Interdisciplinary Neurosurgery 15 (2019) 6–10

Contents lists available at ScienceDirect

Interdisciplinary Neurosurgery

journal homepage: www.elsevier.com/locate/inat

Technical Notes & Surgical Techniques

Is MRA at 3.0 Tesla sufficient for preoperative planning for aneurysmal clipping in patients with contraindicated condition of contrast media?

Ririko Takeda, MD, PhD[a,b,*], Hidetoshi Ooigawa, MD, PhD[c], Akira Uchino, MD, PhD[d], Hiroki Kurita, MD, PhD[a]

[a] Department of Cerebrovascular Surgery, International Medical Center, Saitama Medical University, Hidaka, Japan
[b] Department of Neurosurgery, Mizonokuchi Hospital, Teikyo University School of Medicine, Kanagawa, Japan
[c] Department of Neurosurgery, Teikyo University, Tokyo, Japan
[d] Department of Diagnostic Radiology, International Medical Center, Saitama Medical University, Hidaka, Japan

ARTICLE INFO

Keywords:
Aneurysm
Clipping
MRA
CTA
DSA
Contrast media

ABSTRACT

Background: We evaluated the possibility that 3.0 T MRA was sufficient for unique imaging modality before aneurysmal clipping in patients with contraindication to contrast media.
Method: 13 cases (16 aneurysms) were retrospectively evaluated. Ruptured aneurysms were 3 cases (3 aneurysms). 10 cases (12 aneurysms) were operated on after preoperative evaluation using only 3.0 T MRA because of contraindication to contrast media, whereas both 3D-DSA/CTA and 3.0 T MRA were performed in 3 cases (4 aneurysms) before the operation because of each clinical reasons. In these 13 cases, we compared aneurysmal findings between intraoperative views and images of 3D-time of flight MRA with volume rendering at 3.0 T.
Results: Compared to operative views, the shape of aneurysm including bleb in MRA tended not to be slightly sharp, but the size of neck and dome of aneurysms did not show significant differences. These discrepancies did not affect the intraoperative procedures. Regarding perforators, posterior communicating artery and anterior choroidal artery were confirmed in the operation as same view with MRA findings. It was difficult to distinguish double anterior communicating artery aneurysm by 3.0 T MRA. In thrombosed case, it was necessary to examine raw data of MRA as pretreatment planning tool in order to evaluate the extent of thrombus in aneurysmal neck. Reviewing the cases operated using only 3.0 T MRA retrospectively, there was no case that showed treatment planning by 3.0 T MRA was insufficient.
Conclusions: This paper may suggest that treatment planning of aneurysmal clipping on the basis of 3.0 T MRA is feasible and an effective option for patients with contraindication to contrast media.

1. Introduction

Current techniques of three dimensional computed tomographic angiography (3D-CTA) and three dimensional digital subtraction angiography (3D-DSA) have enabled neurosurgeons to reliably recognize aneurysmal morphology. 3D-CTA and 3D-DSA have been already established as preoperative imaging tools before aneurysmal clipping [1–8]. However, some patients have contraindications to contrast medium because of allergy or renal dysfunction. It remains to be understood whether current MRA technique provides sufficient information for aneurysm clipping. The purpose of this study is to evaluate if 3.0 T MRA was sufficient for unique imaging modality before aneurysm surgery.

2. Patients and methods

Between January 2010 and March 2015, 784 patients with cerebral aneurysms underwent craniotomy and surgical clipping in our institution. All patients underwent unified preoperative imaging evaluation protocol. In patients with unruptured aneurysms, majority of the lesions were detected incidentally by 1.0 or 1.5 T MRA at other outpatient clinics, and introduced to our department for possible surgical repair. If

Abbreviations and acronyms: AcomA, anterior communicating artery; CTA, computed tomographic angiography; DSA, digital subtraction angiography; MCA, middle cerebral artery; MRA, magnetic resonance angiography; PcomA, posterior communicating artery; SAH, subarachnoid hemorrhage; TOF, time-of-flight; 3D, three dimensional; VR, volume rendering

