Objective: We investigated the diagnostic accuracy of high-resolution magnetic resonance angiography (HR-MRA) with volume rendering (VR) post-processing techniques for the detection of cerebral aneurysms compared with conventional MRA (C-MRA) using digital subtraction angiography (DSA) as the gold standard.

Methods: HR-MRA was performed for 51 possible aneurysms of 38 patients on C-MRA. For each possible aneurysm, readers recorded their level of confidence on a 5-point scale. All patients underwent DSA, which was used as the standard of reference. Receiver-operating characteristic (ROC) analysis and the area under the ROC curves (AUC) were used to determine the effectiveness of C-MRA and HR-MRA in detecting cerebral aneurysm with and without VR algorithm. The increased discriminative value was examined by calculation of Net Reclassification Index (NRI) and Integrated Discrimination Improvement (IDI) index.

Results: DSA revealed 37 aneurysms in 26 patients. In aneurysm-based analysis, HR-MRA showed higher diagnostic accuracy than C-MRA, and increased diagnostic accuracy on adding VR (C-MRA vs. HR-MRA, P < 0.01; C-MRA with VR vs. HR-MRA with VR, P < 0.01, respectively). The differences in AUC, IDI (19.38%, Z = 3.18, P < 0.01) and NRI (46.3%, Z = 6.32, P < 0.01), on adding VR to the HR-MRA, were also statistically significant. The application of HR-MRA with VR increased the detection rate of aneurysms less than 3 mm.

Conclusion: The application of HR-MRA with VR algorithm improves diagnostic performance for the detection of intracranial aneurysms, especially when the aneurysm is less than 3 mm. Clinically, HR-MRA with VR algorithm could facilitate the accurate differentiation of aneurysms from infundibula and prevent unnecessary, invasive procedure before aneurysmal rupture.

Keywords: Angiography; Aneurysm; Magnetic resonance

INTRODUCTION

A cerebral aneurysm is an abnormal focal dilatation of a cerebral artery with attenuation of the vessel wall [1]. A subarachnoid hemorrhage caused by a ruptured cerebral aneurysm is frequently associated with a poor outcome [2,3].

Digital subtraction angiography (DSA) is considered the gold standard for the diagnosis of an intracranial aneurysm. However, the procedure is invasive, requires radiation exposure, and carries uncommon risks of associated neurologic complications. Consequently, noninvasive brain imaging techniques such as magnetic resonance angiography (MRA) have been pursued as potential methods for the screening and follow-up of intracranial aneurysms. Time-of-flight (TOF) MRA is a widely available noninvasive technique that requires no radiation exposure and no administration of contrast medium for the evaluation and characterization of an intracranial aneurysm [4-6]. Previous studies have suggested that TOF-MRA could identify aneurysms measuring >3 mm in size with a high sensitivity of 74% to 98% [3,7,8]. However, many lesions, including infundibula, can mimic a small aneurysm and reduce diagnostic performance for the detection of aneurysms using MRA. An infundibulum is a funnel-shaped symmetrical vascular enlargement with a vessel arising from the apex that has a maximum diameter of <3 mm at the base, and lacks an aneurysmal neck [9]. They often occur at branching sites of the posterior communicating and anterior choroidal arteries from the internal carotid artery. The incidence of infundibulum detected by angiography or at autopsy ranges from 7% to 25% [10-12].
Although infundibula are frequently considered normal anatomic variants of no pathogenic significance, some authors consider an infundibulum to be a "pre-aneurysmal" lesion because of the occasional progression of an infundibulum to aneurysm formation and rupture, the risk of which increases with age [13-16].

High-resolution TOF-MRA (HR-MRA) is a noninvasive imaging technique that provides delineation of the vascular structure in detail. This technique enables visualization of the vascular structure with sub-millimeter resolution, it has been used extensively for carotid atherosclerosis, and more recently, for carotid dissection [17,18]. Therefore, we assumed that the application of HR-MRA could improve diagnostic performance for the detection of an aneurysm. Especially for a small aneurysm less than 3 mm, which is difficult to differentiate from an infundibulum, HR-MRA would be more helpful. However, few studies have investigated aneurysm detection using HR-MRA with full correlation of DSA [3,19].

