CT angiography versus Digital Subtraction angiography for intracranial vascular pathology in a clinical setting

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INTRODUCTION

There are myriad causes of intracranial hemorrhage (ICH), which are broadly categorised into traumatic or spontaneous etiologies. The latter has many causes which include vascular pathology (e.g. aneurysm, arteriovenous malformation; AVM, arteriovenous fistula; AVF, cavernous angiomas, amyloid angiopathy, vasculitis, moya moya disease), tumour and systemic disease (e.g. hypertension and bleeding diathesis). Some of the vascular pathologies are amenable to curative treatment; hence, it is crucial to achieve an accurate diagnosis early [1].

It is well established in the literature that computer tomography angiography (CTA) which has a high sensitivity and specificity of more than 90% (with the exception of small intracranial aneurysms measuring less than 3mm) is the preferred initial imaging tool for detecting vascular pathologies [2-10]. On the contrary, digital subtraction angiography (DSA), being superior to CTA in terms of spatial and contrast resolution with no interference from surrounding bony structures, is often regarded as the gold standard diagnostic procedure, especially for equivocal findings [5]. However, DSA is invasive, being associated with a small but significant risk of neurological complications, ranging from of 0.3 to 1.8% [11, 12]. It is also time consuming, operator dependent and the subtracted images obtained may not delineate the important morphological features such as the neck of the aneurysm, vessels arising from the sac, mural calcifications or luminal thrombus [6].

In this retrospective audit, we evaluated 100 patients who presented with ICH and had both CTA and DSA performed in our Institution (one of the leading Tertiary hospitals in Singapore). We aim to determine the level of diagnostic accuracy in an actual clinical setting, between CTA and DSA, in the evaluation of intracranial vascular pathologies. Also, by identifying key areas of discrepancies, we hope to appraise as well as translate our findings into daily clinical practices, for the benefit of future patients.

MATERIALS AND METHODS

Study subjects

We retrospectively reviewed the medical records and images of 100 patients who underwent both CTA and DSA at our institute from January 2007 to December 2009. The majority of these patients presented with headache, vomiting and loss of consciousness or altered mental status as shown in Chart I. Approval from our Institutional Review Board (IRB) was obtained and informed consent for this retrospective study was waived. CTA was performed upon receiving an appropriate request. The imaging was then interpreted either by a registrar (with 3 to 6 years of radiological experience) or consultant (more than 6 years of experience). In the after hour period, registrars were expected to give a preliminary report and check the CT findings with consultants the next morning. In our study, there were altogether 33 radiologists who reported the CTA studies, out of which 22 were consultants and 11 registrars. During the 3-year period, 100 patients who had initial CTA performed underwent subsequent DSA, with the decisions frequently influenced by the level of confidence of the reporting radiologists and the clinical conditions of the patients.

Out of these 100 patients, 73 had no discrepancy between the CTA and DSA reports. 3 other cases were excluded as DSA was performed only after intracranial surgeries. One case was omitted as the patient underwent DSA more than a week after the initial CTA. Of the remaining discrepant 23 cases, only 16 patients had either definitive surgery/angiographic guided coil embolization of the lesion or a subsequent repeat DSA (at least within 6 months of the original DSA) for confirmation of the lesion.

Data evaluation

Only the original reports were reviewed for the purpose of this study and addendums were not considered. In addition, all the originally available source images, as well as reformatted images, including maximum intensity projection (MIP) and volume rendering technique (VRT) of both CTA and DSA were anonymised and evaluated independently by LEH, a consultant who has had 20 years of experience in both diagnostic and interventional neuroradiology. The consultant was blinded to both CTA and DSA reports, as well as the surgical findings. The subjective evaluations included the nature of the vascular pathology (e.g. aneurysm, pseudoaneurysm, AVM, AVF), location and the imaging quality of both CTA and DSA studies (i.e. good, adequate, poor), with the intention of deciding whether an adequate diagnosis could be reached with the available original images on retrospective review. This is illustrated in Table III.

CT angiography (CTA)

Being one of the leading tertiary hospitals in Singapore, different CT scanners with individual characteristics were utilised to cater to the high patient volume. Siemens

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Somatom Sensation, Siemens Somatom Definition and Philips iCT Brilliance, which have capabilities of rapid 3D reconstruction and subtraction algorithms, were introduced in 2005, 2007 and 2009, respectively. The use of the older CT scanner Mx8000quad was conversely phased out in 2009. Scanning protocol specific to each CT scanner was introduced in mid 2008 (Table I). The protocols require patients to be placed supine with the head maintained in neutral position. Pre scan without contrast as a baseline CT mask if required was then obtained. This was followed by injection of 50 ml of non-ionic contrast medium (350 mg iodine/ml), preferably introduced via the right median cubital vein at a rate of 4-5 ml/s. Bolus tracking technique, triggered by adequate enhancement of the carotid artery, was utilised to optimise the enhancement of the vascular structures. Reconstructed image thickness and increments were tailored according to each individual scanner. The field of view (FOV) was approximately 22 cm and the reconstruction kernel was soft. Post processing was performed using different types of software on MultiModality Workplace for the Siemens scanners and Extended Brilliance Workspace for the Philips scanner. This included digital bone subtraction, VRT and MIP reformatted images which usually took not more than 20 minutes of processing time.

Digital subtraction angiography (DSA)

DSA and 3D rotational angiographic (3DRA) images were obtained by a bi-plane angiographic unit and the procedures were performed by a pool of 9 interventional radiologists. Diagnostic 3 to 4-vessel angiography was performed via catheterisation of the femoral artery. Standard views comprising antero-posterior and lateral projections of each cannulated vessel were obtained following injection of non-ionic contrast medium by hand or pump. Oblique and other additional views were obtained, if necessary, to further delineate the vascular anatomy. Amount of contrast medium used was approximately 30-40 ml per study. The FOV was usually 22 cm with a matrix size of 1024 x 1024. For 3DRA, 160 images were acquired during a 200° rotational run in 8 seconds with 25-28 ml of contrast medium injected at rate of 3 ml/s. 3D images were later reconstructed and analysed on a dedicated workstation; screen shots in different projections of volume-rendered 3D images were stored.

