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Diagnostic Value of 64-slice CTA in Detection of Intracranial Aneurysm in Patients with SAH and Comparison of the CTA Results with 2D-DSA and Intraoperative Findings

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ABSTRACT

Objective: To prospectively evaluate the diagnostic value of 64-slice CTA in detecting intracranial aneurysms and to compare it with 2D-DSA and/or intra-operative findings.

Material and Methods: 37 cases with SAH according to unenhanced cranial CT were included in the study. A 64-slice CTA was performed to all cases immediately after the nonenhanced cranial CT. DSA was performed in 24-48 hours following CTA. CT images were reviewed by two radiologists experienced in CT vascular imaging. The DSA reader was the angiographer who performed the DSA. The results of the CTA were compared with the DSA results and/or intraoperative findings in order to determine the diagnostic efficacy of CTA in detecting intracranial aneurysms.

Results: Sensitivity, specificity, positive predictive value, negative predictive value and accuracy of CTA in detecting aneurysms were 92.8%, 83.3%, 96.2%, 71.4% and 91.2% respectively. The diagnostic value of CTA in detecting intracranial aneurysms was found to be equal to DSA by Mcnemar test.

Conclusion: CTA is invaluable in detecting intracranial aneurysms. It may be used as a first line modality in SAH, and DSA may be reserved for patients with negative or equivocal CTA results.

Key Words: Intracranial aneurysm, Multislice CTA, Subarachnoid hemorrhage, Digital subtraction angiography

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Introduction

Rupture of an aneurysm is the major cause of subarachnoid hemorrhage (SAH). This condition has a mortality rate of 40-60%, and 10-20% of the survivors remain functionally dependent (1-3). Rapid diagnosis and an immediate treatment decision are of crucial importance because a delay in diagnosis increases the morbidity and mortality rate. Aneurysms may be treated by surgical clipping or endovascular intervention (4). In order to make the appropriate treatment choice, a neurosurgeon needs to be aware of the characteristics of the aneurysm, such as its localization, size and neck size. Digital subtraction angiography (DSA) has been the standard method for detecting and characterizing the intracranial aneurysms for decades. However, DSA is invasive, time consuming and expensive. It carries a 4% risk of neurological and non-neurological complications and 0.07%-0.5% risk of persistent neurological deficit (5-7). Thus, there is need for an alternate non-invasive modality to detect cerebral aneurysms. Nevertheless, in order to replace DSA, an imaging modality should have at least the same diagnostic accuracy as DSA in detecting and characterizing cerebral aneurysms. CT angiography (CTA) has been increasingly used for the diagnosis of intracranial aneurysms since 1990s (8). CT technology has rapidly evolved in the last decade and, especially with the introduction of multi-detector CT, the accuracy of CTA in detecting and characterizing intracranial aneurysms has increased significantly. The purpose of the present study is to prospectively compare the effectiveness of 64-slice CTA with DSA for the detection of intracranial aneurysms in a patient population with SAH.

Material and Methods

37 patients (14 male, 23 female, age range 27-80, mean age 57.4) who underwent both 64-slice CT angiography (CTA) and digital subtraction angiography (DSA) due to the detection of subarachnoid hemorrhage by non-enhanced cranial CT were included in the study. 64-slice CT (Toshiba Aquillon 64) angiography was performed immediately after the non-enhanced CT scan. A standard protocol (summarized in Table 1) was used in each CTA study. All of the CT images were diagnostic and there were no technical failures or complications. IV sedation was not needed in any patient. DSA, which is not available in our radiology department, was performed within 24-48 hours following CTA in another radiology laboratory. All of the DSA

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examinations were performed in the same laboratory and the DSA reader was the angiographer who performed DSA. CTA image analysis was performed by two radiologists experienced in CT vascular imaging. The reviewers of the CTA studies were aware of the results of the non-enhanced CT scan and they were informed about the clinical status of the patient from the clinical details written by the physician on the radiology request cards.

Image analysis in each CTA study took approximately 15-20 minutes. CT raw data were transferred to a workstation (Vitrea 2, Vital Images Inc., Minnetonka, Minn. USA) for further image processing and analysis. Axial source images were reviewed in the first order; sagittal and coronal reformat images and oblique multiplanar reformate (MPR) images were also used to delineate the features of the aneurysm and its anatomical relations in detail. Thick and thin slab maximum intensity projection (MIP) images and images reconstructed with volume rendering technique (VRD) were reviewed. After the two reviewers reached a consensus on the presence of an aneurysm, its location, shape and size were evaluated and noted.

