320-Row Multidetector CT Angiography in the Detection of Critical Cerebrovascular Anomalies

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ABSTRACT: *Background:* The acquisition of a new 320-row multidetector computed tomography angiography (CTA) scanner at the Montreal Neurological Institute and Hospital has provided higher quality imaging with less radiation exposure and shorter time of acquisition. However, its reliability has not been fully proven in critical vascular lesions when it comes to replacing a more invasive examination such as cerebral angiography. We wished to validate the accuracy of this equipment to investigate four common indications for patients to undergo conventional digital subtraction angiography: subarachnoid hemorrhage, vasospasm, unusual intracerebral hemorrhage, and unruptured aneurysm. *Methods:* Radiological reports and relevant imaging from 82 consecutive subjects who underwent a 320-row multidetector CTA followed by cerebral angiography from February 2010 to February 2014 were retrospectively analysed. A total of 102 cerebrovascular anomalies were found. Reports from both imaging modalities were compared to determine the diagnostic accuracy of CTA. *Results:* The overall sensitivity and specificity of 320-row multidetector CTA for detecting cerebrovascular abnormalities were, respectively, 97.60% and 63.20%. Similar results were obtained for all four categories of clinical indications. *Conclusion:* Results obtained from CTA were consistent with those obtained on digital subtraction angiography regardless of the vascular pathology. To our knowledge, this study is the first validating the accuracy of 320-row CTA in diagnosing critical cerebrovascular lesions.

RÉSUMÉ: Apport de l'angiographie par tomodensitométrie (320 barrettes) dans la détection de graves anomalies cérébro-vasculaires. *Contexte:* L'acquisition par l'Institut et l'hôpital neurologiques de Montréal d'un nouvel appareil d'angiographie par tomodensitométrie (ATDM) de 320 barrettes permet d'obtenir plus rapidement une imagerie de meilleure qualité tout en diminuant l'exposition aux radiations. Lorsqu'il s'agit de remplacer un examen davantage invasif comme l'angiographie cérébrale, sa fiabilité n'a toutefois pas été encore entièrement démontrée dans le cas de graves lésions vasculaires. Nous avons ainsi voulu valider la précision de cet appareil en ce qui regarde quatre indications cliniques fréquentes justifiant chez des patients un examen d'angiographie numérique avec soustraction : une hémorragie méningée, un vasospasme, une hémorragie intracérébrale inhabituelle et un anévrisme non rompu. *Méthodes:* De février 2010 à février 2014, nous avons analysé rétrospectivement des rapports radiologiques et des résultats pertinents d'imagerie chez 82 patients ayant subi des examens d'ATDM (320 barrettes) suivis d'examens d'angiographie cérébrale. Un total de 102 anomalies cérébro-vasculaires a été détecté. Les rapports et résultats de ces deux techniques d'imagerie ont du coup été comparés afin de déterminer l'exactitude diagnostique de l'ATDM. *Résultats:* De façon générale, la sensibilité et la spécificité de l'appareil d'ATDM (320 barrettes) pour détecter des anomalies cérébro-vasculaires ont été respectivement de 97,60% et de 63,20%. Des résultats similaires ont été obtenus pour les quatre catégories d'indications cliniques. *Conclusion:* Les résultats obtenus avec un appareil d'ATDM se sont révélés comparables à ceux obtenus au moyen de l'angiographie numérique avec soustraction, et ce, quel que soit le type de pathologie vasculaire. À notre connaissance, cette étude est la première à valider la précision de l'appareil d'ATDM (320 barrettes) pour diagnostiquer de graves lésions cérébro-vasculaires.

