3D MR Cisternography to Identify Distal Dural Rings: Comparison of 3D-CISS and 3D-SPACE Sequences

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Purpose: The distal dural ring (DDR) is an anatomical landmark used to distinguish intraparenchymal and extradural aneurysms. We investigated identification of the DDR using 2 three-dimensional (3D) magnetic resonance (MR) cisternography sequences—3D constructive interference in steady state (CISS) and 3D sampling perfection with application optimized contrasts using different flip angle evolutions (SPACE)—at 3.0 tesla.

Methods: Ten healthy adult volunteers underwent imaging with 3D-CISS, 3D-SPACE, and time-of-flight (TOF) MR angiography (TOF-MRA) sequences at 3.0T. We analyzed DDR identification and internal carotid artery (ICA) signal intensity and classified the shape of the carotid cave.

Results: We identified the DDR using both 3D-SPACE and 3D-CISS, with no significant difference between the sequences. Visualization of the outline of the ICA in the cavernous sinus (CS) was significantly clearer with 3D-SPACE than 3D-CISS. In the CS and petrous portions, signal intensity was lower with 3D-SPACE, and the flow void was poor with 3D-CISS in some subjects.

Conclusion: We identified the DDR with both 3D-SPACE and 3D-CISS, but the superior contrast of the ICA in the CS using 3D-SPACE suggests the superiority of this sequence for evaluating the DDR.

Keywords: brain aneurysm, cisternography, distal dural ring, SPACE

Introduction

Identification of the distal dural ring (DDR) facilitates discrimination between paraclinoid intraparenchymal and extradural aneurysms, a critical consideration in choosing treatment options.1,2 Because they carry a risk of subarachnoid hemorrhage (SAH), intraparenchymal aneurysms may require treatment, whereas extradural cavernous sinus aneurysms present little or no risk of SAH and usually require only follow-up observation in asymptomatic patients.

The DDR has been identified as the superior border of the cavernous sinus (CS) using fusion images of magnetic resonance (MR) cisternography with 3D-constructive interference in steady state (3D-CISS) sequence and MR angiography (MRA).3 The fusion technique used to identify the artery in the 3D-CISS image with information from MRA indicated that the non-contrast 3D-CISS represented the ill-defined borders of the ICA.

Three-dimensional sampling perfection with application-optimized contrasts using different flip angle evolutions (3D-SPACE) is a 3D turbo spin-echo sequence that allows maintenance of the pseudo steady-state using a variable flip angle.4 Desired contrast can be achieved by adjusting the peak flip angle in 3D-SPACE, and the specific absorption rate (SAR) can be reduced using a low flip angle, an advantage for 3.0T imaging.

We compared DDR identification between the two 3D-MR cisternography sequences, 3D-CISS and 3D-SPACE, at 3.0 tesla.

Materials and Methods

Subjects were 10 healthy adult volunteers (4 men, 6 women; mean age, 33 years) with no known neurological abnormalities. We performed the study
We obtained all MR images using a 32-channel head coil and a 3.0T scanner (Magnetom Vision; Siemens, Erlangen, Germany) and acquired 3D-CISS, 3D-SPACE, and time-of-flight MRA (TOF-MRA) images during a single examination. For 3D-SPACE, we used parameters: repetition time (TR, 1500 ms; echo time (TE), 118 ms; number of excitations (NEX), one; 52-mm slab thickness; 104 partitions; field of vision (FOV) 18 cm; 384×364 matrix; and pararell imaging technique with acceleration factor of 2. Acquisition time was 6 min 45 s. Parameters for 3D-CISS were: TR/TE = 6.3/2.7 ms; FA 40°; 56-mm slab thickness; 112 partitions; FOV 18 cm; and 384×357 matrix. Acquisition time was 6 min 50 s.

MR images were transferred to a 3D workstation (MMWP, Siemens) and analyzed on 3 orthogonal planes. We defined the DDR as the border between the CS and the suprasellar cistern and assessed its identification in the left and right internal carotid arteries (ICA) for each sequence. Two radiologists evaluated the image sets and performed grading or classification by consensus. They scored visualization of the DDR and contrast between the ICA and surrounding CS from one to 3, with 3 = clear, 2 = unclear but visible, and 1 = not visible. The ICA was separated into 3 portions (suprasellar, CS, and petrous), and signal intensity in each portion was also scored out of 3, with 3 = low intensity, 2 = isointensity, and 1 = high intensity compared to the surrounding soft tissue. We used 3D-CISS and 3D-SPACE for separate classification of the shape of the carotid cave into one of 3 dent types, with A = no dent; B = shallow dent, in which the depth was less than the radius of the adjacent ICA; and C = deep dent, in which the depth exceeded the ICA radius (Fig. 1).

Data were expressed as mean ± standard deviation. We analyzed the differences in ICA visualization scores between the 3D-SPACE and 3D-CISS images using Wilcoxon signed-rank sum test and all data using SPSS software (Dr SPSS, SPSS Japan Inc. Tokyo, Japan). Statistical significance was established at P = 0.05.

