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Review article

Presentation, management and outcomes of ruptured intracranial aneurysms in Africa: A systematic review and meta-analysis

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ABSTRACT

Background: Approximately two percent of the world's population are affected by intracranial aneurysms (IAs). This study aimed to evaluate literature regarding presentation, treatment and outcomes of ruptured IAs in Africa.
Methods: A systematic review of the literature using PubMed/MEDLINE, SCOPUS, Web of Science and Google Scholar databases was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.
Results: Twenty-one retrospective studies with 1,109 patients and 11 case reports (10 countries) were included. The mean Methodological Index for Nonrandomized Studies (MINORS) for included articles was 9.1 ± 2.5. The mean age was 43.3 years (95 %CI: 37.8–48.8), with 58.4 % (342/586) female patients. WFNS/H&H grade 1 was reported in 41.2 % (98/238) of cases and Fischer grade 2 was reported in 30.4 % (98/322) of cases. CT angiography was utilized in 94.6 % (560/592, 12 articles). The ICA was reported in 24.5 % of cases (CI: 12.9 %-36.1 %). AComA and MCA were affected in 21.2 % (95 %CI: 15.2–27.2 %) and 21.3 % (95 %CI: 15.2–27.2 %) of cases, respectively. The odds of ruptured aneurysms in the anterior circulation were 14.3 (CI: 6.3–32.2). Surgical clipping was reported in 75.0 % (448/597) and coiling in 20.4 % (122/597) across 13 studies. 66.8 % (95 %CI: 57.4–76.3 %) of patients experienced neurological improvement with a mortality rate of 12.3 % (95 %CI: 7.5–17.1 %) at last follow-up.
Conclusion: Ruptured IAs are small and located in the anterior circulation. The lack of detailed aneurysm size reporting hampers the identification of a critical rupture size for management. More research is needed to understand aneurysm characteristics and predictors of rupture in Africa.

1. Introduction

Intracranial aneurysms are vascular disorders which usually result in outpouchings in blood vessels and are mostly found at the bifurcation of arteries with varying prevalence reported in both the anterior and posterior cerebral circulations [1,2]. The global prevalence of intracranial aneurysms is estimated at approximately 2 % of the population, with an annual incidence around 10 per 10,000 individuals [3]. Globally, these aneurysms are a significant health concern, with incidence and prevalence varying across different continents. Understanding the

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epidemiology and characteristics of intracranial aneurysms in Africa is crucial, given the unique healthcare challenges and population dynamics of the continent. While specific data on intracranial aneurysms in Africa are limited, these aneurysms are not rare in this region [4].

Rupture is the principal complication of cerebral aneurysms, and mainly presents as subarachnoid hemorrhage (SAH) or intracerebral hematoma [5]. SAH accounts for five percent of reported stroke cases, with young adults commonly affected. SAH from rupture of intracranial aneurysms remains a devastating condition, associated with a 30-day mortality of approximately 45 %, with half of the survivors sustaining irreversible neurological deficits [6]. Managing cases requires expertise across all aspects of care due to their complexity [7]. The advent of microsurgical techniques, surgical clipping and endovascular coiling, have revolutionized the management and treatment of SAH in developed countries [8]. However, the adoption of newer treatment modalities, particularly endovascular techniques, poses challenges in Africa, as they are largely inaccessible across many sub-Saharan countries [5]. The scarcity of vascular surgeons, neuroimaging, and even neurosurgical facilities have hindered the ability of researchers to truly understand the prevalence, management, treatment, and outcome of intracranial aneurysms in Africa [9].

This study aims to summarize existing data on ruptured intracranial aneurysms in Africa, specifically focusing on demographic and clinical patient characteristics, assessing the influence of aneurysm size and location on rupture, evaluating treatment options, and investigating associated outcomes, with the goal of informing future interventions and improving patient care in the continent.

2. Methods

2.1. Search strategy

A literature search was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines using electronic databases PubMed, Google Scholar, Embase and Web of Science (Fig. 1). This study was not registered in the International Prospective Register of Systematic Reviews registry. The key search terms employed were: "intracranial aneurysms" OR "cerebral aneurysms" AND "Africa" and "intracranial aneurysms" OR "cerebral aneurysms" AND [*each African Country*]". In addition, the key terms were combined with "presentation", "management" and "outcome" with the aid of Boolean operators AND/OR. There was no timeframe limit to the search strategy. We included observational studies, case series/reports, and clinical trials that reported on the epidemiology, risk factors, clinical presentation, management, or outcomes of ruptured IAs in Africa. To summarize all existing African literature, case reports were included in the criteria but not in the final analysis per PRISMA guidelines. They were summarized separately in table form. Articles were excluded if they were literature reviews, correspondences, commentaries, letters to editors, book chapters, animal studies, opinion pieces, systematic reviews and *meta*-analyses. The Methodological Index for Non-Randomized Studies (MINORS) was used to evaluate the methodological quality of the included studies. This tool assesses studies on a scale from 1 (poor quality) to 16 (high quality), focusing on different elements of study design. For comparative studies, the rating scale extends from 1 to 24.