Cerebral MRA provides a three-dimensional (3D) representation of the intracranial vasculature, which is routinely captured in a two-dimensional perspective by a maximum intensity projection (MIP) algorithm or multiplanar volume reformations that might obscure an abnormality because of vascular overlay or lead to misinterpretation of tortuous vascular structures such as an aneurysm. The implementation of volume rendering (VR) algorithms to evaluate MRA data sets have been recently described by several investigators, but evidence of successful differentiation of an aneurysm from an infundibulum is lacking [15,16,20-23].

The purpose of our study was to evaluate the diagnostic accuracy of HR-MRA with VR for the detection of cerebral aneurysms compared with conventional TOF-MRA (C-MRA), using DSA as the gold standard.

MATERIALS AND METHODS

1. Patients

This retrospective study was approved by the Institutional Review Board of Soonchunhyang University Bucheon Hospital, and the requirement for informed consent was waived. We evaluated patients with suspected or known intracranial aneurysms initially detected by C-MRA, and who underwent both DSA and HR-MRA examinations to confirm the diagnosis of an intracranial aneurysm. From September 2014 to May 2017, 38 consecutive patients (10 men and 28 women; median age, 58 years; range, 31–74 years) with 51 possible aneurysmal lesions on C-MRA, were enrolled in the present study. No patient showed a subarachnoid hemorrhage or neurologic deficit.

2. Imaging protocol

All patients underwent C-MRA, HR-MRA with MIP and VR post-processing methods, and DSA. C-MRA, which is a combined investigation of both the neck and the brain, was performed on a 1.5 T or 3 T scanner (1.5 T in 31 patients and 3 T in 20 patients; 1.5 T SIGNA EXCITE [GE Healthcare, Milwaukee, WI, USA]; 1.5 T Sonata [Siemens Medical Systems, Erlangen, Germany]; and 3 T Trio Tim and Verio [Siemens Medical System]). For 3D C-MRA, the following parameters were used: 3D fast imaging with steady precession; repetition time, 23–37 ms; echo time, 2.4–9.6 ms; flip angle, 20°–25°; effective section thickness, 0.7–1.2 mm; field of view, 180–240 × 215–240 mm; and a 256–640 × 160–336 matrix covering an area from the clivus to the genu of the corpus callosum. Rotational MIP images were available for all cases. Average of resolution in C-MRA is 0.34 (0.71, 0.21, 0.22, and 0.22, respectively).

All HR-MRA examinations were performed on a 3 T system (SIGNA EXCITE; GE Healthcare) with an 8-channel head coil. At first, we obtained 3D TOF-MRA with the following parameters: a spoiled gradient-echo sequence with repetition time 29 ms, echo time 4.7 ms, flip angle 20°, field of view 150 × 150 mm, matrix 512 × 512, and resolution 0.29 × 0.29 × 0.5 mm. The HR-MRA acquisition time was 6 minutes 31 seconds. The MIP reconstructions were performed at the time of imaging. The data were reconstructed around both the head-to-foot axis and the right-to-left axis, and target MIP reconstructions of vessels of interest were made. Furthermore, 3D reconstructed MRA images, for which a VR technique was used, were produced on a workstation (Advantage Windows ver. 2.0; GE Medical Systems, Chicago, IL, USA) by using the source MRA images.

Conventional cerebral angiography was performed using a biplane system (Integris Allura; Philips Medical Systems, Best, the Netherlands) via transfemoral catheterization and the selective injection of contrast media (Pamiray 300; Dongkook Pharmaceutical, Seoul, Korea) at a rate of 3 mL/sec into the carotid and vertebral arteries. Imaging was performed in standard and adequately oblique projections, as required. 3D image reconstruction following rotational angiography was performed. Image data were transferred to a workstation (Octane; Silicon Graphics, Mountain Hill, CA, USA) to reconstruct the images into a 3D volume (Integris
3D-RA Software release 3.2 [Octane, Silicon Graphics]).