CTA results were compared with the results of DSA and/or intraoperative findings to determine the diagnostic value of 64-slice CTA in detecting intracranial aneurysms.

Table 1. CTA protocol

64-slice CT Angiography Protocol	
Tube voltage (Kv)	120
Tube current (mAs)	250
Section thickness (mm)	0.5
Increment (mm)	2
Scan time (sec.)	6-9
Scan direction	caudo-cranial
Scan volume	from the first cervical vertebra to the vertex
Contrast material	
Total volume	65cc
Injection rate	4cc/sec
Concentration	350 mg I/ml
Bolus timing	'SURE START' function was used in which the opacification of ICA at the level of 4-5th cervical vertebra is evaluated by a continuously repeated low dose scan. When the initial filling of ICA with the contrast material is seen the acquisition is started manually

Results

37 cases (14 (37.8%) male, 23 (62.2%) female, age range 27-80 years, mean age 57.4+\-13.5) were included in the study. All of the patients were found to have SAH according to the non-enhanced cranial CT. In five patients no aneurysm was documented by CTA and DSA. Repeat DSA was also negative in these cases, which were considered as true negative CTA. In the remaining 32 cases, CTA identified 41 aneurysms. 32 of these were confirmed by DSA and/or surgery, while 9 aneurysms in 6 cases were not confirmed by either DSA or surgery. DSA identified 33 aneurysms in these patients. Two cases, one with an aneurysm located in the middle cerebral artery (MCA) and the other in the posterior inferior cerebellar artery (PICA) with diameters of 4 mm and 6 mm respectively, were missed by CTA. When the CT images of these cases were retrospectively reviewed, the two aneurysms were visualized (Fig.1). In one case, CTA clearly depicted the aneurysm (basilar artery aneurysm of 5mm), which was missed by DSA. The presence of this aneurysm was confirmed by surgery.

In three cases DSA was considered sub-optimal and its results were equivocal because patient positions needed to obtain the appropriate projections were not possible due to their critical clinical status and incorporation of these patients. On the other hand, the CTA which was performed successfully despite the poor clinical status detected 5 aneurysms in these 3 cases (Fig. 2). Since these three cases died before surgery, we had no opportunity to prove the existence of the aneurysms detected by CTA, Therefore, these cases were not included in the statistical analysis of the study.

Four aneurysms (all <4mm) defined by CTA in 3 cases were not illustrated by DSA. In two of these cases there were extra aneurysms defined both by CTA and DSA at other sites, which were responsible for the SAH. The four sites, which were defined as harboring an aneurysm only by CTA, were not

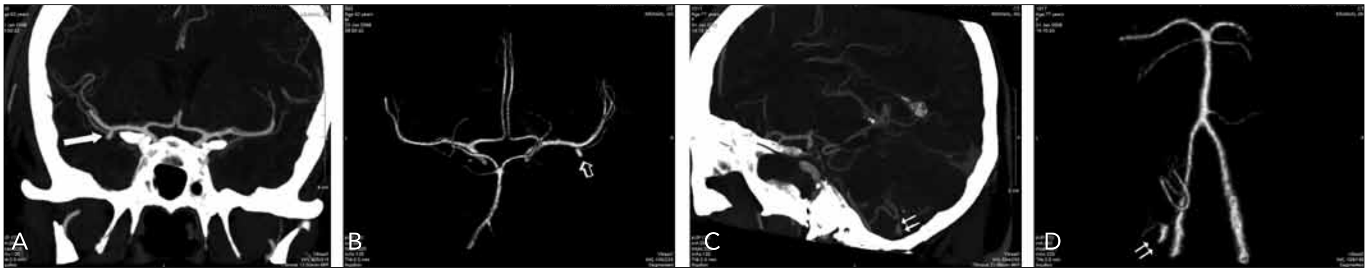

Figure 1. Two false (-) cases of CTA: 52 year-old male with an aneurysm located at the bifurcation of the first segment of MCA, and 77 year old female with an aneurysm located in PICA are shown. Both were depicted when the CT images were reviewed retrospectively. MIP image (A) and VRD image (B) of the MCA aneurysm, MIP image (C) and the VRD image (D) of the PİCA aneurysm

evaluated during the operation, as they were not the sites responsible for the SAH. Hence, their presence was not verified by surgery either. As CTA is not yet a gold standard modality in detection of intracranial aneurysms these 3 cases (4 aneurysms) were considered as false positive cases of CTA (Fig. 3).

