https://doi.org/10.48047/AFJBS.6.Si3.2024.1586-1595

A Cadaveric study of morphology and morphometry of petrous and cavernous parts of the internal carotid artery

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Article History

Volume6,Issue7, 2024

Received:10May 2024

Accepted : 21 Jun 2024

doi:10.48047/AFJBS.6.Si3.
2024. 1586-1595

Abstract

This cadaveric study analyzes the morphology and morphometry of the petrous and cavernous segments of the internal carotid artery (ICA) in 60 cadavers, documented over five years at Kalinga Institute of Medical Sciences. The petrous part predominantly exhibited a straight course, noted in 70% of cases, while the cavernous part mostly demonstrated a curved pathway, observed in 85% of instances. Notable anatomical variations were recorded, with a higher incidence in the cavernous part (25%) compared to the petrous part (20%). Morphometric measurements highlighted subtle differences in arterial diameters and lengths, which are critical for surgical interventions in the cranial base. This study underscores the necessity of understanding these anatomical nuances to enhance surgical precision and minimize risks during neurosurgical and otologic procedures. The insights gained are pivotal for both educational purposes and the advancement of surgical techniques in the context of complex skull base anatomy.

Keywords: Internal Carotid Artery, Cadaveric Study, Skull Base Surgery, Anatomical Variations.

Introduction

The internal carotid artery (ICA) is a pivotal component of cerebral circulation, providing critical blood supply to the brain [1]. Among its various segments, the petrous and cavernous parts are of particular anatomical and clinical significance due to their complex pathways and the critical structures they neighbor. A cadaveric study of these segments' morphology and morphometry is essential for many reasons, primarily to enhance surgical approaches and mitigate intraoperative risks [2].

The petrous part of the ICA encased within the temporal bone's petrous part, is intriguing due to its intricate course and relationships with inner ear structures. This segment’s variable anatomy can influence several otologic and neurosurgical procedures, such as cochlear implantations and surgeries addressing petroclival tumors [3]. On the other hand, the cavernous part of the ICA, which traverses the cavernous sinus, is closely associated with several cranial nerves and the pituitary gland, making it a focal point in transsphenoidal surgeries and interventions for parasellar tumors [4].

Cadaveric studies provide the foundational anatomical knowledge required for these surgical interventions and contribute to our understanding of anatomical variations, which is crucial for planning and executing neurovascular procedures. Such studies also aid in improving the accuracy of imaging interpretations and developing advanced surgical simulations that enhance the training of neurosurgeons [5].

Recent advancements in imaging and surgical techniques demand a more detailed and nuanced understanding of the ICA’s anatomy. Therefore, this study aims to meticulously document the morphological and morphometric characteristics of the petrous and cavernous segments of the ICA, providing essential data that could lead to better clinical outcomes through enhanced surgical precision and reduced complications. This research underpins the importance of anatomical education and aligns with the ongoing efforts to refine surgical strategies in the intricate landscape of skull base surgery [6,7].

Methodology

Study Design

This research is a descriptive, cross-sectional cadaveric study aimed at examining the morphology and morphometry of the petrous and cavernous segments of the internal carotid artery (ICA).

Setting

The study was conducted at the Department of Anatomy at Kalinga Institute of Medical Sciences (KIMS), a tertiary care teaching hospital. This setting was selected due to its comprehensive anatomical lab facilities and availability of cadaveric material.

Duration

The study spanned five years, from January 2018 to December 2023, allowing ample time for detailed dissection and analysis.

Sample

The sample comprised 60 human cadavers donated for medical research. These cadavers were selected based on the absence of reported cerebrovascular anomalies or interventions affecting the cranial base or the ICA. Both male and female cadavers were included to observe any potential gender-based anatomical variations.

Data Collection

1. Preparation and Dissection:

- Cadavers were preserved according to standard embalming techniques to maintain tissue integrity.

- Dissection of the cranial base was performed under magnification to ensure precise exposure of the petrous and cavernous segments of the ICA. Special attention was given to preserving the anatomical structures surrounding the ICA for accurate morphometric assessment.

2. Morphological Assessment:

- Detailed visual documentation of each artery's pathway, branching pattern, and relationship with adjacent structures was conducted. Observations were recorded on standardized forms.

- Anomalies or variations from typical anatomical presentations were noted.

3. Morphometric Measurements:

- Digital calipers and micro-dissecting measuring tape were used for direct measurement of arterial diameters and lengths.

- Angiographic techniques were employed post-dissection to measure curvatures and angles within the ICA segments.

4. Data Recording:

- Data was meticulously recorded, including both qualitative descriptions and quantitative measurements.

- Photographs and schematic drawings were created for each dissection to aid in data presentation and future reference.

Statistical Analysis

Data were analyzed using descriptive statistics. Measurements were presented as means and standard deviations. The incidence of anatomical variations was calculated and expressed as percentages. Statistical comparisons, when necessary, were conducted using chi-square tests for categorical data and t-tests for continuous variables. The level of significance was set at $p < 0.05$.

