Clinical Utility of 64-row Multislice CT Angiography in the Detection of Cerebral Aneurysms in Acute Subarachnoid Haemorrhage

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SUMMARY

CT angiography (CTA) is a fast examination performed with a time-optimised contrast injection to enhance the cerebral arteries. Being a new imaging modality in our hospital, evaluation of the effectiveness of 64–row multislice CTA in detecting intracranial aneurysms in ruptured subarachnoid haemorrhage (SAH) cases is necessary. We conducted a descriptive prospective study by recruiting 30 consecutively operated SAH cases from May 2005 until November 2006. CTA findings were studied by radiologist and neurosurgeon and these were compared with operative findings. The sensitivity and specificity of CTA were 94.4% and 97.2% respectively. Approximately half of the patients were scanned within four hours and operated within 24 hours. In conclusion, CTA proves to be highly sensitive and specific in the diagnosis of intracranial aneurysms in our study.

KEY WORDS:
Subarachnoid haemorrhage, Intracranial aneurysm, Computed tomography (CT), CT angiography (CTA)

INTRODUCTION

Sarawak General Hospital acquired the 64-slice CT scanner which became fully operational on 15 January 2005. The introduction of this versatile tool has opened up an avenue in the investigation of intracranial aneurysms which before this was solely dependent on intra-arterial digital subtraction angiography (DSA). As time is of essence in the treatment of ruptured intracranial aneurysms (as high as 15% of patients are at risk of rebleed within a few hours of initial haemorrhage[2]), prompt localisation and hence appropriate treatment of intracranial aneurysms are crucial to save lives.

A number of studies have been carried out over the last decade or so to assess the effectiveness of CTA in the evaluation of intracranial aneurysms as compared to the gold standard DSA[7,16,18,25,26]. Being a relatively new imaging modality to both neurosurgeons and radiologists locally, a study was therefore initiated to assess the effectiveness of CTA in the accurate detection of intracranial aneurysms.

MATERIALS AND METHODS

Cases presented with acute subarachnoid haemorrhage which subsequently had CTA (with or without intervening DSA) followed by surgery were recruited from May 2005 until November 2006. Non-operated acute SAH cases or those who did not have CTA done (due to moribund state or extreme age) were excluded from the study. Informed consent from alert patients or immediate family members/guardian (if patients were unfit) was taken before each imaging procedure, with particular risk of contrast allergy and nephrotoxicity explained. All patients had their blood urea and serum creatinine checked prior to contrast administration.

CTA was performed with a 64-row detector machine (Siemens Sensation Cardiac, Siemens Medical Solutions, Germany) at 0.6mm collimation and 0.6 mm slice reconstruction. Recruits were injected with 40ml of non-ionic iodinated hypo-osmolar contrast (300 mg/ml) at 4ml per second followed by 50ml of normal saline via manual triggering from a power injector through a 16-gauge brannula set at the antecubital fossa. A region of interest placed within the internal carotid artery (ICA) just below the skull base was used as part of the bolus tracking method. Review of CT angiogram was performed on workstation by radiologist and neurosurgeon on-call using Maximal Intensity Projection (MIP) and 3-dimensional Volume Rendered Technique (VRT).

Data collection was twofold, i.e. demographics of recruits (refer to Part I of Results) and actual CTA results (refer to Part II). Besides age and gender, the former included the presenting symptoms and corresponding World Federation of Neurological Surgeons (WFNS) grading as well as Glasgow Outcome Scale (GOS) upon discharge. The latter looked at the type, multiplicity and morphology (largest dimension and size of neck) of aneurysms. Clinical effectiveness would be gauged with timeline parameters (duration taken from attending to recruits until the time of CTA, and subsequently from CTA until commencement of surgery). Results of CTA were compared with those of DSA and/or surgery to yield the sensitivity and specificity of CTA in the detection of intracranial aneurysms.