3. Assessment of aneurysm probability

Two experienced neuroradiologists (T.J.Y. and A.L.L., with 10 and 6 years of neuroradiology experience, respectively) reviewed the MRA images; disagreements were resolved by consensus, and both clinicians were unaware of the information concerning the clinical history, the findings of other modalities, and final diagnoses. Sets of each modality including C-MRA and HR-MRA, with/ or without application of VR algorithm, were evaluated separately with regular intervals. For the C-MRA and HR-MRA, assessment was performed based on MIP and source image and, for the C-MRA and HR-MRA in which VR algorithm was had been applied, images derived from the VR algorithm were additionally included for the evaluation. Diagnostic confidence in the presence of an aneurysm on MRA images was assessed using a 5-point scale: no lesion, definite infundibulum, suspicious infundibulum, suspicious aneurysm, and definite aneurysm. The lesions identified as suspicious or definite aneurysm were considered as presence of aneurysm; all others were considered as absence of aneurysm. The size, number, and location of aneurysmal lesions were recorded.

We divided the data into two groups according to the size of aneurysm (≥3 mm or less) and evaluated the sensitivity for detection of aneurysm on C-MRA and HR-MRA with or without VR algorith.

4. Statistical analysis

Receiver-operating characteristic (ROC) analysis was conducted to determine the effectiveness of C-MRA and HR-MRA in detecting cerebral aneurysms with and without VR. The sensitivity, specificity, and positive and negative predictive values for each outcome category (presence versus absence of an aneurysm) were calculated. An aneurysm detected on MRA and not detected on DSA was considered a false-positive case. An aneurysm not detected on MRA and detected on DSA was considered a false-negative case. Accuracy, sensitivity, specificity, positive predictive value, and negative predictive value (NPV) were evaluated on aneurysm-based and levels. The area under the ROC curves (AUC) and the 95% confidence interval of the area were computed to evaluate the diagnostic confidence. The AUC could distinguish between less predictive (0.5–0.7), moderately predictive (0.7–0.9), and highly predictive (0.9–1). The AUCs of the three modalities were compared by a non-parametric method by Delong. The increased discriminative value of the biomarkers was further examined by calculation of the Net Reclassification Index (NRI) and Integrated Discrimination Improvement (IDI) indices. NRI indicates the net increase versus decrease in risk categories among aneurysms minus the decrease among non-aneurysms. IDI indicates the difference in the mean difference in predicted probabilities between aneurysms and non-aneurysms. The differences in the sensitivity between the two groups (aneurysms sized ≥3 mm and <3 mm) were evaluated on C-MRA and HR-MRA with and without a VR algorithm.

A two-sided P-value of less than 0.05 was considered to indicate statistical significance. All the statistical analyses were performed using SPSS ver. 14.0 Korean version for Windows (SPSS Inc., Chicago, IL, USA) and R ver. 3.1.3 freely available on the web (http://cran.r-project.org/). Statistical analyses were performed with the MedCalc software package ver. 11.2.1.0 (MedCalc Software Ltd., Ostend, Belgium).

RESULTS

1. Clinical results

A total of 38 patients (10 men and 28 women; mean age, 58 years; range, 31–74 years) were included in our study. DSA revealed 37 aneurysms in 28 patients and infundibular dilatations or no lesion for 14 lesions in 10 patients. The location of the suspicious aneurysmal lesion was the internal carotid artery in 39.2% (n=20), middle cerebral artery in 25.5% (n=13), anterior cerebral artery in 23.5% (n=12), and the vertebrobasilar artery in 11.8% (n=6). DSA confirmed multiple aneurysms in nine patients with 20 lesions. Three aneurysms were detected in two patients, two aneurysms in seven patients, and one in 17 patients. Twenty-two (59.5%) of the 37 aneurysms were ≥3 mm and 15 aneurysms (40.5%) were <3 mm (range, 1–11 mm; mean, 4 mm).

2. Diagnostic performance of 3D TOF–MRA

The results concerning diagnostic confidence of the presence of an aneurysm on MRA and DSA images are summarized in Table 1. The application of HR-MRA with and without a VR algorithm improved sensitivity and specificity.

