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Establishing Flow Velocity of the Common Carotid Artery in Normal adults Using Ultrasonography

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Introduction

The ability to assess and monitor total cerebral blood flow volume (tCBFV) is clinically important particularly in patients with cerebrovascular disorders, serious head trauma, and increased intracranial pressure. Increased intracranial pressure which is a common condition in neurologic intensive care units and reducing tCBFV is among the therapeutic alternatives, [1,2]The prevalence of atherosclerosis, ischemia, infarction, and neurodegenerative disorders increases with age and causes impairment in cerebral perfusion hence, the age-dependent changes in tCBFV should be understood and considered.[3]

Extracranial carotid artery disease is responsible for more than 50% of all the cerebrovascular disorders.[4]Flow limiting stenosis of the carotid artery is a common predisposing cause of cardiovascular diseases including stroke. There is crucial age, body habitus and gender-related differences in the prevalence and burden of cardiovascular disease[5]. An approach to understanding this disparity particularly in stroke is to establish normal characteristic profile of carotid flow velocities. Ultrasonography which is a non-invasive, safe and relatively inexpensive technique devoid of ionizing radiation is increasingly used for evaluation of flow velocities thus detecting early atherosclerosis changes and predicting clinical complications.[6]

The main goal of this study was therefore to assess blood flow velocity and waveform parameters, of the CCAs in healthy adults using ultrasound and to evaluate its relationship with sex, body mass index (BMI) and as well as its age-dependent changes.

Methods

This prospective study was conducted on apparently healthy adult 18 years and above from a Teaching Hospital in north eastern Nigeria. Volunteers were recruited consecutively at random from the neighboring tertiary schools and

within the hospital. Excluded were volunteers with past historyorat risk of cardiovascular disease, currently smoking, pregnant women, individuals on drugs such as opiates or those that consume alcohol. Also those with major anatomic variations of the common carotid arteries were excluded.

Informed written consent was obtained from the subjects before enlistment into the study. Approval to carry out the study was obtained from the Ethical Committee of the institution.

At recruitment, Clinical parameters which include age, sex and height in meters and weight in kilograms were recorded. The BMI was calculated as a ratio of the measured weight to square of the measured height (kg/m2). BMI of<18.50 was categorised as underweight, 18.50-24.99 as normal and 25.00-29.99 as overweight.

The examinations were performed using a high-resolution real-time Doppler ultrasound scanner (Aloka, SSD-3500) equipped with 7.5 MHz linear-array transducer. The 7.5 MHz linear-array transducer provides greater resolution for superficial structures such as the carotid artery.

In a supine position, the patient's shoulder was placed on pillow with the neck extended and turned slightly away from the side being scanned. After applying ultrasound gel to the neck, the transducer was placed above the clavicle first in a transverse projection for the grey-scale examination. The CCA was located and followed proximally as far as the clavicle permitted to the level of the carotid bifurcation (thyroid cartilage). Longitudinal views were similarly obtained.

Doppler interrogation of the CCA was performed in the longitudinal plane using angle $<60^0$. Spectral Doppler waveform was obtained at proximal, middle and distal portions. The PSV and EDV were determined from velocity waveforms at all locations obtained.

The data obtained from the structured data sheet was entered into a computer system. Analysis was performed with statistical package for social science software (SPSS version 16.0 Chicago, IL, USA). The results were expressed as mean ± standard deviation (SD) and presented in the form of tables, charts and graphs as appropriate. Statistical significance was assessed using students' test to compare the mean flow velocities between two sexes. Correlation between the CCA flow velocities with height, weight and BMI were evaluated using Pearson's correlation test. Simple linear regression was used to correlate patient age and sex with CCA flow velocities. P value < 0.05 was considered statistically significant.

Results

Four hundred volunteers participants in the study: 239 (59.80%) males, 161 (40.20%) females. Ages ranged between 18 and 81 years (Mean = 36. 74 ± 14.79 years). The mean age range was 37.18±15.08 and 36 08±14.37 for males and females respectively. Majority of the subjects {148 (37%)} were in the age group 21 to 30 years consisting of 62 (15.50%) females and 86 (21.50%) males (Table 1)

Table 2 shows the relationship between the mean body parameters and age group. All body parameters were high in the age group 41-50 years. Their heights ranged between 1.50 -1.90m (Mean = 1.67±0.75m). The least height (1.62 ± 0.11m) was recorded in the age group 61-70 years. Weight ranged between 40-96kg (Mean = 63.82kg ± 9.87) and the body mass index (BMI) from 15.10 – 37.50 (Mean = 22.87±3.26). The least BMI was in the aged group 81-90 years (20.40 ± 0.00).

