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Original Article

Intracranial aneurysms: epidemiology and morphological analysis by digital angiography

Aneurismas intracranianos: epidemiologia e análise morfológica por angiografia digital

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ABSTRACT: *Introduction:* Intracranial aneurysms (IA) are vascular dilations that are highly prevalent and that can be identified by angiotomography, angioresonance and digital subtraction angiography (DSA), an exam considered the gold standard. For unruptured IA, there is still no absolute consensus on standardization of therapeutic conduct, which depends, intrinsically, on morphological and topographic aspects on angiographic examination. *Objective:* Analyze the epidemiological, morphological and topographic characteristics of unruptured IA identified by DSA and to correlate with risk factors. *Method:* 160 electronic medical records of patients with unruptured IA diagnosed by DSA between 2014 and 2018 were considered. Variables considered were epidemiological (gender, age and ethnic group), morphological aspects (shape, presence or absence of neck and size), topography, number of IA per patient and risk factors (systemic arterial hypertension, smoking and alcoholism), with statistical analysis by Spearman correlation. *Results:* Out of 160 patients, 207 unruptured IA were evaluated. There was a predominance of females, aged 60 to 69 years and white ethnicity. Regarding risk factors, 58.75% had systemic arterial hypertension. Most patients have a single aneurysm, and the most prevalent location was the right internal carotid artery. Saccular, small (less than 7 mm) and large-necked aneurysms predominated. There was a statistical correlation between size and location ($p < 0.001$), size and type of neck ($p = 0.0005$) and between shape and type of neck ($p < 0.001$). *Conclusion:* Prevalence of unruptured IA in middle-aged, white and hypertensive women, with a predominance of a single small non-lobulated saccular aneurysm with a large neck in the right internal carotid artery. Correlation of saccular IA with large neck, giant IA in internal carotid artery, and small IA with large neck.

Keywords: Intracranial aneurysm; Digital angiography; Anatomy.

RESUMO: *Introdução:* Aneurismas intracranianos (AIC) são dilatações vasculares de elevada prevalência que podem ser identificadas por angiotomografia, angiorressonância e por angiografia de subtração digital (ASD), exame considerado padrão-ouro. Para AIC não rotos, ainda inexiste consenso absoluto sobre padronização de conduta terapêutica, que depende, intrinsecamente, de aspectos morfológicos e topográficos ao exame angiográfico. *Objetivo:* Analisar características epidemiológicas, morfológicas e topográficas de AIC não rotos identificados por ASD e as correlacionar com fatores de risco.

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Método: Foram considerados 160 prontuários eletrônicos de pacientes com AIC não rotos diagnosticados por ASD entre 2014 e 2018. Variáveis consideradas foram aspectos epidemiológicos (gênero, idade e grupo étnico), morfológicos (formato, presença ou ausência de colo e tamanho), topografia, número de AIC por paciente e fatores de risco (hipertensão arterial sistêmica, tabagismo e etilismo), com análise estatística por correlação de Spearman. *Resultados:* De 160 pacientes, avaliaram-se 207 AIC não rotos. Houve predomínio do sexo feminino, da faixa etária de 60 a 69 anos e da etnia branca. Em relação a fatores de risco, 58,75% apresentavam hipertensão arterial sistêmica. A maioria dos pacientes apresentava um único aneurisma, e a localização mais prevalente foi artéria carótida interna direita. Predominaram aneurismas saculares, pequenos (menor que 7 mm) e de colo largo. Demonstrou-se correlação estatística entre tamanho e localização ($p < 0,001$), tamanho e tipo de colo ($p = 0,0005$) e entre formato e tipo de colo ($p < 0,001$). *Conclusão:* Houve prevalência de AIC não rotos em indivíduos do sexo feminino de meia idade, brancos e hipertensos, com predomínio de aneurisma sacular não lobulado, único, pequeno, de colo largo em artéria carótida interna direita. Presença de correlação estatística de AIC sacular com colo largo, AIC gigante em artéria carótida interna, e de AIC pequeno com colo largo.

