



Diagnostic Accuracy of Magnetic Resonance Angiography for Detection of Intracranial Aneurysms in Patients with Acute Subarachnoid Hemorrhage; A Comparison to Digital Subtraction Angiography

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► ABSTRACT

Objectives: To determine the diagnostic accuracy of magnetic resonance angiography (MRA) compared to intra-arterial digital subtraction angiography (DSA) in detection of intracranial aneurysms in those suffering from acute subarachnoid hemorrhage (SAH).

Methods: This observational diagnostic study was performed at a tertiary teaching hospital and reference center in Shiraz, Iran. We included 55 patients who presented to our center with the diagnosis of acute SAH. All the patients underwent MRA and DSA during their hospital course in order to detect the intracranial aneurysms. The time-of-flight MRA protocol was used and the results were compared to the results of DSA as the gold standard test. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were calculated for MRA.

Results: The mean age of the patients was 46.3 ± 7.9 including 26 (47.3%) men and 29 (52.7%) women. In 46 patients, 51 intracranial aneurysms were diagnosed by DSA (5 patients had two aneurysms). No evidence of intracranial aneurysm was found in 9 patients with subarachnoid hemorrhage. MRA correctly identified 42 of the 51 aneurysms (sensitivity 82%) and missed 9 small aneurysms (less than 10 mm). MRA revealed one false-positive finding, resulting in a specificity of 88.8%. The PPV and NPV for MRA were 97% and 47%, respectively. The diagnostic accuracy per aneurysm was 0.83 for MRA.

Conclusion: High sensitivity and specificity of MRA compared to DSA in diagnosis of intracranial aneurysms in those with acute SAH indicate that MRA could be reliably used as a diagnostic tool for this purpose. However we cannot recommend it as a routine substitute for DSA before surgery.

Keywords: Intracranial aneurysm; Subarachnoid hemorrhage (SAH); Digital subtraction angiography (DSA); Magnetic resonance angiography (MRA).

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Introduction

Cerebral aneurysms with a prevalence of 0.5-5% of the general population are common vascular anomalies of intracranial arteries. They have a greater incidence in women and increasing incidence with advancing age [1,2]. A ruptured cerebral aneurysm results in significant morbidity and mortality: 30-day mortality can be as high as 60% and the rebleeding

rate is 10% to 50% during the first 6 months in untreated patients [3-6]. The most prominent role for computed tomography (CT) in the patients with a cerebral aneurysm is to identify acute subarachnoid hemorrhage (SAH), which is clearly disclosed as areas of increased density within the sulci and cisternal spaces.

Because of its high spatial resolution, intra-arterial

digital subtraction angiography (DSA) is the gold standard for detecting intracranial aneurysms [3,4]. This technique is the imaging modality of choice for the visualization of aneurysms or other causes of hemorrhage, and may also be used as a treatment tool. Despite these advantages of intra-arterial DSA and modern developments in the achievement of cerebral angiography, the risk of neurological complications associated with this procedure cannot be overlooked [5,6]. The invasive nature of DSA may provoke transient or permanent neurological deficits such as infarction secondary to catheter clot embolus [6,7]. A low but important risk of complications is related to contrast reaction, and arterial puncture, catheter handling, vagal inhibition and bacteremia are other disadvantages [7-10].

During the last two decades, interest has increased in the use of noninvasive imaging to detect intracranial aneurysms. Computed tomography angiography (CTA) is a noninvasive imaging modality that does not require arterial puncture or catheter manipulation [11]. Magnetic resonance angiography (MRA) is also a noninvasive imaging technique based on the detection of blood flow within the cerebral vessels. Its considerable advantage is that it is able to produce source images that can be used in two- and three-dimensional modes. Artifact formation due to flow phenomena and patient motion, in addition to extended acquisition time, are the major disadvantages of MRA [12,13].

Advances in magnetic resonance imaging (MRI) and MRA have produced valuable technologies that show details of intracranial vascular diseases noninvasively [14]. Although MRA is not sensitive enough to detect calcifications and acute subarachnoid bleeding, it is a powerful modality in detecting cerebral vascular lesions of the central nervous system [15,16]. Advanced MRA techniques can thus provide valuable morphological and physiological information about vascular diseases [17,18].

If MRA is to replace intra-arterial DSA in the detection and characterization of intracranial aneurysms, the sensitivity and specificity of these modalities should be at least as good as those of DSA. Our purpose here was to assess the diagnostic accuracy of MRA in the diagnosis of cerebral aneurysms, and to compare and contrast MRA and DSA for this purpose.

