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Evaluation of the Circle of Willis with CT Cerebral Angiography in Patients suspected of Intracranial Aneurysm

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ABSTRACT

Introduction: Intracranial aneurysms are common, occurring in 3.6-6% of the general population, with 85% involving the Circle of Willis. Most aneurysms are asymptomatic, but subarachnoid hemorrhage (SAH) is often the first and potentially fatal presentation. While intra-arterial digital subtraction angiography (DSA) is the gold standard, CT cerebral angiography offers a useful, non-invasive alternative, potentially reducing the need for conventional angiography.

Methods: This descriptive, cross-sectional study was conducted from 31st December 2023 to 30th December 2024 at a tertiary center. Ethical approval was taken from the Institutional Review Committee (Ref: 910/2023). Plain CT head was done in symptomatic patients, which is then followed by CT cerebral angiography in case of intracranial hemorrhage. A purposive sampling technique was used to include 100 patients. Data on demographics, clinical history, and imaging findings were analyzed.

Results: A total of 100 high-risk patients were evaluated using contrast-enhanced CT angiography of the Circle of Willis. The mean age was 66.12 ± 5.77 years, with 56 females (56%) and 44 males (44%). Hypertension (61%) and smoking (51%) were the most common risk factors. Intracranial hemorrhage was most frequently found in the intraventricular region (30% of total cases). Aneurysms were detected in 89 cases, predominantly saccular (86 cases~96.6%), with the anterior communicating artery being the most affected site (23 cases~25.84%).

Conclusions: CT cerebral angiography effectively detects intracranial aneurysms, with saccular aneurysms being the most common type and the anterior communicating artery being the most common location. It is the best modality of choice for patients before undergoing invasive neuro-intervention procedures like DSA.

Keywords: *Cerebral Angiography; Smoking; Subarachnoid Hemorrhage*

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INTRODUCTION

Intracranial aneurysms are relatively common findings, evidenced by a systematic review of studies with over 56,000 patients, concluding that unruptured intracranial aneurysms occur in 3.6 to 6 percent of the general population. The Circle of Willis is involved in 85% of cases of intracranial aneurysms. Most of the aneurysms remain asymptomatic, with subarachnoid hemorrhage (SAH) or other intracranial hemorrhage (ICH), a likely lethal event, being the most common initial presentation [1,2,3,4]

Current neuroimaging techniques for intracranial aneurysms include intra-arterial digital subtraction angiography (DSA), magnetic resonance angiography (MRA), computed tomography (CT) cerebral angiography, and transcranial Doppler ultrasonography. Although intra-arterial DSA is the gold standard, it is an invasive test with a 1 percent risk of transient neurologic complications and 0.5 percent risk of permanent neurologic complications. As such, CT angiography may be a useful modality for the evaluation of suspected SAH or aneurysm and may, in selected cases, eliminate the need for preoperative conventional angiography.[5,6]

METHODS

This was a descriptive, cross-sectional study done by collecting data from 31st December 2023 to 30th December 2024. In this research, patients referred to the radiology department for evaluation of the circle of Willis using CT-angiography were studied. Ethical approval was taken from the Institutional Review Committee (Ref: 910/2023). Data were collected after obtaining written informed consent from the patients included in the study, following a thorough explanation of the nature and purpose of the study.

The symptomatic patients with a high likelihood of aneurysms and/or bleeding with symptoms like headache and vomiting, or asymptomatic patients with various risk factors and/or positive family history, were first evaluated using plain head CT. Patients who tested positive for intracranial hemorrhage in plain head CT scans were further subjected to CT angiography and were included in the study. Traumatic intracranial bleeds and bleeds that were limited to the parenchyma, and non-consenting patients were excluded from the study.

Variables like age, sex, smoking history, hypertension, family history of aneurysms or intracranial bleeds, presenting symptoms, location of the intracranial hemorrhage (ICH), type and location of the intracranial aneurysm were studied. A purposive sampling technique was used for data collection.

This study aims to review the Circle of Willis in symptomatic patients of intracranial aneurysms or intracranial bleeds to find the various types and locations of aneurysms associated with the bleed and to see for any association with various risk factors.