Computed tomography angiography (CTA) of the brain has reached a level of technical accuracy and reliability that will predictably make it the imaging modality of choice to diagnose virtually any vascular lesion, almost completely replacing the traditional digital subtraction angiography (DSA), an invasive and less readily available imaging modality associated with a 1% risk of neurological complications.[1] This shift in diagnostic practices seems even more likely since the advent of 320 multidetector CTAs, which increases diagnostic accuracy and reduces radiation exposure.[2,3] However, there is a lack of published local evidence on the use of this relatively new technique, which is why we decided to analyse a series of consecutive cases with acute intracranial vascular lesions, comparing findings on DSA and CTA.

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Currently, in our institution, indications to undergo DSA to exclude critical cerebrovascular anomalies include: subarachnoid hemorrhage (SAH) on plain CT head, clinical suspicion of unruptured aneurysm, clinical suspicion of cerebral vasospasm following an SAH, and unusual intracranial (intraparenchymal) hemorrhage (ICH) on plain CT head. These critical conditions have in common a high mortality and morbidity rate.[4-6] In our institution, DSA is almost always performed to confirm CTA findings, and in some cases to perform an endovascular procedure.

We hypothesize that, thanks to the high precision allowed by its number of detectors, a 320-row multidetector CTA may be used alone to rule out critical cerebrovascular anomalies when one of the previously mentioned indication warrants vascular imaging. Relying more on CTA would help us avoid unnecessarily submitting some patients to a traditional DSA. To verify this hypothesis, we assessed the reliability of 320-row multidetector CTA in diagnosing critical cerebrovascular anomalies by comparing it with traditional DSA.

METHODS

Data Collection

In our institution, the current standard of care is to first evaluate patients who present with potentially critical cerebrovascular anomalies with 320-row multidetector CTA and then perform DSA to confirm diagnosis or administer endovascular treatment. Retrospective analysis of our institutional databases determined that, between February 2010 and February 2014, 1211 CTAs of the circle of Willis were performed on 1035 patients and 1045 DSAs were performed on 741 patients. These two databases were then crossmatched to select CTA studies that were followed by DSA. To be included in this study, indications to perform the CTA study had to meet one of the following: SAH on plain CT head, suspicion of unruptured aneurysm on plain CT head, clinical suspicion of cerebral vasospasm following an SAH, or unusual ICH (intraparenchymal) on plain CT head. If the indication for the CTA study was either "suspicion of SAH on plain CT head" or "clinical suspicion of cerebral vasospasm," the DSA studies had to be performed within 24 hours following CTA studies because of the dynamic nature of these conditions. The final diagnosis of each CTA and DSA study was determined by analyzing the radiological reports. If more than one cerebrovascular anomaly was found on either CTA or DSA, they were marked as separate entries. Sensitivity and specificity of CTA to accurately detect critical cerebrovascular anomalies was then calculated, using DSA as the gold standard. As a result of this analysis, 83 CTA studies with their accompanying DSA studies met inclusion criteria. These studies were performed on 82 patients (i.e. one patient underwent CTA and DSA twice) and yielded 102 cerebrovascular anomalies (Figure 1).

CTA

All CTA images were acquired using a 320-row multidetector CT scanner (Aquilion One, Toshiba Medical Systems, Tokyo, Japan). Scanning was from skull base to vertex. Intravenous iodinated contrast material (iopamidol, Isovue 370; Regional Health Limited, Auckland, New Zealand) was administered peripherally with an automated injector (BRACCO E-Z EM EmpowerCTA Dual Injector; Siemens Medical Solutions, Malvern, PA). A test bolus, consisting of 20 ml of contrast
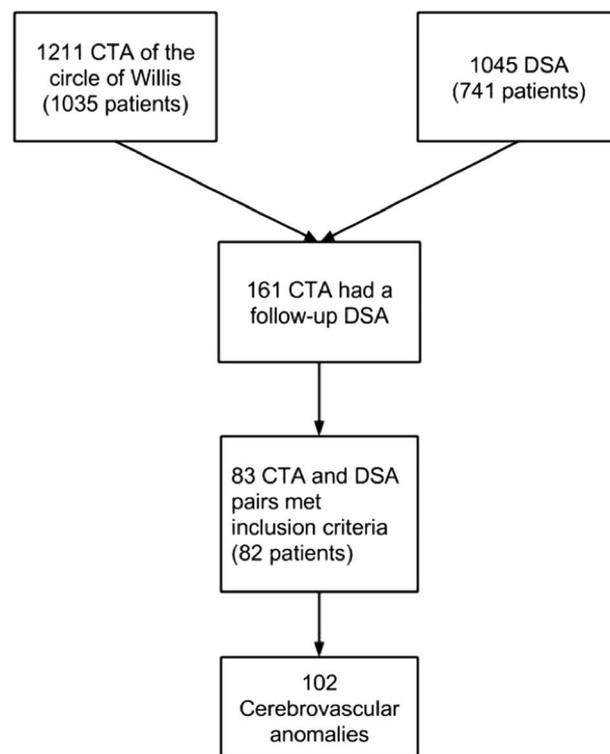