Materials and Methods

Study population

This was an observational diagnostic accuracy study being performed. Nemazee Hospital in Shiraz is the reference center for intracranial aneurysm surgery for about total population of about 5,000,000. Patients admitted to our hospital with non-traumatic SAH or

intracranial hemorrhage, intraventricular hemorrhage or infarction underwent diagnostic intracranial DSA and MRA. Subarachnoid hemorrhage was suspected on the basis of clinical presentation and confirmed by unenhanced CT. This study included 55 patients (26 men and 29 women) with an age range of 22–75 years (mean, 46.3 ± 7.9 years).

All the patients were monitored in a neurosurgical intensive care unit. Computed tomography of the head was done on admission and repeated after any clinical deterioration. All patients underwent DSA within 3 days after admission. Our analysis included patients who underwent cerebral angiography for possible intracranial aneurysm. The exclusion criteria were poor grade of subarachnoid hemorrhage, absolute contraindication for one of the modalities, and age more than 75 years. In patients whose clinical situation was stable we did MRA if DSA was negative or inconclusive. In most patients MRA was done before DSA, or within a maximum of 1 week after DSA. If only MRA or DSA was done, these patients were excluded from our analysis. Two additional patients were excluded because of incomplete DSA secondary to technical problems. All procedures were done in accordance with the guidelines of the Ethics Committee of Shiraz University of Medical Sciences. All the patients provided their informed written consents.

Imaging protocols

Three-dimensional time of flight MR angiograms (3D-TOF MRA) were obtained at 1.5 Tesla with a repetition time (TR) = 23 and echo time (TE) = 6.9, flip angle 20° , a 512×256 matrix, magnetization transfer (MT) prepulse, and field of view 18 cm over 24 slices with 1.7 mm effective thickness. No contrast was used. Post-processing consisted of 60° maximum intensity projections (MIP) at six increments for 360° around the head, in both left-to-right and head-to-foot rotations. Images were reconstructed from the whole data set without editing. Source images were viewed on a routine basis. Intra-arterial DSA studies were done on a digital angiography system (Philips Arcu 48). We used elective three- or four-vessel angiography with a standard projection format (anteroposterior, lateral and reverse-oblique), and additional views were obtained, if required, to identify the parent vessel and aneurysm neck more clearly. The amount of contrast medium (Omnipaque 240 at a 1:1 dilution) was 12 ml for each series, and the injection rate was 10 ml/s with the tip of the catheter placed proximal to the carotid bifurcation. Injections into the vertebrobasilar system were performed at a rate of 8 ml/s to a total amount of 8 ml. Magnetic resonance data were recorded by a radiologist with

experience in image postprocessing; he was aware of the CT results including the sites of SAH and severity of hemorrhage.

The presence of definite aneurysm was determined on a two-point scale of confidence, with 1 indicating definite presence and 2 indicating definite absence. The following parameters were recorded: i) presence or absence of aneurysm, ii) location, size and shape, and iii) the relationship of the aneurysm with the parent and nearby vessels. If multiple aneurysms were detected, the usual criteria were used to decide which aneurysm was responsible for the hemorrhage. These criteria included the CT findings (distribution of blood) and the size and irregularity of the aneurysm. All aneurysm sites and sizes were recorded on an ad hoc data collection form. The site and size of the internal carotid artery (ICA) bifurcation and ICA siphon, the middle cerebral artery (MCA), the anterior cerebral artery (ACA), the posterior cerebral artery (PCA), the vertebral artery, the basilar artery, the anterior communicating artery (ACAM), and the posterior communicating artery (PCAM) were recorded. The size of aneurysms was recorded as maximum dimension smaller than 10 mm (*a*), 10–25 mm (*b*), or larger than 25 mm (*c*)

Statistical Analysis

Statistical analysis

A 2×2 table consisting of true positive, false positive, true negative and false negative was used to compare MRA with the gold standard DSA. Sensitivity, specificity, positive and negative predictive values (PPV and NPV), and accuracy were calculated and compared on a per-patient and per-aneurysm basis.

