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Original Article

Localization and Treatment of Unruptured Paraclinoid Aneurysms: A Proton Density MRI-based Study

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Objective : The purpose of this study was to evaluate the usefulness of proton density magnetic resonance (PD MR) imaging for localization of paraclinoid internal carotid artery aneurysms.

Materials and Methods : From April 2014 to April 2015, 76 unruptured paraclinoid aneurysms in 66 patients were evaluated using PD MR and angiography (CT/MR angiography or digital subtraction angiography). The locations (extradural, transdural, intradural) in relation to the distal dural ring (DDR) and projection (superior, inferior/posterior, medial, lateral) of the aneurysms were assessed and compared.

Results : The most common location of paraclinoid aneurysms was extradural (n = 48, 63.2%), followed by intradural (n = 18, 23.7%), and transdural (n = 10, 13.2%). In the medial projection group (n = 49, 64.5%), 31 were extradural (63.3%), 5 were transdural (10.2%), and 13 were intradural (26.5%). In the inferior/posterior projection group (n = 19, 25.0%), there were 14 extradural (73.7%), 4 transdural (21.0%), and 1 intradural (5.3%). In the superior (n = 4, 5.3%)/lateral (n = 4, 5.3%) projection groups, there were 0/3 extradural (0/75.0%), 1/0 transdural (25.0/0%), and 3/1 intradural (75.0/25.0%).

Conclusion : PD MR showed sufficient contrast difference to distinguish paraclinoid aneurysms from surrounding dural structures.

Keywords Aneurysm, Internal carotid artery, Magnetic resonance imaging

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INTRODUCTION

Unruptured paraclinoid internal carotid artery (ICA) aneurysms are commonly encountered in neurosurgery. However, their surgical treatment is challenging due to the complex anatomical relationship with nearby bony and neurovascular structures. A recent study found that these lesions have a relatively benign natural course.[6] Therefore, consideration of the risks and benefits is important when determining which aneurysms should be treated. Treatment of unruptured paraclinoid aneurysms can differ according to their relationship to the distal dural ring (DDR). The risk of rupture maybe lower for extradural aneurysms, which are located below the DDR, with a more difficult surgical approach, compared with intradural aneurysms. Therefore, determining the relationship between paraclinoid aneurysms and the DDR is important.

Proton density magnetic resonance (PD MR) imaging is a basic spin echo pulse sequence generated from long repetition time (TR) and short echo time (TE), which reflects the number of hydrogen nuclei in a tissue.[1)4)] Therefore, PD MR and its multiplanar reconstruction images can provide clearer and more direct discrimination of arterial structures from dural structures than other MR imaging techniques. The aim of this study was to evaluate the usefulness of PD MR imaging for localization of paraclinoid aneurysms in order to determine the most appropriate treatment strategy.

MATERIALS AND METHODS

From April 2014 to April 2015, a total of 66 patients with unruptured paraclinoid aneurysms were evaluated using PD MR. There were 13 males (19.7%) and 53 females (80.3%) with a mean age of 54.5 years (range, 29 to 72). CT/MR angiography or digital subtraction angiography (DSA) were also performed simultaneously for evaluation of aneurysm size and projection. Neurosurgical treatment for these lesions was considered in cases of 1) maximum aneurysm size of 3 mm or more considering unfavorable morphological parameters,[5] 2) location primarily in the intradural space or a symptomatic lesion in the extradural space, and 3) patient's life expectancy of ten years or more. After review of patients' clinical status and imaging studies, treatment was discussed between the neurosurgeon and neurointerventionalist and a plan was determined with consensus. Clinical and radiologic data were reviewed retrospectively. Informed consent was obtained from the patients or their legal representative.

Imaging acquisition

PD MR imaging (TR/TE = 2000/32.2 ms, thickness = 0.4 mm, field of view = 180 × 180 mm, matrix = 480 × 480, number of signal averages = 1, echo train length = 63, acquisition time = 8-9 min) was obtained using 3T-MR units (Achieva; Philips Medical Systems, Best, Netherlands) and a 32-channel sensitivity encoding (SENSE) head coil on all patients. A variable-flip-angle refocusing plus train was used with an α min of 50 and α max of 120. In both sequences, the coronal section was scanned along the axis of the vertebral artery or the axis of the internal carotid artery and a more appropriate angle was chosen in order to show the neck of the aneurysm clearly. Multiplanar reconstruction was performed for all aneurysms in order to achieve more delicate discrimination of the aneurysm and DDR.

