Journal Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/17770
DOI URL: http://dx.doi.org/10.21474/IJAR01/17770

*RESEARCH ARTICLE*

# CROSS SECTIONAL RETROSPECTIVE ANALYTICAL STUDY OF MORPHOMETRY OF INTERNAL CAROTID ARTERY

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## Manuscript Info

***Manuscript History***
Received: 25 August 2023
Final Accepted: 27 September 2023
Published: October 2023

***Key words:-***
Internal Carotid Artery, Digital Subtraction Angiography, Morphometry

## Abstract

**Background:** The internal carotid artery (ICA) is essential for diagnosing and treating cerebrovascular diseases and plays a significant role in the human head and neck circulatory system. Traditional techniques of ICA research have their limitations, but more recent developments in medical imaging—particularly retrospective angiography—offer more thorough evaluation options.
**Objective:** This study aimed to investigate variations and morphometry of the ICA using 2D digital subtraction angiography (DSA) images, with a focus on age and gender-related differences.
**Methods:** The 149 individuals with subarachnoid hemorrhage who had cerebral angiography were included in the research. Analysis was done on 2D ICA pictures without any obvious pathology. PACS imaging techniques were used to measure morphometric characteristics such as the length, angle, and diameter of the ICA segments.
**Results:** According to the study, ICA length and direction were not substantially affected by age, but segment diameters were highly associated with age, indicating that segment diameters decreased with age. However, gender indicated statistically significant variations in several segment sizes, with males typically having greater diameters than females. Gender had little effect on length and orientation.
**Conclusion:** This study sheds light on ICA changes and morphometry, emphasizing age-related diameter decreases and gender-related variations in segment diameters. These findings highlight the need to take age and gender into account when conducting clinical evaluations and cerebrovascular disease therapies.



## Introduction:-

The internal carotid artery (ICA) is an essential vascular structure that occupies a pivotal position within the complex circulatory network of the human head[1]. The anatomical traits and morphometric qualities of the subject have notable therapeutic significance because of their impact on the evaluation and treatment of cerebrovascular conditions, including strokes and aneurysms.[2] The investigation of the internal carotid artery (ICA) has long been a topic of significant interest among medical practitioners. However, recent progress in medical imaging, namely the use of retrospective angiographic pictures, has provided novel opportunities for thorough examination and accurate evaluation.

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The internal carotid artery originates as a division of the common carotid artery, traverses the neck, and gains entry into the cranial cavity via the carotid canal located within the temporal bone. Within the cranial cavity, it undergoes further division into two primary branches, namely the anterior cerebral artery and the middle cerebral artery. In conjunction with the vertebral arteries, these blood vessels collectively constitute the Circle of Willis, a pivotal arterial configuration responsible for the regulation of cerebral blood flow and the maintenance of a consistent blood supply to the brain. [3]

Historically, the examination of the anatomy and morphometry of the internal carotid artery (ICA) has predominantly depended on the use of cadaveric dissections and two-dimensional radiography pictures.[4] Although these methodologies yielded useful insights, they were constrained in their ability to comprehensively capture the entirety of anatomical variances and dimensions. Nevertheless, the emergence of contemporary medical imaging methods, including retrospective angiographic imaging, has provided researchers with abundant three-dimensional data that presents a more comprehensive and precise depiction of the anatomy of the internal carotid artery (ICA).

Retrospective angiographic images serve as a valuable source of information, as they effectively capture the dynamic characteristics of blood circulation inside the internal carotid artery (ICA) and its adjacent veins[5]. The utilization of imaging methods such as computed tomography angiography (CTA) and magnetic resonance angiography (MRA) enables the non-invasive visualization of the internal carotid artery (ICA) in living subjects. In addition, the inherent digital characteristics of these pictures greatly enhance the feasibility of doing detailed morphometric analysis, allowing researchers to accurately quantify vessel diameters, lengths, tortuosity, and branching patterns to an unprecedented degree of precision.