RESULTS

In our study, we reviewed the 16 patients (10 women and 6 men) whose CTA and DSA reports showed discrepancies. The latter was performed within 1 week after CTA. The mean age of the patients was 54.2 years, ranging from 32 to 75 years. There was no standardised reporting template due to the different individual styles of reporting, varying experience levels of radiologists and working environment at the time of reporting. Not all the reports included important information such as the size of the intracranial lesion, the orientation of the aneurysm, diameter of the aneurysmal neck (if present), feeding arteries and draining veins of AVM. Therefore, all results were tabulated as per the original reports (as shown in Table II) in keeping with a study of actual daily reporting practices and discrepancies.

Out of these 16 cases, 12 were due to errors in CTA reporting and 4 in DSA reporting.

For CTA reporting, these have been separated into lesion-, technical- or interpreter-related discrepancies. Of important note is that dual causes of discrepencies are noted for Patients 3, 7 and 8 with main (1°) and secondary (2°) reasons thought to be the cause of discrepancy are correspondingly reflected in Table III and Chart II. Under the grouping of lesion related errors, one patient (Patient 1) had discrepancy resulting from an overtly small size of the aneurysm (less than 3mm) while another (Patient 2) was due to change in size of the aneurysm during the interval between the CTA and DSA performed. The remaining patient (Patient 3) was secondary to multiple closely related aneurysms at the skull base. Under technical related errors; one of our patients (Patient 4) CTA study lacked VRT, MIP and bone subtracted images. A further four of our patients (Patients 3, 5, 7 and 8) had vascular lesions close to overprojecting bony or calcified structures, which affected their detection even with the benefit of 3D VRT and MIP availability. The last technical related discrepancy (Patient 6) was a result of erroneous deletion from the MIP images of an AVM by a technician. The final group of discrepancies in CTA reporting involved interpreter related errors. These included vascular lesions which were misinterpreted as normal variants – a PCOM aneurysm was mislabeled as an infundibulum (Patient 9). Equally important was failure of interpreter detection of pathology (Patients 7-12). These are all illustrated in Chart 2a.

For DSA reporting, these have similarly been grouped technical and interpreter related errors. Under technical related factors, one patient's (Patients 13) vascular lesion noted on CTA could not be adequately demonstrated on DSA due to difficulty in accessing the source vessel (anatomically challenging vertebral artery). In the remaining three patients (Patients 14-16); errors were likely interpreter related, as re-evaluation by another DSA (within 6 months of initial DSA) failed to re-demonstrate the suspected pathology (Chart 2b).

Separate subjective opinion of the anonymised original CTA and DSA images by the senior neurointerventional radiologist (LEH) showed concurrence with the original CTA report in 2 out of the 3 patients (Patients 1-3) with lesion related discrepancies (when the aneurysm was either too small – 3mm, to be detected on CTA or due to multiple closely clustered aneurysms) and 3 out of the 6 patients (Patients 3-8) with technical related factors (all 3 cases were due to lack of/inadequate supporting bone subtracted, MIP or VRT images). For the remaining CTA (4 patients) and DSA (3 patients) interpreter related discrepancies, the senior neurointerventional radiologist was able to identify correctly the discrepant pathologies, correlating completely with the confirmative surgical or repeat (second) DSA findings (Chart 2c).

DISCUSSION

CTA discrepancies

i. Lesion-related errors

Previous publications have reported that the sensitivity for identifying aneurysms measuring 3mm or more on CTA (with DSA or surgical findings as the gold standard) is high, ranging from 93.3% to 100% [3, 4, 6, 13]. On the contrary, the sensitivity drops significantly for aneurysms measuring less than 3mm, ranging from 38% to 70.4% [3, 4, 13]. Our sensitivity

rate based on the original reports is high (95.7%), even with the inclusion of aneurysms smaller than 3mm. We only have one aneurysm less than 3mm (in Patient 1) which was deemed too small to be identified on CTA even on retrospective evaluation. The discrepancy is thus inherent to the aneurysm size and the relative limited diagnostic accuracy of the CT machine, which remains inferior in comparison to the gold standard of DSA [4, 8-10, 14]. The CT machine used in this case was the *Siemens Somatom Sensation*, interestingly a 16-row CT scanner, which supports the other study findings suggesting that 64- and 128-row multidetector CT scanners are superior to the 4- and 16-row CT scanners in the diagnostic accuracy of small aneurysms [9, 10].

We note that multiple aneurysms, especially if closely related to each other, may also decrease the sensitivity of CTA. For Patient 1, 2 out of the 3 aneurysms were reported on CTA, whilst for Patient 3, only 1 out of the 6 aneurysms was detected on CTA (Figures 1a-1c). Both these patients image quality was exacerbated by the fact that the aneurysms were located near the skull base as well.

There was also a case where there was discrepancy in the measurement of aneurysm size between the two imaging modalities. Patient 2 had an aneurysm which measured 6.0 x 5.5 x 5.5 mm on CTA but subsequent DSA showed significant decrease in size, measuring only 3.9 x 2.6 mm. We postulate that this may be due to interval acute thrombosis within the aneurysm between the two procedures which were 14 hours apart.

ii. Technical-related errors

Studies have shown that detection and demonstration of intracranial lesions is better in a 3D environment and sometimes not as definite when viewed in a 2D mode [15, 16]. This would have contributed to the misdiagnosis of intracranial vascular lesions in the absence of VRT, MIP and bone subtracted images. The CTA of Patient 4 was performed in the old CT scanner, Mx8000quad, which was not capable of producing 3D reformatted or bone subtracted images of decent quality. The limitations of this rather old CT scanner were acknowledged and the use of the scanner was subsequently phased out with the introduction of the newer scanners.

