Original Research Article

INR INTERVENTIONAL NEURORADIOLOGY

Interventional Neuroradiology
1–6

DOI: 10.1177/15910199231222676
journals.sagepub.com/home/ine
Sage

RAPID aneurysm accurately measures aneurysm size on CT angiography compared to three-dimensional digital subtraction angiography

Sarah J Snyder[1], Andrew Gauden[1], Karen Copeland[2], Alejandro M Spiotta[3] and Jeremy J Heit[1]

Abstract

Background: Cerebral aneurysms are often identified and characterized on non-invasive CT Angiography (CTA) images, but digital subtraction angiography (DSA) is the gold standard for aneurysm evaluation.

Objective: We compared cerebral aneurysm size measurements as measured from CTA processed by a semi-automated artificial intelligence software program (RAPID Aneurysm) and three-dimensional rotational DSA (3D-DSA).

Methods: We performed a retrospective cohort study of consecutive patients with a cerebral aneurysm who underwent CTA and DSA with 3D reformations. CTA images were processed by RAPID Aneurysm to determine aneurysm height, width, and neck width. The reference standard was aneurysm measurements on 3D-DSA as measured by two neurointerventionalists. Both readers were blinded to RAPID Aneurysm measurements. Correlation and bias between these measurements were determined.

Results: Results from 50 patients with 50 aneurysms were compared. 32 patients (64%) were female. Median age was 65 (IQR: 56.25–71.75). 37 patients (74%) presented with ruptured aneurysms. The aneurysms represented a range of aneurysm sizes (1.9–33.3 mm; IQR 3.6–7.2 mm). RAPID Aneurysm size measurements showed excellent correlation and low bias (correlation, mean difference) when compared to the reference standard for aneurysm height (0.98, −0.9 mm), width (0.98, 0.1 mm), and neck width (0.94, 1.1 mm). The inter-reader comparison between the two neurointerventionalists was similarly excellent for aneurysm height (0.97, −0.4 mm), width (0.98, −0.2 mm), and neck width (0.89, 0.8 mm).

Conclusion: RAPID Aneurysm measurement of cerebral aneurysm height, width, and neck width on CTA is strongly correlated to expert neurointerventionalist measurements on 3D-DSA.

Keywords

Aneurysm, automated, artificial intelligence, CTA, digital subtraction angiography (DSA), rupture, size, measurement

Received 24 October 2023; accepted: 10 December 2023

Introduction

Cerebral aneurysms arise from intracranial arteries and are present in up to 6% of the population.[1,2] Cerebral aneurysm rupture results in significant morbidity and mortality, but successful aneurysm treatment before or after rupture improves these poor outcomes.[3–6]

CT angiography (CTA) is commonly performed for cerebral aneurysm detection, morphologic evaluation, and treatment planning.[5] Although CTA may accurately detect the presence of a cerebral aneurysm, the morphologic evaluation of aneurysms in the absence of specialized software is relatively limited. Digital subtraction angiography with three-dimensional (3D-DSA) reformatted images is the gold standard for aneurysm evaluation and treatment planning.[7] 3D-DSA images are used by neurointerventionalists to determine endovascular device (coil, stent, flow diverting stent, intrasaccular flow diversion device, etc.) sizing and working projections during aneurysm treatment. However, obtaining and analyzing these images takes time, during which patients are kept under general anesthesia with catheters positioned within the cervical arteries. This delay may increase the risk of a procedural complication and incurs inefficiency in aneurysm treatment. If similar treatment planning could be performed using non-invasive CTA images, patient treatment could likely be expedited.

[1]Department of Radiology, Stanford University School of Medicine, Stanford, CA, USA
[2]Boulder Statistics, Boulder, Steamboat Springs, CO, USA
[3]Department of Neurosurgery, Medical University of South Carolina, Charlestown, NC, USA

Corresponding author:
Jeremy J Heit, Department of Radiology, Stanford University School of Medicine, Stanford, CA, USA.
Email: jheit@stanford.edu

Recently, a new semi-automated artificial intelligence software program, RAPID Aneurysm (iSchemaView, Menlo Park, CA), has been shown to accurately detect cerebral aneurysms[8] and accurately assess aneurysm size[8,9] on CTA. RAPID Aneurysm generates a 3D volumetric image of the cerebral arteries that appears similar to a 3D-DSA image, which suggests that RAPID Aneurysm might be used to facilitate aneurysm treatment planning prior to digital subtraction angiography (DSA). However, how well these CTA-derived images correlate to 3D-DSA images for important aneurysm size measurements has not been established. In this study, we determined the accuracy of aneurysm measurements derived from RAPID Aneurysm compared to 3D-DSA in both ruptured and unruptured aneurysms.

