each cadaver, the cervical internal carotid artery (ICA) courses were categorised according to Weibel and Fields' classification system (Figures 1–5). Tortuosity was defined as an S- or C-shaped elongation with displacement of the ICA. A sharp bend of the vessel was characterised as kinking. Coiling was distinguished as the forming of a loop by the vessel.<sup>3</sup>

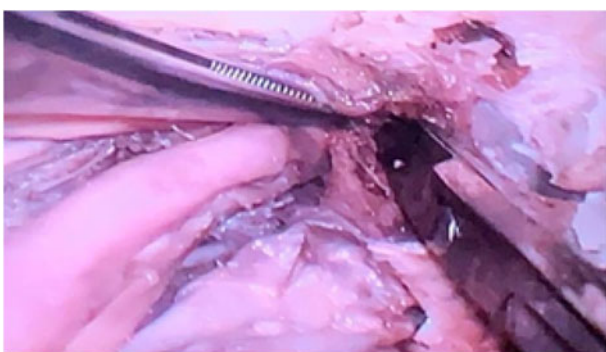
Each vessel's course was evaluated separately for both sides; the unit of analysis was therefore each side of the ICA rather than each cadaver. The distance of the variation from the site of the skull base was also measured and documented. The frequency of each variation type was additionally evaluated and documented.



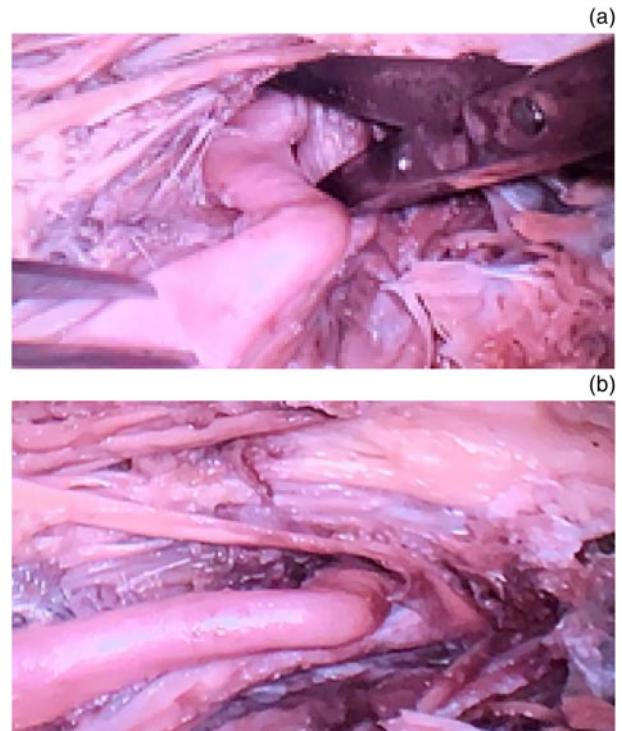
**Fig. 1.** (a & b) Coiling pattern of the internal carotid artery at the skull base before entering carotid canal.



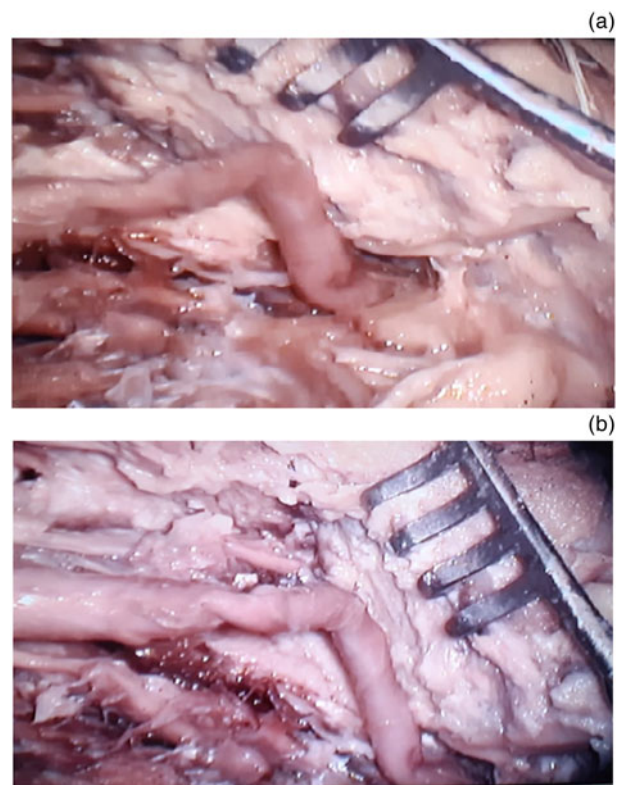
**Fig. 2.** Coiled portion of the internal carotid artery presenting as a node. Note the coiling pattern after the proximal part has been lifted.