* Corresponding author at: Department of Cerebrovascular Surgery, International Medical Center, Saitama Medical University, 1397-1 Yamane, Hidaka City, Saitama 350-1298, Japan.
E-mail address: rtakeda@saitama-med.ac.jp (R. Takeda).

https://doi.org/10.1016/j.inat.2018.09.003
Received 4 April 2018; Received in revised form 9 September 2018; Accepted 15 September 2018

the patient has no contraindication to contrast media, the patient was evaluated by digital subtraction angiography (DSA) or three-dimensional computed tomographic angiography (3D-CTA). After that, treatment decisions including endovascular treatment, surgical clipping, and observation were carefully decided. Conversely, for patients with contraindication to contrast media, three dimensional-time of flight (3D-TOF) -MRA with volume rendering (VR) at 3.0 T was used for preoperative evaluation for treatment decision of surgical clipping or conservative treatment.

Patients with subarachnoid hemorrhage (SAH) underwent DSA or 3D-CTA immediately on arrival for evaluation of ruptured aneurysms followed by urgent surgical or endovascular repair, if the patient had no contraindication to contrast media. On the other hand, 3D-TOF-MRA with VR at 3.0 T was performed for aneurysm evaluation for patients with contrast media contraindication.

Contraindication criteria for use of iodinated contrast media in our institute is as follows:

1. Patients with anaphylaxis or any allergy to prior iodinated contrast media have contraindication. However, when prior allergic reaction was small or doubtful, the contrast media are sometimes used with the premedication of steroids under careful observation.
2. Patients with a history of asthma have contraindication. However, if they have not had asthma attacks for over 5 years, the contrast media is sometimes used with premedication of steroids under careful observation.
3. Patients with estimated glomerular filtration rate (eGFR) $<$ 40 ml/min have contraindication. However, if necessary, the contrast media is sometimes used in patients with eGFR $>$ 30 ml/min with hydration.

The following societies guidelines were referred to when these criteria were created; Japanese College of Radiology (JCR2002), American College of Radiology (ACR2008, ver.6), European Society of Urogenital Radiology (EURS2012, ver.8).

All MRA examinations were performed on a 3.0 T system (Achieva 3.0 T, TX Quasar Dural, Philips Medical Systems, Best, The Netherlands), most with a 32-channel SENCE head coil. Parameters of the standard 3-dimensional (3D) time-of-flight (TOF) MR angiographic protocol were: repetition time (TR), 23 ms; echo time (TE), 3.45 ms; flip angle, 18°; field of view (FOV), 20 × 20 cm; and slice thickness, 0.55 mm (voxel size: anterior to posterior [AP], 0.45 mm; right to left [RL], 0.70 mm; foot to head [FH], 0.55 mm), with acquisition time of 5 min 28 s.

The size of the aneurysm in MRA was measured independently by a neurosurgeon (RT) and a radiologist (AU). Intraoperatively, the real size of the aneurysm was assessed after exposure of the lesion with a micro-scale in microsurgical view in 13 of 16 aneurysms (Fig. A).

