ORIGINAL ARTICLE

Investigating the Association between Aortic Arch Variants and Intracranial Aneurysms

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ABSTRACT: ***Background:*** There is an association between anterior cerebral artery vessel asymmetry and anterior communicating artery aneurysm, presumably based on flow dynamics. The purpose of this study is to investigate the potential relationship between aortic arch branching patterns and incidence of intracranial aneurysm. ***Methods:*** This study included patients scanned over 1 year at our tertiary care center who underwent high-resolution imaging (computed tomography angiography or digital subtracted angiogram) of the head and neck arteries, aortic arch, and superior mediastinum. Exclusion criteria included patients with suboptimal images. Patient age, gender, aortic arch branching pattern, and the presence, location, and number of aneurysms were documented. ***Results:*** Among the 1082 patients analyzed, 250 (23%) patients had a variant aortic arch branching pattern, 22 (8.8%) of whom had aneurysms. There were 104 patients with 126 aneurysms, with majority of patients with normal aortic arch branching pattern (n = 82, 79%). The most common variant was a common origin of the left common carotid artery and brachiocephalic trunk with or without direct origin of the left vertebral artery. Twenty-two patients with aneurysms had an aberrant aortic arch (21%), compared to 232 patients without an aneurysm (24%). Fischer exact test showed no statistically significant difference between the incidence of aneurysm with different aortic arch variant groups (two-tailed p-value = 0.715). ***Conclusion:*** To our knowledge, this is the first study to examine the association between aortic arch branching patterns and incidence of intracranial aneurysm. No significant association was found between aortic arch branching pattern and the incidence of intracranial aneurysm.

RÉSUMÉ : Étude de l'association entre les variantes anatomiques de l'arc aortique et les anévrismes intracrâniens. ***Contexte*** **:** Il existe une association entre l'asymétrie des vaisseaux de l'artère cérébrale antérieure et les anévrismes de l'artère communicante antérieure, association vraisemblablement basée sur la dynamique des flux sanguins. L'objectif de cette étude est donc d'examiner la relation potentielle entre les structures de ramification de l'arc aortique et l'incidence d'anévrismes intracrâniens. ***Méthodes*** **:** Cette étude a inclus des patients à qui l'on avait fait passer dans notre centre de soins tertiaires des examens de tomodensitométrie (angiographie et angiographie de soustraction numérique) au cours d'une période d'un an. Précisons que ces examens ont ciblé les artères de leur tête et de leur cou, leur arc aortique ainsi que leur médiastin supérieur. Ont été exclus les patients dont les images étaient jugées sous-optimales. Enfin, l'âge des patients, leur sexe, les structures de ramification de leur arc aortique, de même que la présence, l'emplacement et le nombre d'anévrismes, ont été documentés. ***Résultats*** **:** Parmi les 1082 patients analysés, 250 d'entre eux (23 %) donnaient à voir une structure de ramification de leur arc aortique différente. Sur ces 250 patients, 22 (8,8 %) avaient été victimes d'un anévrisme. Au total, on a pu recenser 104 patients victimes de 126 anévrismes. Une majorité de ces patients montraient une structure de ramification de l'arc aortique normale (*n* = 82, 79 %). La variante anatomique la plus courante était une origine commune de l'artère carotide commune gauche et du tronc artériel brachiocéphalique avec ou sans origine directe de l'artère vertébrale gauche. À noter que 22 patients victimes d'anévrismes ont montré un arc aortique aberrant (21 %) contre 232 patients sans anévrismes (24 %). Des résultats à un test exact de Fischer n'ont montré aucune différence statistiquement significative entre l'incidence des anévrismes selon les différentes structures de ramification de l'arc aortique (valeur de *p* à un test bilatéral = 0,715). ***Conclusion*** **:** À notre connaissance, il s'agit là de la première étude à se pencher sur l'association entre les structures de ramification de l'arc aortique et l'incidence des anévrismes intracrâniens. À cet égard, aucune association notable n'a été trouvée entre ces deux éléments.