RESULTS

Part I

A total of 30 patients were recruited, with female to male ratio of 1.5:1. The age of recruits ranged from 18 to 78 years, with mean age of 54 years. Sixty percent were aged 50 and above. Chinese stood out as the predominant race in our study

This article was accepted: 28 April 2008
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(50%), followed by the indigenous (30%) and the rest were Malay patients.

Majority of patients presented with headache (73.3%) followed by loss of consciousness (66.7%). Half of the patients experienced nausea and vomiting. Seizure came as the fourth commonest presentation in a fifth of the patients. Approximately one tenth suffered from hemiparesis. Other neurological symptoms presenting in individual cases included hearing loss and aphasia.

The WFNS grading amongst the patients revealed a bimodal pattern, with Grade 4 as the commonest grading (40%) followed by Grade 2 (23.3%). 16.7% of the patients presented with WFNS Grade 1 whereas the remainder were distributed evenly within Grade 3 and 5 (Figure 1). Thirty percent of our patients attained full Glasgow Outcome Scale upon discharge. Three patients (10%) passed away, with one of them dying more than two months after surgical clipping, due to abdominal sepsis.

Part II

There was no complication encountered during the imaging process throughout the study. A total of 36 aneurysms (both true positives and false negatives) were identified based on CTA. Four patients harboured double aneurysms (two had aneurysms arising from a common parent artery whereas the other two from different parent arteries). One patient was found to have three aneurysms from different parent arteries (Figure 2).

The sensitivity and specificity for the presence of aneurysms detected via CTA against operative findings were 94.4% and 97.2% respectively (Table I). The sensitivity for detecting aneurysms sized less than 3mm was 71.4% as compared to 100% for those larger than 3mm.

Majority of the CTA-detected aneurysms (88.9%) were located within the anterior circulation. Out of these, 15 (41.7%) were anterior communicating (ACOM) artery aneurysms, 9 (25%) middle cerebral artery (MCA) aneurysms, 5 (13.9%) distal ICA aneurysms and 3 (8.3%) posterior communicating (PCOM) artery aneurysms. The remaining posteriorly located aneurysms comprised of three vertebro-posterior inferior cerebellar artery (Vertebro-PICA) aneurysms and one posterior cerebral artery (PCA) aneurysm (Figure 3).

CTA detected 7 (19.4%) small aneurysms measuring 3mm or less at their largest dimension (Table II). At the other extreme, CTA picked up 5 (13.9%) aneurysms with the largest diameter of more than 1cm. Mean diameter of the aneurysms detected in our series was 6.2mm. The largest aneurysm detected was that of a ruptured ACOM artery aneurysm which spanned 2cm.

CTA was also able to delineate most (91.7%) of the aneurysmal necks fairly clearly (Table III). Half of the aneurysms detected in our series were narrow-necked, i.e. measuring 3mm and below. The necks were unapparent in 3 ACOM artery aneurysms. These were respectively attributed by an aneurysm's origin at the confluence of anterior cerebral vasculature and, in another scenario, the complexity of double ACOM aneurysms merging at this region.

CTA has enabled prompt detection of intracranial aneurysms in our study. This is evidenced by the fact that nearly half (47.2%) of our patients managed to have CTA done within four hours of diagnoses (based on time of plain CT brain done in our hospital) or presentation to the Accident & Emergency Department (these included diagnosed patients who were referred from other medical centers equipped with CT scan). Nevertheless, the rest of the patients were still able to obtain their CT angiograms within 24 hours after stabilization and preparation (Table IV).

All our patients underwent clipping of aneurysms (one PCOM artery aneurysm was wrapped). More than half (56.7%) managed to be operated within the same day following CTA with or without intervening intra-arterial DSA. A further six patients (20%) had surgery within 24 to 48 hours. One patient with double MCA bifurcation aneurysms was operated only after four days of CTA in view of patient's poor pulmonary status requiring pre-operative optimization. Encouragingly, 76.5% of patients who underwent CTA solely were operated within 24 hours, with nearly a quarter (23.5%) being operated within six hours (Table V).