Overprojection of bony or calcified structures close to the area of the vascular lesion is a known pitfall of CTA, which can hamper detection even with the benefit of 3D VRT and MIP availability [3, 4, 7, 9, 15-18]. This is particularly true for Patient 3 (and to a degree, Patient 5,7 and 8) whereby due to the close proximity of the aneurysm to the skull base, coupled by venous overlay and adjacent atherosclerotic intracranial vessels, the resultant image quality was poor with obscuration of the aneurysms, the largest measuring 5mm.

Technological advancement in the form of bone subtraction, manual or automated bone editing have therefore been developed to address the issue of overprojecting bone, with data showing that the detection rates in these reformatted images may sometimes be as good as DSA [9, 16, 18, 19]. The pitfalls are increased radiation dose to the patients and the lesion demonstration being heavily dependent on the CT technician

Table I: Scanning protocols for different CT scanners utilised at our centre

CT scanner	Siemens Somatom Definition	Siemens Somatom Sensation	Philips iCT Brilliance
FOV (mm)		220	
Volume of contrast (ml)		50	
Rate of injection (ml/s)		4–5	
Size of cannula (G)		18 or 20	
Location of cannula		preferably in the right antecubital fossa	
Tube source (kV)	Dual Tube A – 140kV Tube B – 80 kV	Single 120kV	
mAs	Tube A – 50 Tube B - 210	350	400
Pitch	0.7	0.7	0.804
Slice thickness (thick cuts)		3mm	
Thickness for reconstruction (thickness/ increment)	1mm / 0.6mm	0.75 mm / 0.5 mm	0.8mm / 0.4mm
Triggering technique	Bolus tracking with region of interest (ROI) placed within the carotid artery at the level of C4		
Scan delay (sec)	2	4	4
Detector size (mm)	0.6	0.75	0.625
Detector row	64	16	128
Bone subtraction capability	Yes	Yes	Yes
Post processing software	Dual Energy Application (Bone Head Removal)	Neuro Digital Subtraction Angiography	Advance Vessel Angiography Analysis
Scout view		from C7 to vertex	
Scan coverage		from C3 to vertex	
Other imaging reformations		Axial neuro angio – 3mm/3mm Caudo-cranial MIP – 15mm / 3mm Coronal MIP – 15mm / 3mm Sagittal MIP – 15mm / 3mm VRT COW Edited MIP COW Right / Left and posterior circulation	

Table II: Summary of patient demographics, reported findings, as well as discrepancies between CTA and DSA reports

Patient	Age / gender	Type of lesion / number		Lesion location		Size of lesion / mm (if available)		Discrepancy in the original reports	CT scanner
		CTA	DSA	CTA	DSA	CTA	DSA		
1	46/F	A/2	A/3	R ICA	R ICA L ICA	2x2 2x1	-	CTA: reported 2 R ICA A DSA: reported 2 R ICA A, 1 L ICA A	Sen Cardiac, VRT/MIP
2	38/F	A/1	A/1	ACOM	ACOM	6x5.5	3.9x2.6	DSA: reported size of ACOM A is much smaller compared to that of CTA report	Definition, VRT/MIP
3	75/F	A/1	A/6	R PCOM	R PCOM R ICA (3) L ICA (2)	4.6x5.6	5.7x5.6 2.6, 3.6, 4.9x4.9 5 x5.2, -	CTA: reported 1 PCOM A DSA: reported 6 A (1 R PCOM, 3 R ICA, 2 L ICA)	Definition, VRT/MIP
4	43/M	nil	PA/1	-	R ICA	NA	-	DSA: R ICA PA; not reported on CTA	Mx8000Quad
5	32/M	PA/1	AVF/1	R VA between basilar a & occipital v	6x6	-	CTA: R VA PA	DSA: pathological traumatic AVF between basilar a, R VA, R PICA and occipital venous plexus	Definition, VRT/MIP
6	39/M	nil	AVM/1	-	L Sylvian point	NA	-	DSA: L temporal AVM; not reported on CTA	Definition, VRT/MIP
7	54/M	nil	A/1	-	R VA	NA	-	DSA: R VA A; not reported on CTA	Definition, VRT/MIP
8	42/M	A/1	A/2	L MCA	L MCA ACOM	-	-	CTA: reported L MCA A DSA: reported as L MCA A & ACOM A	Sen Cardiac, VRT/MIP
9	51/F	nil	A/1	-	R PCOM	NA	2x1.8	CTA: reported as R PCOM infundibulum DSA: reported as R PCOM A	Definition, VRT/MIP
10	47/F	nil	A/1	-	L MCA	NA	4	DSA: L MCA A; not reported on CTA	Definition, VRT/MIP
11	62/F	nil	A/1	-	L PCOM	NA	3.8x1.8	DSA: L PCOM A; not reported on CTA	Sen Cardiac, VRT/MIP
12	67/F	nil	A/1	-	R PCOM	NA	-	DSA: R PCOM; not reported on CTA	Sen Cardiac, VRT/MIP
13	62/M	A/2	A/1	L VA R VA	L VA	5 7	-	DSA: R VA not cannulated due to anatomical difficulty	Definition, VRT/MIP
14	56/F	A/1	A/2	R VA	R VA L PCOM	7x6	5.3 3	CTA: reported only as R VA A DSA: reported as R VA and L PCOM A	Sen Cardiac, VRT/MIP
15	50/F	A/1	nil	ACOM	-	3x5	NA	CTA: ACOM A; not reported on DSA	Definition, VRT/MIP
16	76/F	A/2	A/1	R ICA R VA	R ICA	3x2 -	2.8	CTA: R VA A; not reported on DSA	Definition, VRT/MIP