According to the categorization described by Bouthillier A et al [6], ICA may be split into seven segments. The C1 segment (cervical), C2 segment (petrous or horizontal), C3 segment (lacerum), C4 segment (cavernous), C5 segment (clinoid), C6 segment (ophthalmic or supra clinoid), and C7 segment (communicating or terminal) make up these segments. Numerous investigations [7-9] have revealed that anatomical differences in the ICA may be related to different neurovascular disorders, complicating endovascular and surgical methods as a result. Between the sexes, sides, and ages of the patients, differences or changes in the ICA using 2D digital subtraction angiography data (2D DSA) have been described [10].

**Aim:**
To assess the ICA variations and morphometry from 2D DSA images from January 2021- June 2023 in patients presenting with spontaneous subarachnoid hemorrhage in tertiary care hospital

## Methodology:-

This study adhered to ethical guidelines and was conducted following the approval of the institutional ethical committee.

**Inclusion Criteria:**
We selected 149 patients for this study based on specific inclusion criteria, which included individuals diagnosed with subarachnoid hemorrhage who had undergone cerebral angiography. Additionally, patients were required to possess both 2D internal carotid artery (ICA) images devoid of any evident pathology within the ICA.

**Exclusion Criteria:**
Patients presenting with any form of disease at the base of the skull or those lacking complete 2D ICA imaging and other vascular abnormalities like aneurysm ,arteriovenous malformations, stenosis and patients with brain tumors were excluded from the research to ensure the study's integrity.

**Localization and Definition of 2D Images:**
We retrieved the lateral views of both left and right ICA images from the Picture Archiving and Communication System (PACS).

**Morphometric Parameters:**
ICA morphometric analysis encompassed the measurement of three key parameters: angle (A), length (L), and diameter (D). For anatomical reference, we utilized the points C1 through C6, corresponding to the midpoint of the ICA at each bend (C2, C3, C4, and C5), and these landmarks were established according to earlier classifications.

The lengths of the segments C2-C3, C3-C4, and C4-C6 were represented as L1, L2, and L3, respectively. Diameters at specific points were recorded, including C3 (D2), C4 (D4), C5 (D6), and between C2-C3 (D1), C3-C4 (D3), and C4-C5 (D5).the angles (A1- A3) were measured from each bend were measured and recorded using angle measurement tool.

**Measurement Procedures:**
Measurement procedures included the following steps: 1) Selection of the 2D ICA image from the lateral view with optimal contrast media filling in the vessels; 2) Enlargement of images for optimal visualization of all reference points; 3) Marking the locations of C2-6; and 4) Measurement of the lengths (L1-L3), angles (A1-A3), and diameters (D1-D6) as specified. All measurements were conducted using PACS imaging tools. Circular region of interest was employed to localize C2-C6, and ruler tools were utilized to measure L1-L3 and D1-D6 lengths. The measurement of A1-A3 adhered to established protocols, while the angle measuring tool facilitated examination of angles between various components of the ICA.

**Statistical Analysis:**
IBM SPSS version 21 software was employed for data analysis. The Shapiro-Wilk test was used to evaluate data distribution and assess whether the data met the assumption of normality. The Mann-Whitney U test and independent sample t-test were employed to compare all parameters between datasets exhibiting skewed and normal distributions, respectively. Spearman's rho was utilized to analyze relationships between age and sex among the study participants.A significance level of $P < 0.05$ was considered statistically significant in all analyses.

## Results:-
The mean age of the study participants 54.71 ± 11.22, with minimum 11 years and maximum of 85 years.Table 1 provides insights into the length of ICA segments (L1, L2, L3) in males and females across various age groups. Notable findings include an increase in segment length with age, particularly in males, where L1 and L2 segment lengths show a consistent upward trend. Additionally, for females aged 26-35, there is a slight increase in L1 and L2 segment lengths. The age-related variations in ICA segment lengths may have clinical implications in terms of vascular assessments and surgical interventions.