Palavras-chave: Aneurisma intracraniano; Angiografia digital; Anatomia.

INTRODUCTION

Intracranial aneurysms (ICAs) are dilations of the encephalon (brain) arteries, resulting from the weakening of the vascular wall, arising from the lack of type III collagen in the tunica media and internal elastic lamina[1,2], causing physiopathological alterations[3]. These conditions are estimated to be present in about 5% of the general population and represent 2% of the deaths due to the prevalence of ten times more unruptured and asymptomatic aneurysms[4]. Generally, they become symptomatic from 40 to 60 years old, predominantly in the female gender, although there is no preference for any ethnic group[1,5,6]. The etiopathogenesis of ICA tends to be multifactorial, and the risk factors include smoking, systemic arterial hypertension, alcohol consumption, and malformation of the arteriovenous encephalon[5,6]. The related diagnostic and therapeutic costs are significantly high[7].

Morphologically, ICAs are classified into three categories: saccular, fusiform, and desiccant. The first types are the most frequent, they look like focal lobulations with rounded shapes, and the necks are connected to the source artery[1,4,8]. Fusiform aneurysms are characterized by an elongated arterial segment, tortuous, and neckless[9], while desiccant ICAs look like concentric distancing of the tunica arteries[10]. ICAs are considered irregulars with a difference in sizes of 2mm from the largest to the smallest diameters. These ICAs look like bubbles in shape or have a polygonal appearance[11]. Since dysplastic ICAs are caused by fibromuscular dysplasia throughout all the small and medium-sized arterial layers[12]. Regarding the ICA sizes, when they are a few millimeters in size, they are called *baby*[13]. Regarding the neck type, the neck is considered absent (when there is no connection to the source artery), narrow (smaller or equal to 4 mm), or wide (larger than 4 mm)[3].

Digital subtraction angiography (DSA) is the main diagnostic exam for identifying ICAs, based on the number, topography, collateral circulatory potential, and the occurrence of vasospasms[14]. The angiography technique began in 1927, using an opaquer contrast, and perfected a "radio-carousel," a device capable of exposing six images in rapid succession[15]. After multiple enhancements, DSA was developed in the 1970s and significantly impacted the treatment of vascular diseases. Although there are less techniques, such as magnetic resonance angiography (angio-resonance), computerized tomography (angio-tomography), or ultrasonography, DSA is still considered the gold standard for detecting and characterizing ICAs due to the image quality and the representation of the bloodstream in real time[16,17].

As DSA has become increasingly perfected and available, more and more unruptured ICAs have been identified accidentally. However, there is still no absolute consensus on standardizing medical conduct[18], which can cluster more conservative treatment, endovascular therapy, or open surgery[19].

The interventionalist treatment has been the preferred treatment for patients who have large ICAs and aneurysms of the posterior circulation. The surgical approach is recommended for patients who have aneurysms of the anterior circulation, especially for younger patients who have aneurysms of the anterior circulation. Some suggest more aggressive treatments for aneurysms of the posterior circulation, symptomatic aneurysms, and aneurysms of the anterior circulation larger than 7 mm[20]. There is an interposition between both techniques. Depending on other factors, a surgical procedure can treat some aneurysms as well as endovascularly, including the patient's age, surgical and endovascular access, multiple aneurysms, and the patient's preference [19-20].

However, risks and benefits must be considered individually, based on family history, the expectation of the quality of life, and morphological and topographical aspects of each aneurysm[19].

Thus, the therapeutic conduct of ICA intimately depends on anatomic findings from the angiographic exam that will justify additional studies on unruptured ICAs[19].

OBJECTIVE

The purpose of this study is to analyze the epidemiological, morphological, and topographical characteristics of unruptured ICAs identified by DSA and

correlate them to risk factors.

MATERIALS AND METHODS

One hundred and sixty electronic patient medical records were considered after ethical approval from patients with unruptured ICAs diagnosed by DSA from January 2014 to December 2018 from the Main Hospital in São José do Rio Preto (SP). The inclusion criteria included patients from 15 to 90 years old with unruptured ICAs, and the exclusion criteria were based on previous neurosurgery, intracranial tumors, or intracranial metallic (*stents*).