Results

DDR identification was favorable using both 3D-SPACE (3.0 ± 0) and 3D-CISS (2.95 ± 0.22), with no significant difference. Visualization of the outline of the ICA in the CS was significantly clearer using 3D-SPACE (2.6 ± 0.60) than 3D-CISS (1.3 ± 0.47), P < 0.01 (Fig. 2). Signal intensity in the suprasellar portion of the ICA was low (3.0 ± 0) for 3D-SPACE and 2.9 ± 0.31 for 3D-CISS), and a good flow void was identified using both imaging methods. In the CS and petrous portions, signal intensity was lower using 3D-SPACE (CS, 3.0 ± 0; petrous portion, 3.0 ± 0), and the flow void with 3D-CISS was poor in some subjects, leading to significantly lower 3D-CISS intensity scores (CS: 1.9 ± 0.72, P < 0.005; petrous portion: 1.05 ± 0.22, P < 0.001) (Fig. 3). The shape of the carotid cave was classified as A in 10 carotid arteries, B in 8, and C in 2, with no discrepancy between the 3D-CISS and 3D-SPACE sequences.

Discussion

The results of the present study revealed no differences between the 3D-CISS and 3D-SPACE sequences in visualization of the cerebrospinal fluid (CSF) in the suprasellar cistern. However, 3D-SPACE was superior to 3D-CISS in providing clearer ICA visualization in the CS, which allowed

Fig. 1. Configuration of the carotid cave (arrow) visualized with coronal reconstructed 3D-SPACE imaging. The depth of the carotid cave was classified as no dent (A), shallow dent (B), or deep dent (C). *internal carotid artery, ICA
Fig. 2. Comparison of 3D-SPACE (a) and 3D-CISS (b) sequences. The border between the suprasellar cistern and upper rim of the cavernous sinus (CS) (arrow head) was clearly visualized with each sequence. However, using 3D-SPACE, the CS was represented by signals of high intensity, and the margins of the internal carotid artery (ICA) in the CS (arrow) and the borders between the distal dural ring (DDR) and ICA were more clearly visualized.

Fig. 3. Signal intensity in the internal carotid artery (ICA) using 3D-SPACE (upper) or 3D-CISS (lower). Employing 3D-SPACE, the vascular flow void was favorable in all imaging areas, and the lumen of the ICA was visualized as signals of low intensity. Using 3D-CISS, the vascular lumen was visualized as a signal of low intensity in the suprasellar region but showed iso- to high intensity in the cavernous sinus (CS) and petrous portion, making it difficult to identify blood vessels.

easy recognition of the ICA penetration area and precise identification of the DDR.

The DDR comprises tight dural tissue through which the ICA enters the subarachnoid space and essentially creates a border between the intra- and extradural ICAs. Intradural paraclinoid aneurysms carry a risk of subarachnoid hemorrhage (SAH) and can be treated, but extradural cavernous sinus aneurysms present little or no risk of SAH and usually require only follow-up observation in asymptomatic patients. Because the carotid cave, observed in two-thirds of cadavers in 2 studies, is a small intradural recess at the posterior-medial aspect of the DDR, it is difficult to distinguish intra- from extradural aneurysms at the medial side of the C2 portion. Therefore, identification of the DDR is important, especially in cases of medial ICA aneurysms.

A previous study reported that contrast-enhanced 3D-CISS increased signal intensity in the CS and allowed easy DDR visualization and recognition of the ICA in the CS. Another study report-
ed that the ICA in the CS could be identified using fusion images of non-contrast 3D-CISS and MRA. These studies suggest that ICA contrast in the CS is poor only in non-contrast 3D-CISS images and that identification of the ICA requires concomitant use of an additional technique.

In 3D-SPACE sequences, various types of contrast can be obtained by adjusting the peak point of the flip angle. We employed T₂-weighted images because both the CSF and the CS can be visualized as signals with high intensity. T₂-weighted images also provide favorable contrast with the ICA in the CS. In addition, 3D-SPACE sequences use a variable flip angle and a high turbo-factor, which allows good vascular flow void without use of an inversion pulse or presaturation pulse. The good contrast between this low intensity flow void in the ICA and the high intensity venous blood in the CS permits identification of the DDR using the 3D-SPACE sequence alone, without contrast medium or fusion method.

Because we performed transverse image acquisition in this study, the high signal intensity achieved with 3D-CISS in the petrous portion of the ICA is considered to result from the inflow effect. Using coronal data acquisition may reduce signal intensity of the ICA.

Our study has some limitations. First, we could not evaluate the normal variation in signal intensity in the cavernous sinus well because we used a small number of volunteers. Second, the DDR defined by 3D-SPACE or CISS on MR imaging was a hypothetical boundary, so radiological and pathological confirmation is needed in surgical cases and autopsy or cadaver study.

Our results may be clinically applied by using 3D-SPACE in patients with paraclinoid aneurysm. Distinguishing intra- and extradural aneurysms is important in selecting treatment options for patients with large aneurysms and determining the follow-up interval for those with small aneurysms.

In conclusion, we identified the DDR using both 3D-SPACE and 3D-CISS. However, 3D-SPACE provided both superior contrast of arteries in the CS and excellent flow void of the ICA, suggesting it to be more useful for evaluating the DDR.

References