The performance was shown using the sensitivity, specificity, positive and negative predictive value; the area under the ROC curve in Table 2 and Fig. 1, and the IDI and NRI in Table 3 also demon-
strate the diagnostic performance. When using categorized MRA findings, C-MRA showed a worse performance than that shown by HR-MRA regardless of VR use. The differences of AUC were

Table 1. Results obtained on assessment of lesions for cerebral aneurysm detection on C-MRA and HR-MRA (total = 51 possible aneurysms)

<table>
<thead>
<tr>
<th>Variable</th>
<th>C-MRA</th>
<th>HR-MRA</th>
<th>DSA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without VR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aneurysm</td>
<td>43</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>Definite</td>
<td>23</td>
<td>25</td>
<td>16</td>
</tr>
<tr>
<td>Suspicious</td>
<td>20</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Infundibulum</td>
<td>6</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Definite</td>
<td>3</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Suspicious</td>
<td>3</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>No lesion</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Sensitivity (%)</td>
<td>83.8</td>
<td>89.2</td>
<td></td>
</tr>
<tr>
<td>Specificity (%)</td>
<td>14.3</td>
<td>64.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>With VR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aneurysm</td>
<td>43</td>
<td>38</td>
<td>37</td>
</tr>
<tr>
<td>Definite</td>
<td>30</td>
<td>29</td>
<td>16</td>
</tr>
<tr>
<td>Suspicious</td>
<td>13</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>Infundibulum</td>
<td>7</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Definite</td>
<td>1</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Suspicious</td>
<td>6</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>No lesion</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Sensitivity (%)</td>
<td>89.2</td>
<td>94.6</td>
<td></td>
</tr>
<tr>
<td>Specificity (%)</td>
<td>21.4</td>
<td>71.4</td>
<td></td>
</tr>
</tbody>
</table>

Values are presented as number or % unless otherwise stated.

C-MRA, conventional magnetic resonance angiography; HR-MRA, high-resolution magnetic resonance angiography; DSA, digital subtraction angiography; VR, volume rendering.

Table 2. Diagnostic accuracy of various MRA techniques for the detection of cerebral aneurysm by using categorization or grading of MRA findings (aneurysm-based analysis of 51 possible aneurysms)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Accuracy</th>
<th>PPV</th>
<th>NPV</th>
<th>AUC (95% CI of AUC)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C-MRA</td>
<td>HR-MRA</td>
<td>C-MRA with VR</td>
<td>HR-MRA with VR</td>
<td>Comparison (P-value)</td>
<td></td>
</tr>
<tr>
<td>Using categorized MRA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-MRA</td>
<td>6/37 (0.16)</td>
<td>12/14 (0.86)</td>
<td>18/51 (0.35)</td>
<td>6/8 (0.75)</td>
<td>12/43 (0.28)</td>
<td>0.5097 (0.3971–0.6222)</td>
</tr>
<tr>
<td>HR-MRA</td>
<td>33/37 (0.89)</td>
<td>10/14 (0.71)</td>
<td>43/51 (0.84)</td>
<td>33/37 (0.88)</td>
<td>10/14 (0.71)</td>
<td>0.8031 (0.6702–0.9359)</td>
</tr>
<tr>
<td>C-MRA with VR</td>
<td>33/37 (0.89)</td>
<td>4/14 (0.29)</td>
<td>37/51 (0.73)</td>
<td>33/43 (0.77)</td>
<td>4/8 (0.5)</td>
<td>0.5988 (0.4560–0.7217)</td>
</tr>
<tr>
<td>HR-MRA with VR</td>
<td>35/37 (0.95)</td>
<td>11/14 (0.79)</td>
<td>46/51 (0.9)</td>
<td>35/38 (0.92)</td>
<td>11/13 (0.85)</td>
<td>0.8658 (0.7483–0.9803)</td>
</tr>
<tr>
<td>Using the grade of MRA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-MRA</td>
<td>25/37 (0.68)</td>
<td>14/14 (1)</td>
<td>39/51 (0.76)</td>
<td>25/25 (1)</td>
<td>14/26 (0.54)</td>
<td>0.8897 (0.7866–0.9929)</td>
</tr>
<tr>
<td>HR-MRA</td>
<td>25/37 (0.68)</td>
<td>14/14 (1)</td>
<td>39/51 (0.76)</td>
<td>25/25 (1)</td>
<td>14/26 (0.54)</td>
<td>0.9228 (0.8555–0.9901)</td>
</tr>
<tr>
<td>C-MRA with VR</td>
<td>29/37 (0.78)</td>
<td>13/14 (0.93)</td>
<td>42/51 (0.82)</td>
<td>29/30 (0.97)</td>
<td>13/21 (0.62)</td>
<td>0.8986 (0.8038–0.9935)</td>
</tr>
<tr>
<td>HR-MRA with VR</td>
<td>29/37 (0.78)</td>
<td>14/14 (1)</td>
<td>43/51 (0.84)</td>
<td>29/29 (1)</td>
<td>14/22 (0.64)</td>
<td>0.9614 (0.9199–1.0000)</td>
</tr>
</tbody>
</table>