The variables considered included topography (location), morphological aspects (sizes in millimeters, shape, the presence or absence of an aneurysm neck), the number of aneurysms of the patient, and risk factors (systemic arterial hypertension, smoking, and alcoholism). The parameters applied to international studies were utilized for classifying the size of aneurysms and their necks[19-21].

Statistical analysis included descriptive analysis and the Spearman correlation[22] and was performed by running the BioStat 5.3 program[23]. A 5% significance level was adopted (p-value) and the Spearman correlation coefficient (ρ) from -1 to 1 (whereas a zero-correlation value indicates the absence of a linear relationship among variables; ρ values ranging from 0.10 to 0.39 are considered weak; from 0.40 to 0.69, moderate; and from 0.70 to 1, strong)[24].

RESULTS

Two hundred and seven unruptured ICAs were evaluated in 160 patients. There was female gender predominance at 68.75% (110 in 160 cases) and a male/female proportion of 1:2.2 (50/110). The age ranges, 31.25% (50 in 160) from 60 to 69 years old; 20.62% (33 in 160) from 50 to 59; 18.12% (29 in 160) from 70 to 79; 13.75% (22 in 160) from 40 to 49; 8.12% (13 in 160) from 30 to 39; and 5% (8 in 160) from 80 to 89. There were only three patients from 20 to 29 years old; one patient was 15 years old, and another was 18 years old. The average age was 58.83 years old, with a standard deviation of 14.27.

Regarding the ethnic groups, 84.37% (135 in 160) were white, 6.87% (11 in 160) were dark-skinned, and 6.87% (11 in 160) were black; three patients did not declare their specific ethnic group. Related to risk factors, 58.75% (94 in 160) presented systemic arterial hypertension; 20.62% (33 in 160) were smokers, and 5.62% (9 in 160) were alcoholics.

The following lists the number of ICAs per patient, 113 cases (70.62%) presented only one aneurysm; 36 (22.5%), two aneurysms; 8 (5%), three aneurysms; and three patients (1.87%) presented four aneurysms.

Table 1 shows the locations, most of the aneurysms are located on the internal right carotid artery (69 cases or 33.33%), followed by the internal left carotid artery (53 cases or 25.60%).

Table 1. The absolute number and percentage of ICAs followed by their location

Location	Number	Percentage
Right Internal Carotid Artery	69	33.33%
Left Internal Carotid Artery	53	25.60%
Basilar Artery	13	6.28%
Left Anterior Cerebral Artery	13	6.28%
Right Posterior Communicating Artery	9	4.34%
Right Anterior Cerebral Artery	8	3.86%
Right Middle Cerebral Artery	8	3.86%
Left Middle Cerebral Artery	8	3.86%
Anterior Communicating Artery	5	2.41%
Left Posterior Cerebral Artery	4	1.93%
Left Posterior Communicating Artery	4	1.93%
Right Posterior Cerebral Artery	3	1.44%
Right Pericallosal Artery	3	1.44%
Left Posteroinferior Cerebellar Artery	2	0,96%
Right Vertebral Artery	2	0,96%
Left Anterior Choroidal Artery	1	0.48%
Left Anterior Temporal Artery	1	0.48%
Left Vertebral Artery	1	0.48%
Total	**207**	**100%**

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Regarding the format, saccular aneurysms (non-lobular, bilobular, tri-lobular, or multi-lobular) were predominant (187 or 90.33% - Table 2).

Table 2. Absolute numbers and percentages of ICAs related to their formats

Format	Number	Percentage
Non-Lobular Saccular	177	85.55%
Fusiform	12	5.79%
Bilobular Saccular	7	3.38%
Baby	3	1.44%
Dysplastic	2	0.96%
Multi-Lobular Saccular	2	0.96%
Desiccant	1	0.48%
Irregular	1	0.48%
Partially Thrombosed	1	0.48%
Tri-lobular Saccular	1	0.48%
Total	**207**	**100%**

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Regarding the type of aneurysm neck, most aneurysms present wide necks (164 or 79.22% - Table 3).

