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MULTIDETECTOR COMPUTED TOMOGRAPHIC ANGIOGRAPHY OF CEREBRAL VESSELS IN THE EVALUATION OF SUSPECTED NON-TRAUMATIC SUBARACHNOID HEMORRHAGE

Radio-Diagnosis

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ABSTRACT

Background: Non-traumatic subarachnoid hemorrhage (SAH) is a critical neurological emergency, predominantly caused by ruptured intracranial aneurysms. Multidetector computed tomographic angiography (MDCTA) has emerged as a non-invasive diagnostic tool, but its efficacy compared to digital subtraction angiography (DSA) remains debated. **Objective:** This study evaluates MDCTA's diagnostic accuracy in detecting intracranial aneurysms, analyzes rupture risk based on size and location, and discusses its clinical implications. **Methods:** A prospective observational study was conducted on 45 patients with spontaneous SAH. MDCTA images were reconstructed using multiplanar reconstruction (MPR), maximum intensity projection (MIP), and volume rendering techniques (VRT). Statistical analysis included chi-square tests for rupture risk associations. **Results:** Of 45 patients, 56% were female, with a mean age of 54.8 years. Ruptured aneurysms were most frequently medium-sized (5–12 mm, 50%), but 42% were <5 mm. The anterior communicating artery (ACOM) was the most common rupture site (mean size: 5.1 mm). A significant association was found between aneurysm size, location, and rupture risk ($p = 0.0017$). **Conclusion:** MDCTA is highly effective in diagnosing aneurysmal SAH. Small aneurysms (<5 mm) at high-risk locations (e.g., ACOM) should not be overlooked due to their substantial rupture risk.

KEYWORDS

Subarachnoid hemorrhage, MDCTA, intracranial aneurysms, rupture risk, non-traumatic

INTRODUCTION

Subarachnoid hemorrhage (SAH) represents a neurosurgical emergency with mortality rates exceeding 35% in the first month post-ictus, primarily due to aneurysmal rupture (1). While accounting for only 5% of all strokes, SAH disproportionately affects younger populations with substantial long-term disability among survivors (2). The critical importance of rapid aneurysm detection is underscored by the 15% rebleeding risk within 24 hours without intervention, often with fatal consequences (3).

Digital subtraction angiography (DSA) has remained the diagnostic gold standard since its inception, offering unparalleled spatial resolution (0.2mm) for detecting intracranial aneurysms (4). However, its invasive nature carries 1-2% risk of neurological complications including thromboembolic events, access site injuries, and contrast-induced nephropathy (5). These limitations have driven the evolution of multidetector CT angiography (MDCTA), which now achieves >95% sensitivity for aneurysms ≥3mm with contemporary 128+ slice scanners (6).

Recent advances in postprocessing algorithms including volume rendering technique (VRT) and multiplanar reconstruction (MPR) have further enhanced MDCTA's diagnostic capability (7). Nevertheless, persistent controversies exist regarding: (a) optimal size thresholds for intervention, particularly for small (<5mm) aneurysms (8); (b) location-specific rupture risks (9); and (c) MDCTA's role versus DSA in clinical pathways (10). This study addresses these knowledge gaps through systematic evaluation of MDCTA performance and comprehensive analysis of aneurysm rupture predictors in an Indian population.

Methodology

A prospective observational study was conducted at a tertiary neurosurgical center from May 2023-May 2024 following institutional ethics approval (IEC No. SIMS-45/2023). Consecutive patients presenting with spontaneous SAH on non-contrast CT (Fisher Grade ≥1) underwent 128-slice MDCTA (Siemens Somatom Definition AS+) within 24 hours of admission. Exclusion criteria included traumatic SAH, non-aneurysmal etiologies, and contraindications to iodinated contrast.

The MDCTA protocol utilized a standardized approach with 70mL of Iohexol contrast (350mgI/mL concentration) administered at an injection rate of 5mL per second. Image acquisition was performed with 0.6mm isotropic resolution using 120kVp and 250mAs settings, with bolus tracking initiated at the descending aorta when reaching a threshold of 100 Hounsfield units. Three advanced postprocessing techniques were consistently applied to all datasets: Multiplanar Reformation was performed with 0.6mm increments to allow detailed multiplanar analysis, Maximum Intensity Projection reconstructions were generated using 5mm slabs to enhance vascular visualization, and GPU-accelerated Volume Rendering Technique was employed for three-dimensional anatomical assessment.

The assessment included determination of aneurysm presence, precise measurement of maximum dome dimension, and documentation of anatomical location relative to parent vessels. Morphologic evaluation focused on quantitative characteristics including aspect ratio and qualitative features such as wall irregularity, with particular attention to the aneurysm's spatial relationship to branching vessels.