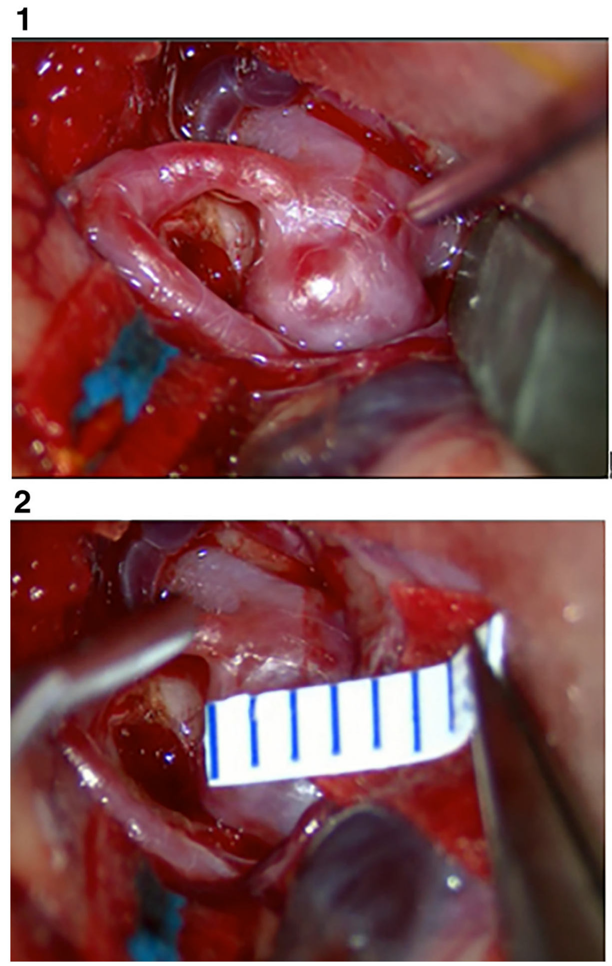

Fig. A. Intraoperative measurement of the aneurysm. After the full exposure of the lesion (A.1), microscale was used as a gauge (A.2).

3. Results

3.1. Incidence and characteristics of patients with 3.0-T MRA evaluation

During the observation period, 13 patients (1.7% of 784) with a total of 16 aneurysms underwent surgical clipping with 3.0-T MRA evaluation. 10 cases (12 aneurysms) were operated after preoperative evaluation using only 3.0 T MRA because of contraindication to contrast media, whereas both 3D-DSA/CTA and 3.0 T MRA were performed in 3 cases (4 aneurysms) before the operation because of each clinical reasons. There were 8 females and 5 males, with a mean age of 56.2 + −11.4 yrs (range 37–75). Three patients had ruptured and 10 had unruptured aneurysms. The most frequent background was past history of contrast media allergy, followed by renal dysfunction and asthma. The location of the aneurysm included anterior communicating artery (AcomA) in 8, middle cerebral artery (MCA) in 6, posterior communicating artery (PcomA) in 2. Clinical characteristics of the patients were summarized in Table A.

3.2. Discrepancy between MRA and intraoperative findings

Approximately, there was no significant discrepancy between intraoperative and 3.0 T-MRA findings in aneurysm morphology, and all aneurysms were successfully repaired by operative approach defined by preoperative MRA evaluation. There were no significant differences between neck and dome size of MRA (neck; mean 3.9 + −1.4 mm, dome; mean 6.2 + −3.0 mm; both N = 16) and intraoperative (neck; mean 3.5 + −1.8 mm N = 13, dome; mean 5.7 + −2.4 mm N = 13) measurement. Compared to MRA findings, the shape of aneurysm in intraoperative findings looked more clearly defined in 3 aneurysms. Especially in Case 7, at first we regarded the aneurysm from the findings of the MRA as the irregular shaped one AcomA aneurysm with the bulging on the AcomA. However, we recognized it not as a bulging but as another small aneurysm on the AcomA in the operative view (Fig. B). Furthermore, 3.0 T MRA occasionally failed to demonstrate small perforators or fine anatomical variations adjacent to aneurysm. In eight cases with AcomA aneurysms, MRA failed to demonstrate Heubner's artery in case 7 (Fig. B), and duplicated AcomA in case 11 (Fig. D). However, PcomA and anterior choroidal artery were confirmed during surgery as same view with MRA findings in 2 cases with PcomA aneurysms (Fig. C).

In 3 cases (Cases 11–13) which had both MRI and CTA/DSA, DSA was overlapped with 3.0 T MRA in Case 11, and CTA was overlapped with 3.0 T MRA in cases 12 and 13. As far as considering cases 12 and

Table A
Patient characteristics.