Table 3. Absolute numbers and percentages of ICAs related to their neck type

Neck	Number	Percentage
Wide	164	79.22%
Narrow	26	12.56%
Absent	13	6.28%
No Precise Borders	4	1.93%
Total	**207**	**100%**

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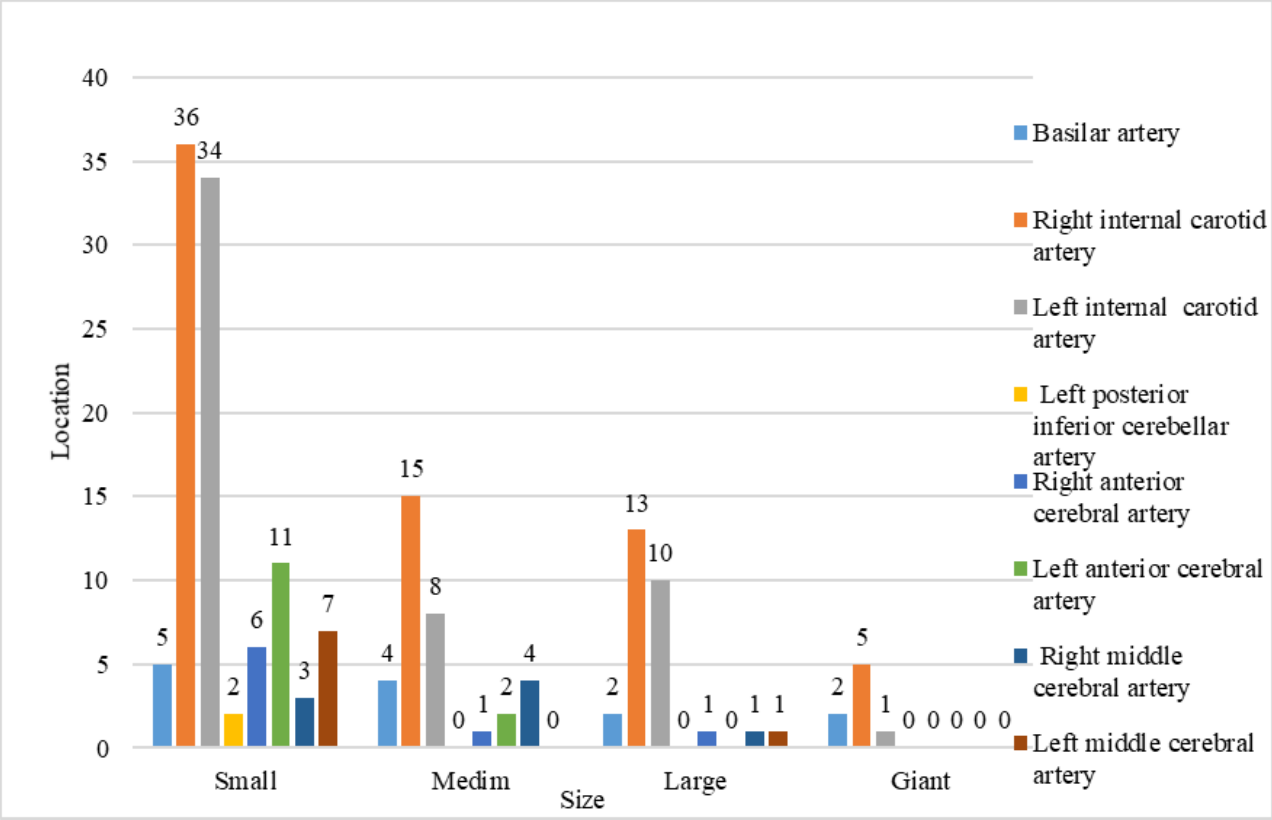
63.76% of the aneurysm sizes (132 of 207) were small (smaller than 7 mm), 18.35% or 38 cases were medium (from 8 to 12 mm), 29 or 14%, large (from 13 to 24 mm), and 8 or 3.86%, giant (larger than 24 mm). The smallest and the largest aneurysms measured 1 mm and 33 mm, respectively.