DISCUSSION

Acute spontaneous SAH accounts for 3% of all strokes, 5% of stroke deaths and more than a quarter of potential life years lost through stroke[1]. Approximately 85% of all spontaneous SAH is secondary to rupture of intracranial aneurysms[2]. As mentioned earlier, at least 15% of affected patients may experience early rebleeding within hours of onset. Hence early intervention is crucial to reduce morbidity and mortality resulting from SAH. The timely launching of a 64-slice CTA in our hospital two years ago served as a promising armamentarium in the prompt diagnosis of intracranial aneurysmal bleed, which before this was solely dependent on intra-arterial DSA prior to October 2005[3].

The demographic results of our studies parallel with that reported in related meta-analyses[4]. Linn *et al.*[2] demonstrated a female to male ratio of 1.6. Headache, as in this study, remained as the clinical hallmark of SAH. Seizure occurred more commonly amongst our patients when compared with various studies[5, 6] (20% compared to 6-16%). The average incidence of operated acute SAH cases had increased compared to five years ago based on the study by Wong *et al.*[3], i.e. 1.6 versus two cases per month. This could be attributed to the increased awareness and expanding healthcare services throughout the state of Sarawak. There were only two general hospitals which were equipped with CT scanner before 2003[3] while currently all the general hospitals have CT scanners.

CTA is a fast thin-section volumetric spiral CT examination performed with a time-optimised bolus of contrast medium in order to enhance the cerebral arteries[7]. Post-processing tools including maximum intensity projection (MIP), shaded surface display (SSD) and direct volume rendering (DVR) are employed complementarily in the precise detection of intracranial aneurysms. The former provides two dimensional images obtained from voxels within a defined volume at a single plane, with resultant loss of depth perception[8, 9, 10]. Unlike MIP, both SSD and DVR offered three dimensional images at a cost of threshold dependency[8, 9].

Table I: Number of Aneurysms based on CTA Findings versus DSA & Operative Findings

Aneurysm	CTA Findings	DSA Done	DSA Not Done	CTA vs. DSA Findings	Operative vs. CTA/DSA Findings
ACOM	15	6	9	same	same
MCA	9	3	6	1 false positive on CTA[1]	1 false negative on CTA[2]
ICA	5	3	2	1 false positive on DSA[3]	same
PCOM	3	3	0	same	same
V-PICA	3	3	0	same	same
PCA	1	1	0	1 false positive on CTA[4]	no operation
Total	36	18	17		

[1] no evidence of aneurysm at MCA trifurcation on DSA
[2] small unruptured bifurcation-M2 aneurysm detected intraoperatively but not on CTA
[3] calcified ICA mimicking aneurysm
[4] 1 false positive on CTA (a patient who was diagnosed to have three aneurysms on CTA was later found to have only two aneurysms, i.e. ACOM and left PCOM artery aneurysms on DSA)

Table II: Largest Dimension of Aneurysms Detected with CT Angiography

Size (mm)	No of Patients (%)
<2	2 (5.6)
2.1-3	5 (13.9)
3.1-4	2 (5.6)
4.1-5	7 (19.4)
5.1-6	6 (16.7)
6.1-7	2 (5.6)
7.1-8	3 (8.3)
8.1-9	3 (8.3)
9.1-10	1 (2.8)
>10	5 (13.9)
Total	36 (100)

Table III: Size of Neck of Aneurysms Detected with CT Angiography

Size (mm)	No of Patients (%)
<2	7 (19.4)
2.1-3	11 (30.6)
3.1-4	4 (11.1)
4.1-5	5 (13.9)
>5.1	6 (16.7)
Unclear	3 (8.3)
Total	36 (100)

Table IV: Intervals taken between Diagnoses (Plain CT Brain) or Admission (Referral Cases) and Time of CT Angiography

Intervals (hours)	No of Patients (%)
<30 minutes	1 (3.3)
30 minutes to 1 hour	3 (10.0)
1 to 2	5 (16.7)
2 to 3	4 (13.3)
3 to 4	4 (13.3)
4 to 5	0 (0)
5 to 6	2 (6.7)
6 to 12	4 (13.3)
12 to 24	7 (23.3)
Total	30 (100)