Figure 1: Data Collection.

material injected at 4 ml/second followed by 20 ml of saline at 4 ml/second, was administered before image acquisition. Next, 60 ml of contrast material was injected at 4 ml/second followed by 20 to 40 ml of saline for the acquisition of images. Adequate timing of the CTA acquisition was achieved using a bolus-tracking technique (Figures 2-4).

Cerebral DSA

With the patient under localized or general anesthesia, the right groin was prepared using standard techniques. Biplane DSA (Advantx, GE Healthcare, Waukesha, WI, or Infinix-i, Toshiba Medical Systems, Tokyo, Japan) was performed using a transfe-moral approach. Using a #4 French Osborn catheter, selective catheterization of the vessels was performed. Anteroposterior, lateral, and when necessary oblique views or three-dimensional angiography of bilateral vertebral and internal carotid artery injections were obtained. The contrast media (Iodixanol, Visipa-que; GE Healthcare Ireland, Cork, Ireland) was injected either manually or through a power injector (BRACCO E-Z EM EmpowerCTA Dual Injector). For the internal carotid artery, the rate of injection was 4 ml/second for a total of 6 ml, whereas for the vertebral arteries the injection rate was 3 ml/second for a total volume of 5 ml.

RESULTS

The median age of the 82 subjects who underwent the diagnostic studies selected for this study was 55.7 years. The proportion of female subjects (67.1%) was higher than that of male subjects. Only one patient underwent more than one CTA study, which met inclusion criteria for this study. The most
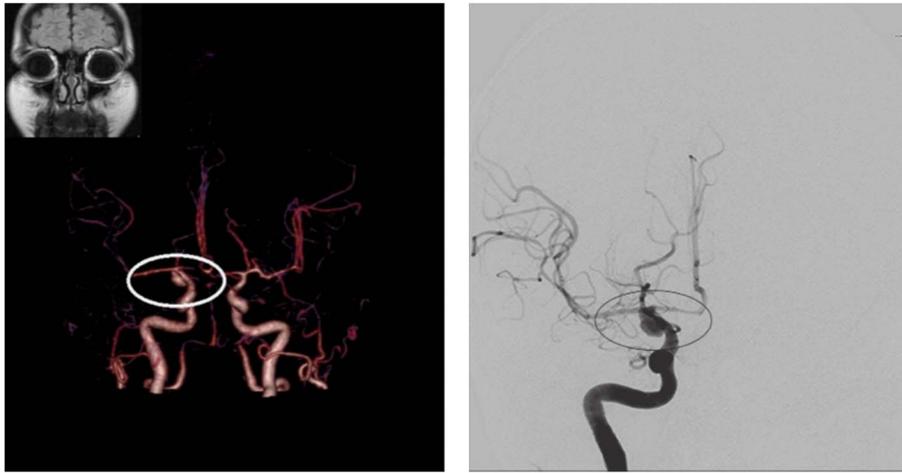
Figure 2: Right internal carotid artery aneurysm as visualized on CTA (left image) and DSA (right image).

common indication to undergo vascular imaging was a finding of SAH on plain CT head (39% of subjects), whereas the least common indication was a clinical suspicion of post-SAH vasospasm (11% of subjects) (Table 1).

