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Radio-Anatomical Variations of Both Origin and Foraminal Entrance of Vertebral Arteries in Black African Human: Experience from Côte d'Ivoire

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Abstract

The vertebral arteries (VAs) are a system of two blood vessels through which blood is transported to the posterior cerebral fossa. VAs may emerge at different sides from the aortic *ostium*. The aim of our study was to establish a reference of radio-anatomical variations of the VAs in black African human from Côte d'Ivoire experience. **Materials and Methods:** Forty patients underwent Computed Angio-Tomography (CAT) of the supra-aortic vessels (SAoVs). Included in our study were patients who underwent CAT of the SAoV from January 2019 to December 2021, those excluded in our study as Caucasians and other leucoderma humans. This exclusion allowed for highlighting only black humans VAs variations. The variations of both origins and foraminal entrance of VA were assessed. We carried out a model of univariate regression for assessing the occurrence of VA variations related to demographic included mainly age, gender and clinical features. **Results:** The

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average age was 48 ± 12 years with 0.66 of sex ratio. The most frequent indication for carrying out CAT was brain ischemic stroke assessment (25%). The atypical origin of the VAs out of subclavian arteries (SCA) was 25%. Origin from the aortic arch (AoA) was 17.5%. Six (15%) were unilateral while one (2.5%) was bilateral variation from a common trunk as pattern. Bilateral sixth cervical foramina inlet was 85%. Female sex and ischemic stroke assessment had a statistically significant correlation. **Conclusion:** VAs variations studies in black African human are lacking in the literature. Our findings depicted a considerable amount of VAs variations opening the field for further observational studies in black African human.

Keywords

Vertebral Artery, Variations, Morphology, Vessels, Supra-Aortic, Back African

1. Introduction

Egaz Moniz first achieved in 1933 cerebral angiography, but authors' works 20 years later such us GUY Lazorthes in 1949, Hutchinson in 1956 and Yasargil in 1957 depicted the importance of VAs and confirmed its role in the occurrence of cervico-cerebral vascular pathology setting. The VAs are two asymmetric vessels which derive from the vertebro-basilar system that supplies the posterior cerebral fossa and the spinal cord [1]. These regions must be normally supplied with arterial blood flow for preserving brain and spinal cord vital functions [2]. Vertebral arteries because of their features such location and shape are a specific pattern of posterior vascular supply system. They originate from different distances of aortic ostium. VAs derive at different angles, getting different lengths, different inner diameters and different spatial patterns [3]. Variations cited above result from human anatomy inter-subject discrepancies not necessarily disease causative. Particular attention has to be taken into account by cervical, thoracic and vascular surgeons for treating pathologies involving VAs [3]. In contrary to other arteries, VAs fuse at their proximal part for giving basilar artery. Basilar artery diameter is relatively great than VAs and gets variable location related to the axial symmetry. This junction is too featured by varied geometry [3]. Thorough VAs discrepancies could result an individual state and are constitutional abnormality not necessarily liable of disease. Multi-Detector-Computed-Tomography-Angiography remains the exam of choice. Highlighting the anatomical scheme variations of VAs should contribute significantly to either ischemic stroke diagnosis work-up and different vascular diseases of posterior supra-aortic circulation [2]. The fundamental aim of our study was to establish a reference of radio-anatomical variations of VAs in black African humans.

2. Materials and Methods

A retrospective and prospective study in single imaging center was carried out from January 2019 to December 2021. The retrospective period extended from

January 2019 to October 2021 and the prospective one was from October to December 2021. VAs CAT data have been collected in the imaging center of polyclinic FARAH which is one of reference centers of imaging in Côte d'Ivoire Republic (CIR). The site of imaging center we chose for our study was explained by the materials features *i.e.*, either good image resolution or fair numeric archives conservation allowing thorough access to data. Forty VAs CAT have been assessed for scrutinizing VA origins and foraminal entrance variations. Magnetic Resonance Images (MRI) and angio-MR images were excluded because they did not assess VAs variations scrutinizing. Our study included black African human patients from all ranges of age who underwent VAs CAT from January 2019 to December 2021 in the imaging center cited above. Those whom VAs CAT had artefacts, those who underwent CAT out of our study period, and those whom CAT were achieved out in other anatomic regions than cervico-cranial, in fine both Caucasians and other white origins were excluded.

