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ROLE OF DIGITAL SUBTRACTION ANGIOGRAPHY IN DETECTION OF INTRACRANIAL ANEURYSMS COMPARED WITH COMPUTED TOMOGRAPHIC ANGIOGRAPHY

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Abstract

Objective To evaluate the role of digital subtraction angiography (DSA) in the detection of intracranial aneurysms among patients with spontaneous subarachnoid hemorrhage (SAH) compared with computed tomographic angiography (CTA) in a single center, Sri Lanka.

Methods A total of 123 patients clinically and CT proven SAH were evaluated with CT angiography and DSA with a median interval of 3 days. The sensitivity, specificity and accuracy of CT angiography in detecting aneurysms were analyzed compared to DSA on a per-patient, per-size, per-site and per morphological basis. All data were analyzed using SPSS analytical package (version 18). Ethical approval for the study was from the institutional ethical review board.

Results Among 123 patients with clinically and CT proven SAH, 51 (41.5%) patients showed aneurysms on CT angiography. 72 were negative for aneurysms in CTA. In 13 out of 72 (18%) CTA negative patients subsequent DSA demonstrated aneurysms. Number of CTA negative but DSA positive aneurysm were 15 as two of the patients had two aneurysms each.

Four CTA detected aneurysms could not be appreciated in the subsequent DSAs. Aneurysms (47) detected by both CT angiography and DSA were more than 6mm in size (56.7%) , saccular type (96.5%) and were located in the anterior circulation system (92.4%).

Most CTA negative aneurysms detected by DSA were less than 6mm in size (80%), saccular type (60%) and were located in anterior (53.8%) and posterior (46.7%) circulation system.

The sensitivity, specificity, positive predictive value and negative predictive value of CT angiography compared to DSA per patient basis were 78.3%, 93.7%, 92.2% and 81.9% respectively.

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CT angiography has a low sensitivity to detect aneurysms less than 6mm size (65.7%%), in posterior circulation (36.4%) and other morphological types (0%) compared to aneurysms more than 6mm size (90.9%), in anterior circulation (85.9%) and saccular type (85.5%).

Conclusion Digital subtraction angiography (DSA) has a significant role in detecting intracranial aneurysms which are less than 6mm in size, are located in posterior circulation system and of non-saccular morphological type.

Introduction

Subarachnoid haemorrhage is associated with high mortality and morbidity[1] and is a health burden globally with an incidence rate of 9 per 100000 populations per year[2]. Re-bleeding is common and can be catastrophic. Delayed cerebral ischemia is a common complication usually occurring in around 33% of patients between 4 to 14 days from the onset of SAH[2]. Early recognition and prompt treatment of underlying etiology reduces the morbidity and mortality and leads to better outcomes among victims. The current accepted practice in patients with spontaneous SAH is either CT angiography and/or Digital Subtraction Angiography (DSA) with a view to detect the underlying etiology of bleeding. DSA is the gold standard investigation[3] to detect intracranial aneurysms, which is an invasive and time-consuming imaging modality and needs to be performed by experienced operators.

There are several international studies that were carried out to compare CT angiography and DSA modalities [4,5]. However, there are no relevant local data available to inform local clinical practice. The value of DSA in CTA negative SAH is still not fully established worldwide while different expert opinions contradict each other. Here we have evaluated the diagnostic accuracy of digital subtraction angiography over CTA in the detection of intracranial aneurysms in patients with spontaneous SAH among 123 patients, with DSA serving as the reference standards in a cohort at a single center in Sri Lanka.

Materials and Methods

Patient Population

123 patients (54 males, 69 females) with clinically proven spontaneous SAH who underwent non-contrast CT brain were included in this retrospective study.

All patients with non-contrast CT proven SAH referred to Angiography section, Neuro-trauma center, National Hospital of Sri Lanka for DSA study from 1st February 2017 to 31st January 2018 were included in this study.

The patients with history of head trauma, known intracranial vascular abnormalities and DSA done after 14 days from the onset of symptoms were excluded from the study.

The patient details were taken from the institutional based records. In patients referred with spontaneous SAH, available printed NCCT brain images were reviewed and confirmed to have SAH by experts in radiology. The CTA findings were obtained from the reports issued by experts in radiology and images assessed by the interventional radiology team. DSA studies were carried out and were reported by a Consultant Interventional Radiologist and a Senior Registrar in Interventional Radiology.