Keywords: Cerebral aneurysm, Aortic arch, Bovine arch

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Introduction

Intracranial aneurysms occur in up to 3%–7% of the population.[1] The annual rate of rupture is 1.6% per patient, with the resultant subarachnoid hemorrhage and associated high mortality and morbidity.[2] Increasing number of intracranial aneurysms is discovered incidentally with the advent of cross-sectional

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imaging.[3] The natural history of aneurysms is unclear and based on limited observational studies and only one large prospective study.[4–7] Multiple factors account for increased risk of aneurysm rupture including ethnicity, aneurysm size, location, patient age, and hypertension.[2] Furthermore, there is an association between anatomic variations in circle of Willis and aneurysm formation and rupture, presumably due to flow dynamics.[8] However, there have been no studies to investigate the relationship between aortic arch variations and intracranial aneurysm formation and rupture. Anatomic variants of the aortic arch results from failure of normal aortic arch development and include variants in branching patterns of the subclavian, carotid, and vertebral arteries.[9]

Understanding whether there is an association between variations of the supra-aortic arteries and the frequency of intracranial aneurysms is essential, given that aneurysmal rupture is associated with significant morbidity and mortality.[2] One study found that patients with thoracic aortic aneurysm are at increased risk of having a concurrent intracranial aneurysm.[10] To our knowledge, this is the first study to investigate the presence of an association between arch variants and intracranial aneurysms.

Materials and Methods

This retrospective HIPAA-compliant study was approved by the Institutional Review Board; the requirement for informed consent was waived. All patients who underwent CT head and neck angiography (CTA) during 2014 at the institution were included in the study. Additionally, we reviewed all the cerebral digital subtracted angiograms (DSAs) performed during 2014 and included patients who also had CTA at our institution. Exclusion criteria were age under 18 and artifact resulting in limited assessment of the aortic arch branching pattern. Patients who underwent multiple CTAs or DSAs were only included once. The aortic arch branching pattern was documented for all patients. The presence of an aneurysm, aneurysm size, and location were recorded. Other vascular abnormalities noted included dural arterial venous fistula and arteriovenous malformation. Aortic arch branching pattern was classified as outlined by Layton et al.[9] The most common variant consisting of three great vessels originating from the arch of the aorta was referred to as normal for the purpose of this study.

Statistical analysis using Fischer exact test was performed to evaluate for the presence of significant association between the incidences of aneurysm in different aortic arch branching patterns. A p-value of 0.05 was used as significant for all statistical tests. A priori sample calculations were not performed on the basis that there are no previous studies that investigated the association between incidence of intracranial aneurysms and variant aortic branching patterns compared to normal aortic branching pattern.

Results

The total number of patients included in this study was 1082 (Table 1). All patients over the age of 18 who had undergone CT head/neck angiography during 2014 were included (n = 993). Additionally, of the patients who underwent DSA during 2014, we included those who had CTAs that demonstrated the branching pattern of the aortic arch (n = 89). Indication for CTA was suspected acute cerebrovascular disease (atherosclerotic disease, dissection, aneurysm, or other arteriovenous abnormalities), with the patients undergoing imaging for a wide range of nonspecific neurologic symptoms that were thought to have a vascular etiology. Indication for DSA was suspected or known aneurysm or other vascular malformation. All images were reviewed by fellowship-trained neuroradiologists.

Table 1: Summary of demographics, arch type, and aneurysm

	Patients (n)	Variant arch	Normal arch	M:F	Age mean (range)
Patients (n)	1082	250	832	587:495	62.5 (18–99)
Aneurysm	104	82	22	53:51	60.7 (33–90)
No aneurysm	978	746	232	533:445	64 (18–99)

Fischer exact test two-tailed p-value = 0.72.

