Original Research Article

Assessment of internal carotid artery dimensions using 3D rotational angiography in Indian population

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Abstract

Background: Knowledge on cerebrovascular geometry in terms of length, calibre, taper and tortuosity are of paramount importance for Neurointerventionist to safely perform endovascular procedures which require placement of multiple endoluminal devices. Till date, only limited literatures describing dimensions of segments of ICA beyond the cervical segment are there. Present study is the single largest study till date, which evaluates the dimensions of ICA in Indian population using 3D RA, a gold standard in assessing the carotid vasculature. **Aim:** To determine the normal dimension of the segments of internal cerebral artery using three-dimensional rotational angiography (3DRA). **Design:** Retrospective cross-sectional study done by reviewing 3DRA images of patients with no angiographic features of intracranial vascular abnormalities. **Results:** Images of 300 patients were analyzed, 161 (53.7%) male and 139 (46.3%) female patients with mean age of 47.2 years. The mean length and diameters of different segment of the ICA were calculated, gender and age-based comparison was done. Male patients had larger caliber of segments of the internal cerebral artery. Length of vessel has variation depending on age of patient however no gender-based difference in length of the segments were noted. **Conclusion:** Our data regarding the normal dimensions of the segments internal carotid artery can help better plan and execute neuroendovascular procedures

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INTRODUCTION

In the present era of rapidly evolving Neuroendovascular interventional procedures a good knowledge and understanding of the anatomical course, dimensions, and variations of the internal carotid are required for the safe execution of the procedures. The caliber of ICA(Internal carotid artery) and its segments are not uniform and can have variations in dimensions depending on age, gender, and race of the patient.[1–3] The majority of the intracranial morphometry studies have been performed using imaging techniques like ultrasonography, doppler, ultrasonography, doppler, computed tomography angiography, and magnetic resonance angiography and they have been conducted predominantly in the western population.[2,4–7] To our knowledge, there are no Indian studies to date accessing the dimensions of ICA and its segments. Therefore, we had undertaken this study to evaluate the dimensions of different segments of ICA in the Indian population using 3DRA(Rotational angiography). The outcomes of the study can further aid in proper preprocedural planning and selection of appropriate devices for our patients.

AIM: To determine the normal dimension of different segments of ICA using 3DRA.

OBJECTIVE: To retrospectively analyze the images of patient patients who have undergone 3DRA.

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METHODS

This is a retrospective cross-sectional study involving patients who had underwent angiography at our institute from April 2013 to April 2016.

PATIENT SELECTION: Patients between the ages of 18 to 80 yrs were recruited for the study based on our patient selection criteria (mentioned below).

Inclusion criteria: Patients should have undergone digital subtraction angiography (DSA) with 3 D Rotational angiography (3D RA).

Exclusion criteria: 1. Patients with angiographic features of atherosclerosis, 2. Patients with intracranial vascular pathologies including arteriovenous malformation, dissection, and aneurysm.

In our study over 3 years (April 2013 to April 2016) we observed a total of 300 patients comprising 161 males and 139 females with a mean age of 47.2 years.

TECHNICAL INFORMATION:

IMAGE ACQUISITION: All digital subtraction angiograms(DSA) were performed under local anesthesia using biplane DSA machine (Allura Xper FD 20/20, Philips Medical Systems, Best, The Netherlands). The transfemoral approach was used for all our patients to perform angiography. A 5 F diagnostic catheter was positioned beyond the carotid bulb and 3DRA was performed using the frontal plane of biplanar C arm. The 3D RA images were acquired at 220° rotational run over 4.1 seconds, 200 images of the area of interest including all the segments of the internal carotid artery (ICA) were acquired. Eighteen milliliters of 300 mg/ml contrast medium was injected at a rate of 3.5 ml per second into the internal carotid artery using a power injector (MEDRAD PROVIS Injector, GERMANY) during the 3DRA image acquisition. Corresponding mask images were also obtained.

IMAGE PROCESSING AND ANALYSIS: The images were transferred to the workstation (3DRA; Xtravision Philips Medical Systems) attached to the DSA machine. The images acquired using the above-mentioned 3D RA protocol were reconstructed using Philips Allura 3D RA Xtravision software. Post-processing of the images was performed at the workstation. Three-dimensional volume rendering images were obtained by subtracting from non-contrast rotational angiogram using the automated removal of bone and soft tissue Bouthillier classification was used for classifying the ICA segments. We had measured the length and diameters of ICA segments namely, Cervical (Ce), Petrous (Pe), Cavernous (Ca), Ophthalmic (Op), and Communicating (Co) for all the patients7. Angiographic identification of laceral and clinoid segments is not possible, hence we have not measured their diameters. The diameter of the carotid bulb was not included as they may cause variations in the true caliber of the cervical ICA Both the length and diameter of the vessels were calculated. The length of ICA was measured by using a system-generated automated centerline along the long axis of the blood vessel from ICA origin to intracranial carotid bifurcation (Fig.1). The length of each segment was measured based on anatomical course and characteristic landmarks. The diameters of the vessel were generated by averaging three values in a plane where the vessel shows circular caliber (Fig 2-6).