CT angiography and DSA imaging studies and analysis

CT angiography

CTA was done using a 16-slice configuration CT system (Somatom Emotion; Siemens Healthcare, Germany). Low osmolar water soluble nonionic iodinated contrast medium was injected at a rate of 4.0 mL/sec into the antecubital vein via a 22-gauge cannula, followed by 20 mL of saline chase. Imaging started 6 seconds after the attenuation reached the predefined 100 HU threshold. Non contrast and contrast CT data were transferred to a Syngoplaza workstation, Siemens Healthcare and image reconstruction was done after removal of bone voxels. Maximum intensity projection, volume rendering, and multiplanar reformation were reconstructed in all cases. CTA images and reports were assessed by a Consultant Interventional Radiologist before proceeding to DSA.

Digital subtraction angiography

DSA studies were performed with catheterization of femoral artery using the Seldinger technique and a biplane DSA unit with 3D rotational capabilities (Infinix-I Biplane, Toshiba, Japan) was used for imaging. Nonionic iodinated contrast medium (300 mg of iodine per milliliter Iopromide, Ultravist 300) was used for each angiogram. Angiographic catheter was used to cannulate carotid and vertebral arteries and standard anteroposterior, lateral, and oblique DSA images were taken. The 3D angiographic data were transferred to Vitrea 3D workstation; Toshiba for visualization and for reformation of images. If an aneurysm was identified, diameter of the aneurysm was measured and the location recorded. The diameter of each aneurysm was measured in millimeters to one decimal place and graded by a Consultant Interventional Radiologist.

Statistical Analysis

All data were entered in Microsoft excel and analyzed using SPSS (version 18) package. The results were expressed as mean ± standard deviation and percentages. The sensitivity, specificity, positive and negative predictive values and accuracy of CT angiography versus DSA were calculated based on size, site, and morphological basis. The P value of ≤ 0.05 was considered as significant.

Ethical approval

The ethical approval was obtained from the ethics review committee of National Hospital of Sri Lanka.

Results

Overall Accuracy of CT angiography and Digital Subtraction Angiography

Among 123 patients with clinically and CT proven SAH, 51 (41.5%) patients had aneurysms while 72 (58.5%) patients had no detectable aneurysms at CT angiography.

Among patients with aneurysms detected by CT angiography, 47 (91.2%) patients were detected to have aneurysms at DSA while 13 out of 72 patients (18.1%) with negative CT angiography were detected to have aneurysms at DSA (Table 1).

Total number of aneurysms detected by DSA was 68 in 60 patients. DSA detected 15 aneurysms in 13 CTA negative patients. DSA confirmed 53 aneurysms in 47 CTA positive patients, while aneurysms were not detected in 4 patients who were reported to be having aneurysms on CTA. (Table 1).

CT angiographic and Digital Subtraction Angiographic accuracy according to aneurysm size

The size of aneurysms detected by CT angiography and DSA are shown in Table 2 and Table 3. The majority of aneurysms detected by CT angiography was more than 6mm in size (Nos-30, 56.7%). The majority of aneurysms detected by DSA among CT negative angiography were less than 6mm in size (Nos-12, 80 %).

CT angiographic and Digital Subtraction Angiographic accuracy according to aneurysm location

Most aneurysms detected by CT angiography were located in the anterior circulation system (Nos-53, 92.9%).

The percentage of aneurysms not diagnosed by CTA is 14% for anterior circulation aneurysms, whereas it is 63% for posterior circulation

The locations of aneurysms detected by CT angiography and DSA were shown in Table 2.

CT angiographic and Digital Subtraction Angiographic accuracy according to aneurysm morphology

All aneurysms detected by CT angiography were of saccular type (100%). Most aneurysms detected by DSA among CT negative angiography were also of saccular type (60%). The morphological types of aneurysms detected by CT angiography and DSA were shown in Table 2.

Statistical analysis

The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive like hood ratio and negative like hood ratio of CT angiography compared to DSA per patient basis were 78.3%, 93.7%, 92.2%, 81.9%, 12.4% and 0.23% respectively (Table 1). The sensitivity, specificity, PPV and NPV of CT angiography compared to DSA per aneurysmal size, location and morphology basis were 79.9%, 93.7%, 92.9% and 79.7% respectively (Table 1).

The sensitivity, specificity, PPV and NPV of CT angiography compared to DSA per aneurysmal size were 90.9%, 96.7%, 93.7% and 81.9 % respectively (Table 1). The sensitivity, specificity, PPV and NPV of CT angiography compared to DSA per aneurysmal location basis were 36.4%, 100%, 100% and 89.4% respectively (Table 1). The sensitivity, specificity, PPV and NPV of CT angiography compared to DSA per aneurysmal morphology basis were 0%, 96.7%, 0% and 90.8% respectively (Table 1).