Graph 1 displays five gigantic aneurysms (from a total of eight) located on the right internal carotid artery, and statistical analysis displayed a weak negative correlation, yet significant, between the giant ICA sizes and the location of the right internal carotid artery ($\rho = -0.2915$; $p < 0.001$). The same type of correlation occurred between the size and type of neck ($\rho = -0.2397$; $p = 0.0005$) as 132 aneurysms were small sizes (smaller than 7 mm), 116 presented a wide neck (larger than 4 mm) (Graph 2).

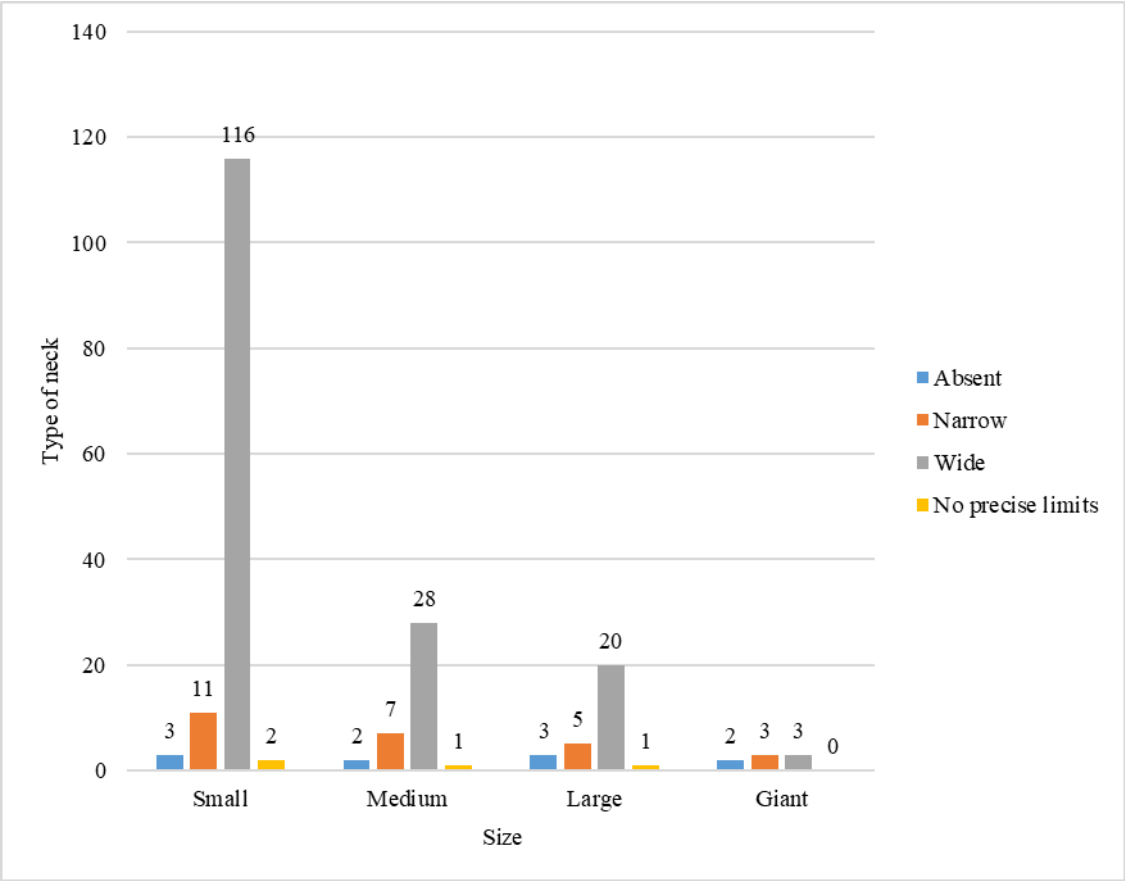
Graph 3 reveals wide necks predominantly (157 aneurysms) saccular format (186 aneurysms), and there was a weak positive statistical correlation, however significant, between the saccular format and the wife neck ($\rho = 0.2897$; $p < 0.001$).

