RAPID Aneurysm: Artificial intelligence for unruptured cerebral aneurysm detection on CT angiography

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Objectives: Cerebral aneurysms may result in significant morbidity and mortality. Identification of these aneurysms on CT Angiography (CTA) studies is critical to guide patient treatment. Artificial intelligence platforms to assist with automated aneurysm detection are of high interest. We determined the performance of a semi-automated artificial intelligence software program (RAPID Aneurysm) for the detection of cerebral aneurysms. *Materials and Methods:* RAPID Aneurysm was used to detect retrospectively the presence of cerebral aneurysms in CTA studies performed between January 2019 and December 2020. The gold standard was aneurysm presence and location as determined by the consensus of three expert neuroradiologists. Aneurysm detection accuracy, sensitivity, specificity, positive predictive value, negative predictive value, and positive and negative likelihood ratios by RAPID Aneurysm were determined. *Results:* 51 patients (mean age, 56±15; 24 women [47.1%]) with a single CTA were included. A total of 60 aneurysms were identified. RAPID Aneurysm had a sensitivity of 0.950 (95% CI: 0.863-0.983), specificity of 1.000 (95% CI: 0.996-1.000), a positive predictive value (PPV) of 1.000 (95% CI: 0.937-1.000), a negative predictive value (NPV) of 0.997 (95% CI: 0.991-0.999), and an accuracy of 0.997 (95% CI: 0.991-0.999) for cerebral aneurysm detection. *Conclusions:* RAPID Aneurysm is highly accurate for the detection of cerebral aneurysms on CTA.

Keywords: Aneurysm—Cerebral—Brain—Artificial intelligence—AI

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Introduction

Cerebral aneurysms are abnormal arterial outpouchings that commonly occur at bifurcations in the cerebral circulation,[1] and they are present in 2-6% of the population.[1] Aneurysm rupture is the most feared complication of having a cerebral aneurysm, and rupture results in mortality in 40% of patients and significant morbidity in 67% of survivors.[1] Therefore, aneurysm identification on CT angiography (CTA) studies is imperative.

Aneurysms are increasingly identified on non-invasive CTA studies that are performed for other indications,[2] which may reduce the likelihood of incidental cerebral aneurysm detection. Artificial intelligence methods that identify cerebral aneurysms may help to improve the ability of a radiologist to detect these lesions.

RAPID Aneurysm (iSchemaView, Menlo Park, CA) is a semi-automated, artificial intelligence software program that was developed to detect cerebral aneurysms on CTA studies. In this study, we determined the accuracy and performance of RAPID Aneurysm for the detection of cerebral aneurysms on CTA.

Methods

Patient cohort and image acquisition

We performed a retrospective cohort study that complied with the Health Insurance Portability and Accountability Act. Our institutional review boards approved the study and waived the need for informed consent.

RAPID Aneurysm training and detection

CTA image data were anonymized and vessel reconstruction and translation into a 3D surface model was performed by the software with the assistance of trained

RAPID biomedical engineers who used a threshold-based, semi-automated image-segmentation technique. Three-dimensional ellipsoids are fitted to the vessel surface points of each potential aneurysm. Parameters that measure the shape, size, and parent vessel proximity are then calculated for each potential aneurysm.

RAPID aneurysm validation study design

We included 51 consecutive CTA studies from 3 medical centers between January 2019 and December 2020 that were selected based on the presence of an unruptured aneurysm of >3 mm according to the radiology report. The reference standard (ground truth) for the study was determined by consensus among three expert neuroradiologists (VSY; 3 years of experience, VMT; 8 years of experience, JMH; 8 years of experience) and an additional blinded neuroradiologist (JJH, 9 years of experience). The neuroradiologists had complete control over window width and levels for all images and were able to reformat axial source images into coronal or sagittal planes per their preference. The neuroradiologists were blinded to the patient's clinical history, original interpretation results of the CTA studies, and the RAPID Aneurysm results.

The primary endpoint was the detection and localization of any aneurysm that measured ≥3 mm in greatest diameter within the intracranial circulation, which was defined as vessels distal to the internal carotid artery (ICA) from the clinoidal segment to the terminus within the anterior circulation or distal to the V3 segment of the vertebral arteries.

Statistical analysis

For the statistical analysis, the presence or absence of aneurysm was considered across predefined vessel segments (See Table 2). Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (LR), negative LR, and accuracy were calculated by comparison of RAPID Aneurysm identification of an aneurysm compared to the reference standard for each. Statistical analyses were performed using JMP Pro 16 (SAS Institute, Cary NC).

Results

51 CTA studies in 51 patients were evaluated. Patient demographic data are summarized in Table 1. CT vendors are summarized in Supplementary Table 1.