The smallest aneurysm defined by CTA and confirmed by DSA had a diameter of 2.5 mm, which was located in the anterior communicating artery (Fig. 4). The largest aneurysm, which was located in the cavernous ICA, had a diameter of 5 cm (mean aneurysm diameter was 7 mm) (Fig. 5). Seven aneurysms (20% of the aneurysms) were smaller than 4 mm while 25 aneurysms (80%) were larger than or equal to 4 mm in diameter. There was inter-technique agreement between CTA and DSA regarding the size of the aneurysms. Six cases (16.2% of the cases) (3 females and 3 males) had more than one aneurysm. The most common localization of the aneurysms was the middle cerebral artery (MCA) M1 segment (43.75%), followed by the anterior communicating artery (Aco A) (34%) (distribution of aneurysm localizations is shown in Table 2).

Table 2. Distribution of aneurysm localizations

Localization of aneurysms	Number of aneurysms	Percentage of distrubation
MCA	14	43.75%
ACoA	11	34.3%
ICA	4	12.5%
ACA	1	3.1%
Basillar Artery	1	3.1%
SCA	1	3.1%

*MCA; middle cerebral artery, ACoA; anterior communicating artery , ICA; internal carotid artery, ACA; anterior cerebral artery, SCA; superior cerebellar artery

Patient data with the classification of aneurysm features (location, size) are summarized in Table 3.

When DSA and/or intraoperative findings were considered as the gold standard, sensitivity, specificity, positive predictive value, negative predictive value and accuracy of CTA in detecting aneurysms were 92.8%, 83.3%, 96.2%, 71.4% and 91.2% respectively. The diagnostic value of CTA in detecting intracranial aneurysms was found to be equal to DSA by the Mcnemar test. Two false negative cases of CTA had aneurysms with 4 mm and 6 mm in diameter. All the small aneurysms (<4 mm), which were detected by DSA and/or surgery, were defined by CTA and the sensitivity of CTA in detecting them was 100%.

Discussion

The use of CTA for the detection of intracranial aneurysms began during the mid-90s. Single slice CTA studies reported sensitivities varying from 67% to 100% (9-14). With the introduction of multi-slice technology, spatial and temporal resolution of CT has increased dramatically, and this increased the diagnostic value of CTA in detecting intracranial aneurysms. Numerous studies that compare the diagnostic efficacy of multi-slice

Figure 2. 53 year-old man with two aneurysms, one located at the fourth segment of vertebral artery and the other one located at the first segment of ICA and 44 year old woman with an aneurysm located at the terminal segment of ICA are shown. DSA results were equivocal in both of these cases due to poor clinical status and lack of cooperation. MIP image (A), VRD image (B) of the V4 aneurysm. MIP image(C) of the C1 aneurysm. Curvilinear calcification on the wall of the aneurysm is clearly depicted. MIP image(D) and VRD image (E) of the C7 aneurysm

Table 3. Patient data with the classification of aneurysm features (location, size)