Imaging analysis

Two independent investigators reviewed all of the PD MR images and angiograms. If the interpretations differed, another investigator reviewed the images and the final interpretation was determined with consensus. Based on the PD MR findings, aneurysms were classified according to the following three categories by location: intradural, transdural, and extradural. Based on the angiography findings, aneurysms were classified according to the following four categories based on projection: superior, inferior/posterior, medial, and lateral. The relationship between aneurysm location and projection was also analyzed.

RESULTS

A total of 76 paraclinoid aneurysms were evaluated, all of which were asymptomatic lesions. The mean aneurysm diameter was 3.9 mm, ranging from 1.6 to 15.0 mm. According to the angiography findings, medial projection was the most common (n = 49, 64.5%), followed by inferior/posterior (n = 19, 25.0%), superior (n = 4, 5.3%), and lateral (n = 4, 5.3%). In 71 aneurysms (93.5%), PD MR coronal images showed the relationship between aneurysm and DDR. In 5 cases (6.5%), PD MR multiplanar reconstruction images were helpful in discrimination of aneurysm and DDR. Finally, all paraclinoid aneurysms could be differentiated from the DDR using PD MR and its multiplanar reconstruction images. According to the PD MR images, there were 48 extradural aneurysms (63.2%), followed by 18 intradural (23.7%) and 10 transdural (13.2%). In the medial projection group, 31 were extradural (63.3%), 5 were transdural (10.2%), and 13 were intradural (26.5%). In the inferior/posterior projection group, there were 14 extradural (73.7%), 4 transdural (21.0%), and 1 intradural (5.3%). In the superior/lateral projection groups, there were 0/3 extra-

Table 1. Distribution of paraclinoid aneurysms by location and projection

Location	Projection				
	Superior	Inferior/posterior	Medial	Lateral	Total
Extradural	0	14 (73.7%)	31 (63.3%)	3 (75.0%)	48 (63.2%)
Transdural	1 (25.0%)	4 (21.0%)	5 (10.2%)	0	10 (13.2%)
Intradural	3 (75.0%)	1 (5.3%)	5 (10.2%)	1 (25.0%)	18 (23.7%)
Total	4 (5.3%)	19 (25.0%)	49 (64.5%)	4 (5.3%)	76

dural (0/75.0%), 1/0 transdural (25.0/0%), and 3/1 intradural (75.0/25.0%). These results are shown in Table 1.

Among the 76 aneurysms, 8 lesions were treated by endovascular coiling under general anesthesia, one transdural and seven intradural lesions. Complete/near complete occlusion could be achieved in six cases (75.0%), while residual neck could be achieved in two cases (25.0%). There was no occurrence of procedure-related complications or technical failure. These results are shown in Table 2.

Case reports

Case I

A 68-year-old female suffering from chronic headache underwent brain CT angiography, which showed an aneurysm of the right distal ICA. DSA showed a 7.9 mm aneurysm with medial projection of the right paraclinoid ICA (Fig. 1A). PD MR showed that the aneurysm was intradural (Fig. 1B), and successful coiling was performed (Fig. 1C) despite coil stretch.

Case II

A 52-year-old female was admitted for incidental finding of an unruptured paraclinoid aneurysm. DSA showed a 5.0 mm aneurysm with inferior/posterior projection. PD MR was performed for localization of the aneurysm (Fig. 2A). However, the distal dural ring and aneurysm could not be discriminated on a PD MR coronal image (Fig. 2B). We were able to identify the transdural location of this aneurysm by multiplanar reconstruction (Fig. 2C).