Table V: Intervals between CT Angiography (with/without intervening DSA) and Operation

Intervals (hours)	No of Patients undergoing both CTA and DSA	No of Patients undergoing CTA only
0-6	4	4
6-12	5	3
12-18	5	3
18-24	3	3
24-30	3	2
30-36	1	1
36-42	2	0
>42	7	1
Total	30	17

Table VI: Overall sensitivities and specificities of CTA from various studies

Author	Year	Sensitivity (%)	Specificity (%)
Hope JK, *et al.*[12]	1996	90.4	50
Tipper G, *et al.*[14]	2005	96.2	100
Rajagopal KV, *et al.*[15]	2003	97.2	100
Wintermark M, *et al.*[16]	2003	94.8	95.2
Ahmetoglu A, *et al.*[17]	2003	97.7	87.5
Alberico RA, *et al.*[11]	2004	96.0	100

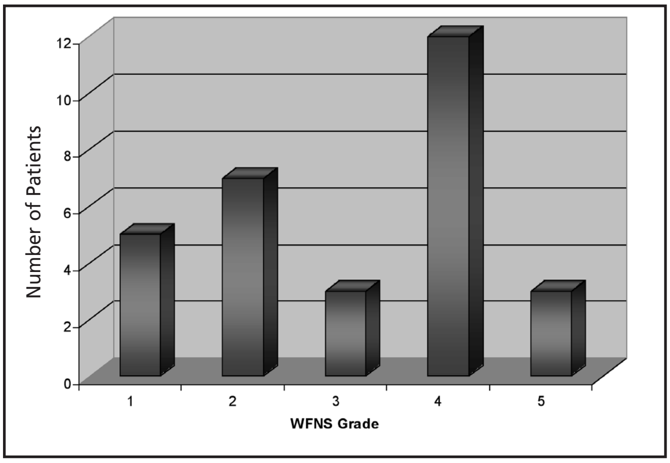

Fig. 1: WFNS Grading at Presentation of Recruited SAH Cases.

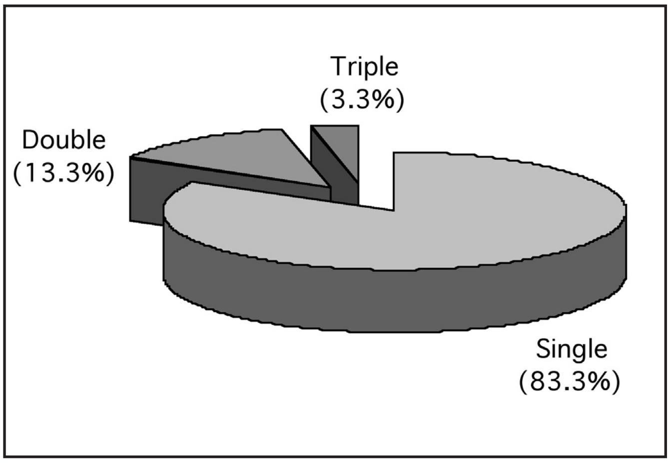

Fig. 2: Number of Aneurysms Detected with CT Angiography

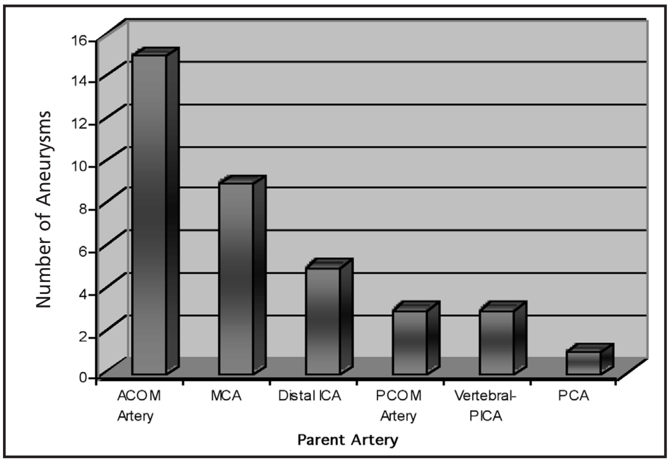

Fig. 3: Distribution of Aneurysms Detected with CT Angiography.