Case	Age	Sex	H&K	Location	AN size in MRA neck/dome (mm)	AN real size neck/dome (mm)	Discrepancy between MRA and intraoperative findings	GOS
1	70	F	0	MCA	4.1/4.3	4.0/4.0	None	GR
2	54	M	0	MCA	5.4/6.3	5.0/6.0	Not sharp in aneurysm shape	GR
3	47	F	0	MCA	3.8/5.8	4.0/6.0	None	GR
4	58	M	0	AcomA	2.7/4.0	2.5/5.0	None	GR
5	75	M	0	AcomA	3.8/8.5	NA/10.0	None	GR
6	63	M	0	AcomA	1.9/3.5	2.0/4.0	None	GR
7	73	F	0	AcomA	3.5/6.0	2.5/4.5, 1.0/3.0	Poor description of associated AcomA AN/Heubner's artery	GR
				MCA	8.3/12.0	8.0/12	Not sharp in aneurysm shape (bleb)	
8	58	F	1	PcomA	5.0/15.0	5.0/NA	None	MD
9	50	F	2	PcomA	3.6/4.7	NA/NA	None	GR
10	37	F	2	AcomA	4.2/6.8	NA/NA	None	GR
				MCA	4.2/4.6	NA/NA	None	
11	55	M	0	AcomA	2.8/4.6	2.5/5.0	Poor description of double AcomA	GR
				AcomA	2.3/4.2	2.0/4.0		
12	39	F	0	AcomA	4.2/4.6	4.5/5.0	None	GR
13	51	F	0	MCA	3.0/5.0	3.0/5.0	None	GR

H & K = Hunt and Kosnic grade, F = female, M = male, MCA = middle cerebral artery, AcomA = anterior communicating artery, PcomA = posterior communicating artery, NA = not available, AchA = anterior choroidal artery, GOS = Glasgow Outcome Scale, GR = good recovery, MD = moderate disability, SAH = subarachnoid hemorrhage, AN = aneurysm, MRA = magnetic resonance angiography.

13, CTA didn't reflect surgical findings more accurately compared to 3.0 T MRA.

4. Discussion

In this study, we compared anatomical correlation of cerebral aneurysms between 3D-TOF-MRA with VR at 3.0 T findings and intraoperative view, to evaluate how 3.0 T MRA served as preoperative planning tools before aneurysmal clipping without CTA and/or DSA. MRA has been established as a tool of screening for unruptured cerebral aneurysms. Furthermore, several studies have reported that 3.0 T MRA appears to be at least as sensitive as CTA in the detection of unruptured [9–11] and ruptured [12] intracranial aneurysms. Many reports have assessed the validity of 3.0 T MRA as a diagnostic technique for the detection of cerebral aneurysms. Conversely, few have evaluated the clinical implications of a protocol using 3.0 T MRA instead of DSA/CTA as a diagnostic and pretreatment planning tool [12]. In addition, there have been no reports of cerebral aneurysmal cases operated using VR 3.0 T MRA as the only pretreatment planning tool. Although the situation that patients who have contraindication to contrast media need