Values are presented as number (%) or AUC (95% CI of AUC) unless otherwise stated.

MRA, magnetic resonance angiography; PPV, positive predictive value; NPV, negative predictive value; AUC, area under the receiver-operating characteristic curve; CI, confidence interval; C-MRA, conventional magnetic resonance angiography; HR-MRA, high-resolution magnetic resonance angiography; VR, volume rendering.

*The P-values for the comparison of the pairs of AUCs were calculated by Delong’s method.
also statistically significant (C-MRA vs. HR-MRA, P < 0.01; C-MRA with VR vs. HR-MRA with VR, P < 0.01). Although the addition of VR to the HR-MRA did not improve the AUC (0.8031 vs. 0.8658, P = 0.16), statistical significance was observed for the IDI (19.38%, Z = 3.18, P < 0.01) and NRI (46.3%, Z = 6.32, P < 0.01). When using the grade of MRA finding, C-MRA showed better performance than that with categorized MRA finding, which was still worse than the performance of HR-MRA regardless of VR use. However, the differences of AUC were not statistically significant (C-MRA vs. HR-MRA, P = 0.27; C-MRA with VR vs. HR-MRA with VR, P = 0.24). The addition of VR to the HR-MRA did not improve the AUC (0.9228 vs. 0.9188, P = 0.14), but the IDI (29.5%, Z = 4.3, P < 0.01) and NRI (73%, Z = 15.39, P < 0.01) were statistically significant.

When the size of the aneurysm was ≥3 mm, detection rates were equal for the four different MRA techniques. However, for small aneurysms (<3 mm), when HR-MRA with and without VR were applied, the detection rate increased (Table 4).

Figs. 2–5 show representative images of patients with an infundibulum, no lesion, and aneurysm on C-MRA and HR-MRA.

**DISCUSSION**

In the present study, we demonstrated that the application of HR-MRA improves diagnostic performance for the detection of unruptured aneurysms. The degrees of improvement in terms of...
Fig. 2. (A, B) An infundibulum (arrow) at the proximal left posterior cerebral artery (PCA) in a 31-year-old man on conventional magnetic resonance angiography (C-MRA) and high-resolution magnetic resonance angiography (HR-MRA) at 3 T. (A) C-MRA shows a probable aneurysmal lesion (arrow) at the proximal left PCA. (B) HR-MRA demonstrates junctional dilatation clearly and even visualizes a segment of the branching artery (arrow).

Fig. 3. (A–E) A 51-year-old woman with one small infundibulum located at the orifice of the left superior cerebellar artery (SCA). (A, B) Maximum intensity projection (MIP) and volume rendering (VR) images on conventional magnetic resonance angiography (MRA) show one small suspicious aneurysmal lesion at the left side of the basilar top (arrow). (C, D) MIP and VR images on high-resolution MRA reveal a branching left SCA at the lesion (arrow). (E) Digital subtraction angiography confirms an infundibulum located at the orifice of the left SCA (arrow).
diagnostic accuracy for HR-MRA were 13.8% and 15.7% when the VR algorithm was or was not applied, respectively. The high degree of accuracy obtained in the present study seems to be the result of several factors; a large acquisition matrix of 512 × 512 pixels in the frequency encoding direction was used to achieve higher spatial resolution.

Interestingly, there was a notable increase in the specificity and NPV, which means that HR-MRA can also exclude an infundibulum or no lesion. These results are clinically relevant because unnecessary and invasive DSA procedures, performed to exclude an infundibulum or no lesion, may be avoided by using HR-MRA.