In a systematic review of studies published between 1988 and 1998, the average sensitivity of CTA for the detection of intracranial aneurysms was about 90%[8]. Others reported sensitivity ranged from 80-97%[11, 12, 13] depending on the size and location of aneurysm. With the improvisation of imaging technology since the 21st century, the overall pick-up rate of confirmed intracranial aneurysms had scored above 90% consistently[14-17] (Table VI). Our series yielded high sensitivity and specificity (94.4% and 97.2% respectively) comparable to that produced overseas[18-20]. This could be explained by the high detector-row set-up of CTA hence with better depiction of aneurysms.

Despite the high overall sensitivity of CTA in the detection of intracranial aneurysms, the main limiting factor which reduces the sensitivity significantly is the size of the aneurysm. The smaller the size of the aneurysm, the lower the detection rate will be. In our study, CTA failed to detect one very small MCA bifurcation aneurysm which was discovered only intra-operatively. This phenomenon was highlighted in various studies as well. Korogi *et al.*[21] reported a corresponding decline in the mean sensitivity of CTA depending on the size of the aneurysms, i.e. 64% for aneurysms <3mm, 83% for 3-4mm, 95% for 5-12mm, and 100% for aneurysms greater than 13mm. Similar observations had been reported by Teksam *et al.*[22] and Wintermark *et al.*[16]. The latter remarked that aneurysm size 2mm or less stood as the cutoff level below which the sensitivity of CTA was statistically lower. According to White *et al.*[23], current meta-analysis supported 3mm as a practical cutoff point, beneath which the sensitivity for aneurysm detection with CTA decreased sharply from 96 to 61%.

The anterior circulation aneurysms remained the predominant subgroups of all aneurysms detected via CTA. A recent study by Uysal *et al.*[9] demonstrated the ACOM artery aneurysms as the commonest (38%) followed by MCA aneurysms (32%). Posterior circulation aneurysms only constituted 9%. Rajagopal *et al.*[15] produced similar results with only 5% contributing to the latter. In our series, 11.1% comprised of aneurysms arising from the posterior cerebral circulation.

Besides high sensitivity and specificity, CTA conferred additional benefit in terms of pre-operative simulation. Three dimensional reconstructions at different planes and angles allow better delineation of aneurysmal neck[17], orientation and spatial relationship than a conventional DSA can offer as the latter usually operates with limited projections with false negatives as high as 5 to 10% in some series[9, 24]. In our study, the orientations depicted on CTA have assisted surgeons in determining surgical approaches, especially the bony anatomy. Predetermination of aneurysmal neck is important in proper selection of clips. Surgeons are also cautioned regarding the presence of calcification at neck which is readily visualized on MIP images[25,26]. The additional information of dome to neck ratio help to identify candidates for endovascular treatment[27].

CTA is not without pitfalls, thus explaining the two false negatives in our study. The infundibular dilatation of the origins of trifurcation of MCA was mistaken for a small aneurysm. There were instances whereby small aneurysms were obscured by arterial branches[8]. Small arteries measuring less than 1.2mm in diameter needing preservation intra-operatively, e.g. anterior choroidals and thalamoperforators, may not be visualized at low spatial resolution[9, 27]. Vascular kinks, kissing vessel artifacts[8], venous contamination and 'difficult' locations of aneurysms (e.g. intra-cavernous ICA segment[28] and posterior circulation) further hinder aneurysm detection. Posteriorly located aneurysms are more difficult to assess due to it close proximity to underlying bony structures[9]. One distal ICA aneurysm in our series was nearly missed due to its partial obliteration by the anterior clinoid process. CTA is also unable to demonstrate collateral flow as in DSA and its image quality may be hampered by the degree of vasospasm.