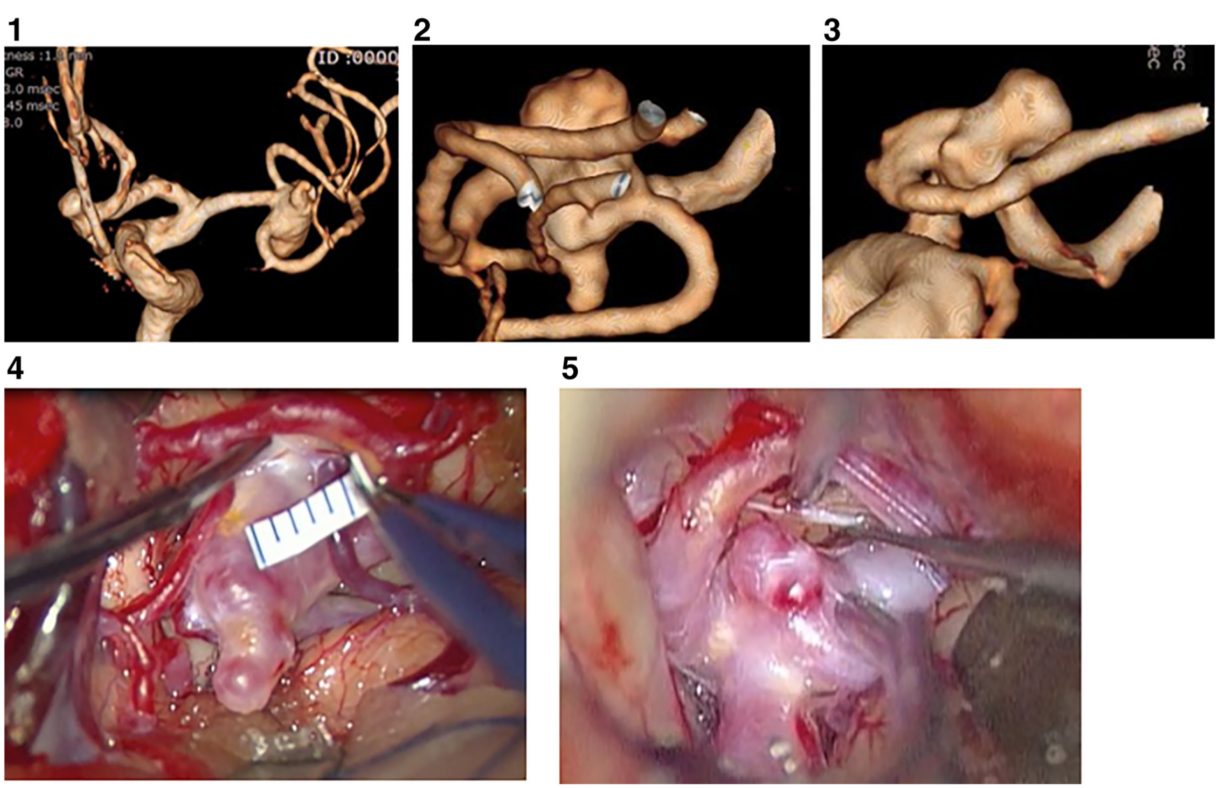

Fig. B. Findings in a 73-year-old female with unruptured left MCA and AcomA aneurysms (case 7) (B.1).
A 73 years old's woman who had allergy to contrast media. 3.0 T MRA showed left MCA (B.2) and AcomA (B.3) aneurysms which had irregular shaped and blebs. In the operation, the real size and shape of the two aneurysms were not much different from findings in 3.0 T MRA. However, compared to MRA findings, the shape of aneurysm in intraoperative findings looked more clearly defined (B.4). Besides, AcomA aneurysm had not a bulging but another small aneurysm on the AcomA in the operative view (B.5).

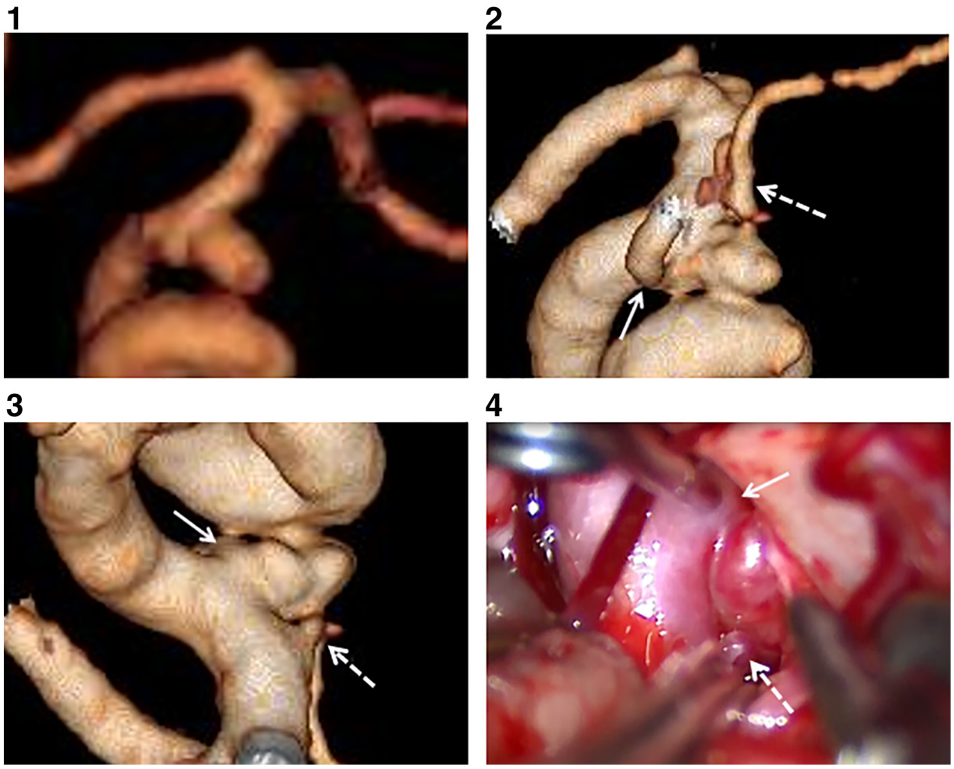

Fig. C. Findings in a 50-year-old female with WFNS grade 2 SAH due to ruptured right IC-PcomA aneurysm (case 9).