CT angiography has low sensitivity to detect less than 6mm size (65.7%%), posterior circulation (36.4%) and non-saccular types (0%) aneurysms compared to more than 6mm size (90.9%), anterior circulation (85.9%) and saccular type (85.5%) aneurysms (Table 1).

Table 1: Role of Digital subtraction angiography and CT angiography to detect intracranial aneurysms per patient, size, location and morphological basis among patients with subarachnoid hemorrhage.

Variables						Statistical	analysis		
	TP	TN	FP	FN	Sensitivity	Specificity	PPV	NPV	Accuracy
Per patient basis	47	59	4	13	78.3(47/60)	93.7(59/63)	92.2(47/51)	81.9(59/72)	86.2(106/123)
Per aneurysms basis	53	59	4	15	77.9(53/68)	93.7(59/63)	92.9(53/57)	79.7(59/74)	85.5(112/131)
Per size of aneurysms basis									
<6mm	23	59	2	12	65.7(23/35)	96.7(59/61)	92.0(23/25	83.1(59/71)	85.4(82/96)
>6mm	30	59	2	3	90.9(30/33)	96.7(59/61)	93.7(30/32)	81.9(59/72)	94.7(89/94)
Per location of aneurysms basis									
Anterior circulation	49	59	4	8	85.9(49/57)	93.6(59/63)	92.5(49/53)	88.1(59/67)	90.0(108/120)
Posterior circulation	4	59	0	7	36.4(4/11)	100(59/59)	100(4/4)	89.4(59/66)	90.0(63/70)
Per morphology of aneurysms basis									
Saccular aneurysms	53	59	2	9	85.5(53/62)	96.7(59/61)	96.4(53/55)	86.8(59/68)	91.1(112/123)
Others	0	59	2	6	0(0/6)	96.7(59/61)	0(0/2)	90.8(59/65)	88.1(59/67)

Note: Abbreviations: TP; True Positive, TN: True Negative, FP: False Positive, FN: False Negative, PPV: Positive Predictive Value, NPV: Negative Predictive Value.

Table 2: Distribution of intracranial aneurysms detected by CT angiography (CTA) and Digital Subtraction angiography (DSA) per size, location and morphological basis among patients with subarachnoid hemorrhage [CTA (+) and DSA (+) ve cases -53, CTA (-) and DSA (+) ve cases -15].

Characteristic of aneurysms	**CTA(+ve) [Number-**	**DSA (+ve) 53]**	**CTA (-) ve [Number-**	**DSA(+ve) 15]**
Size	**Nos**	**(%)**	**Nos**	**(%)**
0-3mm	6	11.3	6	40
4-6mm	17	32	6	40
7-10mm	24	45.2	1	6.7
11-15mm	1	19	1	6.7
16-20mm	3	5.7	1	6.7
>20mm	2	3.8	0	0
Location	**Nos**	**(%)**	**Nos**	**(%)**
Anterior circulation	49	92.4	8	53.8
Anterior cerebral artery	1	1.9	2	13.5
Anterior communicating artery	12	22.6	4	26.7
Internal carotid artery	10	18.8	0	0

Middle cerebral artery	11	20.7	1	6.7
Posterior communicating artery	15	28.3	1	6.7
Posterior circulation	4	7.6	7	46.7
Basilar artery	4	100	1	6.7
Posterior cerebral artery	0	0	3	20
Anterior inferior cerebellar artery	0	0	1	6.7
Posterior inferior cerebellar artery	0	0	1	6.7
Vertebral artery	0	0	1	6.7
Morphology	**Nos**	**(%)**	**Nos**	**(%)**
Saccular aneurysm	53	100	9	60
Fusiform aneurysm	0	0	2	13.3
Complex aneurysm	0	0	3	20
Pseudo aneurysm	0	0	1	6.6

Discussion

CT angiography is the initial imaging modality in acute SAH to detect aneurysms [7, 8] while digital subtraction angiography (DSA) is the gold standard imaging study. DSA may be considered in CTA negative SAH in highly suspicious cases [9, 10].

In our study, among 123 patients with clinically and CT proven SAH, 51 (41.5%) had aneurysms at CT angiography while 13 out of 72 patients (18.1%) with negative CT angiography had 15 aneurysms detected at DSA. The sensitivity, specificity, PPV and NPV of

CT angiography compared to DSA per patient basis were 78.3%, 93.7%, 92.2% and 81.9% respectively in our study. Therefore, our study has proven that DSA has a significant role to detect intracranial aneurysms in comparison to CT angiography.