Patient	Sex/Age	Aneurysm No	CTA result	Localization	Size (maximal diameter)	DSA result
1	F/32	1	positive	ACo A	4mm	positive
2	M/52	2	negative	Right MCA, M1	4mm	positive
3	M/50	3	positive	Basiller artery	5mm	negative (confirmed at surgery)
3		4	positive	Right SCA	6mm	positive
4	F/77	5	negative	Left PICA	6mm	positive
5	F/46	6	positive	Left MCA, M1	9mm	positive
5		7	positive	Basiller artery	2.5mm	negative
6	F/64	8	positive	ACoA	5mm	positive
7	F/65	-	-	-	-	-
8	F/48	9	positive	Left MCA, M1	5mm	positive
9	M/58	10	positive	Right MCA, M1	8mm	positive
10	F/54	11	positive	Left ICA, C6	15mm	positive
11	M/80	12	positive	ACoA	3mm	equivocal
11		13	positive	Right ICA, C5	2.5mm	equivocal
12	F/60	14	positive	ACoA	3mm	negative
13	M/69	15	positive	Right MCA, M1	8mm	positive
13		16	positive	Left MCA, M1	9mm	positive
13		17	positive	Right ACA, A1	2mm	negative
13		18	positive	Right MCA, M1	3mm	negative
14	M/34	19	positive	Left ICA, C4-5	50mm	positive
15	F/45	20	positive	Left ICA	3.5mm	equivocal
16	M/59	21	positive	Left ICA, C1	20mm	equivocal
16		22	positive	Left V4	7mm	equivocal
17	F/71	23	positive	ACoA	15mm	positive
18	F/49	24	positive	ACoA	3mm	positive
19	F/67	25	positive	ACoA	3.5mm	positive
20	F/66	-	-	-	-	-
21	F/77	26	positive	ACoA	3mm	positive
21		27	positive	Right MCA, M1	2.5mm	positive
22	F/58	28	positive	Left MCA, M1	4mm	positive
22		29	positive	Right MCA, M1	3mm	positive
23	M/46	30	positive	Right ICA, C7	15mm	positive
24	M/49	31	positive	Right ICA, C7	5mm	positive
25	M/43	32	positive	ACoA	8mm	positive
25		33	positive	Right MCA, M1	6mm	positive
26	F/65	34	positive	ACoA	4mm	positive
27	M/64	-	-	-	-	-
28	F/49	35	positive	Left MCA, M1	3mm	positive
29	F/73	-	-	-	-	-
30	F/65	36	positive	Right MCA, M1	10mm	positive
31	M/27	-	-	-	-	-
32	F/63	37	positive	Left MCA, M1	9mm	positive
33	M/45	38	positive	ACoA	6mm	positive
34	F/42	39	positive	Right ACA, A1	2.5mm	positive
34		40	positive	ACoA	7mm	positive
35	M/75	41	positive	ACoA	5mm	positive
36	F/64	42	positive	Left MCA, M1	4mm	positive
37	F/64	43	positive	Right MCA, M1	8mm	positive

*MCA: middle cerebral artery, ACoA: anterior communicating artery, ICA: internal carotid artery, ACA: anterior cerebral artery, SCA: superior cerebellar artery, PICA: posterior inferior cerebellar artery

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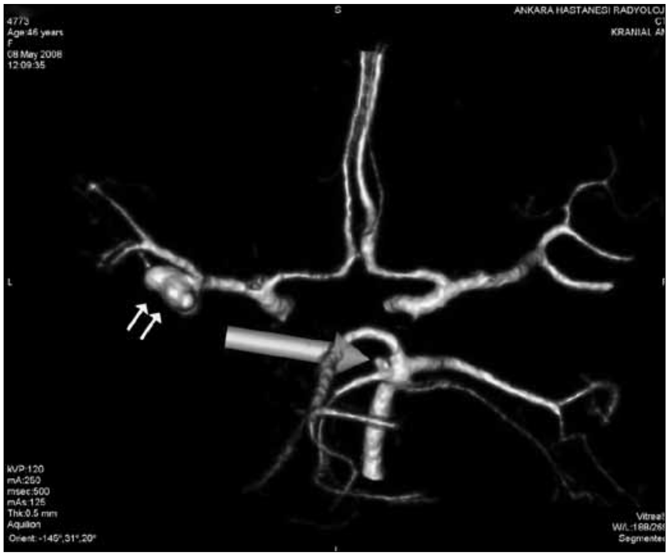

Figure 3. VRD image of a 46 year-old man with SAH. The aneurysm located in MCA was confirmed by DSA and clipped. Two radiologists who reviewed the CTA images had a consensus on the presence of a second aneurysm located at the orifice of left SCA. Because its presence was not confirmed by DSA and this site was not evaluated during surgery, it was considered as a false positive result of CTA

Figure 4. 42 years-old man with SAH. The VRD image of two aneurysms; one located in the ACoA and the other at the bifurcation of the first segment of the MCA (maximal diameter: 2.5mm). Both were confirmed by DSA

CTA with DSA have been published. The reported sensitivities of 4-slice CTA vary in the range of 81-100%, whereas the reported sensitivities of 16- and 64-slice CTA vary in the range of 92-100% (8, 15-24). The sensitivity of 92.8% found in the present study is consistent with the reported sensitivity values.