From the sub-analysis grouped by aneurysm size, our results show that when HR-MRA was performed the sensitivity for an unruptured aneurysm increased for small aneurysms of less than 3 mm. As expected, small aneurysms of less than 3 mm would generate difficulties when differentiating them from an infundibulum. Therefore, for these small aneurysms, HR-MRA seems to be more useful in terms of an accurate diagnosis.

The usefulness of higher field strength HR-MRA has not been established. Some authors compared the delineation ability of 3 T MRA with 1.5 T MRA in patients known to have an intracranial aneurysm and reported that 3 T MRA had a greater ability to delineate an intracranial aneurysm than that of a 1.5 T magnetic resonance scanner [24]. In contrast, Mönninghoff et al. [25] reported that 7 T magnetic resonance imaging (MRI) was superior in spatial resolution, but that all aneurysms were detected with 1.5 T MRI; however, the study was limited to only 10 patients with a known intracranial aneurysm.

Regarding the morphology of the aneurysm, the introduction of a VR algorithm contributed by providing excellent identification of the shape of the aneurysm [26]. The VR algorithm is based on the percentage classification technique, which provides an accurate determination of the amounts of materials when the voxel consists of two or more materials being volume-averaged. The volume-averaged voxels are included in the final image because the VR algorithm calculates a weighted sum from all voxels along a ray projected through the data set. Therefore, VR improves the delineation of small-caliber vessels (parent and branch vessels),

![Fig. 4](image1.png)

**Fig. 4.** (A–C) A 57-year-old woman with an anterior communicating artery fenestration. (A) Conventional magnetic resonance angiography (MRA) shows a suspicious aneurysmal lesion in the anterior communicating artery (arrow). (B, C) Maximum intensity projection and volume rendering (VR) images on high-resolution MRA reveal duplication of the vascular structure, not an aneurysm, and the VR image clearly demonstrates an anterior communicating artery fenestration (arrow).

![Fig. 5](image2.png)

**Fig. 5.** (A–D) Multiple aneurysms at the left internal carotid artery (ICA) bifurcation site and anterior choroidal artery orifice in a 44-year-old woman. (A) Conventional magnetic resonance angiography (MRA) shows two suspicious aneurysmal lesions at the left ICA bifurcation (yellow arrow) and at the terminal segment (open arrow). (B) High-resolution MRA faintly shows a branching vascular structure (white arrow) adjacent to a bulging contour at the terminal segment of the left ICA, representing an infundibulum. (C, D) Digital subtraction angiography confirms two aneurysms located at the left ICA bifurcation (yellow arrow) and terminal segment of the left ICA (open arrow).
the perception of a lobulated aneurysm surface, and contributes to precision in assessing aneurysm size [27]. However, the usefulness of the VR algorithm in a clinical setting has not been established. In this study, our results show that the application of a VR algorithm can improve diagnostic accuracy for differentiating an aneurysm from an infundibulum or no lesion. Virtual views of the vasculature and intracranial vessels, appearing more conspicuously after applying the VR algorithm, seem to have contributed to the higher diagnostic accuracy when the VR algorithm was applied. In addition, easier recognition of anatomic variants and anomalies might result [28]. The results of C-MRA with a VR algorithm and HR-MRA with a VR algorithm suggested that a lesion less than 3 mm in size could be more accurately detected with the implementation of a VR algorithm. This technique does not require any additional image acquisition and can be utilized with previously acquired images. Therefore, the technique is feasible in a clinical setting to increase diagnostic accuracy.

We acknowledge the following limitations of our study. Considering the clinical flow of an aneurysm, we performed the analysis for lesions that were suspected on C-MRA. Therefore, the application of these results in the general population would be limited. In addition, our data for the initial acquisition of C-MRA were acquired using machines with different magnetic fields (1.5 T or 3 T). In summary, we demonstrated that HR-MRA and a VR algorithm improved diagnostic performance for the detection of intracranial aneurysms, especially when the aneurysm was less than 3 mm. In a clinical setting, the application of HR-MRA and a VR algorithm would facilitate the accurate differentiation of aneurysms from infundibula or no lesion and avoid unnecessary invasive procedures.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

REFERENCES

The Application of HR-MRA and a VR Algorithm for Accurate Differentiation of Aneurysms from Infundibula

• Lee A