A total of 43.3% of our patients were subjected to DSA for several reasons. These included confirmation of presence of multiple aneurysms (especially those arising from same parent artery) as well as to better delineate Vertebro-PICA aneurysms in three patients. DSA was also carried out to re-define the morphology of aneurysms located at the confluence of arterial branches, namely the ACOM complex, M1-2 and ICA-PCOM junctions. There had been a decline in the usage of DSA with time (eight patients in the latter half of 2005 versus five in subsequent year) as both surgeons and radiologists alike became more confident with the results produced by CTA.

Despite these shortcomings, there were already reports of cases where CTA revealed aneurysms that were not seen on standard DSA[29]. CTA is readily available with little preparation needed, leading to high proportion of our patients having CTA done within hours of presentation. The examination duration is considerably shorter with minimal motion artifacts[9]. Moreover, CTA may obviate the need of pre-therapeutic DSA in certain cases. Its versatility serves as a one-go imaging tool following the diagnosis of acute SAH[9]. In our series, one patient virtually had CTA done within 30 minutes after diagnosis of SAH was made via plain CT image using the same scanner. Though this translates into shorter waiting time for surgery for more than half of our patients who managed to be operated within 24 hours, the overall proportion of patients being operated within 48 hours has not increased since 2000[3]. This was partially attributed to the relatively static growth of intensive care facility. A number of our patients had to wait for availability of ICU bed before proceeding with surgery. The other reasons included time spent in waiting for the operating theatre to call for patients and in preparing patients for DSA. As mentioned before, patient factor, i.e. poor general condition needing prior optimisation, was a recognizable reason for delay for a few patients in our series. Nevertheless, there has been improvement in the overall survival rate as compared to the study done by Wong *et al.*[3] in Sarawak General Hospital from 2000 until 2002, as evidenced by the reduction of both the operative mortalities (20% to 10.7%).

Being a non-invasive tool with less radiation hazard than DSA[9], CTA is relatively safe in neurologically compromised patients when compared to DSA, as the latter does impose a recognized risk of permanent neurological damage in 0.1 to 0.5% (mean 0.3%) based on studies which recruited more than a thousand subjects[30, 31, 32, 33]. Permanent neurological damage denotes the occurrence of any new neurological sign or worsening of pre-existing neurological deficit during or within 24 hours of procedure which last more than seven days[34]. CTA is patient friendly as it allows short duration of examinations ideal for patients on monitoring and life support devices[9,21,28]. The usage of contrast was considerably less when compared to DSA. One of our patients who had nephrectomy years ago fared well even after usual administration of contrast during CTA.

This study was limited by several factors: as radiologists were not blinded to patients' presentation and both radiologists and neurosurgeons were free to interact at workstation, observer bias might confound the results of this study[23,28]. There was also lack of standardised interpretation method, which should preferably include the use of scoring system to rate the certainty of aneurysm presence and location[28]. Lack of experience in handling operator-dependent CTA data (especially during the earlier stage of the study which include the variable injection rate of contrast) could have influenced the sensitivity and specificity of aneurysm detection to a certain extent.

CONCLUSION

In conclusion, 64-row multislice CTA proves to be a highly sensitive and specific tool in the evaluation of intracranial aneurysms, especially those more than 3mm in size. In view of its favourable safety profile and ease of execution, CTA has become more widely accepted as the sole investigative tool in the evaluation of intracranial aneurysms for both radiologists and neurosurgeons in Sarawak General Hospital, depending on the type and location of the aneurysms. Moreover, being a fast and efficient tool, relatively more patients were able to be operated on the same day the diagnoses were made. Albeit the above benefits, at times CTA has to be substantiated by the gold standard DSA particularly when doubtful cases are encountered.

ACKNOWLEDGEMENTS

The authors would like to extend their gratitude to all the doctors and nurses who rendered tireless care to our patients, and to the staff (radiologists, radiology medical officers, radiographers and supporting staff) of the Department of Radiology. Tributes are also paid to the staff of Medical Record Unit and Neurosurgical Outpatient Clinic for the record-tracing.

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