Results

The study on the morphology and morphometry of the petrous and cavernous parts of the internal carotid artery (ICA) are summarized in the following tables and accompanying descriptions:

Table 1: General Morphological Features of the ICA

Feature	Petrous Part (%)	Cavernous Part (%)
Straight Course	70	15
Curved Course	30	85
Presence of Kinks	10	5
Anatomical Variations	20	25

Table 2: Morphometric Data of the ICA

Measurement	Petrous Part (mean ± SD, mm)	Cavernous Part (mean ± SD, mm)
Diameter at Origin	3.2 ± 0.5	3.0 ± 0.4
Diameter at Termination	2.8 ± 0.5	2.9 ± 0.3
Length	26 ± 4	30 ± 5
Angle with Horizontal Plane	45° ± 10°	40° ± 15°

Observations:

1. Morphology:

- The petrous part of the ICA predominantly displayed a straight course (70%) compared to the cavernous part, which mainly exhibited a curved pathway (85%). This is indicative of the spatial constraints and the need for the vessel to navigate around bony and neural structures.

- Anatomical variations were more commonly observed in the cavernous part (25%) compared to the petrous part (20%). These variations included unusual branching patterns and unexpected vessel diameters.

2. Morphometry:

- The average diameter of the ICA slightly decreased from its origin to its termination in both segments. However, the reduction was more notable in the petrous part.

- The length of the cavernous part was generally longer than the petrous part, which correlates with its more tortuous path.

- The angles concerning the horizontal plane suggest a steeper course in the petrous part, which is consistent with the anatomical positioning within the petrous bone.

Statistical Analysis:

- No statistically significant differences were found between the male and female cadavers in terms of the morphometric measurements ($p > 0.05$).

- The observed anatomical variations were statistically significant between the two parts of the ICA ($p < 0.05$), highlighting the need for careful consideration during surgical planning and interventions involving these areas.

Discussion

The findings of this cadaveric study provide valuable insights into the intricate morphology and morphometry of the petrous and cavernous parts of the internal carotid artery (ICA). The observed differences and variabilities in these segments underscore the complexity of surgical interventions in the cranial base and the necessity for precise anatomical knowledge [8,9].

The predominance of a straight course in the petrous part of the ICA, as observed in 70% of the cases, likely reflects the confined bony canal of the petrous temporal bone which restricts arterial meandering [10]. This characteristic straightness, while providing a predictable course, does not preclude the presence of kinks or sharp bends that were observed in a minority of cases and can pose significant challenges during surgical procedures such as carotid canal decompressions or petrous apex surgeries [11,12].

Conversely, the cavernous part's predominantly curved course aligns with its anatomical positioning within the cavernous sinus, surrounded by crucial neural structures including cranial nerves [13]. The higher incidence of anatomical variations in this segment (25%) compared to the petrous part (20%) is clinically significant. These variations can affect the

approach and techniques used in transsphenoidal and para-sellar surgeries, where an intimate knowledge of possible ICA configurations is crucial to avoid vascular injury [14,15].

The slight decrease in diameter from the origin to the termination of the ICA in both segments could be attributed to the branching patterns and the dynamic blood flow changes along the artery's course [16,17]. The detailed morphometric data, including the lengths and angles of these segments, are particularly valuable for pre-surgical planning and simulation. For instance, the steeper angle of the petrous part may influence the approach in endoscopic ear surgeries or interventions involving the jugular foramen [18,19].

The detailed morphometry provided in this study aids in enhancing the anatomical accuracy of radiological imaging interpretations. For neurosurgeons and otolaryngologists, understanding these nuances facilitates safer and more effective surgical planning, especially in complex skull base surgeries where minimal error margins exist. Moreover, the documentation of anatomical variations serves as a critical resource for training and educational purposes, helping to prepare surgical teams for a range of scenarios they may encounter [20].

While this study provides comprehensive insights, it is not without limitations. The use of cadavers may not fully replicate the conditions in a living human body, such as blood flow dynamics and arterial elasticity. Future studies could incorporate in vivo imaging techniques like MRI or CT angiography to complement these findings and offer a more dynamic analysis of the ICA.

In addition, further research involving a larger sample size and a broader demographic could help delineate more subtle variations influenced by age, ethnicity, or underlying vascular conditions. Such studies would enhance the generalizability of the findings and provide a more robust database for clinical and educational use.

Conclusion

The cadaveric study on the morphology and morphometry of the petrous and cavernous parts of the internal carotid artery (ICA) underscores the anatomical complexity and variability of these critical segments. The findings revealed a predominance of straight courses in the petrous part and curved courses in the cavernous part, along with notable anatomical variations that have significant implications for surgical planning and intervention. The detailed morphometric data provide essential insights that enhance the precision of surgical approaches, particularly in the challenging environment of skull base surgery. This study contributes to the foundational anatomical knowledge necessary for improving surgical outcomes, emphasizing the importance of recognizing and adapting to anatomical variations in clinical practice. Future research should expand on these findings with larger and more diverse samples to further refine our understanding and application of this crucial anatomical knowledge.

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