2.2. Data extraction

The screening process was carried out independently by five authors (**K.D, G.S, E.Y, P.T, C.A**) in accordance with the search strategy using a data extraction form designed by the team. Disagreements were resolved by consensus among the authors. Initially, identified articles were screened based on their titles, followed by a review of abstracts and full texts to determine inclusion. Subsequently, full texts underwent examination by six authors (**K.D, G.S, E.Y, P.T, C.A, B.L**) to finalize included articles and extract relevant data. Additionally, the bibliography of the included articles was carefully examined for additional relevant articles meeting the inclusion criteria. The identified articles were then included in our analysis and assessed using our data extraction methodology.

The following variables were extracted from the included articles: 1) demographic information, including age and sex; 2) preoperative clinical findings; 3) underlying conditions and comorbid conditions; 4) diagnostic modalities; 5) aneurysm characteristics 6) management options; 7) management complications; 8) length of stay during hospitalization; 9) mean follow-up time and 10) clinical outcomes. Additionally, to provide a comprehensive overview of the review and critically evaluate the articles, we documented limitations and conclusions of each study, along with bibliometric details such as the study design and country of origin. We further stratified aneurysms into four primary size groups according to the UCAS study [10]: small (<5 mm), medium (5 mm–10 mm), large (10 mm–25 mm) and giant (>25 mm).

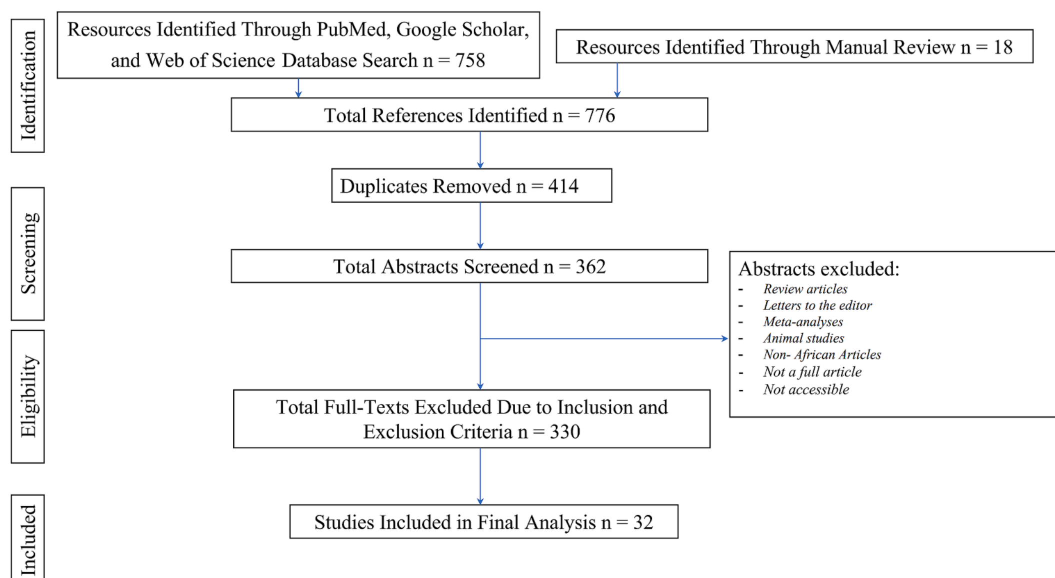

Fig. 1. PRISMA Flow diagram showcasing the methodology employed in conducting the systemic review.

2.3. Statistical analysis and summary of literature

We conducted an odds ratio and proportional *meta*-analysis using the *metafor*, *meta*, and *metadat* packages in R Studio (Version 4.3). This analysis pooled data to estimate the likelihood of aneurysm ruptures in anterior versus posterior circulation and assessed rupture odds by aneurysm size. Small aneurysms served as the reference group in an odds ratio *meta*-analysis, comparing the odds of ruptures in medium, large, and giant aneurysms. A random effects model (REM) was used to pool data, with precision evaluated by 95 % confidence intervals (95 % CI). Heterogeneity was assessed using the Cochran Q and I^2 statistics. For visual representation, odds ratios were depicted in forest plots. We also summarized data by computing frequencies and percentages from individual studies and created maps in Microsoft Excel for Mac *Version 16.8* to visually represent the cumulative number of ruptured aneurysm cases by countries.