A 50 years old's woman who had allergy to contrast media developed SAH (Hunt and Kosnic grade 2) and 1.5 T MRA showed right IC-PcomA aneurysm (C.1). However, its findings were not sufficient for clipping about information of PcomA and anterior choroidal artery. 3.0 T MRA which was performed on the next day revealed clear views of shapes of the aneurysm (C.2, 3), PcomA (C.2, 3 arrow) and anterior choroidal artery (C.2, 3 broken arrow), and the findings were same with its intraoperative views (C.4).

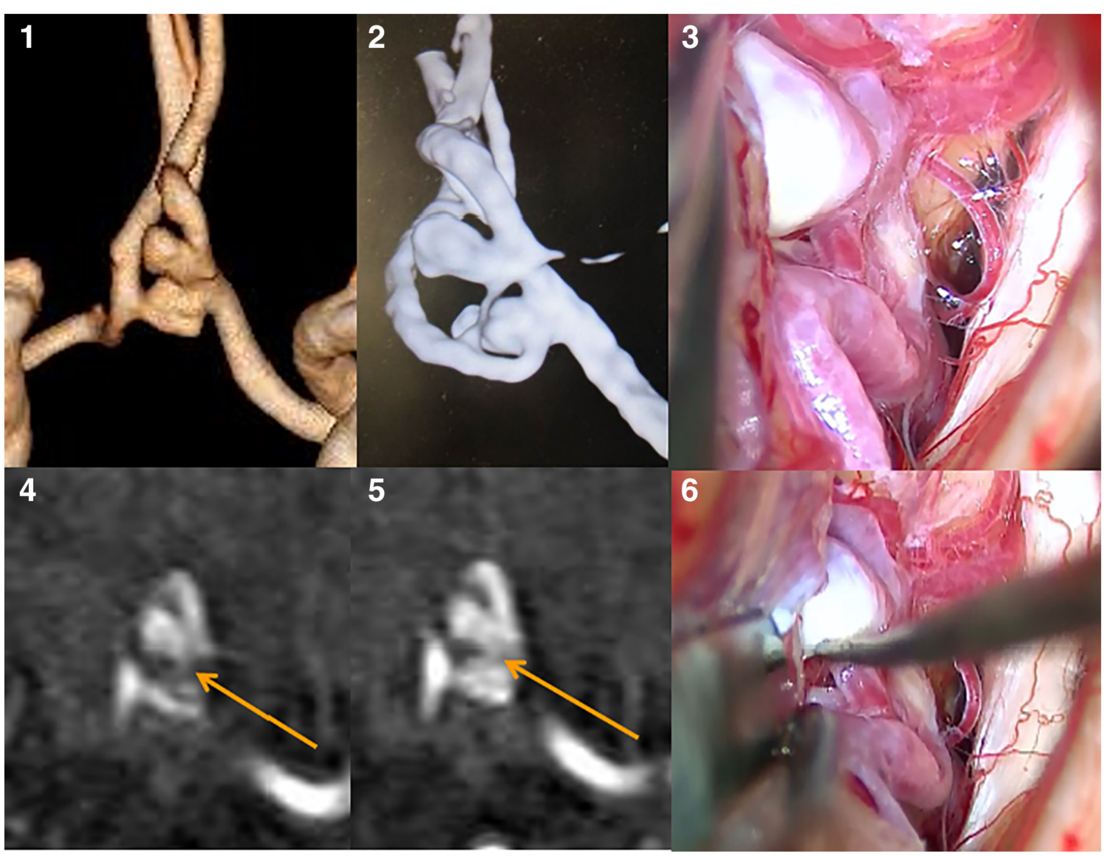

Fig. D. Findings in a 55-year-old male with unruptured duplicated AcomA aneurysms (case 11).