The relationship between sex and mean of body parameters is shown in table 3. All body parameters were lower in females.

In tables 4 & 5, the mean PSV and EDV OF CCA of different age groups for males and females subjects respectively has been shown. The highest mean ± SD PSV for CCA was in the age group of 20years and below and the lowest in the age group>70years. Similar observation was seen for EDV of CCA.

Table 6shows the overall mean PSV and EDV values on the right and left sides of subjects. A trend in PSV was observed along the course of the

CCA. The more distal the measurement, the lower the velocity (Table 7). There was no correlation between the ranges of PSV in the CCA on the left and the right sides (r =0.09).

In contrast, EDV values increased along the course of the CCA. The average right proximal CCA EDV was 14.20cm/sec ± 4.30 compared with the average distal CCA EDV of 19.70cm/sec ± 3.80 (p=0.000). No significant statistical difference was seen between the right and left CCA PSV: t=1.150, P=0.251.

Table: 8 showed the average mean velocities of CCA with different age group in the study population. There was decrease in the mean values of both the PSV and EDV in the CCA with respect to age and was statistically significant. Table 9 summarised the average mean CCA blood velocities for males and females in the study population.

Tables 10 and 11 show the relationship of BMI with PSV and EDV. The mean total PSV was lower in the overweight individual than the normal and the underweight individuals in both males and females, similar findings were seen in the mean total EDV and this was statistically significant.

Table 1: Age group and sex distribution

Age group (years)	Males N (%)	Females N (%)	Total N (%)
≤ 20	20(5.00)	12 (3.00)	32 (8.00)
21-30	86 (21.50)	62 (15.50)	148 (37.00)
31-40	57 (14.25)	42 (10.50)	99 (24.75)
41-50	29 (7.25)	12 (3.00)	41 (10.25)
51-60	25 (6.25)	20 (5.00)	45 (11.25)
61-70	14 (3.50)	11 (2.75)	25 (6.25)
71-80	6 (1.50)	2 (0.50)	8 (2.00)
81-90	2 (0.50)	0 (0.00)	2 (0.50)
Total	*239 (59.80)*	*161 (40.20)*	*400 (100)*

N: Sample population

Table 2: Mean body parameters in each age group.

Age group (Years)	Frequency (N)	Height (M) ±SD	Weight (kg) ±SD	BMI (Kg/m2) ±SD
≤ 20	32	1.64 ± 0.80	59.19 ± 7.90	22.30 ± 3.68
21 – 30	148	1.69 ± 0.74	63.20 ± 9.35	22.30 ± 2.90
31 – 40	99	1.68 ± 0.74	65.34 ± 12.30	23.20 ± 4.02
41 – 50	41	1.71 ± 0.05	70.63 ± 8.45	24.24 ± 2.59
51 – 60	45	1.64 ± 0.42	63.27 ± 6.80	23.56 ± 2.07
61 – 70	25	1.62 ± 0.11	59.76 ± 4.07	23.06 ± 3.57
71 – 80	8	1.65 ± 0.31	58.00 ± 5.18	21.27 ± 1.98
81 – 90	2	1.64 ± 0.00	55.00 ± 0.00	20.40 ± 0.00

BMI: body mass index.
SD: standard deviation.
N: sample population.

Table 3: Sex and overall mean body parameters (height, weight, and BMI)

Sex(N)	Height(m) Mean ± SD	Wight(kg) Mean ± SD	BMI(KG/M^2) Mean ± SD
Male (239)	1.70 ± 0.67	66.03 ± 9.93	22.86 ± 3.26
Female(161)	1.63 ± 0.67	60.54 ± 8.8	16.31 ± 0.66

BMI: body mass index
SD: standard deviation.
N: sample population.

Table 4: Mean CCA and ICA PSV and EDV of different age groups males

PSV(cm/s)	≤20years M±SD	21-30 years M±SD	31-40 years M±SD	41-50years M±SD	51-60 years M±SD	61-70 years M±SD	>70years M±SD
RCCA	52.88±7.76	47.31±6.19	38.89±3.57	37.71±2.64	32.26±3.54	32.21±3.71	29.67±0.91
LCCA	52.83±7.73	47.32±6.21	38.92±3.48	37.68±2.66	32.50±3.12	33.35±3.96	29.65±0.92
Mean Total	105.71±15.50	94.64±12.40	77.82±7.05	75.40±5.30	64.77±6.63	66.57±7.67	59.32±1.83
RCCA	19.04±5.18	14.81±3.99	15.17 ±4.64	13.24±2.92	13.30±3.58	12.47±4.82	10.80±1.07
LCCA	19.16±5.18	14.84±4.00	15 .20 ±4.65	13.46±2.92	13.23±3.54	12.46±5.02	10.97±0.98
Mean Total	38.20±10.36	29.65±7.98	30.37 ±9.29	26.71±5.84	26.54±7.12	24.94±9.84	21.77±2.06

RCCA: Right common carotid artery.
LCCA: Left common carotid artery.
PSV: Peak systolic velocity.
EDV: End diastolic velocity.