Results

A total number of 51 aneurysms were visualized

Table 1. Location of aneurysms in patients examined with digital subtraction angiography (DSA) and magnetic resonance angiography (MRA).

| Aneurysm location | No of aneurysms (%) in DSA | No of aneurysms (%) in MRA |
|-------------------|----------------------------|----------------------------|
| MCA ^a | 15 (29.4%) | 10 (23.8%) |
| ACA ^b | 5 (9.8%) | 5 (11.9%) |
| ACoM ^c | 15 (29.4%) | 14 (33.3%) |
| PCoM ^d | 7 (13.7%) | 4 (9.5%) |
| ICA ^e | 6 (11.7%) | 6 (14.2%) |
| Basilar | 3 (5.9%) | 3 (7.1%) |
| Vertebral | 0 (0%) | 0 (0%) |
| Ophthalmic | 0 (0%) | 0 (0%) |
| Choroidal | 0 (0%) | 0 (0%) |
| Total | 51 (100%) | 42 (100%) |

^aMiddle cerebral artery; ^bAnterior cerebral artery; ^cAnterior communicating artery;

^dPosterior communicating artery; ^eInternal carotid artery

with DSA in 46 (83 %) of 55 patients (Table 1). In five patients, two aneurysms were present. No aneurysm was found with DSA in 9 patients. Thirty-eight (74 %) of the 51 aneurysms were smaller than 10 mm, and 11 (22 %) were between 10 mm to 25 mm. There were two giant aneurysms (larger than 25 mm). Forty-two of 51 aneurysms (82%) were visualized with MRA (Table 1). All aneurysms 10 mm or larger were visualized in 3D reconstructions or source images. Nine small aneurysms (less than 10 mm) were not visualized in MRA.

Overall sensitivity and specificity, as well as the positive and the negative predictive values for MRA, were calculated. The sensitivity of MRA in detecting intracerebral aneurysms was 0.82, and specificity was 0.89. The positive and negative predictive values for MRA were 0.93 and 0.47, respectively. Aneurysms were closely related with parental vessels and adjacent structures. Details of the false-negative and false-positive results of MRA are given in Table 2.

This technique produced 9 false negative readings, all of which were for aneurysms smaller than 10 mm. Five (55%) of the 9 false-negative MRA readings were related to MCA aneurysms; three (33%) to PCAM, and 1 (12%) to an ACAM aneurysm. We found 1 false-positive reading in MRA. Follow-up MRI with contrast for basilar tip aneurysm showed this finding to correspond to the remnant of a small calcified craniopharyngioma in close contact with the circle of Willis. Small aneurysms were detected substantially less well with MRA than aneurysms measuring 10 to 25 mm and larger. There was a trend toward greater diagnostic accuracy for vertebrobasilar and ACA circulation aneurysms compared to MCA or PCAM aneurysms.

Discussion

Intra-arterial DSA is the gold standard for evaluating intracranial vessels, but this procedure is invasive, involving risks of complications such as arterial puncture, emboli, dissection, hemorrhage and septicemia, which can be prevented by using noninvasive imaging tools [7,9,10]. Magnetic resonance angiography offers benefits such as its lower cost and the absence of procedure-associated risk of stroke and arterial injury. Another benefit of MRA is

Table 2. Location of 9 false-negative findings for aneurysm with magnetic resonance angiography.

| Aneurysm location | No of aneurysms (%) |
|-------------------|---------------------|
| MCA ^a | 5 (55%) |
| PCoM ^b | 3 (33%) |
| ACoM ^c | 1 (12%) |

^aMiddle cerebral artery; ^bPosterior communicating artery;

^cAnterior communicating artery

that views can be stored and used by technicians and physicians after the patient has left, and interactive viewing among different users is possible. A distinct advantage of MRA is that it can be used for patients with a critical status in conjunction with anesthetic equipment.

Although MRA is an effective diagnostic procedure to detect cerebrovascular disease, this modality still has important limitations in visualizing intracranial vascular abnormalities. Our study attempted to assess the efficacy of MRA in detecting and delimiting intracranial aneurysms when the 3D TOF method was used together with MIP post-processing enhancements that offer several advantages over conventional MRA [15,17-19].

Certain limitations of MRA can affect its efficacy in detecting intracranial aneurysms. For example, small aneurysms less than 3 mm, distant aneurysms and small vascular lesions such as vasculitis may be overlooked [16,20]. Loop formation and overlapping vessels have been identified as the main sources of false-positive and false-negative results. To overcome these problems, techniques based on the use of source and reconstructed images such as MIP and multiplanar reconstruction may be helpful [11,14,21,22]. Our study used advanced post-processing with MIP to improve visualization of the aneurysms in our patients. The accuracy of intracranial aneurysm detection can be increased with combinations of post-processing methods and improved data acquisition systems in MRA, including the use of thin slices, the magnetization transfer phenomenon or phase-contrast MRA to reduce background signal detection [11,21,23]. Recent blinded-reader studies have reported mean sensitivities of 63% to 93% for the detection of intracranial aneurysms with 3D TOF MRA or MIP, and mean specificities of 92% to 100% [20,24-28].