The shortest time delay between CTA and DSA was for "SAH plain CT" or "post-SAH vasospasm clinically" as an indication for vascular imaging, both having a median delay of 3 hours. The longest delays between CTA and DSA were found when the indication to undergo vascular imaging was "unruptured aneurysm clinically," with a median time of 32 days (Table 2).

When the indication to undergo vascular imaging was either "SAH on plain CT" or "unruptured aneurysm on plain CT," the most likely cerebrovascular anomaly to be found was an aneurysm. This was also true for all indications combined. Arteriovenous malformations were the most common cerebrovascular anomalies found when the indication to undergo CTA was an "unusual ICH on plain CT." Overall, CTA diagnosed arteriovenous malformations more frequently than DSA (12 vs 9), whereas DSA diagnosed a normal vasculature more often than CTA (19 vs 14) (Table 3).

The overall sensitivity and specificity of 320-row multi-detector CTA in diagnosing cerebrovascular anomalies, using DSA as the gold standard, were, respectively, 97.6% and 63.2%. CTA was most sensitive in diagnosing cerebrovascular anomalies when the indication to undergo vascular imaging was either "SAH on plain CT" or "post-SAH vasospasm clinically" (i.e. 100% sensitivity in both cases) (Table 4).

Overall, there were seven false positives and two false negatives (i.e. diagnosing a "normal vasculature" on CTA but later finding a cerebrovascular anomaly on DSA). Most false positives were in the context of an unusual ICH on plain CT (i.e. four of the seven false positives). The false-negative and false-positive cases are detailed further in Table 5.

DISCUSSION

To our knowledge, this is the first study that looked at the diagnostic accuracy of 320-row multidetector CTA for these four common indications to undergo vascular imaging. Our hypothesis that the high precision of 320-row multidetector CTA may allow
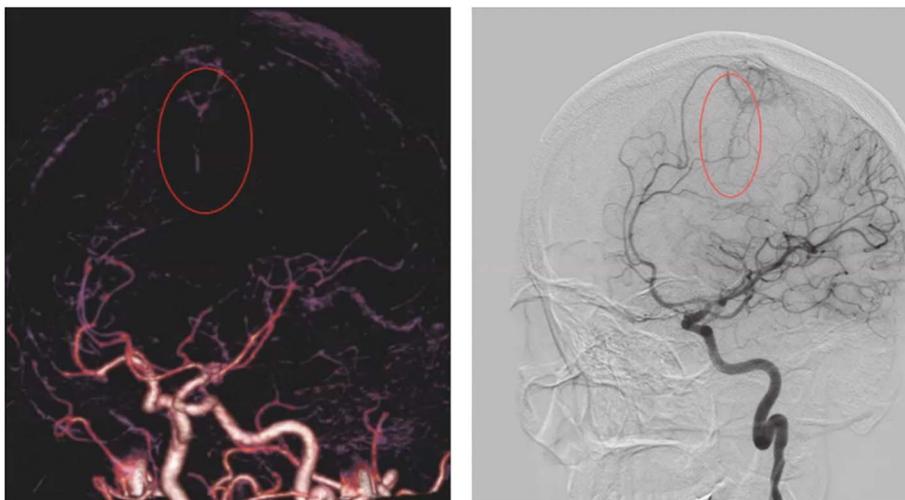