A meta-analysis conducted by Vlak M et al. concluded that the overall prevalence of intracranial aneurysm was 3.2 %.[7]

The sample size was calculated using the following formula:

$N = (Z^2 \times p \times q)/ e^2$

$= (1.962 \times 0.032 \times 0.968)/ 0.052$

~ 47

At a prevalence of 3.2%, a 5% margin of error, and a 95% confidence interval, the sample size was calculated to be 47 cases. To increase the study's accuracy, 100 cases that fulfilled the inclusion criteria were included.

The patients were first examined thoroughly by a physician, their vitals were taken, and all past medical history and risk factors were thoroughly reviewed. Asymptomatic patients with positive risk factors and symptomatic patients were first evaluated using a plain head CT-scan using a Siemens 128 Slice CT Scan. Patients with plain head CT positive for sub-arachnoid and/or intraventricular bleed were further evaluated with

Contrast-Enhanced CT- cerebral angiography using Siemens 128 Slice CT scan with iodine-based contrast medium. To remove the inter-observer bias, all images were reviewed by a single radiologist at an electronic PACS workstation.

The locations of bleeds and aneurysms were recorded according to their anatomical locations. Hypertension was considered positive if systolic blood pressure (SBP) ≥ 140 mmHg or diastolic blood pressure (DBP) ≥ 90 mmHg or with the use of anti-hypertensives for earlier diagnosed hypertension8. Positive family history was taken as ≥1 first-degree relative with intracranial aneurysm or intracranial bleed.

The data were entered in a Microsoft Excel Sheet, and statistical analysis was done with IBM SPSS Statistics for Windows, version 29 (IBM Corp., Armonk, N.Y., USA)

RESULTS

Over the period of 1 year, 100 high-risk cases that fulfilled the inclusion criteria were evaluated using a Contrast-Enhanced CT Angiogram of the circle of Willis. The images were studied by a single radiologist. The cases were sampled using a purposive sampling method until all 100 cases were analyzed. The mean age of patients was 66.12 ± 5.77 years. Other demographic findings are tabulated in Table 1.

Table 1: Demographics and History (N=100)

Variables	Cases
Male	44 cases (44%)
Female	56 cases (56%)
Mean Age of presentation	66.12 ± 5.77 years
History of hypertension	61 cases (61%)
Smoking history	51 cases (51%)
Positive family history	13 cases (13%)

The most common presentation was a headache, seen in 63%, followed by neck stiffness and vomiting in 57% and 54 % of cases, respectively. The description of all symptomatology is tabulated in Table 2.

Table 2: Signs and Symptoms of the cases (N=100)

Signs and Symptoms	Cases
Headache	63 cases (63%)
Neck stiffness	57 cases (57%)
Vomiting	54 cases (54%)
Decreased sensorium	42 cases (42%)
Loss of consciousness	37 cases (37%)
Neck pain	22 cases (22%)
Difficulty breathing	10 cases (10%)
Seizures	9 cases (9%)

The cases underwent a Contrast-Enhanced CT Angiogram to evaluate the Circle of Willis and also to evaluate the region of intracranial bleed. Among the 100 cases that were evaluated, the most common bleed was seen in the intraventricular region, seen in 30 %. The location of subarachnoid and/or intraventricular hemorrhage is tabulated in Table 3.

Table 3: Location of subarachnoid and/or intraventricular hemorrhage (N=100)

Location of bleed	Cases
Multiple site bleeds	15 cases (15%)
Perimesencephalic cistern	22 cases (22%)
Right sylvian fissure	11 cases (11%)
Left Sylvian fissure	14 cases (14%)
Suprasellar cistern	6 cases (6%)
Anterior inter-hemispheric falx	18 cases (18%)
Pre-pontine cistern	16 cases (16%)
Foramen magnum	1 cases (1%)
Intraventricular hemorrhage	30 cases (30%)

Among the 100 cases that were positive for intracranial bleeding, only 89 cases (89 % of total cases) showed aneurysms when evaluated using a Contrast-Enhanced CT Angiogram of the Circle of Willis. The most common type of aneurysm was the saccular type, seen in 86 cases. The types and localization of the aneurysms are tabulated in Table 4.