A 55 years old's man. His two AcomA aneurysms were discovered incidentally. DSA and 3.0 T MRA were performed and 3D DSA showed double AcomA and two aneurysms clearly (D.2:3D DSA, D.5, 6: intraoperative view), On the other hand, double AcomA was not visualized on 3.0 T MRA with VR (D.1, 3, 4).

aneurysmal surgery, seems to be increasing due to improvement of detection ability of intracranial aneurysms by MRA. However, if VR 3.0 T MRA is to serve as a non-invasive replacement for DSA in pretreatment planning, it must provide precise visualization of the aneurysmal neck and its relationships with parent vessels [12].

In our study, basic morphological findings were same between 3.0 T MRA findings and intraoperative views in an aneurysm. Descriptions of main arteries around aneurysms were precise in almost all cases. Regarding perforators, few studies have ever evaluated the clinical performance of 3.0 T MRA as a diagnostic tool of perforators. Sun et al. reported that sensitivity and accuracy was 100% in all patients for detection of infundibula at the anterior choroidal artery [13]. In our cases, anterior choroidal artery and Pcom artery were also visualized clearly in 3.0 T MRA enough to make preoperative planning and operative procedure in aneurysmal clipping.

However, as a matter of course VR 3.0 T MRA has limitations, which includes;

1. In this study, 3D-DSA was easy to visualize double Acom, but this was not the case for 3.0 T MRA. This misinterpretation of the double Acom on the VR 3.0 T MRA images seemed to be due to the proximity of the aneurysm wall to the two Acom at the neck level, and partial volume effects led to difficulties in defining the vessel wall from the proximity of the aneurysm wall [12]. VR 3.0 T MRA still has limitations in visualization of complicated vessel structures around an aneurysm. It seemed to be the same reason that 3.0 T MRA failed to demonstrate two adjacent aneurysms separately in Case 7.
2. The outline of large/giant aneurysms cannot be visualized well by VR 3D-TOF MRA, because saturation of slow moving blood and phase dispersion by complex flow within large/giant aneurysms causes signal loss [14]. Numminen et al. showed an interesting case where blood flow inside proximal ICA aneurysm caused spin saturation distally to the aneurysm, so that distal arteries or a distally located Acom aneurysm were not visible in 3.0 T TOF MRA images [9]. The supplemental use of gadolinium contrast enhanced MRI should be considered in these giant aneurysm's cases. Besides, in partial thrombosed aneurysm, thrombus is not also visualized in MRA, so it is important to evaluate the extent of thrombus to aneurysmal neck using raw data of MRA before the operation [15].
3. MRA is not suitable for evaluation of clipped aneurysm as a matter of course.

Considering these limitations, the aneurysms in two cases with overlap of 3.0 T MRA and CTA were so small and simple that 3.0 T MRA might never be inferior to CTA in the accuracy. Besides, this paper has also limitations. We have experienced only 16 aneurysms and almost of them were anterior circulation small aneurysms. However, our results may mean that 3.0 T MRA is possible to be non-invasive replacement for DSA/CTA in at least anterior circulation small and simple aneurysmal clipping.

5. Conclusions

This paper may suggest that as far as small and simple aneurysm in anterior circulation is concerned, treatment planning of aneurysmal clipping on the basis of VR 3D-TOF-MRA is feasible and effective option for the patients with contraindication to contrast media.

Declarations of interest

None.