A=aneurysm; AVF=arteriovenous fistula; PA=pseudoaneurysm; AVM=arteriovenous malformation; R=right; L=left; ICA=internal carotid artery; MCA=middle cerebral artery; PCA=posterior cerebral artery; VA=vertebral artery; BA=basilar artery; ACOM=anterior communicating artery; PCOM=posterior communicating artery; a=artery; v=vein, VRT=volume rendered technique; MIP=maximum intensity projection

Table III: Summary of the concurrence between the re-evaluations by LEH (diagnostic and interventional neuroradiologist) and the original reports, subsequent surgical or repeat DSA findings (if available), as well as nature of discrepancies

Patient	Discrepancy in the original reports	Concurrence between re-evaluation by LEH and original report		Quality of CT imaging	Follow up surgery/coil embolization / repeat DSA (within 6 months of initial DSA)	Nature of discrepancy
		CTA	DSA			
1	CTA: reported 2 R ICA A DSA: reported 2 R ICA A, 1 L ICA A	Y	Y	good	Aneurysms re-confirmed on repeat DSA	Lesion related: L ICA aneurysm too small to identify on CTA
2	DSA: reported size of ACOM A is much smaller compared to that of CTA report	Y	Y	good	aneurysm confirmed intraoperatively	Lesion related: interval decrease in size of aneurysm likely due to acute thrombosis
3	CTA: reported 1 PCOM A DSA: reported 6 A (1 R PCOM, 3 R ICA, 2 L ICA)	N (detected 2 out of 6 aneurysms)	Y	poor	all 6 aneurysms confirmed on repeat DSA	Lesion related: multiple aneurysms at skull base with heavily calcified & tortuous ICAs (1° cause) Technical related: venous overlay, inadequate bone subtraction (2° cause)
4	DSA: R ICA PA; not reported on CTA	Y	Y	poor	PA re-confirmed on repeat DSA	Technical related: No VRT, MIP, bone subtraction, as well as coronal / sagittal reformatted images
5	CTA: R VA PA DSA: pathological traumatic AVF between basilar a, R VA, R PICA and occipital venous plexus	Y	Y	fair	AVF re-confirmed on repeat DSA	Technical related: lesion at skull base; overprojecting bone
6	DSA: L temporal AVM; not reported on CTA	N	Y	poor	L temporal AVM confirmed on surgery	Technical related: L temp AVM not included on VRT images
7	DSA: Distal R VA A; not reported on CTA	N	Y	poor	Re-confirmed on subsequent follow up CTA's and MRI's	Technical related: heavily calcified R VA A was inadvertently excluded on VRT following bone subtraction (1° cause) Interpreter related: missed aneurysm on axial source images (2° cause)
8	CTA: reported L MCA A DSA: reported as L MCA A & ACOM A	N (suspicious for ACOM A, suggest DSA)	Y	poor	2 aneurysms re-confirmed on repeat DSA	Technical related: inadequate bone subtraction, heavy atherosclerosis (1° cause) Interpreter related: missed ACOM A (2° cause)
9	CTA: reported as R PCOM infundibulum DSA: reported as R PCOM A	N (suspicious for R PCOM A, suggest DSA)	N (R anterior choroidal A)	good	aneurysm confirmed intraoperatively	Interpreter related: missed R anterior choroidal A on CTA Interpreter related: wrongly labeled as PCOM A on DSA
10	DSA: L MCA A; not reported on CTA	N	Y	fair	aneurysm confirmed intraoperatively	Interpreter related: missed L MCA A
11	DSA: L PCOM A; not reported on CTA	N	Y	good	aneurysm confirmed intraoperatively	Interpreter related: missed L PCOM A
12	DSA: R PCOM; not reported on CTA	N	Y	poor	Aneurysm confirmed post coil embolization	Interpreter related: missed R PCOM A
13	DSA: R VA not cannulated due to anatomical difficulty	Y	Y	good	R VA A confirmed on prior MR imaging	Technical related: suboptimal DSA due to inability to cannulate vessel of interest
14	CTA: reported only as R VA A DSA: reported as R VA and L PCOM A	Y	N (L PCOM infundibulum, not aneurysm)	good	L PCOM A not evident	Interpreter related: overcall L PCOM A
15	CTA: ACOM A; not reported on DSA	Y	N	good	ACOM A confirmed intraoperatively	Interpreter related: missed ACOM A
16	CTA: R VA A; not reported on DSA	Y	N	fair	R VA A confirmed on repeat CTA & DSA	Interpreter related: missed R VA A

A=aneurysm; AVF=arteriovenous fistula; PA=pseudoaneurysm; AVM=arteriovenous malformation; R=right; L=left; ICA=internal carotid artery; MCA=middle cerebral artery; PCA=posterior cerebral artery; VA=vertebral artery; BA=basilar artery; ACOM=anterior communicating artery; PCOM=posterior communicating artery; a=artery; v=vein

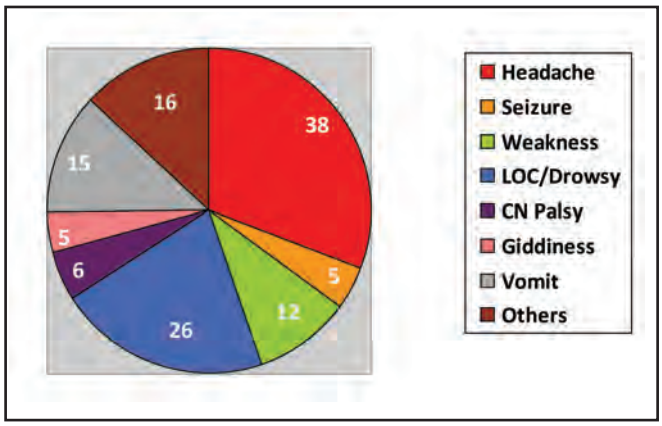

Chart 1 : Clinical presentations of patients referred for CT angiography.

