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ORIGINAL ARTICLE

The added value of 3D CT Angiography and Digital Subtraction Angiography in aneurysmal subarachnoid hemorrhage

Ibrahim M. Eladl[1], Mona Mahmoud Eladl[1]*, Khaled Mohamed Eltaher[1]

1 Diagnostic Radiology Department, Faculty of Medicine, Zagazig University, Zagazig, Egypt

Corresponding author*
Mona Mahmoud Eladl

Email:
mona.eladl1@gmail.com

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ABSTRACT

Background: a relatively little amount of studies that discuss the optimal imaging method for subarachnoid haemorrhage caused by aneurysmal bleeding. In these individuals, a variety of imaging modalities are used despite the fact that they are seen as invasive, not always accessible, and possibly hazardous to the patient. Consequently, there has been a significant need for non-invasive alternatives. We aim To achieve an accurate diagnosis of aneurysmal subarachnoid hemorrhage.Methods: This comparative cross-sectional study was conducted at the Radiology Department, Zagazig University Hospital on 18 male and female patients with aneurysmal subarachnoid hemorrhage, their ages ranged from 30 to 60 years. Digital subtraction angiography and three-dimensional computed tomography were performed for all cases.Results: The sensitivity and specificity of digital subtraction angiography in comparison to 3D CT angiography were 98% and 87.5% respectively with statistically significant value (p= 0.035). The true positive was 16 and the true negative was 1.Conclusion: Recent advances in CT angiography technique, being non-invasive with no procedural neurological complications, add to the advantages of CTA.

Keywords: Aneurysmal subarachnoid hemorrhage, CT angiography, DSA.

INTRODUCTION

Blood leaking into the compartments surrounding the central nervous system, where cerebrospinal fluid resides, is a key indicator of non-traumatic subarachnoid hemorrhage (SAH), often recognized as a neurological emergency. The main leading cause of this condition is the rupture of cerebral aneurysms, accounting for approximately 5% of strokes. It predominantly affects relatively young individuals and carries a grim prognosis. Aneurysms are categorized based on their size and shape, including small (10 mm or smaller), large (10-25 mm), and giant (over 25 mm), as well as by their morphology, such as saccular, fusiform, and dissecting[1].

Aneurysmal SAH occurs following the rupture of an intracranial aneurysm, which is an abnormal localized dilation of a brain artery. These vascular anomalies are commonly found at the base of the brain, particularly where major arteries branch. Various factors influence the prognosis after an aneurysmal SAH, such as previous medical interventions, the severity of the initial hemorrhage, the risk of rebleeding, and the success and timing of aneurysm removal from the cerebral circulation[2].

Three-dimensional CT angiography is a valuable and non-invasive diagnostic imaging technique for assessing cerebral vascular abnormalities, including interactions with bony structures and the presence of calcifications in vascular structures or aneurysm necks. Compared to digital subtraction angiography (DSA), CT angiography is associated with fewer complications such as encephalopathy, headaches, emboli, and bleeding[3].

While digital subtraction angiography (DSA) is considered the gold standard for diagnosis in this field, it is invasive, often unavailable to critically ill patients, and carries inherent risks. Consequently, there is a significant demand for non-invasive alternatives that offer precision and safety in diagnosis [4].

The study aims to achieve an early and accurate diagnosis of aneurysmal subarachnoid hemorrhage to avoid stroke and possible poor prognosis of this condition.

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Methods

This cross-sectional investigation took place at the Radiology Department of Zagazig University Hospital. Approval for the study, labeled as No. 152/27 and dated February 2024, was obtained from the institutional review board (IRB) and the research ethics committee of Zagazig University's faculty of medicine. The study has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki).Written consent was provided by the patients involved.

The study involved eighteen patients diagnosed with aneurysmal subarachnoid hemorrhage, ranging in age from 30 to 60 years, comprising both males and females.

Patients were recruited from the neurology department if they presented with clinical symptoms indicative of aneurysmal subarachnoid hemorrhage. Exclusion criteria encompassed patients deemed neurologically or hemodynamically unstable for either CTA or DSA procedures, as well as those lacking complete clinical and demographic data.