**Fig. 3.** The most common course of the internal carotid artery: straight course.



**Fig. 4.** (a & b) Kinking pattern of the internal carotid artery before entering the carotid canal.



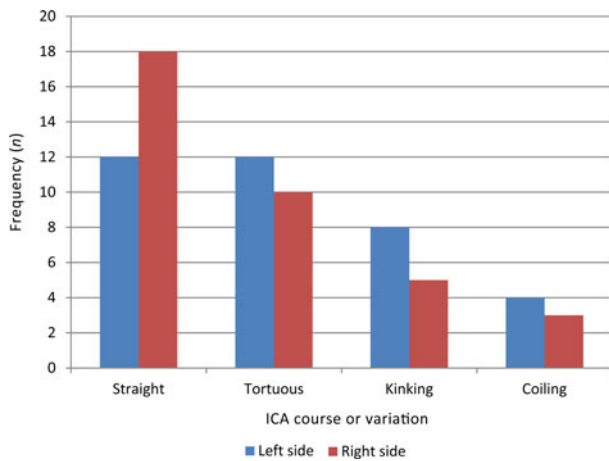
**Fig. 5.** (a & b) Tortuosity of the parapharyngeal portion of the internal carotid artery.

The data were entered onto an Excel® spreadsheet and a detailed descriptive analysis of the above factors was conducted. An attempt was made to correlate the clinical significance and presence of ICA variations at the skull base.

**Results**

In all 36 cadavers, the bilateral internal carotid artery (ICA) was dissected and analysed.





**Fig. 6.** Frequency of each variation type, for the left and right sides.

It was observed that the left side of the neck presented with more variations as compared to the right side. Tortuosity was the most common variation observed, occurring in 12 cases on the left side and in 10 cases on the right side. Kinking was seen in eight cases on the left side and in five cases on the right side. Coiling was seen in four cases on the left side and in three cases on the right side (Figure 6). Tortuosity was also noted to be the most common variation in cadavers with bilateral variations of the ICA.

#### Straight type

The ICA was initially superficial in the carotid triangle, and then passed medial to the posterior belly of the digastric muscle. The internal jugular vein and vagus nerve lie lateral to the ICA within the carotid sheath. The external carotid artery is first anteromedial, and then curves back and becomes superficial. The artery lies lateral in the pharyngeal wall, which was separated by fat and pharyngeal veins. Above the posterior belly of the digastric muscle, the ICA was separated from the external carotid artery by the styloid process and the styloid group of muscles. At the skull base, the lower cranial nerves – namely the glossopharyngeal nerve, vagus nerve, accessory nerve and hypoglossal nerve – were seen between the ICA and internal jugular vein.

#### Tortuosity type

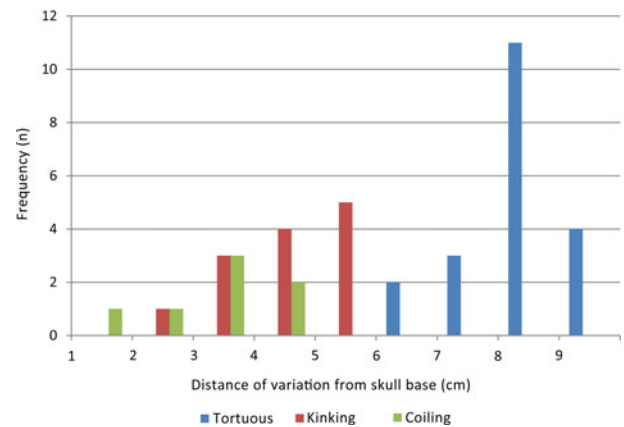
In this variation type, the cervical portion of the ICA was found to be displaced laterally or medially. The entire length of the artery was noted as being C- or S-shaped. This displacement made the ICA come very close to the tonsil.

#### Kinking type

In this variation type, the cervical portion of the ICA had a kinking configuration. This type was observed when the deviation was between 60° and 145°. All of the kinking cases were located at about 5 cm distal to the skull base. There was a higher angle of kinking observed on the left side in comparison to the right side.

#### Coiling type

In this variation type, the cervical portion of the ICA had a coiling pattern where the vessel looped around itself and



**Fig. 7.** Frequency of distances from the skull base, for each variation type.

further ascended to the skull base. This configuration was peculiar and the vessel usually ascended antero-medially. The degree of coiling was seen ranging from 300° to 360°. All cases of coiling were located close to the skull base, at a distance of around 2–3 cm. There was no difference in the pattern of coiling between the left and right sides.

#### Overall findings

Tortuosity was seen in 22 specimens and was most commonly sited 8 cm from the skull base. Kinking was seen in 13 specimens and occurred most commonly at 5 cm from the skull base. Coiling was seen in 7 specimens, and was most commonly observed 3 cm from the skull base (Figure 7).