**Table 1:-** Length of ICA segments and the age.

| **Age** | **Male** | | | **Female** | | |
|---|---|---|---|---|---|---|
| | **L1** | **L2** | **L3** | **L1** | **L2** | **L3** |
| <=25 | 7.63 ± 0.25 | 15.01 ± 0.64 | 11.21 ± 0.27 | 7.76 | 16.36 | 11.34 |
| 26 – 35 | 7.86 ± 0.08 | 15.76 ± 0.08 | 11.19 ± 0.12 | - | - | - |
| 36 – 45 | 8.00 ± 0.55 | 15.69 ± 0.49 | 11.27 ± 0.36 | 8.23 ± 0.76 | 16.06 ± 0.46 | 14.29 ± 04.31 |
| 46 – 55 | 8.17 ± 0.65 | 15.80 ± 0.68 | 11.20 ± 0.49 | 7.92 ± 0.60 | 15.95 ± 0.63 | 11.18 ± 0.48 |
| 56 – 65 | 8.11 ± 0.70 | 17.46 ± 9.59 | 11.29 ± 0.54 | 7.95 ± 0.61 | 15.70 ± 0.73 | 11.14 ± 0.55 |
| 66 – 75 | 8.19 ± 0.52 | 16.16 ± 0.36 | 10.96 ± 0.28 | 7.95 ± 0.39 | 15.54 ± 0.42 | 11.02 ± 0.35 |
| >=76 | 7.91 | 14.81 | 11.75 | 7.38 ± 0.29 | 15.62 ± 0.23 | 11.27 ± 0.08 |

Table 2 presents the angles (A1, A2, A3) of ICA segments in relation to age and gender. While the age-related trends in angle measurements are not as pronounced as segment lengths, there are subtle variations. For instance, in males, A1 and A2 angles exhibit minor fluctuations with age. In females, A1 and A2 angles show a slight increase with age, potentially suggesting age-related changes in the course or orientation of the ICA segments.

**Table 2:-** Angle of ICA segments and age.

| **Age** | **Male** | | | **Female** | | |
|---|---|---|---|---|---|---|
| | **A1** | **A2** | **A3** | **A1** | **A2** | **A3** |
| <=25 | 111.20 ± | 119.95 ± | 90.67 ± | 108.28 | 112.28 | 85.25 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 4.83 | 0.09 | 5.12 | | | |
| 26 – 35 | 111.11 ± 4.29 | 120.88 ± 2.14 | 87.94 ± 0.97 | - | - | - |
| 36 – 45 | 108.38 ± 3.49 | 117.39 ± 3.22 | 87.14 ± 2.74 | 108.48 ± 2.52 | 117.00 ± 2.44 | 89.45 ± 4.43 |
| 46 – 55 | 108.55 ± 4.25 | 118.59 ± 4.02 | 86.91 ± 3.40 | 108.95 ± 4.59 | 117.78 ± 3.60 | 88.86 ± 5.23 |
| 56 – 65 | 106.26 ± 10.14 | 117.55 ± 3.15 | 87.52 ± 4.31 | 108.85 ± 4.63 | 116.00 ± 9.97 | 86.72 ± 4.30 |
| 66 – 75 | 105.57 ± 2.21 | 121.34 ± 0.13 | 86.04 ± 1.32 | 107.42 ± 4.96 | 116.96 ± 4.13 | 86.84 ± 4.83 |
| >=76 | 106.39 | 117.78 | 87.26 | 106.58 ± 5.29 | 118.39 ± 2.02 | 82.33 ± 2.26 |

Table 3 explores the diameters (D1, D2, D3, D4, D5, D6) of ICA segments with respect to age and gender. Notable trends include a decrease in diameter measurements with age in both males and females. This age-related reduction in ICA segment diameters could have implications for blood flow dynamics and may be associated with increased risk factors for vascular diseases in older individuals.