Selected patients underwent comprehensive assessments, including detailed history-taking encompassing complaints, present and past medical history, and family history. A thorough clinical examination comprising systemic or local cardiological evaluation was conducted through inspection, palpation, percussion, and auscultation. The initial assessment involved 3D CT angiography, followed by Digital subtraction angiography.

Digital subtraction angiography (DSA)

DSA was performed under various conditions: post-surgical clipping of the aneurysm, absence of aneurysm in reconstructed CTA images prompting a DSA appointment within one or two days, or before attempted trans-arterial embolization of the aneurysm to ensure a comprehensive four-vessel DSA.

For DSA, femoral catheterization using the Seldinger method was employed with a Siemens Axiom Artis Cath/Angio System 3D device. Standard anteroposterior and lateral projections were acquired for carotid and vertebral catheterization, while rotational 3D angiography was utilized for enhanced visualization of vascular anatomy, particularly in the bilateral internal carotid arteries (ICAs).

3D CT angiography

3D CTA was conducted utilizing a Philips 128 Slice CT Scan apparatus, with 100 ml of nonionic iodinated contrast material (Omnipaque 350) injected via a power injector set at 3.5 ml/s. The scan's initiation was synchronized with the contrast arrival in the ascending aorta using the bolus tracking system. The scan covered the area from the aorta to the vertex of the head, encompassing the Willis circle and posterior inferior cerebellar arteries, with a chosen section thickness of 0.75 mm and a voxel size of 0.35 × 0.35 × 0.7 mm^3.

CTA images were uploaded to a picture archiving and communication system (PACS) for retrieval and analysis. Aneurysms were identified through a systematic review of the images, with adjustments made to contrast and brightness to enhance the visibility of arteries and bone structures. Volume-rendering techniques were applied to reassemble the original images in three dimensions, allowing for close examination of arterial branching points, including the Willis circle and intracranial arteries. Detected aneurysms underwent a thorough 360-degree rotation and detailed examination using interactive controls to adjust volume-rendering settings for comprehensive evaluation.

STATISTICAL ANALYSIS

The statistical data analysis was conducted through the SPSS (Statistical Package for Social Science) version 26 application. (ROC) curve study was used for assessing the prediction ability of variables.

RESULTS

This research involved 18 participants in total, with an average age of 46.9 years and a standard deviation of 9.3. Eleven males (61.1%) and seven females (38.9%)were among them .

The anterior communicating artery was the most frequent site of aneurysms (27.8%), followed by the posterior communicating artery (22.2%). A total of 24 aneurysms were identified through 3D CT angiography, while digital subtraction angiography (DSA) revealed 27, detecting three additional aneurysms not seen in CT angiography. Most patients had a solitary aneurysm detected by DSA.

The mean size of the aneurysms was 6.9 mm, with 16.7% of patients having aneurysms smaller than 3 mm, 66.7% having aneurysms sized between 3 and 10 mm, and 11.1% having aneurysms larger than 10 mm.

Regarding Hunt and Hess classification [5] , the distribution was as follows: 16.7% class 1, 27.8% class 2, 27.8% class 3, 22.2% class 4, and 5.6% class 5. According to Fisher grading [6] , 33.3% were grade 1, 22.2% were grade 2, 33.3% were grade 3, and 11.1% were grade 4.

The area under the curve (AUC) was 96.9%. The sensitivity and specificity of 3D CT angiography with DSA showed a sensitivity of 98% and specificity of 87.5%, yielding a statistically significant result (p=0.035).(Figs1).

Table 1. Location of the aneurysms by DSA and 3D CT angiography among the participants.

Variable	n (%) by Digital subtraction angiography (DSA).	n (%) by 3D CT angiography
Posterior communicating artery	4 (22.2)	4 (22.2)
Anterior communicating artery	5 (27.8)	5 (27.8)
Middle cerebral artery	2 (11.1)	2 (11.1)
Internal carotid artery	3 (16.7)	2 (11.1)
Anterior choroid	1 (5.6)	1 (5.6)
Basilar tip	2 (11.1)	1 (5.6)
Anterior cerebral artery	2 (11.1)	1 (5.6)
Posterior inferior cerebellar artery	1 (5.6)	1 (5.6)
Posterior cerebral artery	1 (5.6)	1 (5.6)
Dissection	1 (5.6)	1 (5.6)
Total No. aneurysms	27	24

Table 2. Number of aneurysms by CTA among the participants.