Expert radiologists determined the median aneurysm diameter to be 5.4 (IQR: 4.3-7.3). The most common aneurysm locations were the ICA/PCOM (36.7%), MCA (30.0%), and ACOM (25.0%) (Supplemental Table 2).

CTA studies were tested by RAPID Aneurysm. After segmentation, automated processing times were <60 seconds. 60 aneurysms were identified by the expert neuroradiologists, and RAPID Aneurysm correctly identified 57 of these aneurysms (Supplemental Table 3). RAPID Aneurysm correctly determined the absence of an aneurysms in 909 vessel segments (Supplemental Table 1). RAPID Aneurysm had a sensitivity of 0.950 (95% CI: 0.863-0.983), specificity of 1.000 (95% CI: 0.996-1.000), a positive predictive value (PPV) of 1.000 (95% CI: 0.937-1.000), a negative predictive value (NPV) of 0.997 (95% CI: 0.991-0.999), and an accuracy of 0.997 (95% CI: 0.991-0.999) for cerebral aneurysm detection (Table 2). False negative calls localized to the ICA (1 call) and MCA (2 calls) (Fig. 1); the average size of these aneurysms was 4.0 mm. Representative case examples are shown in Fig. 2.

Table 1. *Patient demographic details.*

Age and Sex	
Age (years), mean (SD)	56.2 (15.1)
Age (years), median (IQR)	56 (42-68)
Female, n (%)	24 (47.1%)
Hypertension	
No, n (%)	20 (39.2%)
Yes, n (%)	19 (37.3%)
Unknown, n (%)	12 (23.5%)
Smoking	
Current Smoker, n (%)	7 (13.7%)
Never Smoked, n (%)	18 (35.3%)
Prior Smoker, n (%)	8 (15.7%)
Unknown, n (%)	18 (35.3%)
Family History of Cerebral Aneurysm	
No, n (%)	10 (19.6%)
Yes, n (%)	2 (3.9%)
Unknown, n (%)	39 (76.5%)

Table 2. *Rapid aneurysm performance metrics.*

Measure	Estimate	Lower 95% CI	Upper 95% CI
Sensitivity	0.950	0.863	0.983
Specificity	1.000	0.996	1.000
Positive Predictive Value	1.000	0.937	1.000
Negative Predictive Value	0.997	0.990	0.999
Accuracy	0.997	0.991	0.999

Table legend: Vessel segments evaluated included anterior cerebral artery (ACA), anterior communicating artery (ACOM), anterior inferior cerebellar artery (AICA), basilar artery, internal carotid artery or posterior communicating artery (ICA/PCOM), middle cerebral artery (MCA), posterior cerebral artery (PCA), posterior inferior cerebellar artery (PICA), superior cerebellar artery, or vertebral artery.

Discussion

In this study, we found the semi-automated artificial intelligence RAPID Aneurysm software platform to be very accurate in the detection of unruptured cerebral aneurysms on CTA. Our findings suggest that adoption