**Table 3:-** Diameters of ICA segments and age.

| **Age** | **Male** | | | | | | **Female** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **D1** | **D2** | **D3** | **D4** | **D5** | **D6** | **D1** | **D2** | **D3** | **D4** | **D5** | **D6** |
| <=25 | 4.77 ± 0.30 | 4.49 ± 0.05 | 4.45 ± 0.01 | 4.33 ± 0.04 | 4.25 ± 0.05 | 4.21 ± 0.00 | 4.98 | 4.52 | 4.44 | 4.36 | 4.21 | 4.21 |
| 26 – 35 | 4.65 ± 0.27 | 4.60 ± 0.26 | 4.57 ± 0.30 | 4.50 ± 0.37 | 4.33 ± 0.17 | 4.33 ± 0.31 | - | - | - | - | - | - |
| 36 – 45 | 4.78 ± 0.28 | 4.64 ± 0.30 | 4.59 ± 0.31 | 4.50 ± 0.32 | 4.35 ± 0.16 | 4.32 ± 0.22 | 4.67 ± 0.21 | 4.56 ± 0.14 | 4.53 ± 0.15 | 4.41 ± 0.22 | 4.30 ± 0.10 | 4.28 ± 0.17 |
| 46 – 55 | 4.63 ± 0.17 | 4.56 ± 0.14 | 4.51 ± 0.13 | 4.39 ± 0.16 | 4.07 ± 0.83 | 4.26 ± 0.12 | 4.63 ± 0.21 | 4.51 ± 0.09 | 4.47 ± 0.05 | 4.34 ± 0.07 | 4.25 ± 0.09 | 4.21 ± 0.04 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 56 – 65 | 4.30 ± 0.33 | 4.09 ± 0.41 | 4.03 ± 0.43 | 3.94 ± 0.41 | 4.07 ± 0.21 | 3.96 ± 0.26 | 4.23 ± 0.33 | 4.09 ± 0.37 | 4.02 ± 0.39 | 3.90 ± 0.42 | 4.02 ± 0.24 | 3.95 ± 0.27 |
| 66 – 75 | 3.96 ± 0.04 | 3.73 ± 0.18 | 3.77 ± 0.40 | 3.70 ± 0.43 | 3.96 ± 0.16 | 3.82 ± 0.25 | 4.07 ± 0.24 | 3.96 ± 0.27 | 4.07 ± 0.30 | 4.05 ± 0.29 | 4.05 ± 0.22 | 4.01 ± 0.23 |
| >=76 | 3.93 | 3.94 | 4.24 | 4.19 | 4.15 | 4.11 | 3.92 ± 0.01 | 3.94 ± 0.00 | 4.24 ± 0.00 | 4.19 ± 0.00 | 4.16 ± 0.01 | 4.13 ± 0.01 |

Table 4 compares the lengths of ICA segments between genders. While there are some differences, the study found that these variations are not statistically significant, as indicated by the p-values. Therefore, gender does not seem to have a substantial influence on the length of ICA segments.

**Table 4:-** Length of ICA segments and gender.

| **Gender** | **Right** | | | **Left** | | |
|---|---|---|---|---|---|---|
| | **L1** | **L2** | **L3** | **L1** | **L2** | **L3** |
| Male | 8.10 ± 0.67 | 15.79 ± 0.93 | 11.28 ± 0.51 | 8.05 ± 0.58 | 17.03 ± 12.05 | 11.22 ± 0.54 |
| Female | 7.96 ± 0.63 | 15.85 ± 0.70 | 11.22 ± 0.56 | 7.94 ± 0.58 | 15.75 ± 0.70 | 13.73 ± 16.56 |
| P value | 0.139 | 0.809 | 0.498 | 0.191 | 0.216 | 0.346 |

Table 5 assesses the angles of ICA segments concerning gender. The results show no significant gender-related differences in the angles of ICA segments, except for the A1 angle in the left ICA, where females exhibit a statistically significant difference (p = 0.023).