A significant observation of the present study is that the 64-slice CTA does not provide additional sensitivity over the 4- and 16-slice CTA in detecting intracranial aneurysms. Other authors (8, 23, 25, 26) have made the same observation, conclud-

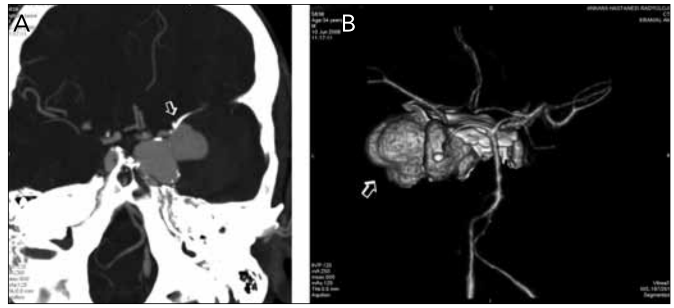

Figure 5. A 34 year-old man with SAH. MIP (A) and VRD (B) images of an aneurysm located at cavernous segment of ICA are seen. The aneurysm has a maximal diameter of 5cm. The thrombosed component and calcifications of the aneurysm are clearly depicted in the MIP image. In VRD image, while it is successful in depicting the calcifications, thrombus cannot be visualized

ing that 16-slice CT technology is adequate for the diagnosis of intracranial aneurysms. Mucelli et al. (8) has noted that 64-slice technology is superior in the evaluation of coronary arteries.

The size of an intracranial aneurysm is the most important factor influencing the sensitivity and specificity of CTA in its detection. There are studies that report a decrease in the sensitivity of CTA compared to DSA for the detection of intracranial aneurysms that are smaller than 3-4 mm (2, 4, 17, 20, 22, 23, 27-29), whereas others reported the superiority of CTA over DSA (26, 30, 31). In a report on the accuracy of 16-slice CTA, Chen et al. (26) found CTA to be 100% sensitive in detecting small aneurysms, 3 of which were missed by DSA. They also added that the major advantage of 16-slice technology over single-slice and 4-slice technologies is the increase in the detection sensitivity of these small aneurysms. According to DSA and/or intraoperative findings, 7 aneurysms (20%) were smaller than 4 mm in diameter in the present study. CTA clearly depicted all of them and the sensitivity in detecting small aneurysms was found to be 100%.

Two aneurysms, which were missed by CTA in the present study, were detected in the retrospective review of the CT images. Both of these cases occurred early in the study (the case with the 4 mm aneurysm located at RMCA was our first patient) when our experience was sub par. Lack of experience has been reported as a cause of misdiagnosis by other studies as well (2, 8, 18, 24, 32). Pedersen et al. (32) reported an increase in the sensitivity of CTA from 88% to 94% after 1 year's experience. Westerlaan et al. (1) recommends that if a cranial CTA study is reported as normal despite a strong clinical suspicion of a ruptured aneurysm, a second radiologist should review the study before scheduling a repeat angiography.

Previous studies reported that aneurysms in certain locations such as posterior communicating artery aneurysms, might be missed by CTA (2, 27, 33). The poor sensitivity in detecting posterior communicating artery aneurysms in these studies was attributed to their small size and their similar morphological characteristics with infindubular dilatations. Therefore, it is advisable to pay more attention when interpreting small aneurysms arising from the posterior communicating artery (2). Detection of aneurysms located adjacent to bone, such as petrous ICA, is limited both in single-slice and multi-slice CTA (2, 21, 23, 34). Although methods have been developed to subtract bone in CTA images (35, 36), we believe that visualization of the anatomy in three dimensions with 64-slice CTA, which has sub-millimeter section thickness and isotropic spatial resolution, mitigates this problem. Other authors have also supported this idea and reported that bone removal is not necessary (18). Venous contamination, especially when it occurs in the cavernous sinus, is reported as a limitation in detecting cerebral aneurysms by CTA (2). However with the 64-slice CT, improvement in the temporal resolution resulted in limited venous contamination. Using the appropriate CT protocol and evaluating the CT images with appropriate window and level settings are important in order to overcome the above-mentioned problems. Source images should be reviewed in each patient, as some information may be lost in the reconstructed images. In thick slab MIP images anatomical and pathological details adjacent to structures with a high density such as bone or calcified plaque may be obscured (18). In our experience, VRT images are better than MIP images in delineating the cerebral vascular anatomy as well as aneurysms.