Images have been acquired on 128 helicoidally tomography pattern. Protocol was as follow: cranio-cervical volumetric acquisition from aortic arch to the vertex. Acquisition orientation was from out and triggering was automatic using bolus track system. The rotation cycle was 0.5 second, allowing an anatomical exploration duration of 2.8 seconds. Machine electric parameters were 120 Kilovolt, 142 average milli-ampere, Collimation 40 × 1 millimetre (mm) and 2.8 pitches. Contrast enhancement used was 1 to 2 millilitre (ml)/Kilogram (Kg) dosage of iodine at a rate of 1 to 2 ml/second through the catheter inserted on median cephalic vein. Images acquisition were triggered automatically when bolus threshold was reached which varied from 40 to 60 seconds injection. The acquisition was followed by 2 reconstructions in axial plane from raw data. The first was acquired in a 5 mm thick section and the second in 1 mm one. Sagittal and coronal planes were reconstructed by computer. All patients underwent contrast enhancement injection of non-ionic iodine after kidney function disorders have been ruled out. Injection dose was 120 ml at a rate of 3 ml/second during for a delay of 70 to 90 seconds of portal time. A senior radiologist of more than 10 years' experience in assessing and interpreting the VAs CAT. Images assessment has been carried out on both coronal and axial reconstructions. Morphologic variations assessment takes into account following anatomical structures: VA origin in relation to SAoVs *i.e.* Left Common Carotid Artery (LCCA), Right Common Carotid Artery (RCCA), Left Subclavian Artery (LSCA), Right Subclavian Artery (RSCA), Left Thyrocervical Trunk (LTCT), Right Thyrocervical Trunk (RTCT), Left External Carotid Artery (LExCA), Right External Carotid Artery (RE × CA) as described by LAZARIDIS *et al* [2]. Different patterns were established according to the origin type of VAs. When VAs originated from AoA this represented pattern (RA. LA) with letter A meaning origin from AoA. The VA double origin pattern was represented by RR or LL which double letters meant VA double origin [2]. The level of foraminal entrance was assessed too. A univariate regression statistic model for making correlation between VAs variations occurrence and both demographic and clinical features was performed.

Statistical analysis was performed with an acceptable type 1 error set at 0.05. In addition, the Cramer's coefficient was calculated for establishing the variables independence link. Adobe Photoshop Application 2021 version has been used for highlighting the native CAT images. Ethic approval was obtained in accordance both with Human Normal Morphology Anatomy Laboratory's headmaster authorization at the Training and Research Unit of Medical Science Department of CIR and Polyclinic FARAH headmaster's approval too.

3. Results

Fifteen thousand five hundred and eighty-seven images, both CT and MRI with and without contrast enhancement injection were performed from January 2019 to December 2021 at the Polyclinic FARAH imaging center. Average 10185 CT-scans (65.34%) in which 61 SAoVs CAT images were collected. After exclusion criteria, we retained 40 SAoVs CAT images.

4. Discussion

During our study period, we got 40 patients who underwent a SAoVs computed angiography tomography (**Figure 1**). VAs origin variations are of clinically and surgically utmost importance in diagnostic approaches for cerebrovascular disorders, cranio-cervicofacial surgery, SAoVs arteriography and placement of carotid or vertebrobasilar stents. Furthermore, any patient in our study did not perform a SAoVs angiography in view of preoperative exam setting [4].