**Table 5:-** Angle of ICA segments and gender.

| **Gender** | **Right** | | | **Left** | | |
|---|---|---|---|---|---|---|
| | **A1** | **A2** | **A3** | **A1** | **A2** | **A3** |
| Male | 108.52 ± 12.47 | 118.42 ± 4.41 | 87.14 ± 4.92 | 106.64 ± 5.25 | 117.73 ± 4.84 | 87.49 ± 5.31 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Female | 108.57 ± 5.59 | 116.33 ± 12.28 | 87.68 ± 5.54 | 108.59 ± 5.60 | 117.38 ± 5.60 | 87.55 ± 6.12 |
| P value | 0.228 | 0.357 | 0.749 | 0.023 | 0.794 | 0.768 |

Table 6 investigates the diameters of ICA segments in relation to gender. While there are some differences in diameter measurements between males and females, these variations are only statistically significant for the D1 diameter in the right ICA (p = 0.033). The remaining diameter measurements do not show significant gender-related differences.

**Table 6:-** Diameters of ICA segments and gender.

| **Diameter** | **Male** | **Female** | **P value** |
|---|---|---|---|
| **Right** | | | |
| D1 | 4.50 ± 0.36 | 4.38 ± 0.36 | 0.033 |
| D2 | 4.34 ± 0.42 | 4.26 ± 0.36 | 0.133 |
| D3 | 4.30 ± 0.43 | 4.24 ± 0.35 | 0.094 |
| D4 | 4.21 ± 0.42 | 4.13 ± 0.35 | 0.118 |
| D5 | 4.15 ± 0.43 | 4.13 ± 0.21 | 0.073 |
| D6 | 4.13 ± 0.27 | 4.09 ± 0.23 | 0.139 |
| Left | | | |
| D1 | 4.50 ± 0.36 | 4.40 ± 0.36 | 0.062 |
| D2 | 4.35 ± 0.42 | 4.27 ± 0.35 | 0.151 |
| D3 | 4.31 ± 0.42 | 4.25 ± 0.35 | 0.060 |
| D4 | 4.21 ± 0.42 | 4.14 ± 0.35 | 0.096 |
| D5 | 4.15 ± 0.43 | 4.13 ± 0.21 | 0.057 |
| D6 | 4.13 ± 0.27 | 4.09 ± 0.23 | 0.127 |

The correlation analysis conducted between gender and various morphometric parameters provides insights into potential gender-related differences in the internal carotid artery (ICA) characteristics. The length of ICA segments (L1, L2, L3) exhibited weak negative correlations with gender, with correlation coefficients (r values) ranging from -0.056 to -0.126.None of these correlations reached statistical significance (p > 0.05), indicating that there are no significant gender-related differences in the lengths of ICA segments.The angles of ICA segments (A1, A2, A3) showed weak correlations with gender, with correlation coefficients (r values) ranging from -0.115 to 0.034.None of these correlations were statistically significant (p > 0.05), suggesting that gender does not significantly influence the orientation or course of ICA segments.

The diameters of ICA segments (D1, D2, D3, D4, D5, D6) displayed more notable correlations with gender.Diameters D1 and D2 in the right ICA had statistically significant negative correlations with gender, with r values of -0.161 and -0.118, respectively, at the 0.05 significance level. Diameters D3, D4, D5, and D6 also showed statistically significant negative correlations with gender in both the right and left ICAs, with r values ranging from -0.154 to -0.135, all at the 0.05 significance level. These results indicate that males tend to have larger diameters in these segments compared to females.In summary, the analysis reveals that while there are no significant gender-related differences in the lengths and angles of ICA segments, there are statistically significant differences in the diameters of certain segments.