A
B
C

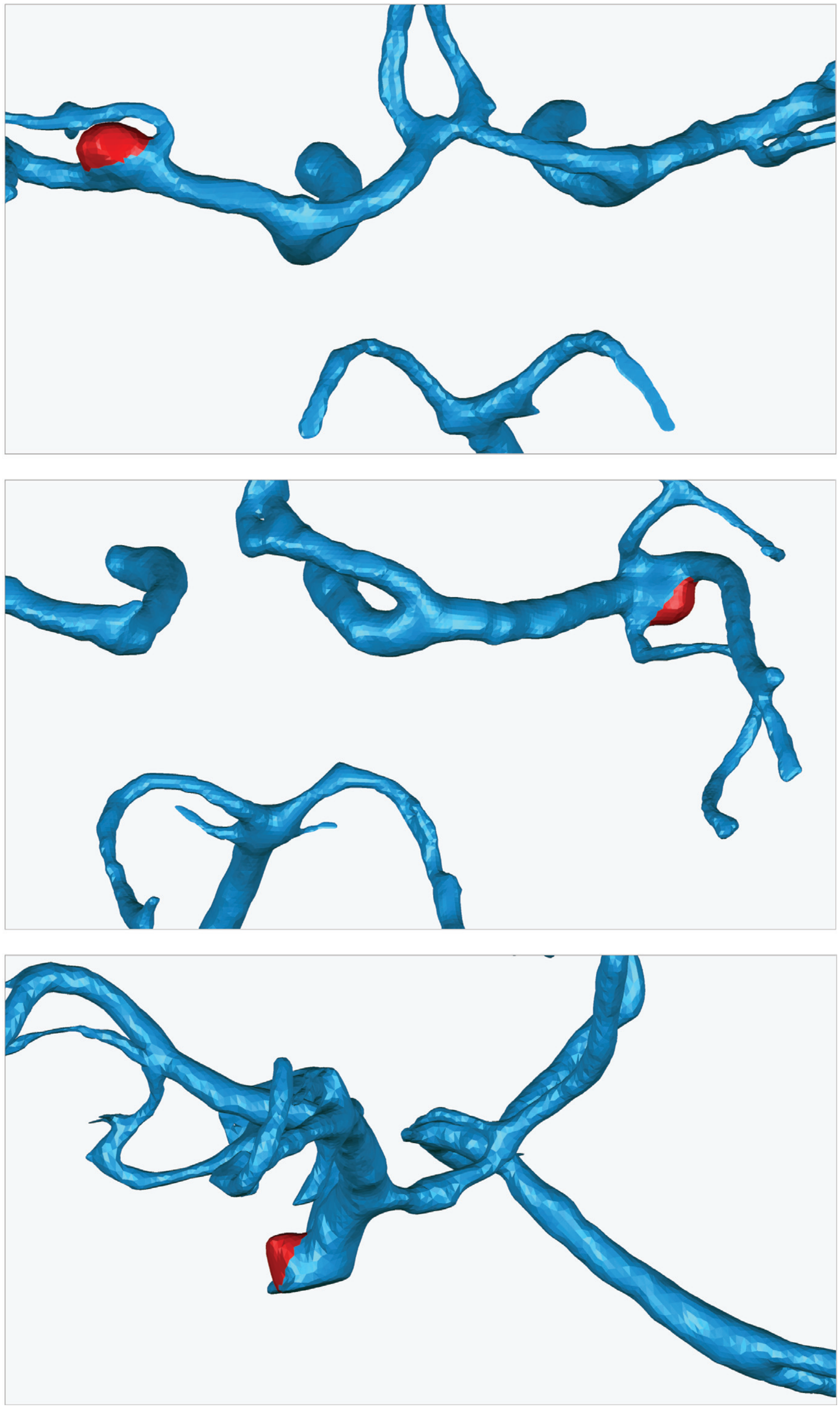

Fig. 1. *False negative aneurysm cases. RAPID aneurysm failed to identify a 4.2-mm MCA aneurysm (A, red), a 3.6-mm MCA aneurysm (B, red), and a 4.1-mm ICA aneurysm arising at the ophthalmic artery origiin (C, red). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.).*

of aneurysm detection platforms like RAPID Aneurysm may be a valuable tool to assist radiologists in their interpretation of CTA studies.

Cerebral aneurysms are "do not miss" lesions on CTA examinations of the brain given the potentially devastating outcome of rupture of an undetected cerebral aneurysm. The reported sensitivity of radiologists in identifying these lesions on CTA ranges from 76-98% in the absence of computer assisted detection or artificial intelligence software aided