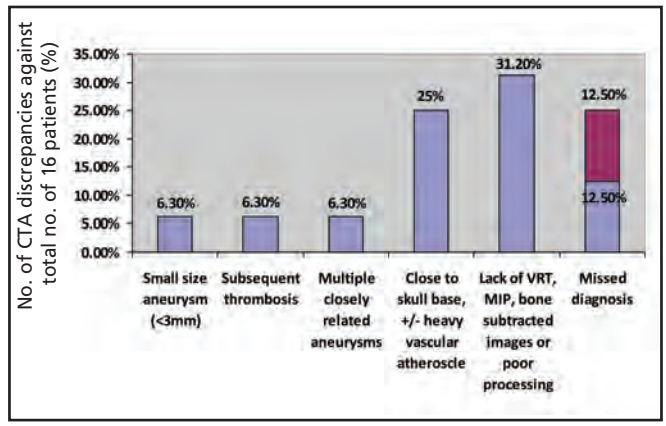

Chart 2a : Causes of discrepancies in CTA reporting.

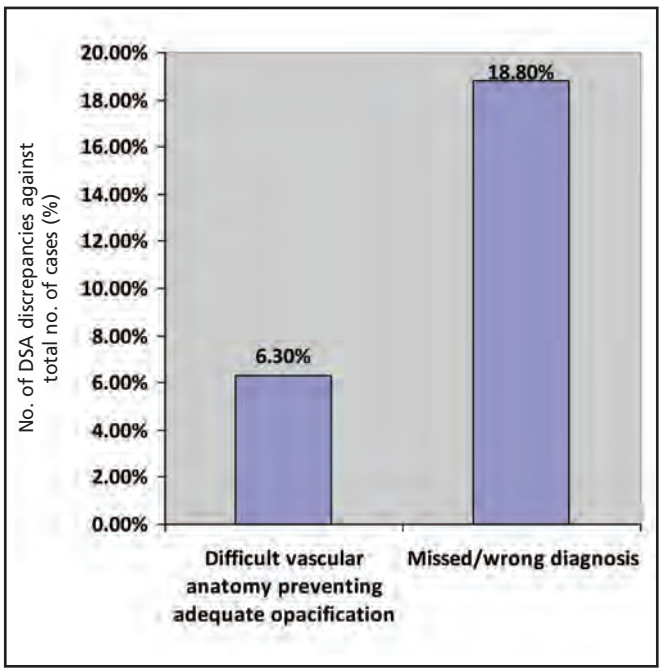

Chart 2b : Causes of discrepancies in DSA reporting.

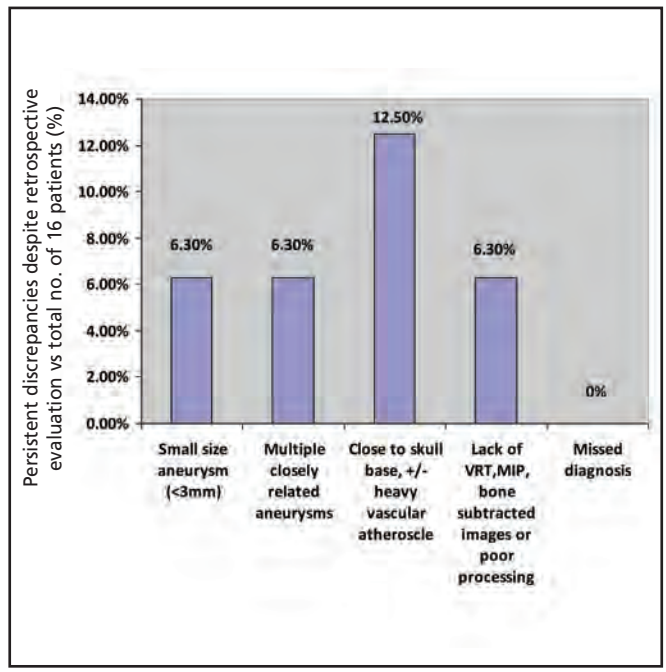

Chart 2c : Re-evaluation of images by Snr Neurointerventional radiologist.

involved with the post processing process. This was unfortunately illustrated in Patient 6, whereby the CT technician, assuming it as a normal vascular structure, unknowingly excluded a small AVM during bone subtraction process, resulting in the misdiagnosis (Figures 2a and 2b). CT technicians who are involved with post processing process must therefore be well trained and have adequate knowledge of the vascular anatomy.

iii. Interpreter-related errors

The initial reporting radiologists failed to detect 4 vascular lesions (Patients 9-12) – 3 of which were aneurysms in the PCOM region. Two of these 4 CTA studies (Patients 9, 11) were read initially by the less experienced on-call registrars. For Patient 9, a PCOM aneurysm was mislabeled as an infundibulum, whereas for Patient 11, the registrar reviewed the axial source images (Figures 3a-3d) that were the only available images on PACS (Picture Archiving and Communication System). The important VRT and MIP images were not available to the registrar for viewing during the on-call period.

From previous literature, shortcomings of bone subtracted CTA with reformatted 3D imaging include the difficulty in differentiating arterial loops or infundibula from aneurysms [12, 20, 21], particularly in the Posterior communicating artery (PCOM) region [6, 22, 23]. Experience, coupled with the necessity of 3D reformatted images is thus vital in minimising false negative findings.