Table 4: Types and Location of aneurysm (N=89)

Types of Aneurysm	Cases
Saccular	86 cases (96.6%)
Fusiform	3 cases (3.4%)
Location of aneurysm in the Circle of Willis	**Cases**
ACOM	23 cases (25.84%)
Right ACA	10 cases (11.23%)
Left ACA	6 cases (6.74%)
Right MCA	11 cases (12.35%)
Left MCA	12 cases (13.48%)
Right ICA	2 cases (2.24%)
Left ICA	1 case (1.12%)
Right PCOM	2 cases (2.24%)
Basilar artery	10 cases (11.23%)
Right VA	3 cases (3.37%)
Left VA	4 cases (4.49%)
Right PICA	2 cases (2.24%)
Left PICA	1 case (1.12%)
Right SCA	1 case (1.12%)
Left SCA	1 case (1.12%)

**ACOM-Anterior Communicating artery; ACA-Anterior Cerebral Artery; MCA- Middle Cerebral Artery; ICA- Internal Carotid Artery; PCOM: Posterior Communicating Artery; VA: Vertebral Artery; PICA- Posterior inferior cerebellar artery; SCA-Superior Cerebellar

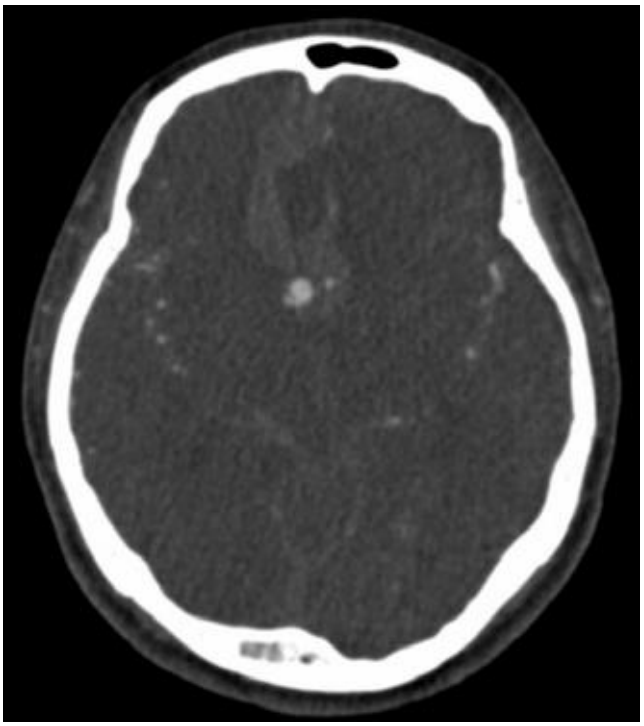

Figure 1*: CT cerebral angiogram shows an Anterior communicating artery (ACOM) saccular aneurysm in the Circle of Willis*

Figure 2: *CT cerebral angiogram shows the Left Internal carotid artery (ICA) saccular aneurysm in the circle of Willis*

DISCUSSION

The systematic review by Rinkel et al. found that the prevalence of cerebral aneurysms in the general population was 0.4% in retrospective autopsy studies, 3.6% in prospective autopsy studies, 3.7% in retrospective angiography studies, and 6% in prospective angiography studies. In adults without the presence of risk factors, it was found to be around 2.3%. The most common age of presentation of ICH was found to be in the age group of 65-74 in a 2022 systematic review by Wang et al. In our study, the mean age of presentation was 66.12 ± 5.77 years, which is similar to the study by Wang et al. The mean age of unruptured intracranial aneurysms is reported to be lower, at about 50 years of age. In our study, we evaluated only cases with positive ICH; as such, our study was not able to find the status of unruptured aneurysms in our population. The incidence of ICH and cerebral aneurysms both shows an exponential rise in incidence with age, leading to the conclusion that age is a potential risk factor for both aneurysm and intracranial hemorrhage.[1,7,9,10]

The incidence of aneurysms is more common in females than in males, as evidenced by the study of Vlak et al. The incidence of ICH is also more common in women than in men. However, men usually suffer ICH at a younger age, while women exhibit increased severity during the initial presentation. Estrogen may be linked with the delayed development of aneurysms in pre- and post-menopausal women and can explain how the incidence of intracranial aneurysms increases after menopause [7,11]