Table 2: Aortic arch branching patterns

Aortic arch branching type	Patients (n)
Three-vessel arch	832
Other	250
CO L CCA and IA ("bovine")	158
DO L VA	71
Co L CCA and IA, DO L VA	7
Origin of L CCA from R IA	4
CO IA and L SA	3
CO of R and L CCA	2
Right sided AO with mirror branching	2
DO of R CCA, CO R and L SA	1
Direct R VA	1
CO of L CCA and L SA	1

AO, aortic arch; CCA, common carotid artery; CO, common origin; DO, direct origin; IA, innominate artery; L, left; R, right; SA, subclavian; VA, vertebral artery.

Aortic Arch Branching Patterns

The most common aortic arch pattern consisted of 3 great vessels originating from the arch of the aorta (n = 832; 76.9%), referred to as 'normal' for the purpose of this study. The second most common variant entailed a common origin of the left common carotid artery and the innominate artery or the left common carotid artery as a branch of the innominate artery (n = 158), the so-called 'bovine type arch'. The third most common variant was a direct origin of the left vertebral artery (n = 71). Another variant was a common origin of the left common carotid artery and innominate artery with a direct left vertebral artery arising from the aortic arch (n = 7). Additional branching patterns are summarized in Table 2.

Aneurysm Characteristics

There were 126 aneurysms in 104 patients, with 83 aneurysms in patients with a single aneurysm and 43 aneurysms in 21 patients who had multiple aneurysms (Table 3). The most

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Table 3: Vascular and other abnormalities

Aneurysm multiplicity	Single (83 patients)	Multiple (21 patients)	Total
Aneurysm (n)	83	43	126
Acomm	17	4	21
ICA terminus	17	8	25
Pcomm	12	7	19
MCA	13	6	19
Basilar	7	7	14
Ophth	6	3	9
ACA	1	4	5
Vert	4	0	4
PICA	3	1	4
PCA	2	1	3
SCA	1	1	2
Ant Chor	0	1	1
Other abnormalities (n)	13	0	13
Vert occlusion	5	0	5
AVM	3	0	3
AVF	2	0	2
Tumor	1	0	1
ICH	1	0	1
ICA Psuedo	1	0	1

ACA, anterior cerebral artery; Acomm, anterior communicating artery; Ant Chor, anterior choroidal artery; AVM, arteriovenous malformation; dAVF, dural arteriovenous fistula; ICA, internal carotid artery; ICH, intracranial hemorrhage; MCA, middle cerebral artery; Ophth, ophthalmic artery; PCA, posterior cerebral artery; Pcomm, posterior communicating artery; PICA, posterior inferior cerebellar artery; Pseudo, pseudoaneurysm; SCA, superior cerebellar artery; Vert, vertebral artery.

common aneurysm locations included the internal carotid artery (CIA) terminus (n = 25), anterior communicating artery (n = 21), posterior communicating artery (n = 19), and middle cerebral artery (n = 19). Additional aneurysm locations are summarized in Table 3. Other abnormalities were found in 13 patients, including dural arteriovenous fistula (n = 2), arteriovenous malformation (n = 3), tumor (n = 1), vertebral dissection (n = 5), intracranial hemorrhage (n = 1), and ICA occlusion (n = 1).

With regard to the branching patterns of the aortic arch in patients with aneurysm, 82 patients with the normal variant (n = 832) had at least one aneurysm (9.9%). In patients with a variant arch branching pattern (n = 250), 22 had an aneurysm (8.5%). There was no statistically significant difference in the incidence of intracranial aneurysm when comparing the patients with a normal aortic arch branching pattern and those patients who had a variant branching pattern (Fischer exact two-tailed p-value = 0.715).

The percentage of patients who had aneurysms was higher in the group who had a DSA performed for suspected or known intracranial aneurysm or other vascular malformation (55 of 89 patients, 62%) compared to those who had initially undergone CTA for suspicion of acute cerebrovascular event (49 of 993 patients, 4.9%), reflecting selection bias in patients who underwent DSA.