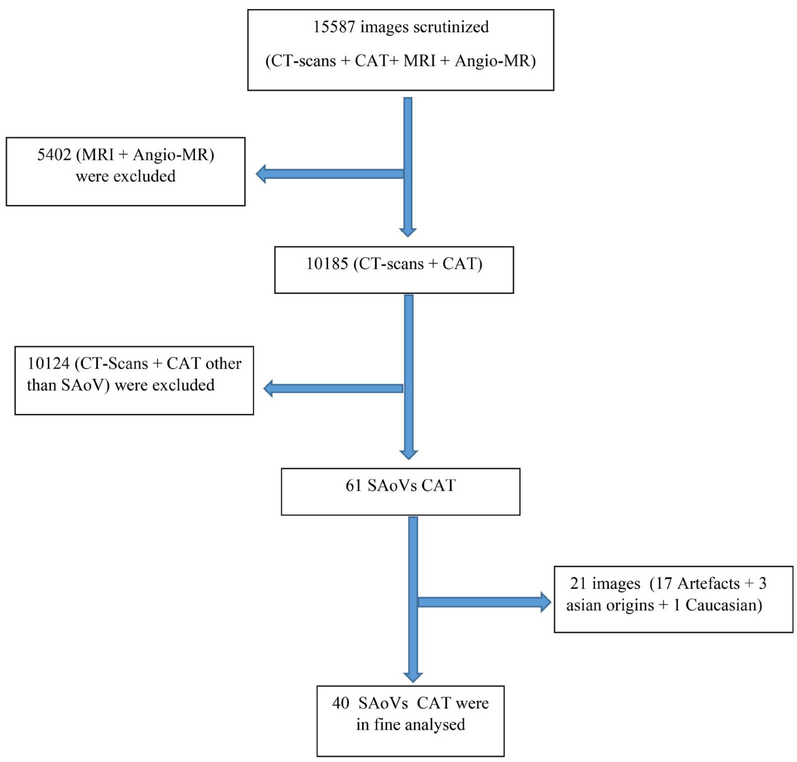

Figure 1. SAoVs CAT data flow-chart.

VAs origin is commonly the sight of anatomical variations related to aortic arch embryonic development disorders [5]. Our study reported 25%, *i.e.*, 10 out of 40 patients of VAs morphological variations (**Table 1**). Our study reported that the typical origin of VAs was from SCA in 82.5%. TITIKER and *Co-authors* reported in a 79 SAoVs CAT sample, 96% of VAs origin from SCA [6]. This finding, different from our reporting, might be related to different population samples, namely Caucasians versus black African humans. Our study reported 17.5% of atypical VAs originated from AoA *i.e.*, 7 out of 40 patients (**Table 1**). Six patients had a unilateral variation in the left side (15%) emerging from AoA (**Figures 2-4**). We reported 1 case of common core of LVA and RVA, both off AoA origin (2.5%) (**Figure 5**). The remainders unilateral VAs variation were emerging from left side as before last aortic branch (**Figures 6-9**). The double origin of VAs from SCA is rare and generally reported in some case-report [7]. Our study reported 3 duals origins of the VAs emerging from SCA (7.5%). One was on the left (**Figure 10**), and two tins were on the right (**Figure 11** and **Figure 12**).

Table 1. Demographic, radio-anatomical and clinical features of our sample with statistic rates.

Variable types	Number in relation to our headcount	Frequency
Average age	48 ± 12 Y	
Sex ratio	0.66	
Indication of SAoVs CAT	Ischemic stroke diagnosis work-up (10 out of 40)	25%
VA morphology variations	10/40	25%
VA originated from AoA	7/40	17.5%
LVAs originated from AoA	1/40	15%
RVAs originated from AoA	1/40	2.5%
VA double origin from SCA	3/40	7.5%
VA double origin from RSCA	2/40	5%
VA double origin from LSCA	1/40	2.5%
Bilateral C6 foraminal entrance	34/40	85%
Uni or bilateral C5 foraminal entrance	3/40	7.5%
Arterial dominance RVAs > LVAs	22/40 > 18/40	55% > 45%
Sex/VAs morphology variations	Six females out of 24 had VA morphology variations	$P = 0.001$
Clinical suspicion/VA morphology variations	10 out of 40 ischemic stroke suspicion had 5 VA morphology variations	$P = 0.003$

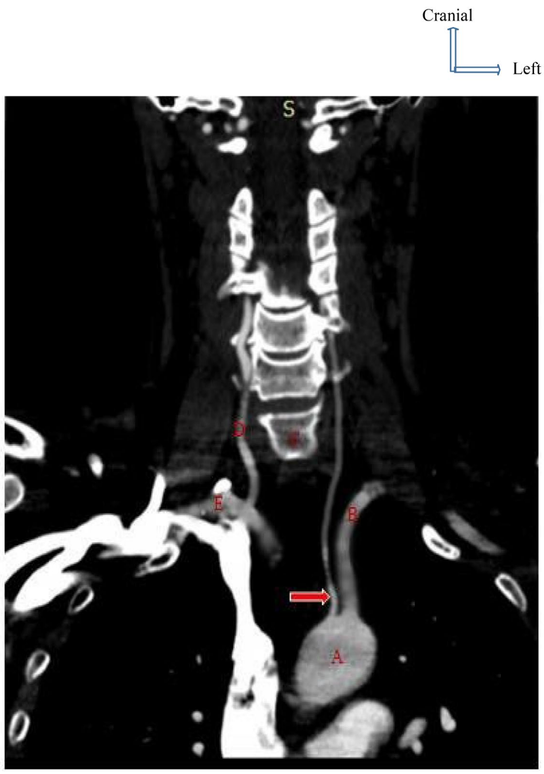

Figure 2. 55 year female SAoVs CAT image. Coronal reconstruction showed (red arrow) LVA originated from AoA as before last aortic branch (LA. RV pattern). (A) AoA, (B) LSCA, (C) 6th cervical vertebrae, (D) RVA, (E) RSCA [HAIDARA O, 2022].