The risk factors for aneurysm formation and rupture leading to ICH are well-studied. Smoking has been considered one of the leading risk factors in the development and rupture of intracranial aneurysms. In our study, the most common risk factor was smoking, present in 51 cases or 51% of the study population. The prevalence of smoking in the general population is around 19.7%, which is far lower than the prevalence of smoking in the intracranial aneurysm study group. Smoking cessation has been shown to help

lower the risk of growth and rupture in the case of unruptured cerebral aneurysms. Hypertension is another leading risk factor for the rupture of cerebral aneurysms, leading to ICH. In a study by Biffi et al., they found that more than 60% of the survivors of ICH at 3 months had uncontrolled hypertension. Hypertension has been widely regarded as one of the leading causes of primary ICH, with hypertensives being 3.5 times more likely to suffer ICH than non-hypertensive individuals. In our study, we found hypertension to be present in 61 cases or 61% prevalence. Positive family history is a non-modifiable risk factor for the development of intracranial aneurysms and ICH. In our study, 13 % of patients had a positive family history, which might have increased the likelihood of developing an aneurysm and hemorrhage. Some diseases, such as Autosomal Dominant Polycystic Kidney Disease, predispose patients to the development of cerebral aneurysms with a high likelihood of positive family history.[12,13,14,15,16,17,18]

Intracerebral aneurysms, when symptomatic, are most commonly present as SAH or ICH, with headache being the most common symptom.3,4The headache is also regarded as "the worst headache of my life." Even unruptured aneurysms may lead to chronic headaches. The estimated prevalence of headaches in intracranial hemorrhages is around 57%. In our study, we found the prevalence of headaches in ICH at around 63%, which is similar to the study by Melo et al. (57%) and Sadasivam et al. (60%). Neck stiffness, vomiting, and decreased sensorium are relatively common symptoms of intracranial hemorrhages as well. Such symptoms were seen during our study as well [19,20,21,22]

During our study, the most common location of the intracranial bleed, as evaluated by the plain CT head, was the intraventricular region, followed by the perimesencephalic cistern and the anterior interhemispheric falx. Multiple areas of hemorrhage were seen in 15% of cases. According to the study by Jabbarli et al., the areas of hemorrhage of ICH associated with cerebral aneurysm are highly variable and are usually located near the aneurysm and the major artery from which the aneurysm arises. ICH associated with intracranial aneurysms is considered to have a poorer prognosis [23]

In our study, we found that 89 (89%) cases of aneurysms are associated with ICH. Alberico had a high detection rate of around 23 among 24 cases (>95%) of aneurysm by CT-Angiography of the Circle of Willis, which is similar to our study. In a different study by Katada, the detection of an aneurysm by CT-Angiography was only 57%. This is far lower than what our study found. It is highly likely that as the standard of the imaging quality of CT scans progresses, the case detection rate increases.[6,24]

The anterior communicating artery has long been considered to be the most common artery affected by cerebral aneurysms. According to a large bibliometric analysis of the top 100 cited articles by Pahwa et al., the occurrence of anterior communicating artery aneurysms is around 23-40%. This high value is due to the distinctive anatomy that the aneurysm arises from, as the aneurysm arises from the pentacomplex of arteries, owing to its frequent occurrence and increased chance of rupture. In our study, anterior communicating artery aneurysm was involved in 23 cases (25.84% of total aneurysms) and was the most common site of aneurysms. This is similar to the bibliometric analysis. According to the study by Kaminogo et al., the occurrence of multiple aneurysms is about 15-35% of the cases.[25,26,27]

Saccular aneurysms develop from defects in the muscular layer (tunica muscularis) and internal elastic membrane (lamina elastica interna) of cerebral arteries. These changes most frequently develop at sites of vessel bifurcation, where blood flow is most turbulent and shear forces against the arterial wall are greatest. Fusiform aneurysms develop from ectatic, tortuous cerebral arteries, most often in the vertebrobasilar system. Patients with fusiform aneurysms rarely cause intracranial hemorrhage. Saccular aneurysms are the most common type of aneurysm and are reported to be present in more than 90% of cases of cerebral aneurysms. Similarly, in our study, we found a high rate of saccular aneurysms at about 86 cases (96.62% of total aneurysms).[28,29,30]

CONCLUSION

The majority of the cases of non-traumatic intracranial hemorrhage have a positive aneurysm status in cerebral angiography by CT angiogram. Most of the aneurysms were found to be saccular, with the most common location in the anterior communicating artery. CT Angiogram is a useful and best modality of choice for patients before undergoing any neuro-intervention procedures like DSA.

CONFLICT OF INTEREST

None

SOURCES OF FUNDING

None

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