ETHICAL CLEARANCE: Relevant ethical clearance was obtained from the institutions ethic committee and the need for consent was waived off since it was a retrospective observational study.

STATISTICAL ANALYSIS: The data entry was done on Epidata version 3.1. and SPSS v.20 was used for analysis. The nominal variables were depicted in terms of numbers and percentages. The continuous variables like 3D dimensions of cervical, petrous, cavernous, ophthalmic, and communicating segments of ICA were expressed in terms of Mean, Range, and Standard deviation. Statistical significance among variables was evaluated by student t-test, bivariate analysis, and linear regression methods. Statistical significance was set at $p < 0.05$.

RESULTS

A total of 300 patients were included in our study, 161 (53.7%) male and 139 (46.3%) female patients. The ages of the patients ranged from 18 to 80 yrs with a mean age of 47.2 yr. Diameters of segments of ICA showed a significant difference, with male patients having greater diameters than female patients. We found the right ICA segments namely petrous, cavernous and ophthalmic segments, to be significantly larger in male patients compared to the female patients. Similarly, bilateral cervical segments and left communicating segments were found to be significantly larger in male patients compared to female patients. There was no significant difference in lengths of ICA segments between male and female patients. The mean lengths and diameters of each segment of ICA in both male and female patients are mentioned in Tables 1 and 2.

Table 1: Comparison of 3D DSA ICA segments length on right and left sides between male and female

3D Length	Right side Male		Right side Female		T test	*P* value	Left side Male		Left side Female		T Test	*P* value
	Mean	SD	Mean	SD			Mean	SD	Mean	SD		
Ce	59.29	7.5	60.93	8.7	-1.74	0.81	60.48	8.3	61.22	10	-0.69	0.48

Pe	33.22	5.6	32.16	5.3	1.67	0.09	32.31	5.2	32.87	4.8	-0.95	0.34
Ca	26.98	5.2	27.81	5.5	-1.34	0.18	26.92	4.6	27.24	5.2	-0.56	0.57
Oph	10.26	2.2	10.08	2.1	0.69	0.48	10.3	1.9	10.53	2.4	-0.90	0.36
Co	5.47	1.6	5.41	1.5	0.36	0.71	5.75	1.7	5.71	1.7	0.18	0.85

Cervical segment (Ce), Petrous segment (Pe), Cavernous segment (Ca), Ophthalmic segment (Oph), Communicating segment (Co), **P* value<0.05. The table depicts that there is no significant difference in lengths of different segments of ICA between male and female.

Table 2: Comparison of 3D DSA ICA segments diameter on right and left sides between male and female

3D Diameter	Right side Male		Right side Female		T test	*P*value	Left side Male		Left side Female		T Test	*P*value
	Mean	SD	Mean	SD			Mean	SD	Mean	SD		
Ce	5.1	0.51	5.05	0.54	2.3	0.02*	5.1	0.44	5.03	0.47	2.9	0.004*
Pe	4.51	0.53	4.36	0.56	2.37	0.01*	4.4	0.4	4.4	0.41	1.42	0.15
Ca	4.3	0.55	4.36	0.56	2.37	0.01*	4.4	0.53	4.3	0.48	1.7	0.07
Oph	3.6	0.45	3.5	0.46	1.94	0.05*	3.7	0.48	3.6	0.78	1.68	0.09
Co	3.17	0.39	3.13	0.42	0.81	0.41	3.3	0.57	3.1	0.40	2.31	0.02*

Cervical segment (Ce), Petrous segment (Pe), Cavernous segment (Ca), Ophthalmic segment (Oph), Communicating segment (Co), **P* value<0.05.The table depicts that there is significant difference in diameter of different segments of ICA between male and female with male having greater diameter than female.