3. Results

3.1. Electronic search yield

776 sources were initially identified. After removing 414 duplicate sources and assessing 362 sources against our inclusion and exclusion criteria, we retained 32 articles from different regions of the African continent for this systematic review (Fig. 1). These studies included 11 case reports/case series with 15 patients [11–21] (Supplemental Table 1) and 21 retrospectives, prospective and comparative articles [1,4,5,22–41] (Supplemental Table 21) with 1,109 patients for a total of 1,124 patients. The 32 articles originate from 10 African countries (Egypt, Ivory Coast, Kenya, Mali, Morocco, Nigeria, Senegal, South Africa, Tanzania and Tunisia) illustrated in Fig. 2**.** Of the contributing countries, Egypt and South Africa led with the highest number of studies, contributing 9 articles (26.5 %) each. Regarding patient cohorts, South Africa accounted for the majority, with 359 out of 1,124 patients (31.9 %), followed by Morocco contributing 176 out of 1,124 patients (15.7 %). The mean MINORS score for included articles was 9.1 ± 2.5 (see Supplemental Table 2).

Fig. 2. A Map Showcasing the Cumulative Frequency of Ruptured Aneurysm Cases by Country In Africa.

3.2. Demographics, pre-clinical characteristics, management strategies and outcomes

Table 1, 2 and 3 provide descriptive and *meta*-analysis on the data derived from the 1,109 patients in the retrospective and prospective studies included in our study. *El Khamlichi et al.* [4] in Morocco had the largest sample size with 173 patients with ruptured aneurysms.

Among 17 studies reporting age, the mean age was 43.3 years (95 % CI: 37.8–48.8). From the 17 papers reporting gender, 57.7 % (95 % CI: 52.1–63.2 %) were female. The most reported presenting symptom reported was headache, observed in 96.0 % (95 % CI: 91.1–100.0 %)

Table 1
Descriptive and REM pooled *meta*-analyses of demographics, clinical features and SAH gradings from the included studies.

Variable	Percentage (Sum/Total Number of Patients)	Prevalence (95 % CI)	Number of Articles Containing Variable	I^2
Demographics				
Mean Age, Years (95 % CI): 43.3 (37.8–48.8)			17	98.0
Male	41.6 (244/586)	42.4 (36.8–47.9)	16	39.1
Female	58.4 (342/586)	57.7 (52.1–63.2)	16	39.1
Clinical Signs and Symptoms and Co-Morbidities				
Headache	96.6 (394/408)	96 (91.1–100.0)	5	94.1
Neck Stiffness	97.3 (179/184)	79.6 (35.6–100.0)	2	88.9
Motor Deficits	32.6 (44/135)	26.2 (10.1–42.3)	3	71.3
Dysphasia/ Aphasia	9.7 (3/31)	9.6 (0.0–19.9)	2	0.0
Seizures	16.3 (22/135)	16.3 (8.6–24.1)	3	13.6
Altered Mental Status	11.1 (15/135)	28.2 (0.0–59.6)	3	89.9
Medical Co-Morbidities				
Hypertension	41.5 (95/229)	38.1 (21.7–54.4)	6	86.1
HIV	4.2 (6/142)	6.7 (0.0–20.7)	2	84.7
Smoking	10.4 (14/135)	15.8 (0.0–34.6)	3	85.0
Diabetes Mellitus	12.3 (19/154)	11 (2.8–19.3)	3	58.1
Previous SAH/ ICH	1.2 (2/166)	0.7 (0.0–1.9)	4	0.0
Subarachnoid Hemorrhage Grading Scales				
WFNS/H&H Grade 1	41.2 (98/238)	31.6 (18.7–44.4)	9	80.2
WFNS/H&H Grade 2	21 (50/238)	26.3 (16.3–36.3)	9	59.7
WFNS/H&H Grade 3	24.4 (58/238)	18.8 (10.8–26.8)	9	52.6
WFNS/H&H Grade 4	10.5 (25/238)	8.5 (4.9–12.1)	9	0.0
WFNS/H&H Grade 5	2.9 (7/238)	0.8 (0.0–2.7)	9	4.0
Fisher Grade 1	15.2 (49/322)	17.5 (4.9–30.1)	5	87.3
Fisher Grade 2	30.4 (98/322)	22.3 (8.6–36.1)	5	84.4
Fisher Grade 3	25.8 (83/322)	23.8 (11.2–36.4)	5	84.2
Fisher Grade 4	28.6 (92/322)	29.2 (15.0–43.3)	5	90.4

Abbreviations: HIV: Human immunodeficiency virus; ICH: Intracerebral hematoma; SAH: Subarachnoid hemorrhage; WFNS: World Federation of Neurological SurgeonsH&H: Hunt and Hess.