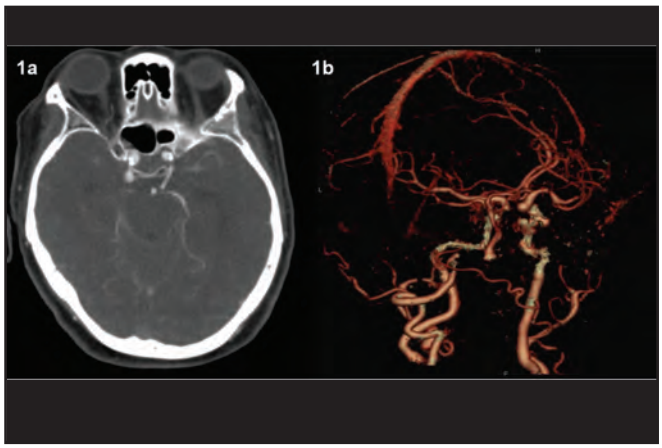

Fig. 1a : Axial CTA image shows right PCOM aneurysm with heavily calcified internal carotid arteries nearby.
Fig. 1b : VRT image with suboptimal bone subtraction (due to the heavily atherosclerotic carotid arteries at the skull base) poorly delineates the aneurysm.

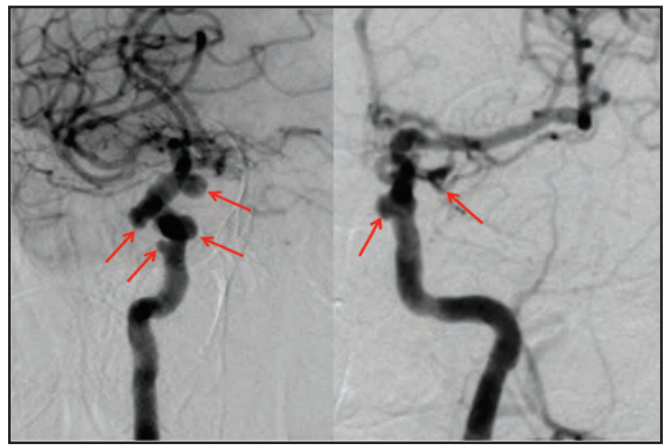

Fig. 1c : Selective angiograms of the right and left internal carotid arteries of the same patient demonstrate 6 aneurysms in total, all of which are located at the skull base (arrows).

Fig. 2a : Left parietal AVM is inadvertently excluded by the CT technician on bone subtracted 3D image.
Fig. 2b : The left parietal AVM is re-demonstrated on subsequent bone subtracted 3D image (arrow).

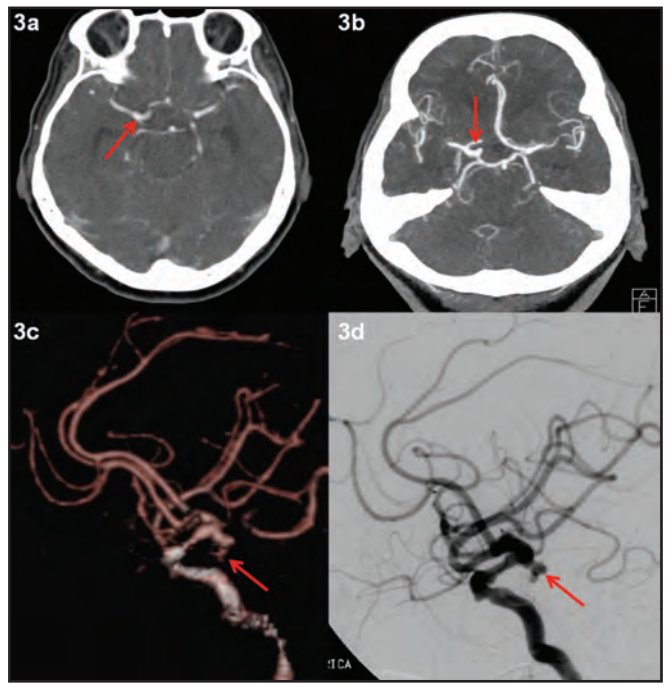

Fig. 3a & 3b : Axial CTA and MIP images, respectively, show right PCOM aneurysm (arrows) which is more conspicuous on the latter image. The aneurysm was initially missed by the registrar on-call, without the benefit of VRT and MIP images.
Fig. 3c : VRT image of the right anterior circulation demonstrates the right PCOM aneurysm (arrow). Figure 3d: Selective angiogram of the right internal carotid artery in lateral projection confirms the right PCOM aneurysm (arrow).

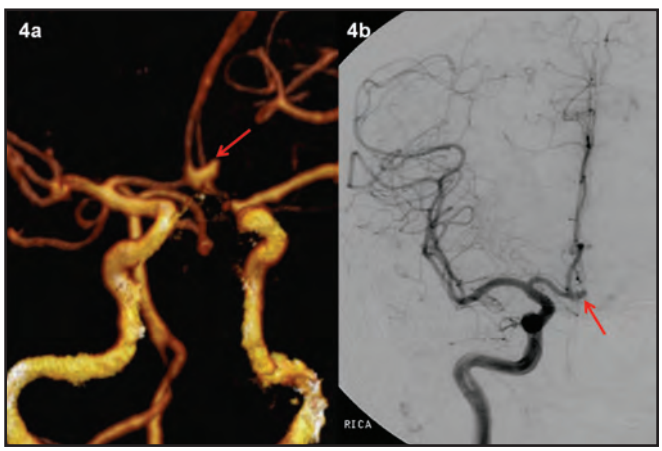

Fig. 4a : VRT image demonstrates ACOM aneurysm.
Fig. 4b : Selective angiogram of right internal carotid artery in AP projection confirms the CTA finding. This was, however, missed by the procedurist initially.

iv. Separate evaluation of anonymised images by Snr Neurointerventional radiologist

There was high concordance of LEH's CTA findings with subsequent definitive surgery/coil embolization results, in particular those cases with interpreter related errors (100% concordance). This suggests that the errors made (and hence unnecessary DSA) were less likely with increased experience of the reporter, where conscious effort had been made to review the PCOM (Patients 9, 11 and 12) / base of skull (Patients 7 and 8) regions. For lesion and technical related discrepant cases, those with either too small an aneurysm (< 3mm, Patient 1), multiple closely clustered aneurysms (Patient 3), base of skull lesions with overprojecting bony structures/heavy vascular calcification (Patient 3 and 6) and lack of/inadequate VRT/MIP/bone subtracted images (Patient 4), prevented accurate diagnosis, even on further retrospective review. From this vital point, it can be inferred that there can be substantial limitations to CTA. By being aware, should there be strong clinical suspicion of intracranial vascular pathology (eg unaccounted subarachnoid hemorrhage at the base of skull region), the clinician must not hesitate requesting DSA for further evaluation.