Variable	n (%)
Solitary aneurysm	13 (54.2)
Two aneurysms	4 (33.3)
Three aneurysms	1 (12.5)

Table 3. Number of aneurysms by DSA among the participants.

Variable	n (%)
Solitary aneurysm	16 (59.3)
Two aneurysms	4 (29.6)
Three aneurysms	1 (11.1)

Table 4. Hunt and Hess classification and Fisher grading among the participants.

Variable	n (%)
Hunt and Hess classification	
Class 1	3 (16.7)
Class 2	5 (27.8)
Class 3	5 (27.8)
Class 4	4 (22.2)
Class 5	1 (5.6)
Fisher grading	
Grade 1	6 (33.3)
Grade 2	4 (22.2)
Grade 3	6 (33.3)
Grade 4	2 (11.1)

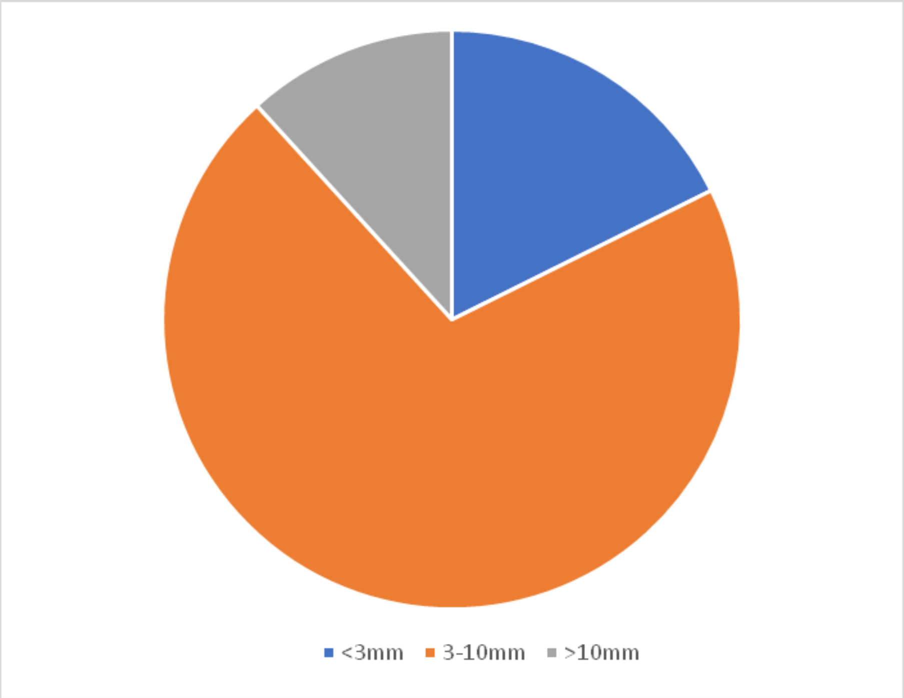


Fig.1. Size of aneurysm among the participants.
The majority of aneurysms have had size range of 3-10 mm (66.7%).