Nine symptomatic aneurysms that were missed by MRA were smaller than 10 mm in diameter. The stagnant flow close to the aneurysm may make small aneurysms invisible secondary to decreased MRA signal intensity. We found that 38 (72%) of 51 aneurysms were small (<10 mm), and the sensitivity of detection of small aneurysms was 76% (versus 100% for larger aneurysms). Small aneurysms are much harder to detect than larger ones, and the accuracy in detecting small aneurysms has been reported to be as

low as 56% with MRA [22]. Most of the false-negative results in this study were caused by aneurysms smaller than 10 mm, especially aneurysms smaller than 6 mm. In general, MRA was better at detecting aneurysms larger than 10 mm in patients with acute SAH.

Although the sensitivity and positive predictive value of MRA in the present study were acceptable, we cannot recommend it as a safe substitute for DSA to detect small aneurysms in patients with acute SAH. However, MRA is a useful alternative for aneurysms larger than 10 mm or as a noninvasive method in critically ill patients or in patients for whom DSA is contraindicated. The low negative predictive value (47%) showed that negative results with MRA should be re-evaluated with DSA to seek out intracranial aneurysms. For patients with SAH in whom an aneurysm is strongly suspected, we believe that although MRA can help to rule out the existence of an aneurysm larger than 10 mm reliably, DSA should be carried out if the MRA findings are negative but insufficiently conclusive to rule out the possibility of a smaller aneurysm.

Our study points to a number of important considerations regarding the use of MRA to detect intracerebral aneurysms. First, diagnostic accuracy is substantially limited by aneurysm size. Second, at certain sites, particularly in areas of vessel overlap or MCA bifurcation, MRA may miss some lesions. Therefore, caution should be exercised in the interpretation of small aneurysms arising from the MCA bifurcation or in vessels that overlap, such as the internal carotid artery bifurcation or the posterior communicating artery.

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References

- Costa Jr LB, Morais JV, Andrade A, Vilela MD, Pontes RP, Braga BP. Surgical treatment of intracranial aneurysms: six-year experience in Belo Horizonte, MG, Brazil. *Arq Neuropsiquiatr* 2004;**62**(2A):245-9.
- Menghini VV, Brown RD Jr, Sicks JD, O'Fallon WM, Wiebers DO. Incidence and prevalence of intracranial aneurysms and hemorrhage in Olmsted County, Minnesota 1965 to 1995. *Neurology* 1998;**51**(2):405-11.
- Brott T, Mandybur TI. Case control study of clinical outcome after aneurysmal subarachnoid hemorrhage. *Neurosurgery* 1986;**19**(6):891-5.
- Jane J A, Kassel NF, Torner JC, Winn HR. The natural history of aneurysms and arteriovenous