Table 2
Descriptive and REM pooled *meta*-analyses of diagnostic imaging and aneurysm characteristics from the included studies.

Variable	Percentage (Sum/Total Number of Patients)	Prevalence (95 % CI)	Number of Articles Containing Variable	I^2
Diagnostic Modalities				
CTA	94.6 (560/592)	76.2 (54.5–97.9)	12	99.9
CT	75.6 (316/418)	86.5 (65.1–100.0)	9	99.8
Cerebral Angiogram	41.4 (283/683)	34.2 (7.6–60.9)	12	100.0
DSA	38.3 (223/576)	45.3 (16.1–74.5)	11	100.0
MRA	29.7 (171/576)	20.8 (0.0–43.4)	11	99.9
Lumbar Puncture	3.8 (16/418)	20.2 (0.0–43.9)	10	99.9
MRI	1.9 (11/576)	10.8 (0.0–27.3)	11	99.9
Ultrasound	1.6 (9/576)	10.5 (0.0–26.6)	11	99.9
Aneurysm Location				
ICA	27.7 (265/957)	24.5 (12.9–36.1)	21	96.9
AComA	25.9 (242/936)	21.2 (15.2–27.2)	20	82.2
MCA	22.6 (212/936)	21.3 (16.1–26.5)	20	72.1
PComA	18.3 (152/829)	14.2 (8.6–19.8)	19	86.5
ACA	15.2 (126/829)	11.9 (7.2–16.5)	19	82.3
PCA	6 (50/829)	4.8 (1.6–8.0)	19	90.6
BA	4.9 (41/829)	3.4 (1.5–5.3)	19	60.3
VA	3 (25/829)	1.2 (0.4–1.9)	19	0.0
PeriA	3 (25/829)	8.6 (0.0–18.1)	19	99.5
PICA	1.1 (9/829)	0.8 (0.2–1.4)	19	0.0
OphA	0.8 (7/829)	0.7 (0.1–1.2)	19	0.0
VBA	0.6 (5/829)	0.7 (0.1–1.2)	19	0.0
SCA	0.4 (3/829)	0.7 (0.1–1.2)	19	0.0
AICA	0.4 (3/829)	0.7 (0.1–1.2)	19	0.0
Aneurysm Features				
Saccular	93 (132/142)	93.4 (89.3–97.4)	4	0.0
Fusiform	8.5 (12/142)	8.3 (3.8–12.8)	4	0.0
Aneurysm Dimensions*				
Mean Aneurysm Diameter, mm (95 % CI): 4.9 (2.2–7.6)			4	95.8
Range of Mean aneurysm diameter (mm): 1.4 – 8.6				
Small Aneurysms	45.8 (184/402)	55 (36.4–73.6)	11	95.6
Medium Aneurysms	52.5 (267/509)	40.3 (23.1–57.5)	12	97.0
Large Aneurysms	12.9 (52/402)	10.3 (4.5–16.0)	11	75.1
Giant Aneurysms	6.4 (37/575)	4.1 (0.9–7.3)	12	78.1

*[small (<5 mm), medium (5 mm–10 mm), large (10 mm–25 mm) and giant (>25 mm)].
Abbreviations: ACA: Anterior Cerebral Artery; AComA: Anterior Communicating Artery; AICA: Anterior Inferior Cerebellar Artery; BA: Basilar Artery; CT: Computed tomography; CTA: Computed tomography angiography; DSA: Digital subtraction angiography; Giant Aneurysms: >25mm; ICA: Internal Carotid Artery; Large Aneurysms: 10mm-25mm; MCA: Middle Cerebral Artery; Medium Aneurysms: 5-10mm; mm: Millimeters; MRA: Magnetic resonance angiography; MRI: Magnetic resonance imaging; OphA: Ophthalmic Artery; PCA: Posterior Cerebral Artery; PComA: Posterior Communicating Artery; PeriA: Pericallosal Artery; PICA: Posterior Inferior Cerebellar Artery; SCA: Superior Cerebellar Artery; Small Aneurysms: <5 mm; VA: Vertebral Artery; VBA: Vertebrobasilar Artery.