Figure 3. Same 55 year female who underwent SAoVs CAT as showed just above. Coronal reconstruction and subtracted image showed (red arrow) LVA originates form AoA. (A) AoA, (B) LCCA, (C) RVA, (D) LSCA [HAIDARA O, 2022].

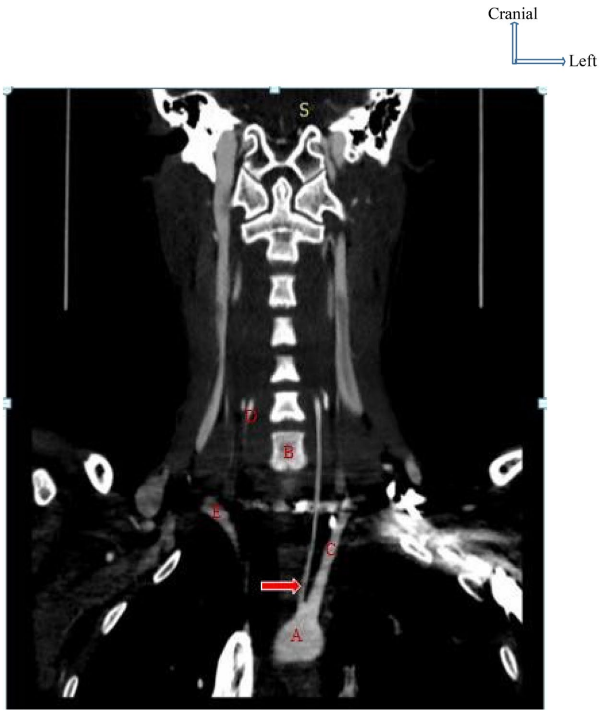

Figure 4. 18 year male underwent SAoVs CAT. Coronal reconstruction (red arrow) showed LVA originated from AoA (RV.LA pattern). (A) AoA, (B) 7th cervical vertebrae, (C) LSCA, (D) RVA, (E) RSCA [HAIDARA O, 2022].

Figure 5. 39 year female underwent a SAoVs CAT. Coronal reconstruction (red arrow showed a common trunk origin from AoA both LVA and RVA (RA. LA pattern). (A) AoA, (B) 6th cervical vertebrae, (C) LSCA, (D) C7 VAs foraminal entrance [HAIDARA O].

Figure 6. 63 year male underwent a SAoVs CAT. Coronal reconstruction showed (red arrow) LVA originated from AoA as before last arterial branch (RV.LA). (A) AoA, (B) LSCA, (C) RSCA, (D) RVA, (E) 6th cervical vertebrae [HAIDARA O, 2022].

Figure 7. 50 years male underwent a SAoVs CAT. 3 dimensional reconstruction (red arrow) showed the LVA originated from AoA as before last aortic branch between LCCA and LSCA (RV.LA pattern). (A) AoA, (B) LCCA, (C) RCCA, (D) LSCA, (E) LVA, (F) RVA [HAIDARA O, 2022].

Figure 8. 50 year male underwent a SAoVs CAT. Coronal reconstruction showed (red arrow) the LVA originated from AoA as before last aortic branch (RV.LA pattern). (A) AoA, (B) RCCA, (C) RSCA, (D) LSCA, (E) 6th cervical vertebrae [HAIDARA O, 2022].

Figure 9. 43 year male underwent a SAoVs CAT. Coronal reconstruction (red arrow) showed the LVA originated from AoA as before last aortic branch (RV.LA pattern). (A) AoA, (B) LSCA, (C) RSCA, (D) RVA, (E) 6th cervical vertebrae [HAIDARA O, 2022].

Figure 10. 46 year male underwent SAoVs CAT. Coronal reconstruction showed (red arrow) a double origin of LVA upon LSCA (LLV.RV pattern). (A) RSCA, (B) RVA, (C) LSCA, (D) AoA, (E) 6th cervical vertebrae [HAIDARA O, 2022].