Table 5: Mean CCA and ICA PSV and EDV of different age groups females

PSV(cm/s)	≤20years M±SD	21-30 years M±SD	31-40 years M±SD	41-50years M±SD	51-60 years M±SD	61-70 years M±SD	>70years M±SD
RCCA	47.38±7.50	46.19±6.80	39.63±3.36	37.26±3.20	30.98±3.17	32.90±3.33	29.60±0.00
LCCA	47.48±7.32	46.17±6.80	39.60±3.36	37.18±3.42	31.02±3.11	32.86±3.31	29.60±0.00
Mean total	94.86±14.83	92.36±13.61	79.23±6.73	74.45±6.62	62.00±6.27	65.77±6.65	59.20±0.00
EDV(cm/s)							
RCCA	14.81±3.97	14.09±4.28	14.50 ±3.88	11.45±2.14	11.25±4.45	14.48±4.28	7.80±0.00
LCCA	14.95±3.98	14.19±4.25	14 .50 ±3.91	11.33±1.86	11.48±4.33	14.87±4.67	8.00±0.00
Mean total	29.76±7..95	28.21±8.52	29.00 ±7.80	22.78±3.99	22.73±8.87	29.35±8.92	15.80±0.00

RCCA: Right common carotid artery.
LCCA: Left common carotid artery.
PSV: Peak systolic velocity.
EDV: End diastolic velocity

Table 6: Overall range and means of average CCA and ICA flow velocity

Variable	Simple size (N)	Range	Mean (±SD)
AVFs (cm/sec)			
Carotid Arteries			
RCCA $_{PSV}$	400	24.00-55.43	37.56±7.18
RCCA $_{EDV}$	400	10.23-28.77	17.03±3.88
LCCA $_{PSV}$	400	24.37-55.43	37.56±7.16
LCCA $_{EDV}$	400	10.30-28.83	17.09±3.87

SD: standard deviation; CCA: common carotid artery; RCCA: right common carotid artery; LCCA: left common carotid artery; psv: peak systolic velocity; edv: end diastolic velocity.
AVFs: average flow velocities.

Table 7: Mean PSV and EDV of the Right and left Carotid arteries

Artery	Right PSV	EDV	Left PSV	EDV
Distal CCA	33. ± 6.60	19.70 ± 3.80	33.80 ± 6.50	19.80 ± 3.80
Middle CCA	37.50 ±7.20	17.10 ± 4.00	37.50 ± 7.30	17.10 ± 400
Prox. CCA	41.30 ± 8.10	14.20 ± 4.30	41.30 ± 8.00	14.30 ± 4.40

Note: The values (cm/sec) given, expressed as the mean ± SD, and were obtained from all the 400 subjects.
PSV: peak systolic velocity.
EDV: end diastolic velocity.
Prox: proximal.

Table 8: Average mean CCA and ICA blood velocities of different age group

Vessel	Age (years)	N	PSV (cm/sec)	P value	EDV (cm/sec)	P value
RCCA	18-50	320	40 ± 6.30	P <0.001	25 ± 3.80	P <0.001
	51-81	80	29 ± 3.20		20 ± 3.30	
LCCA	18-50	320	40 ± 6.30	P <0.001	18 ± 3.70	P <0.001
	51-81	80	29 ± 3.20		15 ± 3.80	

RCCA: Right common carotid artery, LCCA: Left common carotid artery
PSV: Peak systolic velocity, EDV-End diastolic velocity.

Table 9: Average mean CCA and ICA blood velocity for males and females.

Vessel	Sex	N	PSV(cm/sec)	P value	EDV(cm/s)	P value
RCCA	**M**	239	38 ± 3.70	P=0.275	24 ± 4.40	P=0.89
	F	161	37 ± 6.90		23 ± 4.00	
LCCA	**M**	239	38 ± 7.30	P=0.272	17 ± 0.40	P=0.83
	F	161	37 ± 6.90		17 ± 0.40	

RCCA: Right common carotid artery, LCCA: Left common carotid artery
PSV: Peak systolic velocity, EDV-End diastolic velocity.
M: males.
F: females.