Figure 3: Left frontal arterio-venous malformation as seen on CTA (left image) and DSA (right image).
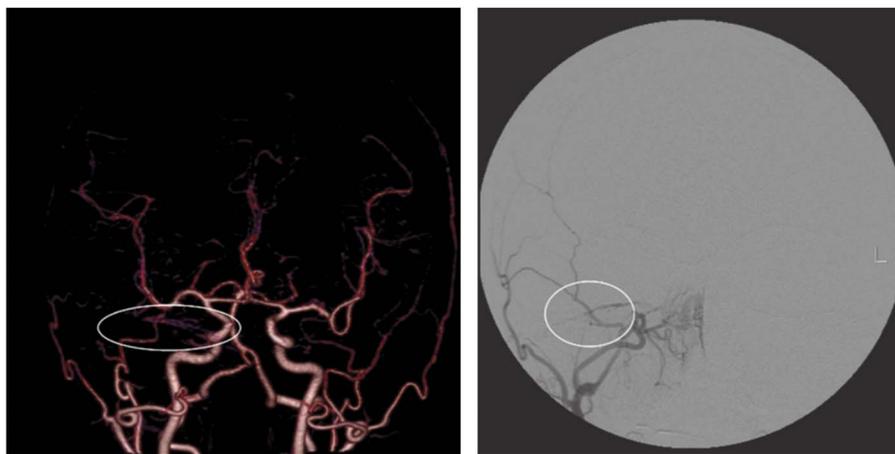
Figure 4: *Dural arterio-venous fistula visualized on CTA (left image) and DSA (right image).*

to accurately exclude critical cerebrovascular condition was supported by the overall high sensitivity (97.6%) found in this study. This high sensitivity was consistent throughout the four categories of indications to undergo vascular imaging that were investigated in this study. There were only two cerebrovascular anomalies that were missed on CTA. One of them was a small (2 mm), unruptured aneurysm that was incidentally found on DSA and was unrelated to the clinical presentation. In the second case, a small aneurysm (2 mm) was found 41 days after CTA on a follow-up DSA for a patient who presented with an unusual bleed on plain head CT.

Although the overall specificity was relatively low (63.2%), it is important to note that because of the potentially disastrous consequences of misdiagnosing a critical cerebrovascular anomaly, it may be wiser to err on the side of caution even if this implies having some false positives. This lower specificity was also possibly confounded by a low number of true negatives. This low specificity could also be due to selection bias because, in our institution, we do not necessarily do cerebral angiograms for negative CTAs in which we do not suspect a cerebrovascular anomaly. Furthermore, in at least one case (case 4), there was a strong clinical suspicion that the aneurysm had spontaneously thrombosed by the time DSA images were acquired.

Bearing in mind that it is difficult to compare the accuracy of multidetector CTA as assessed by different studies because of the lack of uniform protocols for interpreting CTA and variations in image acquisition techniques, the sensitivity of CTA in detecting cerebrovascular anomalies in the context of a SAH on plain CT (100%), as found in this study, does seem to be in agreement with the current literature. The specificity of CTA in this context (83.3%) is however lower than found in the literature using CTA with a smaller number of detectors. In a meta-analysis that included 41 studies and 4097 patients, Westerlaan et al indeed found that CTA had a pooled sensitivity of 98% and a pooled specificity of 100% in the diagnosis of cerebral aneurysms in patients with acute SAH. The gold standards used were either DSA or surgical findings. Thirty of the studies analyzed in this meta-analysis used a four-row multidetector CTA, whereas the balance used 16- and 64-row multidetector CTAs. There was no statistically significant difference in sensitivity and specificity between the different numbers of detectors.[7] Since the publication of this meta-analysis, Wang et al have looked at the diagnostic accuracy of 320-row multidetector CTA for the detection of cerebral aneurysms in the context of an acute SAH using DSA and surgical findings as the gold standard. They found similar results, with a sensitivity and specificity of, respectively, 96.3% and 100%.[8] In our series, the low specificity is, again, likely related selection bias because we did not include traumatic or perimesencephalic SAH, but only SAH in which aneurysm was thought to be the cause.