Several studies were carried out previously to compare the diagnostic accuracy of CT angiography with DSA in literature (4,5). Some studies have concluded that negative CTA can exclude aneurysm without evaluation by DSA [11, 12, 13.] However, our study has depicted that CT angiography has a sensitivity of more than 90 % in depicting more than 6mm size of intracranial aneurysms while sensitivity is only 65% in detecting aneurysm less than 6mm in size. The CTA in our study were done with a 16 slice CT scanner which may be the reason for this difference.

There were four false positive CTA results observed on the basis of DSA findings. In our study two of those four aneurysms were more than 6mm in size, while two were less than 3 mm in size. They were saccular (Nos-2) and fusiform (Nos-2) in morphological types. Three false-positive aneurysms were found in the middle cerebral artery, while one was arising from internal carotid artery.

CTA is a solely reliable imaging modality in many institutions globally, even though some centers considered DSA for CT angiography negative cases. The American Heart Association endorses evaluation of aneurysmal SAH[7] by DSA, according to American College of Radiology Appropriateness criteria[14]. Majority of research experts have revealed that both imaging modalities have an acceptable accuracy for detecting a cause for SAH[15] whereas clinical practice still varies among different institutions without a basis in clinical evidence.

SAH due to vertebro-basilar system aneurysm rupture at base of skull region is considered to be major challenge to be detected by CTA [9]. This was evident in our study as well. We found that CT angiography failed to detect 7 out of 11 aneurysms (63.6%) in the vertebro-basilar system. However, in some studies in literature [13, 16,17] high quality CT angiography sufficient to accurately diagnose these vertebro-basilar aneurysms without DSA. The CTA in our study were done with 16 slice CT scanner which may be the reason for this difference as well.

Sensitivity and specificity of CTA are considered to be 100% to detect aneurysms more than 3 mm in size which is comparable with DSA[18, 19] while conventional CTA is less reliable in detecting less than 3mm size aneurysms. The common aneurysms detected by CT angiography were more than 6mm in size (56.7%) and saccular type (96.5%) which were commonly located anterior circulation system (92.4%) in our study. The sensitivity, specificity, positive predictive value and negative predictive value CT angiography compared to DSA per aneurysmal size, location and morphology basis were 79.9%, 93.7%, 92.9% and 79.7% respectively which were similar to previous studies[20, 21.] A previous study revealed that the overall sensitivity, specificity and accuracy of CT angiography on a per-aneurysm basis were 95.1%, 94.1%, and 95%, respectively[22]. Furthermore, it revealed that the sensitivity, specificity, overall accuracy of aneurysms less than 3 mm in size were 86.1%, 94.1%, and 88.6%, respectively. More recently, another study revealed that overall sensitivity, specificity and accuracy of CT angiography per aneurysms basis were 92.5%, 93.3%, and 92.6%, respectively [23]. This study also showed that sensitivity was greater for detecting aneurysm more than 3mm in size aneurysms (96%) compared to 3mm or smaller (61%).

Multi-slice CT angiography with 64 to 360 detector rows have been shown to have a higher accuracy in detecting aneurysms less than 3mm in size in recent literature [24,25]. DSA has a major role to rule out small aneurysms among CTA negative diffuse SAH cases[26] which should be repeated within 2-6 weeks time if the initial DSA is negative [27]. Most of the aneurysms detected by DSA among CT negative angiography were less than 6mm in size (80%), saccular type (60%) which were in located anterior (53.8%) and posterior (46.7%) circulation system in our study. CT angiography has a low sensitivity to detect less than 6mm size (65.7%%), posterior circulation (36.4%) and other morphological types (0%) of aneurysms compared to more than 6mm size (90.9%), anterior circulation (85.9%) and saccular type (85.5%) aneurysms.

Limitations:

Retrospective study

CTA and CT brain images were assessed by the research team only using the hard copy images. (The Reporting Radiologists reports were taken in to consideration)

Conclusion

We conclude that DSA has a significant role in detecting intracranial aneurysms which are less than 6mm in size, located in posterior circulation system and of different morphological types.

Among patients with acute SAH and CT negative angiography DSA should be considered as a diagnostic modality to evaluate intracranial aneurysms due to high diagnostic accuracy.

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Conflicts of interest

The authors have no conflict of interest in publishing this research paper

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