Two-dimensional DSA has some limitations in depicting aneurysms in certain locations due to rotational limitation of the C-arm fluoroscopy or inadequate projections owing to lack of patient cooperation (2). Therefore aneurysms located in vessel bifurcations, in regions with complex vascular anatomy and small aneurysms may be missed by DSA (7, 8, 37). These limitations may lead to ambiguous results with DSA and decreases its diagnostic value (8). 3D rotational DSA has become increasingly used since its introduction in the last decade and has overcome the limitations described for 2D-DSA. It is reported that 3D-DSA can depict more aneurysms than 2D-DSA alone (8, 37, 38). Mc Kinney et al. (22) published a study on the comparison of the diagnostic value of 64-slice CTA with 3D-rotational DSA, and reported that 3D-DSA is more sensitive than 64-slice CTA in detecting intracranial aneurysms. In the present study, DSA results were equivocal in 3 cases due to poor clinical status and cooporation of the patient. CTA was successfully performed in them and detected 5 aneurysms. In two cases, CTA defined 4 aneurysms, all of them smaller than 4 mm in diameter, which were not confirmed by DSA and they were accepted as false positives in the present study. Given the fact there was no opportunity to exclude the presence of these aneurysms with another technique such as 3D-rotational DSA or surgery, we are not sure whether they were really false positive. Chen et al. reported that in studies where aneurysms were considered as false positive due to non-visualization by 2D-DSA were not always false positive results. They added that the theoretical criterion standard in detecting intracranial aneurysms should be 3D-DSA or surgery.

The role of medical imaging in patients with a ruptured intracranial aneurysm is not solely for depicting the aneurysm. It should delineate the morphological characteristics of the aneurysm, such as size (maximal diameter of the aneurysm and diameter of the neck), configuration, presence of thrombosis or calcifications, relation with the parent artery, presence of branch arising from the sac and relation with the surrounding soft tissue and bone (22, 24, 38). It is crucial to be aware of these characteristics to appropriately choose the treatment option (surgery or endovascular treatment) and minimize the operational complications. Numerous reports stated that patients with ruptured intracranial aneurysms could be treated based solely on the CTA findings (1, 23, 24, 30, 39). Westerlaan et al. (1) reported that they were able to treat more than 50% of their patient population based on CTA findings, while this percentage was reported as 95.7% and 86% by Agid et al. (24) and Hoh et al. (39), respectively. Studies which investigate the value of CTA in characterizing intracranial aneurysms have found that CTA results regarding the maximal diameter of the aneurysm and ratio between neck and dome diameter had good correlation with the findings of 2D and 3D- DSA (2, 22-24). In the present study, there was a good correlation between CTA and DSA in determining the maximal size of the aneurysms. CTA was also helpful in visualizing thrombosis or calcifications associated with the aneurysms.

There is a tendency to use CTA as the first-line modality in SAH patients and to reserve DSA for patients with equivocal CTA results. It is stated by various authors that, if an aneurysm is detected by CTA, there is no need for a DSA (1, 8, 22-24, 26). Kinney et al. (22) reported that detection of an aneurysm by CTA could be followed by selective DSA of the vessel harboring the aneurysm instead of complete (4 vessel) diagnostic DSA. When the CTA is normal in patients with SAH, it is advisable to perform DSA (23).

Conclusion

64-slice CTA is invaluable in evaluating patients with SAH. It is non-invasive, fast and easy to perform even in non-cooperative patients. It is possible to perform CTA immediately after a non-enhanced cranial CT. Hence, the elapsed time between the patients' arrival and achieving a diagnosis has been decreased by CTA, which is of crucial importance in the patient population with SAH which requires urgent treatment. It must be kept in mind that usage of the correct CT protocol and the experience of the radiologist on vascular CT and on reviewing the images at the workstation are important factors, which have an effect on the diagnostic efficacy of CTA in detecting and characterizing intracranial aneurysms.

Conflict of Interest
No conflict of interest was declared by the authors.

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