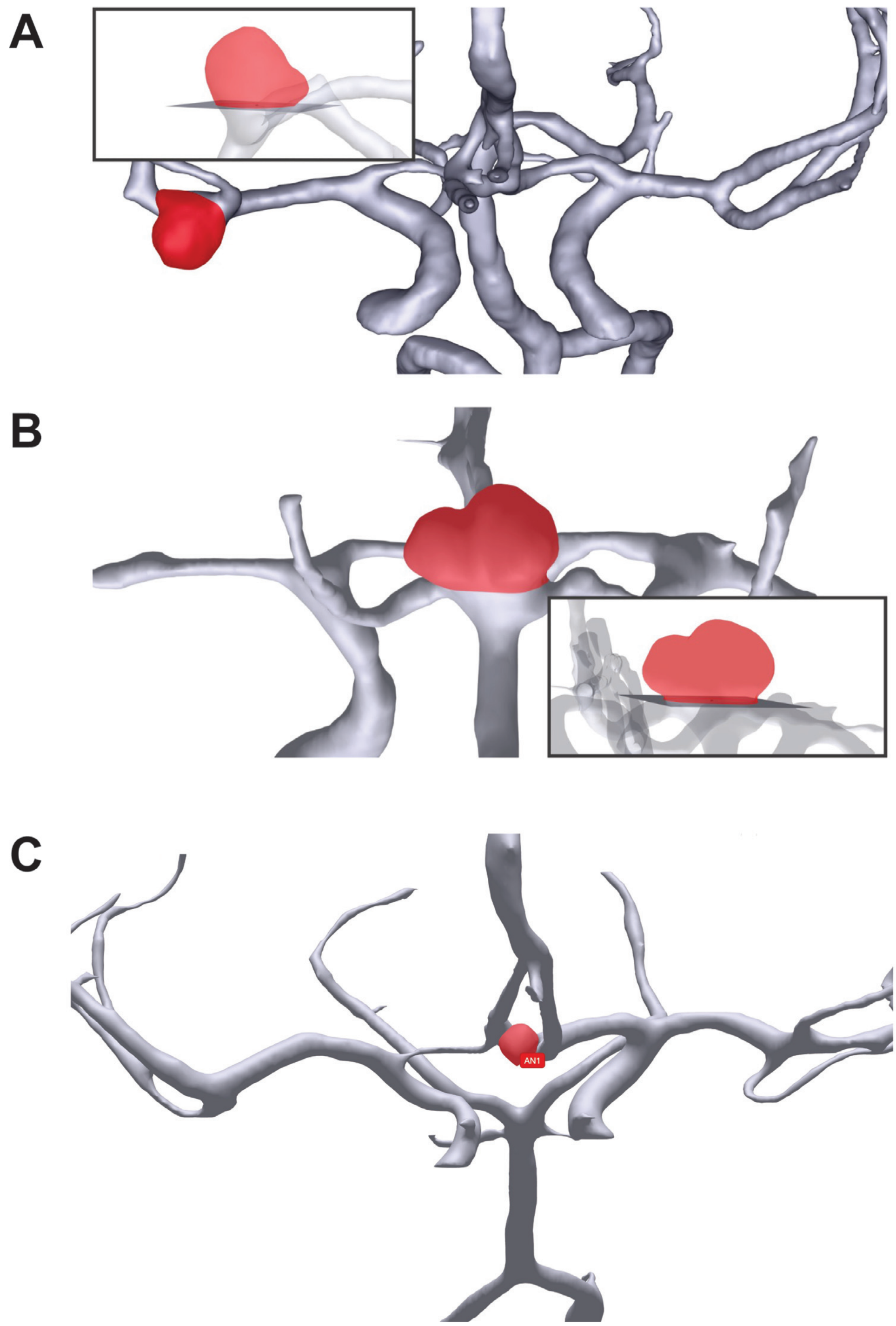

Fig. 2. *Representative true positive aneurysm cases. RAPID aneurysm correctly identifies a 9-mm MCA aneurysm (A, red), a 13-mm basilar apex aneurysm (B, red), and a 4-mm ACOM aneurysm (C, red). Insets in A and B show aneurysms in more detail. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.).*

interpretation.[3] The growth of imaging and increasing workload of radiologists[2] are expected to increase the risk of not identifying important imaging findings such as a cerebral aneurysm. As such, the development of artificial intelligence platforms that detect important pathology and improve diagnostic accuracy are of high interest.

Several other studies have used automated computer-assisted or artificial intelligence techniques to detect the presence of cerebral aneurysms on CTA or MRA examinations.[4−8] Few studies have used these techniques to detect cerebral aneurysms on CTA studies,[7,8] and these studies reported sensitivities of 82-98%[7,8] and specificity of 0-19%[8] for cerebral aneurysm detection. The sensitivity

(95.0%) and specificity (100%) of RAPID Aneurysm in our study compares favorably with these prior studies.

Others have detected cerebral aneurysms on MRA studies, which have less imaging noise and reduced conspicuity of native brain, bone, and soft tissues compared to CTA studies. These computer assisted detection and artificial intelligence platforms have reported sensitivities that range from 81-91% and specificities from 93-94% for non-radiologist assisted aneurysm detection on MRA studies.[4–6]

A well-validated artificial intelligence program that detects cerebral aneurysms is expected to be an asset to radiologists. Artificial intelligence programs that detect cerebral aneurysms on CTA[8,9] have been shown to improve radiologists' sensitivity for the detection of aneurysms. It will be of interest to conduct additional studies to see how RAPID Aneurysm affects radiologists' performance in interpreting CTA studies in future studies.

Our study has several limitations. The retrospective design and relatively small case numbers may introduce bias. Our study was comprised of a limited number of CT vendors, which may limit generalizability of our findings. We restricted our analysis to aneurysms that measure greater than 3 mm, but smaller aneurysms may be clinically meaningful. We did not include ruptured cerebral aneurysms in our dataset, and whether the performance of RAPID Aneurysm differs for the detection of ruptured aneurysms requires further study. We also excluded studies with metal artifact, so the performance of RAPID aneurysm for the detection of aneurysm recurrence after clip or coil embolization was not evaluated in this study. Whether RAPID aneurysm improves the performance of human radiologists was not assessed in this study and requires further investigation.

Conclusions

RAPID Aneurysm is accurate in the detection of cerebral aneurysms.

Summary statement

RAPID Aneurysm is accurate in the detection of cerebral aneurysms.

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None

Disclosures

JJH is a member of the iSchemaView Medical and Scientific Advisory Board.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.jstrokecerebrovasdis.2022.106690.

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