DSA discrepancies

DSA is widely accepted as the 'gold standard' for investigation of intracranial vascular lesions, offering better spatial and contrast resolution with no interference from bony structures. In addition, 3D rotational angiography (3DRA) is able to provide more exact and precise anatomical details [24, 25]. However, it is heavily operator-dependent and time consuming. Furthermore, DSA is not absolutely without errors. Pathirana et al reported initial negative IA-DSA results in 20.3% of patients with SAH; whereupon repeat angiography demonstrated aneurysms in 30% of these patients [26]. Other authors have reported incidence of aneurysms in 11.7% and 21% on repeat angiograms [27, 28]. In our series, 5 (31.2%) of the discrepancies were DSA-related.

i. Technical-related errors

Postulated explanations for vascular lesions, in particular aneurysms, being demonstrated on CTA but not DSA include complex regional vascular anatomy, rotational limitations of the C-arm fluoroscopy, location of aneurysm at vessel bifurcation and inadequate projections due to patient incorporation or projections out of standard protocol [6, 29]. Similarly, in one of the patients (Patients 13), the aneurysm reported on CTA could not be confirmed due to the underlying vascular anatomy, preventing optimal delineation of the region of interest on DSA. However on follow up CTA/MRI studies, the lesion in the right vertebral artery (7mm aneurysm) was convincingly re-demonstrated.

ii. Interpreter-related errors

In an another patient (Patients 14), the reported small aneurysm was probably 'overcalled', with the reported 'PCOM aneurysm' not reproducible on the subsequent follow up DSA studies, as well as not detected during the re-evaluation and thus deemed to be the infundibulum rather than an aneurysm.

In two patients (Patient 15-16), the procedurists failed to identify the vascular lesions despite the availability of prior CTA reports for comparison. During the re-evaluation the DSA images demonstrated 2 out of the 3 vascular lesions (Figures 4a and 4b). These errors were probably experience- and situational-related, and have been discussed during discrepancy rounds to prevent similar occurrences in the future.

iii. Separate evaluation of anonymised images by Snr Neurointerventional radiologist

There was again complete concordance of LEH's DSA findings of the discrepant cases with subsequent definitive surgery/coil embolization results after review of the available images. This confirms error occurrences as detailed are likely related to the experience/interpretation of the individual operators.

CONCLUSION

With technological advancement and the increasing availability of CT scanners, CT brain and CTA has become a useful and necessary tool for initial evaluation of the obtunded patient. It is thus imperative to be aware of not only the benefits of CT, but also its limitations; request for further DSA evaluation is suggested should there be strong clinical suspicion of intracranial pathology. From the results of our study, we recognise the need for up to date CT scanners which can provide high level image quality, and more importantly, the necessity of post processing 3D reformations (e.g. VRT, MIP) and bone subtraction techniques. Emphasis on the importance of well-trained technical staff who are familiarised with the scanning protocol specific to each CT scanner, is pivotal to ensure high image quality to improve the diagnostic accuracy of CTA.

A significant proportion of the discrepancies were related to the inexperience of the reporting staff involved; 4 during CTA reporting and 3 during DSA reporting (these had all been accurately diagnosed on retrospective audit by our senior neurointerventional radiologist). Discrepancies encountered were also possibly aggravated by work environmental factors such as stress and fatigue, especially during the on-call hours. This could partially be off-set by having protocols whereby cases encountered by junior doctors on-call were to be reviewed as soon as possible by a senior radiologist. Constructive feedback should be provided to the staff involved for future improvement and errors can be further minimized by fostering an amicable environment where the junior staff can consult their senior colleagues without difficulty. Whilst DSA is undoubtedly superior in many aspects to CTA, it does have its limitations, such as difficult vascular access and being heavily operator (also the interpreter)-dependent.

It is to our knowledge that there has been no similar audit in the available literature detailing the common errors encountered during daily reporting practice. Thus, by identifying and increasing awareness of these discrepancies, we hope that future errors can be minimized, to the benefit of the patient and the healthcare system.