Materials and methods

Study design

We performed a retrospective cohort study of patients who had a CTA prior to a 3D-DSA at our institution. Consecutive patients were included between two time periods 10/2017–5/2020 (3D-DSA images acquired on Siemens Artis Zee biplane system) and 11/2020–5/2022 (3D-DSA images acquired on Philips Azurion biplane system). Our study complied with the Health Insurance Portability and Accountability Act, and our institutional review board waived the need for informed consent.

Patient data collection, inclusion/exclusion criteria

Patient demographic data were collected from the electronic medical records system. CTA studies were performed on a variety of CT scanners (GE, Siemens, and Philips) from multiple institutions who referred patient to our neurovascular center. All CT scanners had a minimum of 64 detector rows for inclusion. CTA was performed by injection of iodinated contrast into an antecubital vein by power injection, and acquisition timing varied by site.

Inclusion criteria were: presence of a saccular aneurysm on CTA and 3D-DSA, CTA images with a slice thickness of 0.625 mm or less, and 3D DSA source images available for measurements. Exclusion criteria were: patients with blister, fusiform or pseudoaneurysms, artifact due to previously placed coils, stents or surgical clips, and CTA or 3D-DSA studies with excessive motion that degraded image quality. Patients with isolated cavernous internal carotid artery aneurysms were also not included given the extremely low risk of rupture and different natural history of these aneurysms.

RAPID aneurysm

RAPID Aneurysm is a semi-automated artificial intelligence software platform that was designed to automatically detect and measure cerebral aneurysms from CTA and MR Angiography images, and the performance of the software has been previously described.[8,9] In brief, the software ingests axial head CTA or 3DRA images and performs a thresholding-based, semi-automated image segmentation. The segmentation technique applies both global and local thresholds, and region-growing, to reconstruct a 3D surface model of the intracranial vasculature. Aneurysm detection and measurements are automatically generated by the software based on these 3D surface models.

Imaging analysis

All CTA and 3D-DSA images were anonymized for the analysis. CTA images were processed by RAPID Aneurysm, and aneurysm measurements (height, width, and neck) were automatically determined by the software.

3D DSA source data were analyzed using Horos (Horosproject version 4.0.0) in an independent and blinded manner by two neurointerventionalists (JJH with 10-years of experience and AJG with 2-years of experience). First, volume rendered images were constructed from the 3D-DSA source images to identify the largest aneurysm height, width and neck regions and to delineate the aneurysm neck. Next, the source data were analyzed in three orthogonal planes relative to the aneurysm neck based upon the volumetric views, and the largest aneurysm height, width and neck width measurements were obtained on two-dimensional images in the orthogonal planes described above. Raters were instructed to window the contrast to an approximate density of 800–900 Hounsfeld Units before performing measurements.

The reference standard (ground truth) for the study was pre-specified as the measurements obtained by an experienced diagnostic and interventional neuroradiologist (JJH with 10-years of experience). The measurements of the second rater were used to determine the inter-rater reliability of the reference standard.

Statistical analysis

Summary statistics are reported. Data counts with percentages or medians and shown with interquartile ranges (IQR). Paired differences and correlations were used to assess agreement and bias between methods. Statistical analyses were performed with IBM SPSS statistics (v 26.0).

Results

A total of 66 patients were identified, and 50 patients with 50 ipsilateral aneurysms on 3D-DSA met inclusion criteria and were analyzed (Supplemental Figure). Patient demographic, medical comorbidity, and family history data are summarized in Table 1. Aneurysm rupture was present in 37 patients (74%).

The anterior communicating artery was the most common aneurysm location (15 patients, 30%), and the distribution of the aneurysms is shown in Table 2. Multiple aneurysms were present in eight patients

Table 1. Patient characteristics.