Table 3
Descriptive and REM pooled *meta*-analyses of intracranial aneurysm treatment strategies, complications, and outcomes from the included studies.

Variable	Percentage (Sum/Total Number of Patients)	Prevalence (95 % CI)	Number of Articles Containing Variable	I^2
Surgical Management Strategies				
Surgical Clipping	75 (448/597)	75.0	13	–
Endovascular Coiling	20.4 (122/597)	20.4	13	–
Wrapping	4.4 (26/597)	4.4	13	–
Immediate Post-Surgical Outcomes				
Total Occlusion After Endovascular Coiling	88 (22/25)	85.7 (56.8–100.0)	2	71.5
Partial Occlusion After Endovascular Coiling	18.7 (14/75)	18.6 (9.8–27.4)	2	0.0
Non-Surgical/Adjunct Medical Management Strategies				
Calcium Channel Blocker – Nimodipine	100 (140/140)	99.4 (98.1–100.0)	2	0.0
Post-Management Complications				
Neurological Deficits	31.2 (62/199)	32.6 (18.9–46.3)	5	70.9
DCI	13.1 (27/206)	12.6 (7.9–17.2)	3	4.3
Vasospasm	23.9 (52/218)	23.2 (7.2–39.3)	4	82.8
Hydrocephalus	19.7 (70/356)	19.2 (15.1–23.2)	7	0.0
Rebleed	6.1 (20/328)	18 (0.0–40.3)	5	99.0
Range of Length of Hospital Stay (Days): 10.5 – 26				
Outcomes at Last Follow Up				
Improved	65.5 (315/482)	66.8 (57.4–76.3)	11	78.8
Death	13.1 (66/502)	12.3 (7.5–17.1)	10	63.3

Abbreviations: DCI: Delayed cerebral ischemia; LOS: Length of stay.

across 5 studies, while other signs and symptoms at presentation included neck stiffness at 79.6 % (95 % CI: 35.6–100.0 %, 2 articles), altered sensorium at 28.2 % (95 % CI: 0.0–59.6 %, 3 articles), and motor deficits at 26.2 % (95 % CI: 10.1–42.3 %, 3 articles). Hypertension was reported as a medical co-morbidity in 41.5 % (95/229) of cases across 6 articles, while a history of smoking and diabetes was noted in 10.4 % (14/135, 3 articles) and 1.2 % (19/154, 3 articles) of cases, respectively.

Nine papers provided complete World Federation of Neurological Surgeons (WFNS) and Hunt and Hess grading data, revealing that grade 1 was reported in 41.2 % (98/238) of cases, and grade 3 in 24.4 % (58/238). Complete Fisher grading was detailed in 5 articles, showing grade 2 in 30.4 % (98/322) of cases, and Fisher grade 4 in 28.6 % (92/322) of cases. The full description of clinical severity scales for subarachnoid hemorrhage is provided in Table 1.

3.3. Diagnostic tools and aneurysm characteristics

In diagnosing intracranial aneurysms, CT brain angiography was adopted in 76.2 % (95 % CI: 54.5–97.9 %) of cases across 12 articles, while cerebral angiograms were used in 34.2 % (95 % CI: 7.6–60.9 %). Digital subtraction angiography was reported in 45.3 % (95 % CI: 16.1–74.5 %) across the same 12 articles. Magnetic resonance angiography was discussed in 11 articles, representing 20.8 % (95 % CI: 0.0–43.4 %) of cases. See Table 2 for details on reported diagnostic imaging modalities.

Among the 1,109 patients included in the study, there were a total of 1,165 aneurysms, with some patients presenting with multiple

aneurysms. In 21 articles discussing the location of ruptured aneurysms, the internal carotid artery (ICA) was the most affected site, seen in 24.5 % (95 % CI: 12.9–36.1 %) of cases, followed closely by the anterior communicating artery (AComA), affecting 21.2 % (95 % CI: 15.2–27.2 %) of aneurysms reported in 20 articles (Table 2). The middle cerebral artery (MCA) was affected in 21.3 % (95 % CI: 15.2–27.2 %) of cases, and the posterior communicating artery was next, representing 14.2 % (95 % CI: 8.6–19.8 %) of ruptured aneurysms, reported across 19 articles.