Regarding the use of 320-row multidetector CTA in the context of unruptured cerebral aneurysm on plain CT,

Table 1: Subject characteristics

Characteristic	Number $\pm$ SD (%)
Total number of subjects	82 (100)
Males	27 (32.9)
Females	55 (67.1)
Median age, year	55.7 $\pm$ 12.6
>1 CTA/DSA*	1 (1.2)
>1 cerebrovascular anomaly on either CTA or DSA†	23 (28.0)

*Number of patients of underwent more than one CTA/DSA.
†Number of patients in whom more than one cerebrovascular anomaly was found.
SD = standard deviation.

Table 2: Time delays between CTA and DSA

Indication for vascular imaging	Median $\pm$ SD (range)
SAH on plain CT	3.0 $\pm$ 9.0 (0.5-24) hours
Unruptured aneurysm clinically	32 $\pm$ 36 (<1-130) days
Post-SAH vasospasm clinically	3 $\pm$ 9 (0.5-21) hours
Unusual ICH on plain CT	3.5 $\pm$ 47.3 (1-184) days

ICH = intracranial hemorrhage.

Table 3: Cerebrovascular anomalies found on CTA and DSA per indication category

Indication for vascular Imaging	Number of imaging studies (%)*	Cerebrovascular findings, number (CTA-DSA)						
		Normal vasculature	Aneurysm	AVM	Pseudo-aneurysm	Vasospasm	MoyaMoya	Total number of findings
SAH on plain CT	32 (39.0)	5-6	36-35	1-1	0-0	0-0	0-0	42
Unruptured aneurysm clinically	18 (21.2)	1-1	21-21	0-0	0-0	0-0	1-1	23
Post-SAH vasospasm clinically	9 (11.0)	0-1	0-0	0-0	0-0	9-8	0-0	9
Unusual ICH on plain CT	23 (28.0)	8-11	8-8	11-8	1-1	0-0	0-0	28
All indications	83 (100)	14-19	65-64	12-9	1-1	9-8	1-1	102

*Numbers are for study pairs; for example, there were 32 CTAs accompanied by 32 DSAs that were performed for an SAH found on plain CT.

Ogawa et al, using a single-detector CTA, have found that CTA has a sensitivity and specificity in this context of, respectively, 70% and 100% when comparing it with DSA.[9] Subsequently, using a 64-row multidetector CTA, Hiratsuka et al found that CTA was 87% sensitive and 79% specific in detecting unruptured aneurysms.[10] The data obtained in our study confirm the trend whereby a higher number of detectors allows for a higher degree of sensitivity, with a calculated sensitivity of 95.5%. Whether or not this is accompanied by a decrease in specificity could not be assessed in this study because we had no true-negative findings in this category of indication.

In our study, 320-row multidetector CTA was found to have a sensitivity of 100% in detecting vasospasm following an SAH, which is higher than what had been reported previously in the literature. The false positive reported here may, in fact, represent a case of vasospasm that resolved with medical management in the 20 hours that elapsed between CTA and DSA image acquisitions. The prior studies published in the literature, which used 1-, 16-, and 64-row multidetector CTA, have found sensitivities that ranged between 63% and 98.1% and specificities that ranged between 81.5% and 99.2%. Again, specificity for this particular parameter could not be calculated because there were no true negatives of cerebral vasospasm found. In these studies, there was no strong correlation between the number of detector and sensitivity or specificity.[11-15]

Finally, the last indication to undergo vascular imaging investigated in this study was an "unusual intracerebral hemorrhage on plain CT." The high sensitivity (94.1%) found in this study was similar to what has been previously reported in the literature, with sensitivities ranging between 89% and 97.3%. These studies used 4-, 16-, and 64-row multidetector CTA.

The specificity found in this study for this particular indication (63.4%) was however markedly lower than what has been reported in the literature (92%-100%).[16-18] This may again constitute a selection bias, in that we do not perform vascular imaging for patients who are thought to have bleeding secondary to hypertension or amyloid angiopathy.