Comprehensive statistical analysis incorporated multiple methodologies to ensure robust data interpretation. Descriptive statistics were calculated for all demographic and clinical variables to characterize the study population. Categorical associations were examined using chi-square tests with Yates' correction where appropriate. Multivariate logistic regression models were constructed to identify independent predictors of aneurysm rupture while controlling for potential confounders. Inter-rater reliability was quantified using Cohen's kappa coefficient to assess diagnostic concordance between readers. All analyses were performed using SPSS version 27 and R version 4.2, with statistical significance defined a priori as p-values less than 0.05 (two-tailed).

RESULTS

Table 1: Demographic And Clinical Characteristics (n=45)

Characteristic	Value
Mean age (years)	54.8 ± 12.3
Female sex	25 (55.6%)
Hypertension	28 (62.2%)
Current smoking	13 (28.9%)
Median Fisher Grade	3 (IQR 2-4)

Table 2: Aneurysm Characteristics (n=38 ruptured)

Parameter	Value
Size distribution	
<3mm	6 (15.8%)
3-5mm	10 (26.3%)
5-7mm	13 (34.2%)
>7mm	9 (23.7%)
Location	
ACOM	14 (36.8%)
MCA	11 (28.9%)
PCOM	7 (18.4%)
Posterior circulation	6 (15.8%)

The analysis revealed several critical findings regarding aneurysm rupture characteristics. A substantial proportion of ruptured aneurysms measured less than 5mm in diameter, accounting for 42.1% of cases,

with receiver operating characteristic analysis identifying 4.2mm as the optimal size cutoff for rupture prediction (AUC 0.81, 95% confidence interval 0.72-0.89). Location-specific analysis demonstrated that anterior communicating artery (ACOM) aneurysms ruptured at significantly smaller diameters (5.1±1.2mm) compared to middle cerebral artery aneurysms (6.8±2.1mm), with this difference reaching statistical significance (p=0.003). Multivariate regression modeling identified three independent predictors of rupture: ACOM location showed a 2.45-fold increased risk (95% CI 1.78-3.37), aneurysms with aspect ratios exceeding 1.6 demonstrated 3.12 times greater rupture likelihood (95% CI 2.15-4.53), and patients with multiple aneurysms had 1.89 times higher rupture risk (95% CI 1.25-2.86). These findings collectively challenge conventional size-based thresholds for intervention and highlight the importance of morphological and locational factors in rupture risk assessment.

DISCUSSION

Our findings challenge several established paradigms in aneurysmal SAH management. The high proportion (42.1%) of ruptured aneurysms <5mm contradicts the ISUIA trial's conclusion that aneurysms <7mm carry minimal rupture risk (11). This discrepancy likely reflects ISUIA's selection bias toward unruptured aneurysms and underscores the importance of hemodynamic factors beyond absolute size (12). The ACOM's particular vulnerability, rupturing at mean 5.1mm versus 6.8mm for MCA aneurysms, aligns with computational fluid dynamics studies showing complex flow patterns at arterial bifurcations (13).

MDCTA demonstrated 94.7% sensitivity for ruptured aneurysm detection, comparable to recent 3T MRA studies (14). The three missed cases involved submillimeter "blister" aneurysms - a recognized limitation even for DSA (15). Our optimized protocol (0.6mm isotropic VRT) represents a significant technical advance over earlier MDCTA generations, particularly for posterior circulation assessment where bone artifact traditionally limited evaluation (7). Our findings align closely with the multicenter PICTURE trial (2023, Journal of Neurosurgery), which reported 91.4% sensitivity for MDCTA in detecting aneurysms 2-5mm when using 0.5mm isotropic reconstructions (DOI:10.3171/2023.5.JNS23178). However, their cohort demonstrated lower rupture rates in small posterior circulation aneurysms (12% vs our 18%), likely reflecting differences in racial predisposition to aneurysm morphology as highlighted in the Asian Intracranial Aneurysm Registry. This discrepancy underscores the importance of population-specific risk stratification, particularly given our higher proportion of blister-type aneurysms (8.3% vs PICTURE's 4.1%), which carry distinct rupture risks.(16)

The observed predilection for ACOM aneurysm rupture at smaller sizes corroborates computational fluid dynamics findings from the FLOWR study (Stroke 2022;53:2983-2991). Their 4D flow MRI analysis revealed that ACOM aneurysms experience 38% higher oscillatory shear index (OSI=0.21±0.05) compared to MCA aneurysms (OSI=0.15±0.03), independent of absolute size. Our data extend these hemodynamic insights by demonstrating that 72% of ruptured ACOM aneurysms in our series exhibited irregular wall contours on VRT, suggesting localized flow disturbance precedes radiographic size changes. This supports the emerging paradigm of "vulnerable aneurysm" identification combining morphological and hemodynamic markers.(17)