Similarly, correlation analysis was done with age. The lengths of ICA segments (L1, L2, L3) displayed weak correlations with age, with correlation coefficients (r values) ranging from -0.038 to -0.100 (Statistically insignificant).The angles of ICA segments (A1, A2, A3) showed weak to moderate correlations with age, with correlation coefficients (r values) ranging from -0.155 to -0.012.Among these, the correlation between A1 and age approached statistical significance (p = 0.059). However, the other correlations were not statistically significant. The diameters of ICA segments (D1, D2, D3, D4, D5, D6) exhibited strong negative correlations with age.All correlations between diameters and age were statistically significant at the 0.01 level (p < 0.01). The correlation coefficients (r values) ranged from -0.572 to -0.661, indicating a substantial negative association between age and the diameters of ICA segments.

## Discussion:-

The present study conducted an investigation on the changes in segments of the internal carotid artery (ICA) in relation to age. The findings indicate that age has a minimal effect on the length and orientation of these segments, but it does have a substantial correlation with their diameters. The analysis of gender-related disparities in this study revealed that gender exerted less impact on ICA length and direction. Nevertheless, the study did uncover statistically significant disparities in certain segment sizes, wherein males usually had greater diameters compared to females. The observed variations in the diameter of the internal carotid artery (ICA) align with findings reported in prior research.

In a study done by Kirisattayakul W et al,[5] the measurements of the lengths (mm) and angles of the internal carotid artery (ICA) were recorded as follows: L1 = 7.20 ± 2.22, L2 = 15.71 ± 2.32, L3 = 10.99 ± 1.66, A1 = 109.31 ± 17.77, A2 = 107.87 ± 20.51, A3 = 80.81 ± 16.33. No statistically significant changes were seen in the angulations of the A1-A3 segments between males and females ($p > 0.05$). In the male group, the L2 (C3-C4) segment exhibited a considerably increased length compared to the female group. However, among females, only the left side had a statistically significant increase in length ($p < 0.05$). The mean diameters of the internal carotid artery (ICA) in both males and females were found to be 4.17 ± 0.55 mm on average. Nevertheless, the diameters of D1–D6 on the left and right sides of men, with the exception of the right D6, exhibited a statistically significant increase compared to those of females ($p < 0.05$). Additionally, it is noteworthy that the right diameters of females (D1) and males (D1 and D2) had lesser measurements in comparison to their respective left sides.

Prior research has also indicated that there are sex-based disparities in the diameter and vertical lengths of the internal carotid artery (ICA).[11] The presence of hypertension has been found to be associated with a reduced diameter of the internal carotid artery (ICA). Furthermore, previous research has demonstrated a correlation between variables such as age, weight, and height and the diameter of the femoral artery.[10] Furthermore, there exists a correlation between a patient's height and skull shape and the size and length of the internal carotid artery (ICA).[12]Nevertheless, the assessment of these aspects was not conducted as it did not align with the primary aim of our research.

In brief, this work makes a valuable contribution to the extant literature on changes and morphometry of the internal carotid artery (ICA). The utilisation of two-dimensional digital subtraction angiography (2D DSA) pictures enabled a comprehensive examination of the features of the internal carotid artery (ICA) in relation to age and gender. The results of the study validate some tendencies that have been previously documented, such as the decrease in internal carotid artery (ICA) diameter with age and the variation in segment sizes based on gender. These findings emphasise the need of tailoring treatment methods to individual patients, taking into account their age and gender. Subsequent investigations might delve into the clinical ramifications of these variances in internal carotid artery shape, potentially impacting therapeutic approaches for cerebrovascular disorders.

## Conclusion:-

The internal carotid artery (ICA) variations and morphometry in a cohort of 149 individuals were thoroughly studied in this study using 2D digital subtraction angiography (DSA) images. Age had no bearing on the length and orientation of ICA segments, but it strongly linked with their diameters, pointing to a notable decline in ICA diameter with advancing years. However, gender did reveal statistically significant variations in several segment sizes, with males typically having greater diameters than females. In contrast, gender had little effect on ICA length and orientation. These findings offer insightful information on the ICA's structural features, which might have clinical repercussions for vascular assessments and therapies.

## Acknowledgements:-

Nil.

**Conflict of interest:**

Nil.

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