Table 10: Mean total PSV verses BMI.

BMI	**Males**	**Females**
	CCA (M±SD)	**CCA (M±SD)**
Under weight	43.73±6.3	44.35±4.77
Normal weight	41.26±8.41	42.35±7.84
Over weight	36.45±5.02	35.72±5.37

Table 11: Mean total EDV verses BMI

BMI	**Males**	**Females**
	CCA(M±SD)	**CCA(M±SD)**
Under weight	14.81 ± 3.76	16.58±4.90
Normal weight	14.76 ±4.44	13.59±3.95
Overweight	13.98±4.48	12.61±4.47

Discussion

Measurement of cerebral blood flow is an important parameter in the diagnosis and follow-up of cerebrovascular disease.[7]Several studies have demonstrated the normal dimensions of CCA arteries[8,9,10] and their flow velocities in normal adults.[11,12] Thomas et al[13] found that the normal CCA PSV was <100cm/sec and EDV was < 40cm/sec. Vivian et al[11] observed a trend in PSV along the course of the CCA; The more distal the measurement, the lower the velocity. The average PSV (±SD) in the distal CCA (75.20cm/sec ± 2.37) was significantly lower than that in the proximal CCA (86.90cm/sec ± 25.6) (P<0.001). This study has observed that the range of peak systolic velocity (PSV) in CCA was 24.00cm/sec-55.43cm/sec and EDV was 10.23cm/sec-28.77cm/sec.In both measurements, the PSV and EDV in CCA were<110cm/sec and <40sec/sec respectively which agree with the findings of Brian et al and Vivian et al. This study also observed a trend in PSV along the course of the CCA. The more distal the measurement the lower the velocity which therefore collaborated with the study by Vivian et al.[11] However, the mean PSV±SD of the CCA (33.80cm/sec ± 6.60) and the proximal CCA (41.30cm/sec ± 8.10) when compared to the findings of Vivian et al, distal CCA (75.20cm/sec ± 23.70) and proximal CCA (86.90cm/sec ± 25.60) tend to be lower in this study. This may be due to differences in equipment or physiologic factors such as cardiac output[14] or even geographical differences and standard of living between the two populations studied.

The variability of velocities along the course of the CCA may be a result of several factors. Laminar flow within a rigid tube is governed by the law of conservation of momentum.[15] In the CCA however, blood flow is not laminar where the vessel is tortuous, or where it bifurcates[16]. Furthermore, the normal compliance of the vessel wall may serve to dampen velocities and thereby contribute to the progressive decline in velocity along the course of CCA.[17]

Ultrasonographic studies to ascertain the relationship between the CCA flow velocities (FVs) with age and sex were done by previous researchers.[18]Burhan et al[7] evaluated cerebral blood flow measurements of the extracranial carotid arteries with Doppler ultrasonography in healthy adults. They found a significant decrease in blood velocities in the CCA with increasing age. Vivian et al[15] in their study on the variability of Doppler USS measurements along the common carotid artery. They found that, the PSV and EDV value in the CCA were consistently lower in the older group at all locations of measurements. This study showed an age dependent decline in all FVs of the CCAs which is in agreement with the previous studies above.

In studies where a decrease in cerebral blood flow was detected related to age, the decrease was related to a decrease in the perfusion demand of the brain, secondary to atrophy from progressive neuronal loss.[19] Again increases in carotid diameter with age result in a decrease in velocity to maintain flow.[20] Another important reason for the reduction in FV with age may be reduced cardiac output.[21]

Burhan et al[7] evaluated the relationship between CCA flow velocities with sex. They found that in females PSV and EDV in ICA were higher as compared to males however in the CCA, the difference was not significant. Hüsseyin et al[18] in their study found no significant differences between females and males with respect to FV.

The effect of height, weight and BMI on carotid artery flow velocities were also evaluated by previous researchers. Hüsenyin et al[18] found in their study that PSV and EDV in CCA were significantly lower in the over weight than the normal individual, however, found no correlation between flow velocities of carotid arteries with height. This present study found that the FV in carotid arteries were lower in over weight individuals. The mean right PSV in CCA was 34 ± 6cm/sec in over weight and 42 ± 8cm/sec in normal individuals (p=0.000). The mean right EDV in CCA was 23 ± 4cm/sec in over weight and 26 ± 5cm/sec in normal individuals. No correlation between carotid arteries flow velocities with height was found (r=0.036; p=0.5). The present study showed agreement with the finding above.

Conclusion

Established values of the flow velocities will serve as reference points in our environment and will equally add to the pool of literature available for academic and research references.

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