DISCUSSION

The cavernous sinus is covered by two layers of dura mater, the periosteal layer, and the meningeal layer, which continues to the distal dural ring (DDR) and diaphragm.[11] Identification of paraclinoid aneurysms and DDR can be helpful in determining the appropriate management of these lesions. In some studies, CT scan landmarks, carotid artery concavity, and optic

Table 2. Outcome of endovascular coiling of paraclinoid aneurysms

	Projection	Location	Size (mm)	Angiographic outcome	Procedure-related events
1	Inferior/posterior	TD	5.0	Complete	None
2	Medial	ID	5.4	Residual neck	None
3	Superior	ID	3.6	Residual neck	None
4	Medial	ID	7.8	Complete	Coil stretch w/o symptomatic complication
5	Medial	ID	4.2	Complete	None
6	Medial	ID	3.7	Complete	None
7	Medial	ID	4.0	Near complete	None
8	Medial	ID	8.0	Near complete	None

TD = transdural type; ID = intradural type; w/o = without

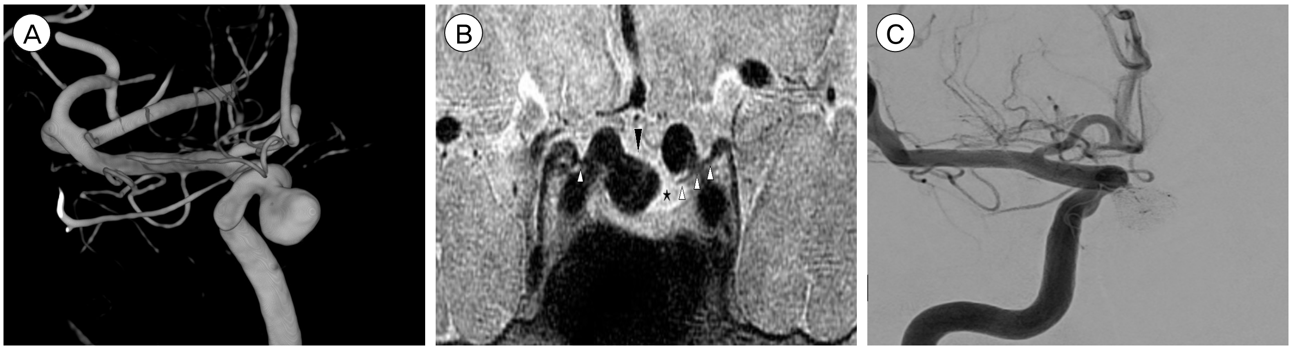

Fig. 1. (A) Three-dimensional (3D) DSA reconstruction shows a 7.9 mm aneurysm with medial projection at the right paraclinoid ICA. (B) PD MR coronal imaging shows the aneurysm (arrow head), distal dural ring/diaphragm (open arrow head), and cerebrospinal fluid space (star). (C) Successful coiling of the right paraclinoid aneurysm. DSA = digital subtraction angiography; ICA = internal carotid artery; PD MR = proton density magnetic resonance.

strut, were evaluated to determine aneurysm location instead of direct visualization of the DDR.[2][8] Other studies have shown that high-resolution T2-weighted 3D fast spin-echo (3D-FSE)[7][9] or 3D constructive interference on steady-state MR (3D-CISS)[3][10] imaging could provide valuable information about aneurysm location in relation to the DDR. These MR techniques can clearly discriminate between the "white" subarachnoid space and "black" cavernous sinus. However, in our experience, MR coronal images do not discriminate inferior/posterior projecting aneurysms from the DDR because the ICA clinoid segment can overlap the neck of the aneurysm in this view. The current study showed that PD MR multiplanar reconstruction images can be used effectively in such cases.

The risk of rupture is relatively low for patients with paraclinoid aneurysms compared with other ICA aneurysms because half of them were non-branching