References

[1] B.K. Velthuis, G.J. Rinkel, L.M. Ramos, T.D. Witkamp, J.W. van der Berkerlbach Sprenkel, W.P. Vandertop, et al., Subarachnoid hemorrhage: aneurysm detection and preoperative evaluation with CT angiography, Radiology 208 (1998) 423–430.
[2] R. Anxionnat, S. Bracard, X. Ducrocq, Y. Trousset, L. Launay, E. Kerrien, et al., Intracranial aneurysm: clinical value of 3D digital subtraction angiography in the therapeutic decision and endovascular treatment, Radiology 218 (2001) 799–808.
[3] K. Papke, C.K. Kuhl, M. Fruth, C. Haupt, M. Schlunz-Hendann, D. Sauner, M. Fiebich, et al., Intracranial aneurysm: role of multidetector CT angiography in diagnosis and endovascular therapy planning, Radiology 244 (2007) 532–540.
[4] Q. Li, F. Lv, Y. Li, T. Luo, K. Li, P. Xie, Evaluation of 64–section CT angiography for detection and treatment planning of intracranial aneurysm using DSA and surgical findings, Radiology 252 (2009) 808–815.
[5] B.L. Hoh, A.C. Cheung, J.D. Rabinov, J.C. Pryor, B.S. Carter, C.S. Ogilvy, 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 54 (2004) 1329–1340.
[6] B.K. Velthius, M.S. Van Leeuwen, T.D. Wiktanp, L.M. Ramos, J.W. van Der Berkelbach Sprenkel, G.J. Rinkel, Computerized tomography angiography in patients with subarachnoid hemorrhage: from aneurysm detection to treatment without conventional angiography, J. Neurosurg. 91 (1999) 761–767.
[7] I. Pechlivanis, K. Schmieder, M. Scholtz, M. Konig, L. Heuser, A. Harders, 3-Dimensional computed tomographic angiography for use of surgery planning in patients with intracranial aneurysms, Acta Neurochir. 147 (2005) 1045–1053.
[8] A.R. Dehdashti, D.A. Rufenacht, J. Delavelle, A. Reverdin, N. de Tribolet, Therapeutic decision and management of aneurysmal subarachnoid haemorrhage based on computed tomographic angiography, Br. J. Neurosurg. 17 (2003) 46–53.
[9] J. Numminen, A. Tarkiainen, M. Niemelä, M. Porras, J. Hernesniemi, M. Kangasniemi, Detection of unruptured cerebral artery aneurysms by MRA at 3.0 Tesla: comparison with multislice helical computed tomographic angiography, Acta Radiol. 52 (2011) 670–674.
[10] Y. Hiratsuka, H. Miki, I. Kiriyama, K. Kikuchi, S. Takahashi, I. Matsubara, K. Sadamoto, T. Mochizuki, Diagnosis of unruptured intracranial aneurysms: 3T MR angiography versus 64 – channel multi detector row CT angiography, Magn. Reson. Med. Sci. 7 (2008) 169–178.
[11] K. Igase, I. Matsubara, M. Igase, H. Miyazaki, K. Sadamoto, Initial experience in evaluating the prevalence of unruptured intracranial aneurysms detected on 3-Tesla MRI, Cerebrovasc. Dis. 33 (2012) 348–353.
[12] Yuan-Chang Chen, Zhen-Kui Sun, Ming-Hua Li, Yong-Dong Li, Wu Wang, Hua-Qiao Tan, Bin-Xian Gu, Shi-Wen Chen, The clinical value of MRA at 3.0 T for the diagnosis and therapeutic planning of patients with subarachnoid haemorrhage, Eur. Radiol. 22 (2012) 1404–1412.
[13] Z.K. Sun, Y.D. Li, M.H. Li, S.W. Chen, H.Q. Tan, Detection of infundibula using three-dimensional time-of-flight magnetic resonance angiography with volume rendering at 3.0 Tesla compared todigital subtraction angiography, J. Clin. Neurosci. 18 (2011) 504–508.
[14] H.R. Jäger, H. Ellamushi, E.A. Moore, J.P. Grieve, N.D. Kitchen, W.J. Taylor, Contrast-enhanced MR angiography of intracranial giant aneurysms, AJNR Am. J. Neuroradiol. 21 (2000) 1900–1907.
[15] H. Ooigawa, R. Takeda, H. Nakajima, T. Ikeda, S. Yoshikawa, M. Otsuka, K. Suzuki, A. Shibata, S. Ikeda, R. Nishikawa, H. Kurita, Preoperative evaluation and surgical clipping of intracranial aneurysms with 3D-MRA, CI Kenkyu 36 (2014) 17–21 (in Japanese).