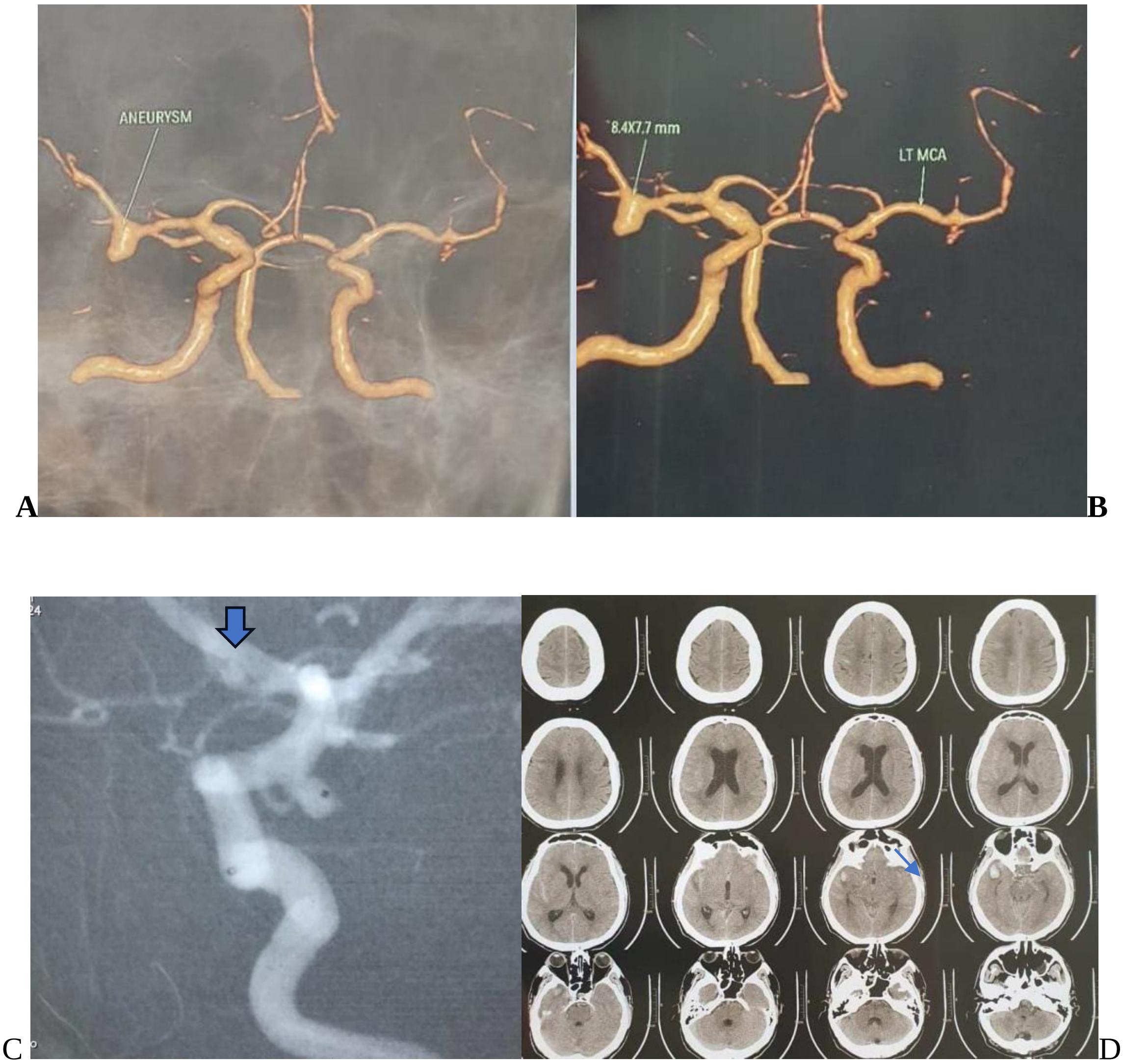
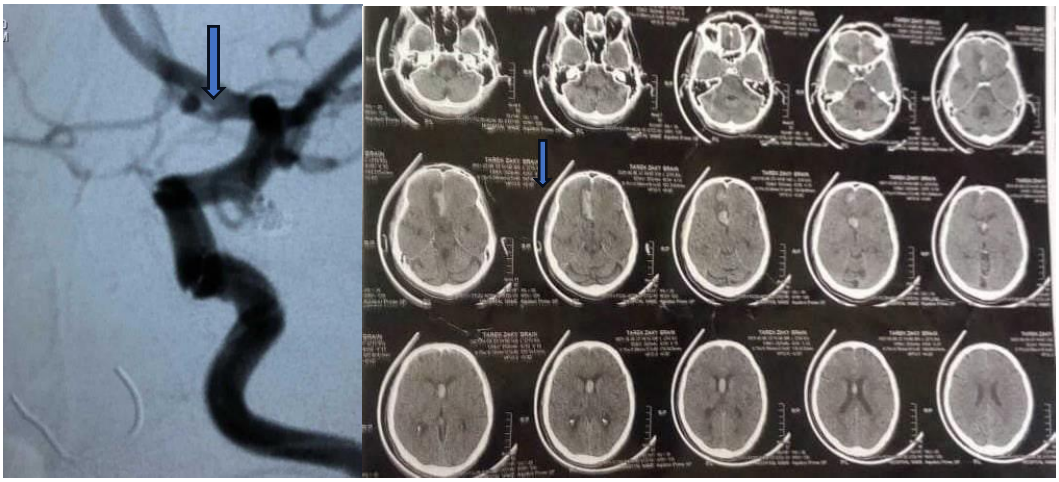


Fig.2. 3D DSA (A,B,C) reveal right MCA aneurysm measuring 8.4x7.7 mm with associated right temporal lobe subarachnoid hemorrhage annotated at CTA (D) .