#### Discussion

Many anatomical studies of internal carotid artery (ICA) anomalies have been published. A wide range of ICA abnormalities has been reported previously, affecting 10–40 per cent of the general population.

Injury to the ICA during head and neck surgery can result in life-threatening complications. The surgeon should be careful in performing routine surgical procedures in the area of the upper pharynx, such as adenoidectomy, tonsillectomy and uvulopalatopharyngoplasty, which generally represent the most frequent interventions carried out by novice surgeons. Hence, surgeons have been advised to palpate the posterior and posterolateral wall for any pulsations during procedures such as adenoidectomy.<sup>4–6</sup>

It has been reported that 2 per cent of cases have lateral pharyngeal wall pulsation. In the presence of great vascular anomalies, the surgical post- and peri-operative risks increase remarkably. The hidden presence of an asymptomatic anomaly of the ICA can result in a life-threatening haemorrhage.<sup>3,7</sup>

Kinking was seen in 18 per cent of the cases in the current study, and coiling was observed in 10 per cent. Metz *et al.* graded kinking pattern based on its angulation. In our series, all the cadavers with kinking had a grade 1 pattern according to this categorisation.<sup>8</sup> The coiling and looping of the ICA around itself appeared as a cervical lymph node on palpation. Meticulous dissection helped in identifying the artery. The coiling of the artery may be mistaken for a node, and any unwarranted dissection near the skull base can lead to life-threatening complications. Kinking and coiling of the ICA may play a role in determining cerebral ischaemic attacks.<sup>8</sup>

Tortuosity was the most frequent variation seen, accounting for 30 per cent of the cases. A high arterial blood flow correlates with increased arterial wall shear stress in arterial elongation and the development of tortuosity.<sup>9</sup>

Tortuosity, kinking and coiling of the ICA are thought to be congenital anomalies, as they have been observed in infants and even fetuses. Normally, the dorsal aortic root descends into the chest by the eighth week of development, thereby straightening the course of the ICA. A failure in this process, incomplete development or an accelerated linear growth of the artery can result in persistence of the loop. According to a US study, a loop is formed at the junction between the two blood vessels, and reaches its maximal extension in the fifth and sixth embryonic weeks. If the embryological state persists, it produces different kinds of tortuosity, kinking and coiling. Kinking and looping of the ICA may result partly from embryological development and partly as a secondary result of atherosclerotic changes. The frequency of such embryological and developmental disturbances has been reported to vary between 5 and 10 per cent in infancy.<sup>3-6</sup>

In a study by La Barbera *et al.*, histological investigation of ICA anomalies revealed a modification in the structure of tunica media of the ICA, with kinking and coiling involving both elastic and muscular tissue, substituted by a loose connective tissue.<sup>10</sup>

In the current study, various anomalies of the cervical portion of the ICA were categorised as tortuous, coiling or kinking. This study of 36 cadavers, with 72 specimens of the ICA, demonstrated the variability of the ICA course. The described ICA variations occurred with frequencies of: 42 per cent for the straight course, 30 per cent for the tortuous course, 18 per cent for kinking and 10 per cent for coiling. Tortuosity was significantly more frequent than kinking or coiling, as in other studies.<sup>11</sup>

We observed that 30 per cent of ICA variations in cadavers were bilateral. From the 36 cadavers dissected, 12 were found to have bilateral variations of the ICA. Hence, we observed a 30 per cent frequency of bilateral variation of the ICA, which is a slightly higher rate than reported in other studies.

- It is important for surgeons to know about internal carotid artery (ICA) variations at the skull base, to avoid injury to the vessel
- Three variations are seen: tortuosity, kinking and coiling
- The most common course of the ICA is a straight course
- Thirty per cent of cases had bilateral variations
- Coiling may present as a node and should be evaluated well prior to surgery
- Detailed anatomy of the ICA and its variations will help otorhinolaryngologists operating near the skull base

In the determination of these abnormalities, the posterior pharyngeal wall constitutes a risk factor for considerable

intra- and post-operative haemorrhage. The presence of an asymptomatic ICA anomaly can lead to a life-threatening haemorrhage. Magnetic resonance imaging and Doppler ultrasonography imaging techniques allow precise evaluation of ICA anomalies. This can prevent life-threatening complications in patients with ICA anomalies.

## Conclusion

Variations of the internal carotid artery (ICA) at the skull base pose a challenge to the surgeon and can lead to life-threatening haemorrhage. Presentation of these variations differs, and hence can mislead the surgeon while identifying important structures and landmarks. A detailed knowledge of anatomy, along with its variations, and surgical expertise, lessen the likelihood of surgical complications. Coiling of the ICA may present as a node; therefore, meticulous dissection is advocated near the skull base, to avoid complications.

**Competing interests.** None declared

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