Age and Sex	
Age (years), median (IQR)	65 (55.5–72)
Female, n (%)	32 (64%)
Hypertension	
Yes, n (%)	23 (46%)
No, n (%)	27 (54%)
Smoking Status	
Current Smoker, n (%)	8 (16%)
Former Smoker, n (%)	9 (18%)
Never Smoker, n (%)	30 (60%)
Unknown, n (%)	3 (6%)
Family History of Cerebral Aneurysm	
Yes, n (%)	1 (2%)
No, n (%)	8 (16%)
Unknown, n (%)	41 (82%)
Presentation with Aneurysm Rupture	
Yes, n (%)	38 (76%)
No, n (%)	12 (24%)

Table 2. Aneurysm characteristics.

Aneurysm Location	
Posterior communicating artery, n (%)	13 (26)
Anterior communicating artery, n (%)	19 (38)
Internal Carotid Artery, Ophthalmic Artery, n (%)	5 (10)
Internal Carotid Artery, Superior Hypophyseal, n (%)	4 (8)
Internal Carotid Artery, Anterior Choroidal, n (%)	1 (2)
Middle Cerebral Artery, n (%)	5 (10)
Basilar Artery, n (%)	3 (6)
Aneurysm Measurements (Reference Standard)	
Dome height (mm), median (IQR)	4.2 (4.2–7.4)
Dome width (mm), median (IQR)	6.3 (6.3–8.9)
Neck width (mm), median (IQR)	5.5 (5.5–7.4)

Table 3. Aneurysm agreement.

Correlations	Dome height	Dome width	Neck width
Reference & RAPID	0.9759	0.9767	0.9286
Inter-reader	0.9576	0.9808	0.8766
Mean Difference (mm)			
Reference & RAPID	0.8664	−0.0846	−1.0528
Inter-reader	0.3982	−0.2447	−0.8384

(16%), but none was within the same circulation as the 3D-DSA images, so only one aneurysm per patient was assessed. The median aneurysm dome height, dome width, and neck width measurements were 4.5 (IQR: 3.6–6.7), 6.3 (IQR: 4.3–8.5), 4.8 (IQR: 3.8–6.7), respectively (Table 2).

Automated RAPID Aneurysm size measurements showed excellent correlation and low bias (correlation, mean difference) when compared to the reference standard for aneurysm height (0.98, 0.9 mm), width (0.98, 0.08 mm), and neck width (0.93, −1.05). The inter-reader comparison was similarly excellent for the same parameters: height (0.96, 0.4 mm), width (0.98, −0.2 mm), and neck width (0.87, 0.8 mm) (Table 3). Representative case examples are shown in Figures 1 and 2.

Discussion

In this study, we found that RAPID Aneurysm accurately measures cerebral aneurysm size on CTA compared to 3D-DSA measurements performed by experienced interventional neuroradiologists. These results indicate that accurate aneurysm measurements may be obtained from non-invasive CTA imaging processed by RAPID Aneurysm prior to aneurysm evaluation by 3D-DSA. Our findings have important implications for neurointerventional aneurysm treatment planning.

Cerebral aneurysms are often initially evaluated on CTA, which is known to be sensitive for aneurysm detection.[5,7,10] Recently, RAPID Aneurysm was found to be highly accurate for aneurysm detection[8] and for aneurysm size determination[8,9] on CTA. While CTA is considered fairly accurate for aneurysm size assessment, it is challenging to accurately determine aneurysm size and morphology with submillimeter accuracy given the inherent spatial resolution of CTA.[5,11–14] Despite these limitations, there is generally good to very strong agreement between CTA and DSA measurements of aneurysm size.[14,15]

Aneurysm neck evaluation is known to be more challenging on CTA, and aneurysm neck size is a critical variable when considering endovascular and surgical treatment approaches.[14] For instance, wide-necked aneurysms are more commonly treated by endovascular flow diversion, stent-assisted coil embolization, Woven EndoBridge embolization, or surgical clipping. In our study, we found that RAPID Aneurysm had a stronger agreement with the reference standard for aneurysm neck measurement compared to a second rater, and aneurysm height and width measurements were strongly correlated to 3D-DSA measurements of both raters. We hypothesize that the superior performance of the software for aneurysm neck size measurements reflects the surface volume rendering technique that is more analogous to DSA than cross-sectional CTA source images.