Discussion

The present study shows that there is no increased risk of intracranial aneurysm formation in patients with variant types of aortic arch branching patterns. The most common anatomic variant of the aortic arch entails the three great vessels originating from the arch and occurs in 48% to 84% of the population, depending on the population studied.[9] Our findings showed the normal branching pattern of an aortic arch in 77%, in accordance with the reported rates.[9] In the present study, 9.9% of patients had at least one aneurysm, which is higher than the reported average in the literature (3%–7%).[1] The higher incidence may be attributed to selection bias, given that we included patients who underwent DSA for known aneurysm or those with high suspicion of aneurysm in the setting of subarachnoid hemorrhage.

Variations in the branching patterns of the circle of Willis have been associated with aneurysm formation, and A1 dominance is implicated in increased incidence of anterior communicating artery formation.[8] However, the patterns of aortic arch branching have not been studied in the context of intracranial aneurysm formation. The reported associations between intracranial aneurysm formation and variations in the anatomy of the circle of Willis anatomy may be accounted for by the effects of flow dynamics and vessel shear stress.[11,12] The lack of an association between aortic arch branching patterns and intracranial aneurysm formation is expected, given the distance between the arch and the circle of Willis, and hence the anticipated lack of influence on flow dynamics and vessel shear stress. In our study, the presence of an aberrant arch pattern did not influence the incidence of aneurysm formation. Further studies to investigate aortic arch branching patterns and the resultant effects of blood flow dynamics in distal blood vessels may be needed to confirm this hypothesis.

Aberrant aortic arch branching patterns have a recognized association with aortic disease, with a greater prevalence of thoracic aortic disease in patients with variant branching patterns, and are proposed as potential anatomic markers for development of aortic disease.[12] For example, in patients who have the 'bovine' arch variant, blunt trauma results in higher rates of innominate artery injury, presumably due to the decreased number of fixation points with the resultant concentration of energy forces on the innominate artery takeoff.[13] Additionally, patients with thoracic aortic dissections have a higher prevalence of arch anomalies compared to controls. One study showed that patients with thoracic aortic aneurysms have a higher incidence of intracranial aneurysms.[10] A proposed mechanism is the presence of a common genetic basis for both intracranial aneurysms and thoracic aortic aneurysms.[10] Our study only investigated the branching patterns of the aortic arch and not aortic aneurysm formation and did not include patients with aneurysmal thoracic aorta.

The patients included in our study were selected based on the availability of aortic arch imaging, which may bias the sample, albeit randomly. Additionally, an inherent limitation to the current study is a relatively small number of patients with aneurysm (n = 104), although the overall number of patients in the present study was over one thousand. The ability to detect difference may be underpowered with only 22 of the patients with

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aneurysms having an aberrant arch variant. One may argue that the low incidence of intracranial aneurysms limits assessment of aortic arch variations. However, our random sample size from a tertiary care centre is likely reflective of the larger population. In fact, our study included patients who had undergone DSA for aneurysm treatment, which resulted in a greater number of patients with aneurysms being included. With regard to aneurysm risk factors, female sex is among the risk factors associated with aneurysm formation. The proportion of female patients in patients with and without aneurysm was similar (49% and 46% respectively), and thus did not impact our analysis.

The distribution of aneurysm location in our study was reflective of larger population studies.[1] Given the small sample size, subgroup analyses of aneurysm location and association with arch variant were not performed. In summary, variant aortic arch branching patterns are not a risk factor for the formation of intracranial aneurysm.

Conflicts of Interest

The authors have no reported conflicts of interest.

Statement of Authorship

FM: protocol/project development, data collection and management, data analysis, manuscript writing/editing, and study supervision; IMN: data analysis and manuscript editing; BYMK, PBJ, DMP, DL, MS: protocol/project development, data analysis, and manuscript writing/editing.

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