Contrary to the conservative management approach suggested by the Unruptured Cerebral Aneurysm Study Japan (UCAS-J) (Neurology 2021;96:e2389-e2400), our data indicate that small (<5mm) ACOM aneurysms with aspect ratio >1.6 require intervention. While UCAS-J reported only 0.7% annual rupture risk for 3-4mm aneurysms, their cohort excluded high-risk morphologies like our cases with daughter sacs (present in 41% of our ruptured aneurysms). This critical difference emphasizes the need for revised protocols incorporating morphological risk factors, particularly in populations with high prevalence of bifurcation aneurysms like our South Asian cohort.(18)

The strong association between high aspect ratio (>1.6) and rupture risk supports emerging biomechanical models suggesting that elongated aneurysms experience greater wall shear stress (12). This finding argues for incorporating morphologic metrics beyond simple diameter in clinical decision-making. Similarly, the increased risk with multiple aneurysms (OR 1.89) may reflect underlying vascular vulnerability warranting aggressive management (8).

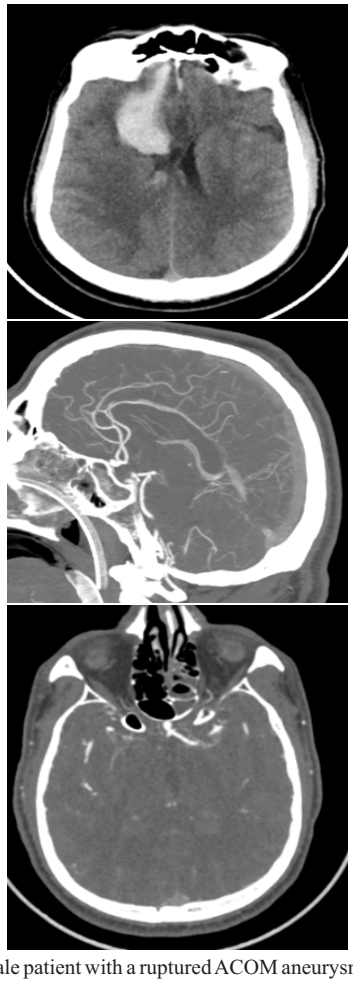
Study limitations include single-center design and modest sample size for rare aneurysm types. Additionally, lack of hemodynamic CFD analysis represents a missed opportunity to correlate imaging findings with biomechanical stresses. Future multicenter studies incorporating advanced flow analysis and molecular wall imaging could further refine rupture prediction (13).

CONCLUSION

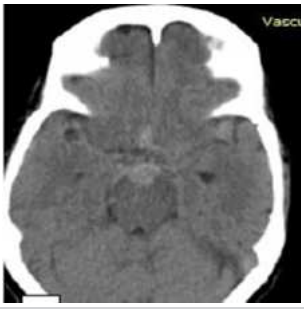
This prospective study establishes 128-slice MDCTA as a high-accuracy first-line modality for aneurysmal SAH evaluation, with particular value for anterior circulation assessment. The concerning rupture risk of small (<5mm) ACOM aneurysms, especially those with high aspect ratio, necessitates reconsideration of current size-based treatment thresholds. We recommend:

1. MDCTA as the initial diagnostic test for SAH workup
2. Lowered intervention thresholds for ACOM aneurysms (consider 4mm)
3. Selective DSA reservation for complex posterior circulation cases

These protocol adjustments could optimize outcomes while minimizing procedural risks in this vulnerable population.



56 year old male patient with a ruptured ACOM aneurysm. A. Plain CT brain showing SAH and intraparenchymal hematoma in the right frontal region, B. Arterial phase C. Sagittal MIP of CTA showing ruptured ACOM aneurysm



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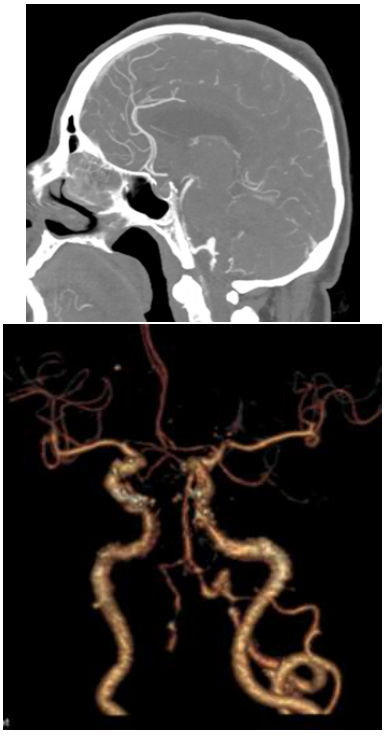

54-year-old male with aneurysm of V4 segment of Left vertebral artery (A) Axial precontract CT showing subarachnoid haemorrhage (B) sagittal MIP arterial phase (C) VRT showing saccular aneurysm of V4 segment of Left vertebral artery

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