Neurointerventionalists routinely review CTA images prior to aneurysm treatment, and CTA evaluation of aneurysms has been used to determine endovascular embolization versus surgical clip treatment decisions.[16–18] Endovascular treatment of cerebral aneurysms continues to expand in scope, and accurate endovascular treatment planning based upon non-invasive CTA or MRA imaging is likely to allow for streamlined patient consent and adequate equipment procurement prior to treatment.

3D-DSA is considered the gold-standard imaging modality for the evaluation of cerebral aneurysms, and aneurysm characteristics on 3D-DSA are used to determine endovascular treatment decisions.[19,20] Detailed assessment of aneurysm size and morphology on 3D-DSA is somewhat time consuming and often occurs during aneurysm treatment. At our institution, we routinely spend 20–30 min processing and studying 3D-DSA images. While

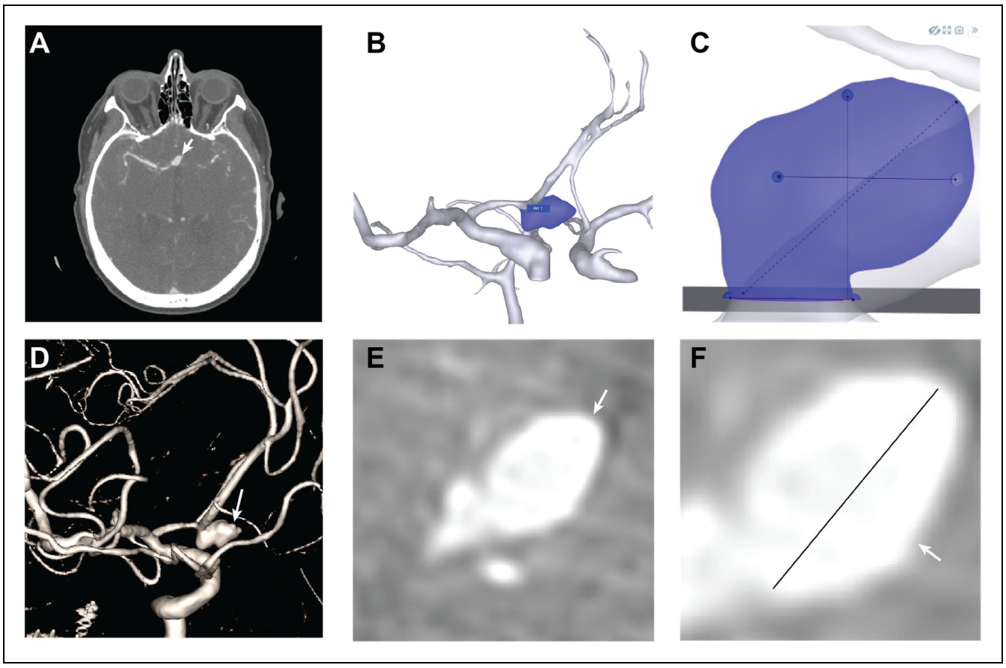

Figure 1. Representative case from a patient with a ruptured anterior communicating artery aneurysm. A 10.2 mm aneurysm arising from the anterior communicating artery is shown on CTA source images (A, arrow). RAPID Aneurysm correctly identified this aneurysm (B, purple shading) and automatically provided size measurements (C). 3D-DSA images (D-F) demonstrate the aneurysm on volumetric images (D, arrow) and 2D images in the anteroposterior (E, arrow) and lateral oblique (F, arrow) views. Reference standard measurements were derived from the 3D-DSA data (F, inset) and showed an excellent agreement with those generated by RAPID Aneurysm.