Fig.3. 3D CTA and DSA reveals ACA aneurysm measuring 4.7X6.9 mm with subfalcine subarachnoid hemorrhage.



C D

Fig.3. DSA (A,B,C) reveals ACA aneurysm measuring 4.7X6.9 mm with subfalcine subarachnoid hemorrhage (blue arrow) observed at image (D) .

DISCUSSION

In the study's demographics, 18 patients participated, with a mean age of 46.9 years and a gender distribution of 61.1% men and 38.9% women. Aneurysms had a mean size of 6.9 mm, with 16.7% smaller than 3 mm, 66.7% sized between 3 and 10 mm, and 11.1% larger than 10 mm.

Regarding Hunt and Hess classification [5] , there was a distribution across classes 1 through 5 among our patients; there were 16.7% class 1, 27.8% class 2, 27.8% class 3, 22.2% class 4, and 5.6% class 5. Fisher grading[6] showed various grades among patients, six patients (33.3%) were grade 1, 4 patients (22.2%) were grade 2, 6 patients (33.3%) were grade 3, and 2 patients (11.1%) were grade 4.

Our study utilized 3D CT angiography, which offers advantages over traditional DSA, including better visualization of concealed aneurysms. The comparison with Singh et al.'s study [7] highlighted differences in aneurysm detection rates between the two methods.

Luo et al. demonstrated the superiority of subtracted CTA over non-subtracted CTA in identifying small aneurysms and those near bony structures. Liu et al. [8] also emphasized the usefulness of 3D CTA in assessing aneurysm location and size, particularly with MDCTA's quantitative approach.

By digital subtraction angiography among our participants, there were a total number of 27 aneurysms. As regards the location of the aneurysms, the most common site was in the anterior communicating artery (27.8%), then 22.2% in the posterior communicating artery, 11.1% middle cerebral artery, 16.7% internal carotid artery, 5.6% in the anterior choroid, 11.1% basilar tip, 11.1% anterior cerebral artery, 5.6% PICA, 5.6% PCA, and 5.6% dissection.

Comparatively,Sobh et al. studied 560 patients with SAH symptoms, identifying different aneurysm sizes and grades. Our study's most common site of aneurysms was the anterior communicating artery, consistent withSobh et al.'s findings [9] .

By DSA, among our participants, only one patient had no aneurysms, 16 patients had solitary aneurysms, four patients had two aneurysms, and only one patient had three aneurysms.

Kokkinis et al. observed similar patterns in their 205 patient' study group as DSA revealed varying numbers of aneurysms per patient, with some having solitary aneurysms and others having multiple[10].

3D DSA was performed in our study. Because conventional DSA can only produce 2D pictures, other projections must be made to identify the surrounding vascularity. Like 3D-CTA, 3D-DSA has become available recently and may reconstruct the picture in any selected projection. Research indicates that 3D-DSA is more sensitive than traditional 2D-DSA in identifying concealed aneurysms and the anatomy of arteriovenous malformations. [11]

During our study, we examined our patients by 3D CT angiography and found that there were a total number of 24 aneurysms.

The limited sensitivity of CTA in identifying smaller-sized aneurysms can be partly explained by the fact that CT has a poorer spatial resolution than DSA. Additionally, aneurysms may be missing in the posterior fossa due to their proximity to bony structures. [12]

Luo et al. [13] demonstrated the superiority of subtracted CTA over non-subtracted CTA in identifying small aneurysms and those near bony structures. Liu et al. [8] also emphasized the usefulness of 3D CTA in assessing aneurysm location and size, particularly with MDCTA's quantitative approach. The ability of CTA to identify intraluminal thrombus and mural calcifications is its second key benefit. Regarding calcification and thrombus identification, CTA is more effective than DSA.