In conclusion, we found that 320-row multidetector CTA has an excellent ability to detect an entire range of critical cerebrovascular anomalies in any of the common indications to undergo vascular imaging, with an overall sensitivity of 97.6% when compared with DSA. When compared with studies that used CTA with fewer detectors, 320-row multidetector CTA seems to increase sensitivity at the cost of a lower specificity. Because of the high reliability of 320-row multidetector CTA for the four indications investigated in this study, the appropriateness of undergoing DSA following a negative CTA will need to be reassessed at our institution. These results will help us tailor our imaging protocols to avoid exposing patient, many of whom are quite sick, to an unnecessary procedure. We, however, expect that there will still be a need for DSA, especially when endovascular treatment is needed.

This study has some limitations. First, there was a relatively small number of subjects (82 patients, 83 study pairs), especially when divided by indication to undergo vascular imaging. Second, the absence of true negatives, probably resulting from selection bias, in some categories of indication prevented us from calculating specificity for two categories of indications (i.e. "aneurysm on plain CT" and "post-SAH vasospasm clinically"). Third, there was a significant variance of time between CTA and DSA when the indication to undergo vascular imaging was an unruptured aneurysm clinically or an unusual intracerebral hemorrhage on

Table 4: Sensitivity and specificity of the 320-row multidetector CTA in detecting cerebrovascular anomalies

Indication for CTA	Cerebrovascular anomalies found	False positive	False negative	True Positive	True negative	Sensitivity	Specificity
SAH on plain CT	42	1	0	36	5	100	83.30
Aneurysm on plain CT	23	1	1	21	0	95.50	NA
Post-SAH vasospasm clinically	9	1	0	8	0	100	NA
Unusual ICH on plain CT	28	4	1	16	7	94.10	63.40
Overall	102	7	2	81	12	97.60	63.20

NA = not available.

Table 5: Characteristic of false positive and false negative cases

Patient no.	Indication for vascular imaging	Age (year)/sex	Finding on CTA	Finding on DSA	Delay between CTA and DSA
False positives					
1	SAH on plain CT	56/M	Small (<2 mm) left supraclinoid ICA aneurysm	Normal vasculature	1 hour
2	Unruptured aneurysm clinically	36/F	6-mm infundibulum seen in right MCA. Aneurysm vs venous artifact	Normal vasculature	119 days
3	Post-SAH vasospasm clinically	48/M	Diffuse mild vasospasm (right supraclinoid ICA and left A1)	Normal vasculature	20 hours
4	Unusual ICH on plain CT	56/M	Right 4 mm PCA dissecting/mycotic aneurysm	Normal vasculature	2 days
5	Unusual ICH on plain CT	55/M	Right basal ganglia AVM supplied by right PCA	Normal vasculature	154 days
6	Unusual ICH on plain CT	35/M	Left choroidal vein developmental venous anomaly	Normal vasculature	9 days
7	Unusual ICH on plain CT	46/F	Right superficial temporal artery dural AV fistula	Normal vasculature	184 days
False negatives					
8	Unruptured aneurysm clinically	56/F	Normal vasculature	Left PICA 2 mm saccular aneurysm (incidental finding)	26 days
9	Unusual ICH on plain CT	63/F	Normal vasculature	2 mm A.Com. saccular aneurysm	41 days

A com = anterior communicating artery; AV = atrioventricular; F = female; ICA = internal carotid artery; M = male.

plain CT. This could be significant because vascular anomalies, such as aneurysms, can change in size over time; however, the nature of the vascular lesion would remain the same. Finally, the retrospective nature of this study warrants caution in generalizing our results to other institutions. Assessment of the reliability of 320-row multidetector CTA would benefit from further investigations in a larger randomized control trial.

DISCLOSURES

The authors have nothing to disclose.

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