Figure 11. 40 year female underwent a SAoVs CAT. Coronal reconstruction showed (red arrow) a double origin of RVA originated from RSCA (RRV.LV). (A) RSCA, (B) LSCA, (C) LVA, (D) 6th cervical vertebrae [HAIDARA O, 2022].

Figure 12. A 64 year male underwent a SAoVs CAT. Coronal reconstruction showed (red arrow) a double origin of RVA originated from RSCA (RR.LV). Fifth cervical vertebrae foraminal entrance of VAs. (A) RSCA, (B) LSCA, (C) AoA, (D) 5th cervical vertebra [HAIDARA O, 2022].

In general, we had most of times variable origins of the LVA with variations occurrence from AoA reported in 15% of our series. VUJMILOVIC and co-authors reported in a sample including 112 patients, a LVA variation occurrence in 4.47% [8]. This discrepancy might be related to different population sample *i.e.*, ethnic differences. In a cadaveric Japan's series of 516 (404 males and 112 females), LVA origin from the AoA was reported in 5.4% [4]. This latter was different from our findings while sample size and study method (dissection versus radio-anatomy) were different as well. In a recent literature review, LAZARIDIS and co-authors reported VAs variations within a range of 3.1 to 8.3% [2]. In a large sample, using the same study design as our radio-anatomical series, UCHINO and co-authors reported 4.1% of LVA originated from the AoA with overall prevalence of LVA variations from the AoA amounted of 6% [9]. We reported a case of RVA which emerged from the AoA (2.5%) (**Figure 5**). LAZARIDIS and co-authors reported an atypical origin of VAs in 4.6% (676 out of 14738 subjects). Atypical origin was reported most often unilaterally in 3.9% (574 out of 14738 subjects) than bilaterally in 0.05% (7 out of 14,738) [2]. These findings were different from our reporting. This latter might be related to different population features *i.e.* Caucasians versus black African human. In case of unilateral variation, LVA originated most often from an atypical side in 4% (587 out of 14,738) than RVA in 0.7% (101 out of 14,738). Bilateral atypical origin was reported sporadically. We reported a bilateral atypical origin in common trunk pattern of LVA and RVA

(2.5%) (**Figure 5**). When LVA atypical origin occurred, the artery originated from AoA in 89.8% of LCCA and LSCA, which was the most common variation reported (86.3%). These findings were in approximation with our series in which LVA emerged from the AoA between LCCA and LSCA in 71.4% (5 out of 7 LVA variations) [2] (**Figure 3**, **Figure 4**, **Figures 6-9**).

Cervical foraminal process entrance of VAs may vary either superior or inferior related to C6 foraminal process. Our study reported C6 right and left entrance in 85% (34 out of 40 patients) (**Figure 2**, **Figure 4**, **Figure 6**, **Figure 8**, **Figure 9** and **Figure 11**), followed by C5 (7.5%) (**Figure 2**, **Figure 10** and **Figure 12**), C7 (5%) (**Figure 5**). UCHINO *et al.* reported in a sample of 700 VA foraminal entrance, a C6 inlet in 87.5% and LVA C6 entrance in 93% in a cohort of 2287 patients [9]. TETIKER and co-authors reported 76 VAs which emerged from SCA while 88.1% inlet C6 foraminal process, 8% in C7, 2.63 in C5 and 1.31% in C4. These overall findings were similar to our study [6]. VAs asymmetric diameter was assessed in our study. We reported 55% RVA dominance while 40% dominance was LVA. The proportion of co-dominance was the remaining 5%. Through statistical correlation test, only female gender and ischemic stroke etiology assessment were statistically significant in patients scrutinized for VAs morphological variations in our study, respectively ($P = 0.01$; $P = 0.03$) (**Table 1**).

5. Conclusion

The overall VAs variations were 25% in our series while foramina C6 predominance inlet was respected as in the literature. Our findings depicted a considerable amount of VAs variations, opening the field for further observational studies in black African human. The prevalence of VAs variations in our study, however, was superior to those reported in the literature and numbers of authors reporting are difficult to carry out a fair comparison because of variable sample structures and sizes, different types of study, different ways of reporting data, different regional, ethnic and environmental potentials. The very precise design of these studies is of utmost importance for a more contributory analysis for VAs morphological and cervical process foraminal entrance variations assessment. In fine, our findings may improve clinical decision-making process in some surgical approaches, namely cranial, facial and cervical surgery.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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