In terms of accuracy, our study found high sensitivity and specificity for 3D CT angiography compared to DSA (98% and 87.5%, respectively), and the area under the curve was 96.9%. Consistent with findings from Kokkinis et al. [10] who reported very high sensitivity (97.9 and 99.3%, respectively) of both CTA and DSA, and their specificity was 100%. Three aneurysms, ranging in size from 2 to 3 mm, were missed by CTA. The primary cause of the initial erroneous negative CTA interpretation was low picture quality brought on by patient motion artifacts.

In a similar direction, Young et al. [14] reported that out of 200 patients who had CTA, DSA, and surgery, 140/144 rupture aneurysms were appropriately diagnosed by CTA, with eight false positive results. Therefore, the sensitivity of CTA was 97%, and the specificity was 86%.

Furthermore, in a sample of 32 patients with spontaneous SAH, Uysal et al. [15] compared CTA findings with MIP reconstructions to DSA and surgical findings. They found that 33 out of 34 aneurysms were appropriately diagnosed by CTA (sensitivity 97%, specificity 100%).

The study of Donmez et al. [16] highlighted that sensitivity increased as MDCT technology advanced and that 16-detector CT's sensitivity, specificity, and accuracy were, respectively, 95.1%, 94.1%, and 95%.

As the number of detectors rose, the system's sensitivity to identify aneurysmal SAH improved. For instance, the sensitivity of the 64-slice CT detector was 95.8%, while the sensitivity of the 320-detector was 96[17] .

Regarding the size of aneurysm, various studies have investigated the detection capabilities of CTA and DSA, showing comparable results in detecting large aneurysms but differences in sensitivity for smaller ones. Post-processing techniques aim to address CTA's limitations in spatial resolution, enhancing its ability to detect aneurysms effectively[18].

Size analysis demonstrated that DSA was

more accurate in cases with aneurysms <1 cm, while both DSA and CTA exhibited equal proportions of sensitivity in aneurysms >1 cm [19] .

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Medenica[20] compared CTA with DSA and surgical findings and showed that the sensitivity of CTA in detecting SAH and aneurysms of size less than 4 mm was only 88.8% .

According to Luo et al. [13] ,The CTA's reduced sensitivity in detecting smaller-sized aneurysms can partly be explained by the CT's inferior spatial resolution than the DSA. Several post-processing approaches have been developed to improve the spatial resolution of CTA, allowing better aneurysm visualization.

Our study has limitations, mainly the retrospective design and the need for long follow-up. More extensive studies are recommended with long periods of follow-up to accurately detect the consequences of aneurysmal subarachnoid hemorrhage.

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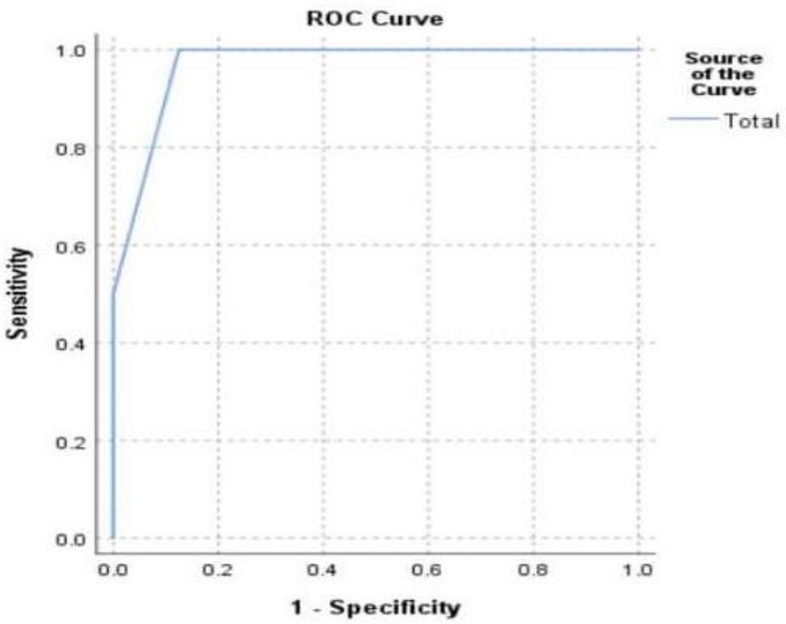

Fig.s1 . ROC curve analysis of 3D CTA in comparison with DSA .

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