Regarding aneurysm size, the pooled mean aneurysm diameter was 4.9 mm (95 % CI: 2.2–7.6) across 4 articles, with the mean ranging from 1.4 to 8.6 mm in 7 articles. Aneurysms were categorized as small in 55.0 % (95 % CI: 36.4–73.6 %, 11 articles), medium-sized in 40.3 % (95 % CI: 23.1–57.5 %, 12 articles), and large in 10.3 % (95 % CI: 4.5–16.0 %, 11 articles). Additionally, 4.1 % (95 % CI: 0.9–7.3 %) of aneurysms reported in 12 articles were giant, with a diameter exceeding 25 mm. Saccular aneurysms constituted 93.0 % (132/142) of cases across 4 articles. Table 2 provides further details regarding aneurysm location, morphology and size.

3.4. Comparative meta-analysis of ruptured aneurysms by location and size

The *meta*-analysis included all 21 non-randomized studies [1,5,20,22–33,35–38,40,41] that reported on the occurrence of ruptured aneurysms differentiated by location. Studies showed higher odds of ruptured aneurysms located in the anterior circulation with a pooled OR of 14.3 (95 % CI: 6.3–32.2, $p < 0.001$) compared to the posterior circulation (Fig. 3A). In the *meta*-analysis examining the likelihood of ruptured aneurysms categorized by size, the pooled OR indicated a higher odd associated with small aneurysms compared to medium ones, with an OR of 2.7 (95 % CI: 0.5–14.3, $p = 0.258$) see Fig. 3B. The odds increase when comparing small to large aneurysms, with an OR of 12.7 (95 % CI: 2.9–54.2, $p < 0.001$) (Fig. 3C). The odds increase further when small aneurysms were compared to giant ones, with an OR of 49.7 (95 % CI: 19.6–126.2, $p < 0.001$) (Fig. 3D).

3.5. Management and outcomes

Surgical management was detailed in 597 patients from 13 studies. The most reported was surgical clipping in 75.0 % (448/597) of patients. Endovascular coiling was reported in 20.4 % (122/597) of cases. The reported length of hospital stay ranged from 10.5 to 26 days. Regarding outcomes at the last follow-up, discussed in 11 articles, 66.8 % (95 % CI: 57.4–76.3 %) of cases were reported to have improvement in symptoms and neurological deficits, while the mortality rate at the last follow-up was 12.3 % (95 % CI: 7.5–17.1 %). Table 3 provides a summary of intracranial aneurysm treatment strategies, complications, and outcomes post-management and at last follow-up.

4. Discussion

This systematic review of intracranial aneurysms in Africa, encompassing 32 articles with a total of 1,124 patients, offers a broad view of the current landscape of ruptured aneurysm characteristics, diagnostic modalities, management strategies, and outcomes within Africa. The mean patient age was 43.3 years, with a majority being female. Headaches, neck stiffness, altered sensorium and motor deficits were common reported symptoms. The internal carotid artery was the most common aneurysm site. Most aneurysms were small and saccular. Our *meta*-analysis found that ruptured aneurysms were significantly more likely to be situated in the anterior circulation, with smaller aneurysms having higher odds of rupture compared to larger ones.

The results of the study showed that the occurrence of ruptured intracranial aneurysms in Africa is more common in females. In a cross-sectional study done by *Jeong et al.* [42] that studied the size and location of ruptured aneurysms, and found that 65.7 % of patients with ruptured aneurysms were in female patients. *Zhao et al.* [43] in their retrospective analysis of 1,256 cases reported similar trends with the female/male ratio of 1.66. These findings support the notion that females are at an increased risk of ruptured aneurysms, consistent with our results. While the reasons for this increased risk in females are beyond the scope of this study, they are well-documented in existing literature [44].

Understanding the differences in rupture risk between IAs located in the anterior and posterior circulations is crucial for effective clinical management, as aneurysm location significantly influences rupture likelihood [45]. In our analysis, ruptured aneurysms were most prevalent in the anterior circulation, particularly in the internal carotid artery (ICA), anterior communicating artery (AComA), and middle cerebral artery (MCA). Most of the ruptured aneurysms were also small to medium in size.

Previous studies indicate that posterior circulation IAs have a higher annual bleed rate and rupture risk compared to anterior circulation IAs [45,46]. In a *meta*-analysis on the risk of rupture of unruptured intracranial aneurysms conducted by *Wermer et al.* [47] posterior circulation aneurysms were found as a significant risk factor for rupture (RR: 2.5, 95 % CI: 1.6–4.1). *Wiebers et al.* [48] found that IAs located in the anterior circulation had a lower 5-year cumulative rupture rate compared to those in the posterior circulation. These results contrast with our findings, which suggest a novel observation contrary to established literature. In our analysis, anterior communicating artery aneurysms (AComAs) were the second most reported site of aneurysmal rupture. Despite the generally lower risk of rupture for anterior circulation aneurysms, AComAs are clinically significant due to their high prevalence and elevated rupture risk compared to other anterior circulation IAs. This may partially explain our results. However, these findings should be interpreted with caution, highlighting the need for longitudinal studies in Africa to better understand rupture rates and provide stronger evidence for our observations.