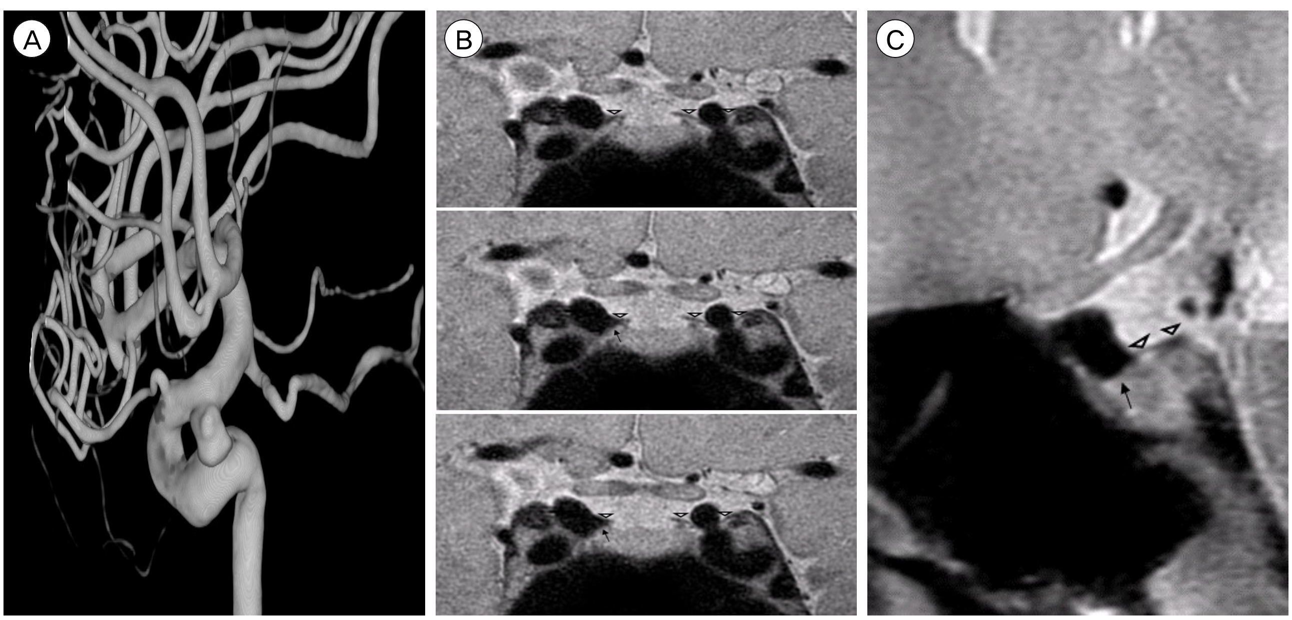

Fig. 2. (A) Three-dimensional (3D) DSA reconstruction shows a 5.0 mm aneurysm with an inferior/posterior projection at the right paraclinoid ICA. (B) PD MR coronal imaging cannot discriminate between the distal dural ring (open arrow head) and aneurysm (arrow). (C) PD MR multiplanar reconstruction shows the distal dural ring (open arrow head) and a transdural aneurysm (arrow). DSA = digital subtraction angiography; ICA = internal carotid artery; PD MR = proton density magnetic resonance.

or extradural lesions. In our study, 48 cases were extradural lesions (63.2%), a significantly higher proportion in inferior/posterior (14/19, 73.7%) and lateral (3/4, 75.0%) lesions. None of the aneurysms in the superior projection group (0/4) were extradural. Our findings indicate that asymptomatic paraclinoid aneurysms, particularly those that are inferior/posterior or lateral projecting, should be evaluated by MR to determine their relationship with the DDR. The appropriate treatment strategy can then be carefully determined based on MR as well as angiographic findings. In our series, endovascular coiling proved to be a successful treatment modality for paraclinoid aneurysms with no treatment-related complications.

This study was not without limitations. First, our results cannot be easily generalized due to the small sample size (n = 76). Second, none of the aneurysms could be directly visualized and identified on surgical exploration. In our series, most of the treated aneurysms were intradural and medial projecting lesions and we prefer endovascular coiling to surgical clipping in such cases. However, a surgical approach will be performed in a future study and we anticipate confirmation of PD MR findings, and comparison with other MR techniques should be evaluated in future study.

CONCLUSION

Proton density MR with multiplanar reconstruction can provide better localization of paraclinoid aneurysms in relation to the DDR. This MR technique may provide additional information about the natural history of paraclinoid aneurysms in future studies.

Disclosure

The authors report no conflicts of interest concerning the materials or methods used in this study or the findings described in this paper.

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