The Spearman coefficient was near zero or absent regarding all the other possible considered variable associations (topographic, morphological, and risk factors).

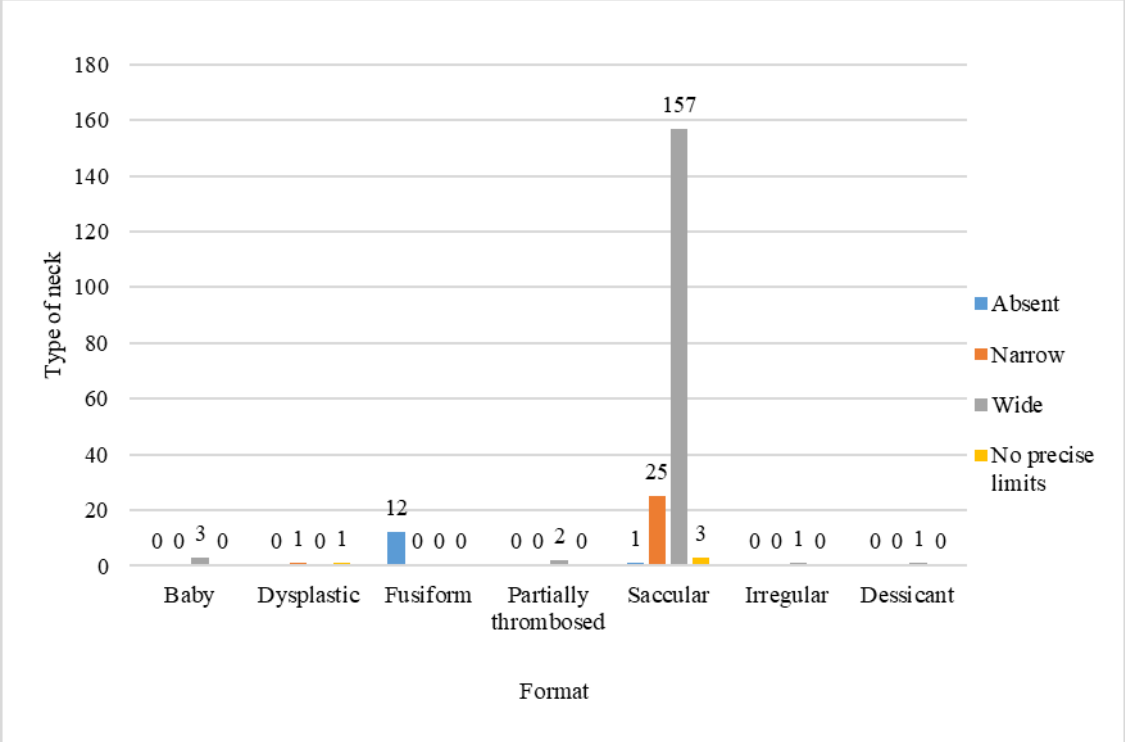
Graph 1. The absolute number of ICAs regarding their sizes and location



Graph 2. The absolute number of ICAs regarding their sizes and neck type.



Graph 3. The absolute number of ICAs related to their format and neck type



DISCUSSION

The present study analyzed the epidemiological, morphological, and topological characteristics of unruptured ICAs in 160 patients for five years who had performed intra-hospital DSA since the size, topology, and morphology of unruptured ICAs have been determined as being essential for making the therapeutic decision[25,26].

The study pointed out the most significant prevalence of ICAs in the female gender was (68.75%) related to epidemiological data, which corroborates with data from the literature[4,6,25,27]. It has been postulated that the female gender hormones play an essential role in cerebrovascular homeostasis. The decrease in its production after menopause would result in a more significant predominance of ICAs in women[6,27,28]. The average age of patients with ICAs tends to oscillate from 50 to 60 years old[26, 29], however in this specific study, the highest frequency (31.25%) ranged from 60 to 69 years old, yet the equivalent average age was 58.83 years old.