Naamansen et al. [49] and *Bijlenga et al.* [50] found that small aneurysms, especially those less than 7 mm, frequently rupture, suggesting that size may be an independent risk factor for rupture. *Tarkiainen et al.* [51], in a retrospective analysis, observed a downward trend in the median size of IAs at rupture, decreasing from 10 mm to 6 mm. Similarly, a *meta*-analysis by *Sanchez et al.* [52] reported a mean size of 6.1 mm for ruptured aneurysms. Our review, along with these prior findings, indicates that small aneurysms in the anterior circulation may have a higher likelihood of rupturing. Consequently, early detection and management are crucial for preventing brain bleeds and improving patient outcomes. The absence of a standardized consensus on size categorization is noteworthy, and our application of the UCAS size classifications to this cohort of ruptured aneurysms may introduce potential limitations in accurately assessing rupture risk associated with size as presented in this report. Nonetheless, these findings imply that the small size of an unruptured IA should not preclude it from prophylactic treatment, given its potential to rupture.

The outcomes of patients with ruptured intracranial aneurysms are significantly impacted by complications such as hydrocephalus, vasospasm, and neurological deficits. Our study identified hydrocephalus as the most frequently reported complication, consistent with findings from other studies [53,54]. Prompt intervention, such as external ventricular drain (EVD) placement, may be necessary for managing hydrocephalus and preventing further neurological damage. In the unique context of Africa, EVDs may not be widely available with cost being a major limiting factor [55]. In a review of low-cost alternatives, the aggregated data from the identified studies showed that 54 % of patients survived post-EVD insertion. The incidence proportion of EVD-related infections was 24 % [56]. While these low-cost options appear promising, they are still far from being recommended as alternatives to the standard EVD placement. Vasospasm, typically occurring within 3 to 14 days post-rupture, poses a major risk due to its potential to cause