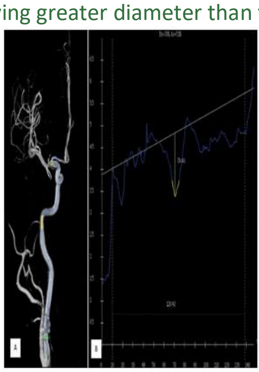
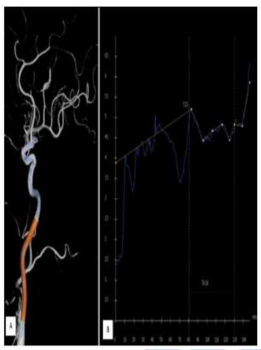
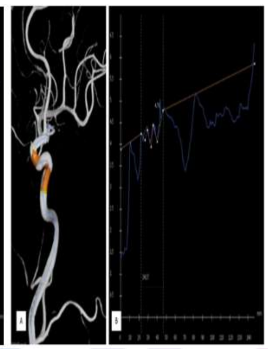
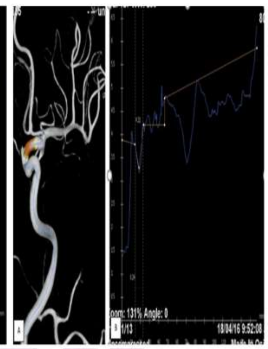
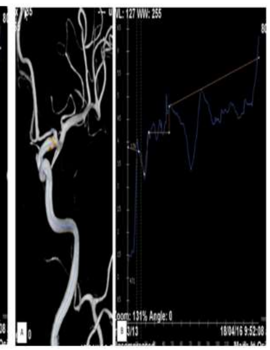

Figure 1 **Figure 2** **Figure 3** **Figure 4** **Figure 5**

FIG 1: A. System generated automated central line from cervical ICA excluding carotid bifurcation to ICA bifurcation, B. Histogram analysis showing length of left ICA from carotid bifurcation excluding carotid bulb to ICA bifurcation; **FIG 2:** A. System generated software allowing measurement of left cervical ICA, B. Histogram analysis showing cervical ICA length of ~49.6mm and diameter of ~5.6mm; **FIG 3:** A. Petrous ICA volumetric measurements, B. Histogram analysis of left petrous ICA having length of 31.8mm and diameter of 4.3mm; **FIG 4:** A. Cavernous ICA morphometric analysis, B. Histogram showing left cavernous ICA length of ~24.6mm and diameter of ~4.9mm; **FIG 5:** A. Left ICA Communicating segment, B. Histogram analysis showing length of ~5.5 mm and diameter of ~4.4 mm of ophthalmic segment of right ICA

DISCUSSION

Knowledge and understanding the vascular morphometry in terms of length and caliber of the ICA segments are fundamental for Neurointerventional procedures for safely executing the procedure. The earlier works of literature on the dimensions of the carotid vasculature are predominantly cadaver-based studies.[7–9] and may not accurately reflect the true in vivo state of a patient. Neuroimaging techniques like ultrasonography, doppler, CTA, and MRA have been used to evaluate the intracranial vasculature, but are considered inferior to digital subtraction angiography.[10] Measurement of the length and diameter of the carotid and vertebral vasculature under in vivo physiological conditions are possible due to these neuroimaging techniques. Digital subtraction angiography with 3D RA imaging techniques incorporated with advanced post-processing and vascular analysis software, allow more accurate measurements of the carotid vasculature independent of the user, thus making it the gold standard in vascular analysis and scores over other imaging techniques. In our study, we did not find any significant gender-based difference in the length of the ICA segments. However, we had observed that the extracranial cervical ICA segment was longer on the left side than the right in both genders. Our results corroborate the finding of previous studies done using CTA that there is an increase in length of ICA with increasing age.[7] On bivariate analysis of length, there was a steady increase in the length of ICA with increasing age irrespective of gender. With regards to diameters of segmental vessels, most of the right segmental vessels except communicating segment were found to be larger in male patients however left segmental vessels except for cervical and communicating segment did not show any difference in diameter. Similar gender-based variation was reported by multiple previous studies however right-side predominant variation was not observed in the previous studies.[1,11]

Krejza *et al.* in their USG based study attributed this phenomenon due to increase blood pressure in male patients as compared to female patients(2). According to ruan *et al.*, the variation could be due to the effect of sex hormone on vascular remodeling (1), and many previous studies support the estrogen protection hypothesis.[12,13] We did not find the diameter of the vessels on the left side to be significantly larger than right, On contrary to the observations made by Yasuda *et al.* based on an assessment of cross-sectional area and diameter of the carotid artery using TOF (Time of flight) MR angiography and CT angiography. Similarly, we did not observe any change in the diameter of ICA segments with age in both genders. Similar observations were made by the study conducted by FA Choudary *et al.* based on CTA findings.[7]

CONCLUSION

Our study on dimensions of extracranial and intracranial ICA using the "gold standard" 3DRA in the Indian Population is the single largest study. This baseline study will give an insight into ICA dimensions which are important for safely performing neuroendovascular procedures. This knowledge will aid in choosing the appropriate device and improve the success rate of endovascular management of intracranial and extracranial internal carotid vessel diseases like atherosclerotic, aneurysms, and stroke.

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