Analogously to this study, 58.75% of the patients presented systemic arterial hypertension; other authors have observed a high prevalence of ICAs in the hypertense[25,26,28], and smokers[28-31], although there is no evidence related to such risk factors increasing the chances of increased aneurysmal rupture[29]. The data on alcoholism in the literature as a determining risk factor for ICAs are controversal[29]. The size of the ICA is related to smoking, including increased susceptibility to multiple aneurysms in up to 40% of cases[30]; however, in this study, there has been no association to the number and aneurysmatic size to smoking.

Regarding the number of ICAs per patient, Sá Júnior et al.[29] observed that 70.2% of the cases had a single aneurysm, and 29.8% had multiple aneurysms. In the Santos A et al.[5] study, 30% of the patients displayed multiple aneurysms, and most of them had two aneurysms. The data from this study confirmed those findings as 70.62% of the cases had a single aneurysm and two aneurysms per patient in 22.5%.

Anterior circulation was present in (89.85%) topographically in this study (Table 1), and 21 of them (10.14%) were in the posterior territory. In comparison, the other authors pointed out a prevalence of 90.24% in the anterior circulation and 7.32% in posterior circulation[22]. There were also reports of those who have shown ICAs in both encephalic circulations in up to 2.44% of the cases[26].

There have been discrepancies in the literature data related to the most affected arteries, indicating the most significant prevalence of ICAs (42.6%) in the internal, carotid artery[29,] or the middle cerebral artery in up to one-third of the cases[5]. Following that, the posterior communicating artery was pointed out in up to 21.4% of the cases, and the frequency of the anterior cerebral artery in 10.9%[5]. In this study, 58.93% of the cases presented ICAs in the internal carotid arteries (Table 1 and Graph 1), including an additional contribution of stipulating a slight correlated trend between gigantic aneurysms in the internal carotid arteries.

This study indicated the predominance of ICAs in a non-lobular saccular format (Table 2), which corroborates with literature findings[26,32], as that points out the cause of up to 85% as non-traumatic subarachnoid hemorrhages[20]. Regarding the neck type and the aneurysmal size, Aletich *et al.*[33] report on a significant variability of sizes (from 3 to 30 mm), thereby confirming the finding in this study that revealed ICAs ranging from 1 to 30 mm. Otherwise, while this study presented a greater frequency of wide-neck ICAs (Table 3 and Graph 3), data in the literature indicated a trend predominance of narrow necks (smaller or equal to 4 mm)[33]. This study determined a slight statistical correlation between saccular-shaped ICAs and wide necks and small sizes with wide necks.

Generally, the aneurismal diameter tends to be smaller than 12 mm[26,34]. Similarly, as shown on Graph 2, the present study presented 63.76% of small aneurysms (smaller than 7 mm) and 18.35% of medium sizes (from 8 to 12 mm), confirming the data from other authors[35]. There is evidence that the sizes of ICAs from 11 to 15 mm have shown the most significant probability of resulting in rupture[35], especially in cases of saccular aneurysms in female-gender individuals[36]. In this study, there is still no predominance of ICAs in women in a proportion of 2.2:1 related to men, as there is no significant correlation between genders and aneurysmal size.

CONCLUSIONS

The analysis of unruptured ICAs identified by DSA proved the prevalence of female gender individuals who were middle-aged, white, and hypertense. There was a predominance of small-sized single non-lobular saccular aneurysms (smaller than 7 mm) with a wide neck on the right internal carotid artery. A correlation was observed of saccular format ICAs with a wide neck, as well as giant aneurysms of the internal carotid artery, and small-sized ICAs with a wide neck.

Author's participation: *Gabriel de Pontes Figueira:* Data collection, statistical interpretation, original article writing, and text revision. *Gabriela Modulo Molina:* Data collection, statistical interpretation, original article writing, and text revision. *Narayana Silva Paiva:* Data collection, statistical interpretation, wrote the original article, and text revision. *Fernando Batigália*: Guidance, original article writing, and text revision. *Raquel Cristina Trovo Hidalgo:* Data collection and text revision.

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