- malformations. *J Neurosurg* 1985;**62**(3):321-3.
5. Kassel NF, Torner JC. Size of intracranial aneurysms. *Neurosurgery* 1983;**12**(3):291-7.
 6. Juvela S, Porras M, Heiskanen O. Natural history of unruptured intracranial aneurysms: A long term follow up study. *J Neurosurg* 1993;**79**(2):174-82.
 7. Guo Y, Piza M, Rubin GL, Dorsch N, Young N, Wong KP. Neurological complication of cerebral angiography performed for hospital inpatients. *J HK Coll Radiol* 2007;**10**:9-15.
 8. Heiserman JE, Dean BL, Hodak JA, Flom RA, Bird CR, Drayer BP, et al. Neurologic complications of cerebral angiography. *AJNR Am J Neuroradiol* 1994;**15**(8):1401-7; discussion 1408-11.
 9. Leffers AM, Wagner A. Neurologic complications of cerebral angiography: A retrospective study of complication rate and patient risk factors. *Acta Radiol* 2000;**41**(3):204-10.
 10. Cloft HJ, GJ Joseph, JE Dion. Risk of cerebral angiography in patients with subarachnoid hemorrhage, cerebral aneurysm, and arteriovenous malformation. A meta-analysis. *Stroke* 1999;**30**(2):317-20.
 11. Atlas SW, Sheppard L, Goldberg HI, Hurst RW, Listerud J, Flamm E. Intracranial Aneurysms: Detection and characterization with MR angiography with use of an advanced postprocessing technique in a blinded-reader study. *Radiology* 1997;**203**(3):807-14.
 12. Kouskouras C, Charitanti A, Giavroglou C, Foroglou N, Selviaridis P, Kontopoulos V, et al. Intracranial aneurysms: evaluation using CTA and MRA: Correlation with DSA and intraoperative findings. *Neuroradiology* 2004;**46**(10):842-50.
 13. Tang PH, Hui F, Sitoh YY. Intracranial aneurysm detection with 3T magnetic resonance angiography. *Ann Acad Med Singapore* 2007;**36**(6):388-93.
 14. Adams WM, Laitt RD, Jackson A. The role of MR angiography in the pretreatment assessment of intracranial aneurysms: a comparative study. *AJNR Am J Neuroradiol* 2000;**21**(9):1618-28.
 15. Isoda H, Takehara Y, Isogai S, Masunaga H, Takeda H, Nozaki A, et al. MRA of intracranial aneurysm models: a comparison of contrast-enhanced three-dimensional MRA with time-of-flight MRA. *J Comput Assist Tomogr* 2000;**24**(2):308-15.
 16. White PM, Teadsale E, Wardlaw JM, Easton V. What is the most sensitive non-invasive imaging strategy for the diagnosis of intracranial aneurysms. *J Neurol Neurosurg Psychiatry* 2001;**71**(3):322-8.
 17. Jäger HR, Mansmann U, Hausmann O, Partzsch U, Moseley IF, Taylor WJ. MRA versus digital subtraction angiography in acute subarachnoid haemorrhage: a blinded multireader study of prospectively recruited patients. *Neuroradiology* 2000;**42**(5):313-26.
 18. Anderson CM, Saloner D, Tsuruda JS, Shapeero LG, Lee RE. Artifacts in maximum intensity projection display of MR angiograms. *AJR Am J Roentgenol* 1990;**154**(3):623-9.
 19. Watanabe Z, Kikuchi Y, Izaki K, Hanyu N, Lim FS, Gotou H, et al. The usefulness of 3D MR angiography in surgery for ruptured cerebral aneurysms. *Surg Neurol* 2001;**55**(6):359-64.
 20. White PM, Teasdale EM, Wardlaw JM, Easton V. Intracranial aneurysms: CT angiography for detection--prospective blinded comparison in a large patient cohort. *Radiology* 2001;**219**(3):739-49.
 21. Blatter DD, Parker DL, Ahn SS, Bahr AL, Robison RO, Schwartz RB, et al. Cerebral MR angiography with multiple overlapping thin slab acquisition: Early clinical experience. *Radiology* 1992;**183**(2):379-89.
 22. Korogi Y, Takahashi M, Mabuchi N, Nakagawa T, Fujiwara S, Horikawa Y, et al. Intracranial aneurysms: diagnostic accuracy of MR Angiography with evaluation of maximum intensity projection and source images. *Radiology* 1996;**199**(1):199-207.
 23. Dagirmanjian A, Ross JS, Obuchowski N, Lewin JS, Tkach JA, Ruggieri PM, et al. High resolution, magnetization transfer saturation, variable flip angle, time-of-flight MRA in the detection of intracranial vascular stenoses. *J Comput Assist Tomogr* 1995;**19**(5):700-6.
 24. Wilcock D, Jaskan T, Holland I, Cherryman G, Worthington B. Comparison of magnetic resonance angiography with conventional angiography in the detection of intracranial aneurysms in patients presenting with subarachnoid haemorrhage. *Clin Radiol* 1996;**51**(5):330-4.
 25. Raaymakers TW, Buys PC, Verbeeten B Jr, Ramos LM, Witkamp TD, Hulsmans FJ, et al. MR angiography as a screening tool for intracranial aneurysm: feasibility, test characteristics and interobserver agreement. *AJR Am J Roentgenol* 1999;**173**(6):1469-75.
 26. Ross JS, Masaryk TJ, Modic MT, Ruggieri PM, Haacke EM, Selman WR. Intracranial aneurysms: evaluation by MR angiography. *AJR Am J Roentgenol* 1990;**155**(1):159-65.
 27. Schuierer G, Huk WJ, Laub G. Magnetic resonance angiography of intracranial aneurysms: comparison with intra-arterial digital subtraction angiography. *Neuroradiology* 1992;**35**(1):50-4.
 28. Pierot L, Portefaix C, Rodriguez-Régent C, Gallas S, Meder JF, Oppenheim C. Role of MRA in the detection of intracranial aneurysm in the acute phase of subarachnoid hemorrhage. *J Neuroradiol* 2013;**40**(3):204-10.