REFERENCES

1. Qureshi AI, Tuhrim S, Broderick JP, *et al.* Spontaneous Intracerebral Hemorrhage. New England Journal of Medicine. 2001; 344(19): 1450-60.
2. Yoon DY, Chang SK, Choi CS, *et al.* Multidetector row CT angiography in spontaneous lobar intracerebral hemorrhage: a prospective comparison with conventional angiography. AJNR Am J Neuroradiol. 2009; 30(5): 962-7.
3. Romijn M, Gratama van Andel HA, van Walderveen MA, *et al.* Diagnostic accuracy of CT angiography with matched mask bone elimination for detection of intracranial aneurysms: comparison with digital subtraction angiography and 3D rotational angiography. AJNR Am J Neuroradiol. 29. United States2008. p. 134-9.
4. Lubicz B, Levivier M, Francois O, *et al.* Sixty-four-row multisection CT angiography for detection and evaluation of ruptured intracranial aneurysms: interobserver and intertechnique reproducibility. AJNR Am J Neuroradiol. 2007; 28(10): 1949-55.
5. Chappell ET, Moure FC, Good MC. Comparison of computed tomographic angiography with digital subtraction angiography in the diagnosis of cerebral aneurysms: a meta-analysis. Neurosurgery. 2003; 52(3): 624-31.
6. Karamessini MT, Kagadis GC, Petsas T, *et al.* CT angiography with three-dimensional techniques for the early diagnosis of intracranial aneurysms. Comparison with intra-arterial DSA and the surgical findings. Eur J Radiol. 2004; 49(3): 212-23.
7. Teksam M, McKinney A, Casey S, *et al.* Multi-section CT angiography for detection of cerebral aneurysms. AJNR Am J Neuroradiol. 2004; 25(9): 1485-92.
8. Tipper G, JM UK-I, Price SJ, *et al.* Detection and evaluation of intracranial aneurysms with 16-row multislice CT angiography. Clin Radiol. 2005; 60(5): 565-72.
9. Yoon DY, Lim KJ, Choi CS, *et al.* Detection and characterization of intracranial aneurysms with 16-channel multidetector row CT angiography: a prospective comparison of volume-rendered images and digital subtraction angiography. AJNR Am J Neuroradiol. 2007; 28(1): 60-7.
10. Dammert S, Krings T, Moller-Hartmann W, *et al.* Detection of intracranial aneurysms with multislice CT: comparison with conventional angiography. Neuroradiology. 2004; 46(6): 427-34.
11. Willinsky RA, Taylor SM, TerBrugge K, et al. Neurologic complications of cerebral angiography: prospective analysis of 2,899 procedures and review of the literature. Radiology. 2003; 227(2): 522-8.
12. Cloft HJ, Joseph GJ, Dion JE. Risk of cerebral angiography in patients with subarachnoid hemorrhage, cerebral aneurysm, and arteriovenous malformation: a meta-analysis. Stroke. 1999; 30(2): 317-20.
13. van Gelder JM. Computed tomographic angiography for detecting cerebral aneurysms: implications of aneurysm size distribution for the sensitivity, specificity, and likelihood ratios. Neurosurgery. 2003; 53(3): 597-605.
14. Villablanca JP, Hooshi P, Martin N, *et al.* Three-dimensional helical computerized tomography angiography in the diagnosis, characterization, and management of middle cerebral artery aneurysms: comparison with conventional angiography and intraoperative findings. J Neurosurg. 2002; 97(6): 1322-32.
15. Sakamoto S, Kiura Y, Shibukawa M, *et al.* Subtracted 3D CT angiography for evaluation of internal carotid artery aneurysms: comparison with conventional digital subtraction angiography. AJNR Am J Neuroradiol. 2006; 27(6): 1332-7.
16. Villablanca JP, Jahan R, Hooshi P, *et al.* Detection and characterization of very small cerebral aneurysms by using 2D and 3D helical CT angiography. AJNR Am J Neuroradiol. 2002; 23(7): 1187-98.
17. Tomandl BF, Hammen T, Klotz E, *et al.* Bone-subtraction CT angiography for the evaluation of intracranial aneurysms. AJNR Am J Neuroradiol. 2006; 27(1): 55-9.
18. Jayaraman MV, Mayo-Smith WW, Tung GA, *et al.* Detection of intracranial aneurysms: multi-detector row CT angiography compared with DSA. Radiology. 2004; 230(2): 510-8.
19. Abrahams JM, Saha PK, Hurst RW, *et al.* Three-dimensional bone-free rendering of the cerebral circulation by use of computed tomographic angiography and fuzzy connectedness. Neurosurgery. 2002; 51(1): 264-8.
20. Fishman EK, Ney DR, Heath DG, *et al.* Volume rendering versus maximum intensity projection in CT angiography: what works best, when, and why. Radiographics. 2006; 26(3): 905-22.
21. Tomandl BF, Kostner NC, Schempershofe M, *et al.* CT angiography of intracranial aneurysms: a focus on postprocessing. Radiographics. 2004; 24(3): 637-55.
22. Velthuis BK, Rinkel GJ, Ramos LM, *et al.* Subarachnoid hemorrhage: aneurysm detection and preoperative evaluation with CT angiography. Radiology. 1998; 208(2): 423-30.
23. Velthuis BK, Van Leeuwen MS, Witkamp TD, *et al.* Computerized tomography angiography in patients with subarachnoid hemorrhage: from aneurysm detection to treatment without conventional angiography. J Neurosurg. 1999; 91(5): 761-7.
24. Hochmuth A, Spetzger U, Schumacher M. Comparison of three-dimensional rotational angiography with digital subtraction angiography in the assessment of ruptured cerebral aneurysms. AJNR Am J Neuroradiol. 2002; 23(7): 1199-205.
25. Anxionnat R, Bracard S, Ducrocq X, *et al.* Intracranial aneurysms: clinical value of 3D digital subtraction angiography in the therapeutic decision and endovascular treatment. Radiology. 2001; 218(3): 799-808.
26. Pathirana N, Refsum SE, McKinstry CS, *et al.* The value of repeat cerebral angiography in subarachnoid haemorrhage. Br J Neurosurg. 1994;8(2):141-6.
27. Juul R, Fredriksen TA, Ringkjob R. Prognosis in subarachnoid hemorrhage of unknown etiology. J Neurosurg. 1986; 64(3): 359-62.
28. Iwanaga H, Wakai S, Ochiai C, *et al.* Ruptured cerebral aneurysms missed by initial angiographic study. Neurosurgery. 1990; 27(1): 45-51.
29. Hashimoto H, Iida J, Hironaka Y, *et al.* Use of spiral computerized tomography angiography in patients with subarachnoid hemorrhage in whom subtraction angiography did not reveal cerebral aneurysms. J Neurosurg. 2000; 92(2): 278-83.