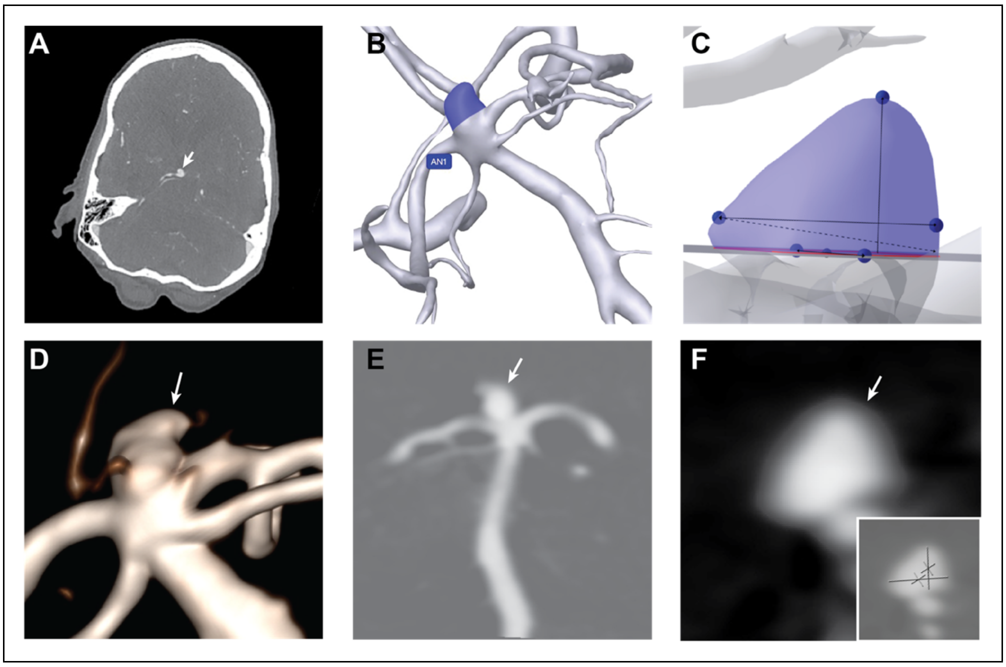

Figure 2. Representative case from a patient with a ruptured basilar artery aneurysm. A 6.3 mm aneurysm arising from the basilar artery terminus is shown on CTA source images (A, arrow). RAPID Aneurysm correctly identified this aneurysm (B, purple shading) and automatically provided size measurements (C). 3D-DSA images (D-F) demonstrate the aneurysm on volumetric images (D, arrow) and 2D images in the anteroposterior (E, arrow) and lateral oblique (F, arrow) views. Reference standard measurements were derived from the 3D-DSA data (F, inset) and showed an excellent agreement with those generated by RAPID Aneurysm.

the neurointerventionalist is processing 3D-DSA data and obtaining aneurysm size measurements, a catheter is often left within the ipsilateral common or internal carotid artery. Increased catheter indwelling time during 3D-DSA image processing therefore adds risk of a thromboembolic complication at a time when little else is actively happening during the procedure. Strategies that expedite neurointerventional treatment are desired for patient safety and workflow efficiency.

The results of our study suggest that aneurysm treatment planning using RAPID Aneurysm analysis of CTA data may be performed prior to DSA. The non-invasive imaging analysis would then allow the neurointerventionalist to determine the anticipated optimal device selection and sizes needed for treatment prior to the procedure. In addition, we hypothesize that industry representatives could more accurately determine what devices and sizes are needed for a specific procedure and provide the appropriate range of devices in advance of the treatment. DSA will still be necessary during aneurysm treatment, but software advances that reduce procedure time and allow for treatment planning prior to DSA would be well received by the neurointerventional community. Future prospective studies should investigate these hypotheses and determine if RAPID Aneurysm CTA assessment before treatment reduces catheter indwelling time and/or thromboembolic complications.

This study has several limitations. The relatively small sample size as well as single center design may introduce bias. In addition, the use of biplane angiography equipment manufactured by only two vendors, the exclusion of patients with artifact on CTA studies, and the exclusion of prior aneurysm treatment with clips or coils all may limit the generalizability of our study. RAPID Aneurysm does not assess all aneurysm configurations, such as fusiform aneurysms, which may limit the generalizability of the software in clinical practice.

Conclusions

RAPID Aneurysm accurately measures cerebral aneurysm size and morphology CTA compared to 3D-DSA. These findings suggest that neurointerventional aneurysm device sizing and treatment planning may be performed prior to DSA, which may reduce procedure times.

Declaration of conflicting interests

JJH and AMS are members of the medical and scientific advisory board for iSchemaView.

Funding

This work was supported by a generous donation from the CYNL Foundation to Dr Heit.

ORCID iD

Jeremy J Heit https://orcid.org/0000-0003-1055-8000

Supplemental material

Supplemental material for this article is available online.