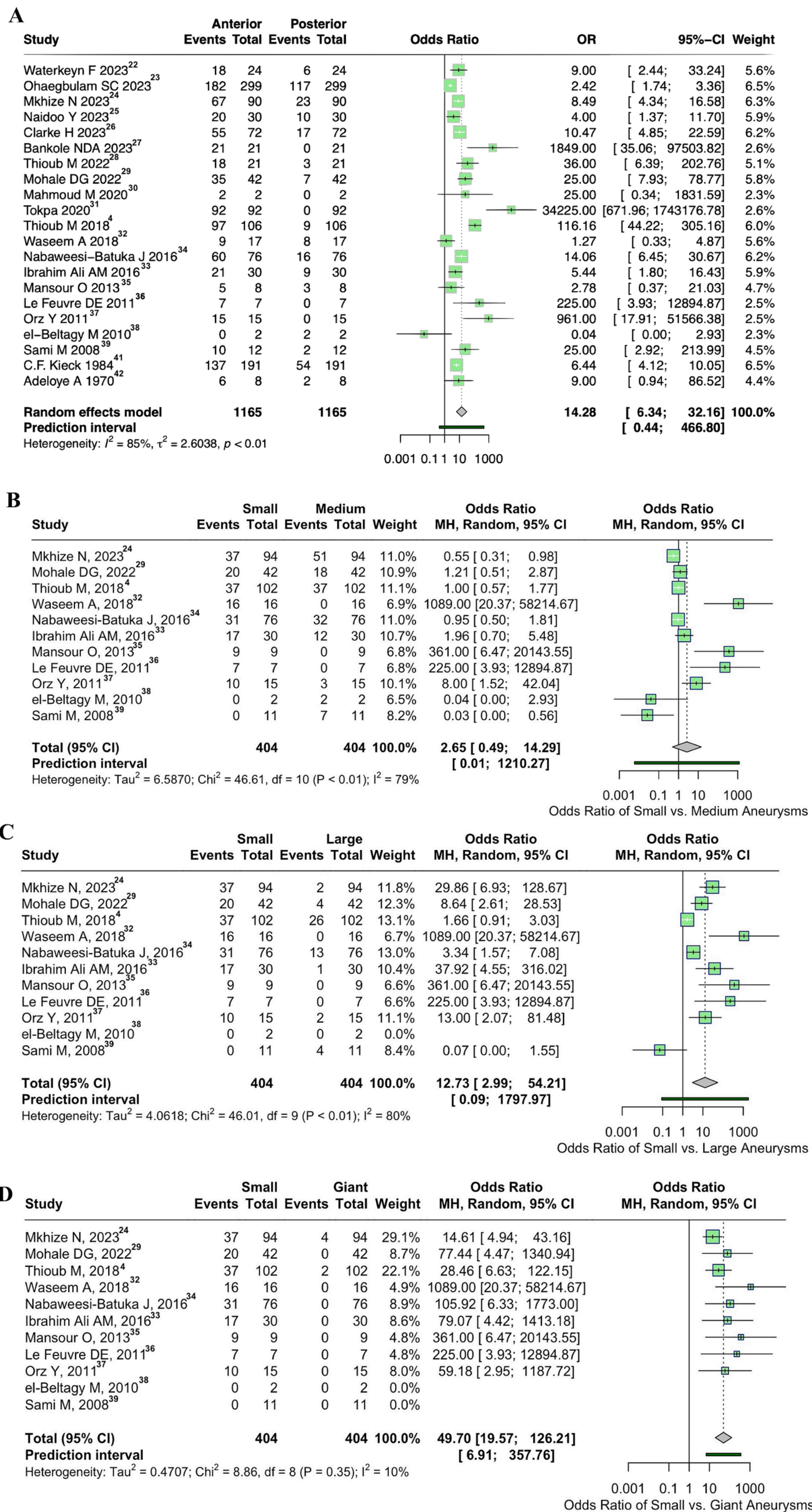

Fig. 3. (A) Odds Ratios of Ruptured Aneurysms by Anterior and Posterior Circulation. (B): Odds Ratios of Ruptured Aneurysms by Small vs. Medium Aneurysms. (C): Odds Ratios of Ruptured Aneurysms by Small vs. Large Aneurysms. (D): Odds Ratios of Ruptured Aneurysms by Small vs. Giant Aneurysms.

delayed cerebral vasospasm and subsequent ischemic stroke [57]. Despite prophylactic and therapeutic measures like calcium channel blockers and endovascular interventions, vasospasm remains a significant cause of morbidity and mortality [58]. In the study by *Thioub et al.* [5] vasospasm was prevented with nimodipine and controlled hypertension. The study notes that no mechanical or chemical expansion techniques were used because they were not available in the country.

In the present analysis, open surgery was more reported than minimally invasive approaches with appreciable outcomes. Endovascular treatment of aneurysms is an evolving field that has demonstrated better outcomes compared to conventional surgical clipping in some reports [59]. However, its implementation in Africa remains suboptimal due to challenges such as high costs, limited access to specialized equipment, and inadequate training infrastructure [1,60]. Despite these barriers, successful models have been reported in existing African studies, highlighting the need to scale such initiatives to improve patient outcomes across the continent [1,60].

4.1. Limitations

Despite the comprehensive nature of this systematic review, several limitations warrant consideration. Firstly, the study's reliance on published literature inherently limits its scope to the information available in these sources. The heterogeneity in the study design of the included articles is a significant limitation. Most of the included studies were retrospective and non-comparative, which limits the quality of evidence and increases the potential for bias. The prevalence of missing data and the inconsistent reporting of key variables such as clinical grading scales across studies limited our ability to perform a more uniform analysis. This limitation is further compounded by the variability in the presentation of data across the included studies, which may impact the reliability of the synthesized results. The geographic representation within the study is another limitation. Although the review includes studies from various regions of the African continent, the distribution of studies may not fully represent all African countries. This geographic disparity could introduce a selection bias, influencing the generalizability of the findings to the entire continent. Objective outcome measures, such as the modified Rankin Scale, were reported less frequently, which hinders our ability to accurately assess neurological outcomes across the studies. The relatively low quality of the included studies further contributes to potential inaccuracies in the observed figures, raising concerns about the reliability and validity of the reported results. Despite the stated limitations, the focus on a unique population adds to the relevance of this study.

5. Conclusion

In this review, we find that most ruptured aneurysms were small and located in the anterior circulation. However, the paucity of detailed reporting on aneurysm size characteristics, with a preference for broad size categorizations, impairs the identification of a critical rupture size, critical to guiding management. There is the need for more detailed research to fully understand aneurysm characteristics and the factors influencing rupture in African patients.

6. IRB compliance statement and ethical adherence

This study was written in compliance with our institutional ethical review board. IRB approval was waived given the de-identified nature of the information presented.

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CRediT authorship contribution statement

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jocn.2025.111054.

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