References

1. Brown RD. Unruptured intracranial aneurysms. *Semin Neurol* 2010; 30: 537–544.
2. Nakagawa T and Hashi K. The incidence and treatment of asymptomatic, unruptured cerebral aneurysms. *J Neurosurg* 1994; 80: 217–223.
3. International Study of Unruptured Intracranial Aneurysms Investigators. Unruptured intracranial aneurysms–risk of rupture and risks of surgical intervention. International study of unruptured intracranial aneurysms investigators. *N Engl J Med* 1998; 339: 1725–1733.
4. Molyneux AJ, Kerr RS, Yu LM, et al. International subarachnoid aneurysm trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomised comparison of effects on survival, dependency, seizures, rebleeding, subgroups, and aneurysm occlusion. *Lancet* 2005; 366: 809–817.
5. Villablanca JP, Duckwiler GR, Jahan R, et al. Natural history of asymptomatic unruptured cerebral aneurysms evaluated at CT angiography: growth and rupture incidence and correlation with epidemiologic risk factors. *Radiology* 2013; 269: 258–265.
6. Investigators UJ, Morita A, Kirino T, et al. The natural course of unruptured cerebral aneurysms in a Japanese cohort. *N Engl J Med* 2012; 366: 2474–2482.
7. McDonald JS, Kallmes DF, Lanzino G, et al. Use of CT angiography and digital subtraction angiography in patients with ruptured cerebral aneurysm: evaluation of a large multihospital data base. *AJNR Am J Neuroradiol* 2013; 34: 1774–1777.
8. Heit JJ, Honce JM, Yedavalli VS, et al. RAPID Aneurysm: artificial intelligence for unruptured cerebral aneurysm detection on CT angiography. *J Stroke Cerebrovasc Dis* 2022; 31: 106690.
9. Sahlein DH, Gibson D, Scott JA, et al. Artificial intelligence aneurysm measurement tool finds growth in all aneurysms that ruptured during conservative management. *J Neurointerv Surg* 2023; 15, 766–770.
10. Heit JJ, Gonzalez RG, Sabbag D, et al. Detection and characterization of intracranial aneurysms: a 10-year multidetector CT angiography experience in a large center. *J Neurointerv Surg* 2016; 8: 1168–1172.
11. Philipp LR, McCracken DJ, McCracken CE, et al. Comparison between CTA and digital subtraction angiography in the diagnosis of ruptured aneurysms. *Neurosurgery* 2017; 80: 769–777.
12. Dammert S, Krings T, Moller-Hartmann W, et al. Detection of intracranial aneurysms with multislice CT: comparison with conventional angiography. *Neuroradiology* 2004; 46: 427–434.
13. Ishida F, Kawaguchi K, Mizuno M, et al. The accuracy and usefulness of 3D-DSA and 3D-CT angiography for cerebral aneurysms. *Interv Neuroradiol* 2001; 7: 181–186.
14. Kapsalaki E, Brotis AG, Karagiorgas G, et al. Morphological characteristics of ruptured intracranial aneurysms: a comparative study between CTA and DSA. *Hellenic Journal of Radiology* 2020; 6: 13–27.
15. Sui RD, Wang CG, Han DW, et al. Application of computed tomography angiography for evaluating clinical morphology in intracranial aneurysms - monocentric study. *J Int Med Res* 2020; 48: 300060519894790.
16. Chen W, Yang Y, Xing W, et al. Applications of multislice CT angiography in the surgical clipping and endovascular coiling of intracranial aneurysms. *J Biomed Res* 2010; 24: 467–473.
17. Hoh BL, Cheung AC, Rabinov JD, et al. Results of a prospective protocol of computed tomographic angiography

in place of catheter angiography as the only diagnostic and pretreatment planning study for cerebral aneurysms by a combined neurovascular team. *Neurosurgery* 2004; 54: 1329–1340.
18. Hayashida E, Sasao A, Hirai T, et al. Can sufficient preoperative information of intracranial aneurysms be obtained by using 320-row detector CT angiography alone? *Jpn J Radiol* 2013; 31: 600–607.
19. Gauvrit JY, Leclerc X, Vermandel M, et al. 3D Rotational angiography: use of propeller rotation for the evaluation of intracranial aneurysms. *AJNR Am J Neuroradiol* 2005; 26: 163–165.
20. van Rooij WJ, Sprengers ME, de Gast AN, et al. 3D Rotational angiography: the new gold standard in the detection of additional intracranial aneurysms. *AJNR Am J Neuroradiol* 2008; 29: 976–979.