Magnetic Resonance Imaging of Thrombosed Dural Sinuses

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Background and Purpose Magnetic resonance imaging should have the potential to replace angiography in the diagnosis of dural sinus thrombosis. Concerning time-dependent signal changes of the thrombus, we intended to develop a standardized examination protocol for routine use in suspected dural sinus thrombosis.

Methods The time-dependent signal changes of thrombosed dural sinuses were studied in 23 consecutive patients by multiplanar spin-echo and flow-sensitive sequences. Signal intensities and thrombus homogeneity were graded and related to the time after clinical onset and the results of the magnetic resonance angiography.

Results Four stages of the thrombus evolution could be observed. The acute thrombosis (days 1 to 5) appeared strongly hypointense in T1-weighted images and isointense in spin density- and T2-weighted images. In the subacute stage (up to day 15) the thrombus signal was strongly hyperintense in T1- and T2-weighted images. The third stage began in the third week after clinical onset. The thrombus signal was decreased in all sequences and showed an increasing inhomogeneity. The fourth (late) stage was characterized by either the restitution of blood flow or the persistence of a residual thrombus.

Conclusions Each stage requires a different diagnostic approach. With the combined use of spin-echo and gradient-echo sequences, it is possible to make the diagnosis of acute thrombosis; in the second stage, multipplanar spin-echo sequences are sufficient. Diagnosis of dural sinus thrombosis can be established accurately with magnetic resonance imaging in the first two stages. However, the diagnosis of the later stages is difficult because of inhomogeneous signs of recanalization and flow phenomena. Therefore, a suspected older dural sinus thrombus still requires intra-arterial angiography as the primary diagnostic tool.

Key Words • diagnostic imaging • magnetic resonance imaging • sinus thrombosis

The clinical appearance of dural sinus thrombosis includes focal or generalized seizures, acute forms with intracerebral hematomas as well as chronic forms resembling the pseudotumor cerebri syndrome.1-3,5

The best diagnostic tool is intra-arterial angiography.4,6 However, the hazards of this invasive method may lead to a restricted or delayed use, in some cases causing a delay of diagnosis and therapy.

Some authors suggest that magnetic resonance imaging (MRI) can replace angiography for the diagnosis of dural sinus thrombosis.7-12 Our goals in this study were to describe the time-dependent signal changes of a thrombosed dural sinus and to determine if the diagnosis is possible throughout the duration of the disease. Furthermore, we tried to develop an examination protocol for routine clinical use.

Subjects and Methods

This study included 23 patients with dural sinus thrombosis: 17 females (mean age, 28.8; range, 7 to 69 years) and 6 males (mean age, 51.2; range, 25 to 70 years). We analyzed only the cases of proven thrombosis. Patients with tumorous sinus occlusion were excluded.

We studied 19 patients prospectively; 4 patients were included retrospectively. The diagnosis was confirmed by angiography in 18 cases. In the other 5 cases, the combination of clinical presentation and computer tomography (CT) and MRI findings were so unambiguous that angiography was abandoned. One patient suffered from septic sinus thrombosis caused by an otitis media, and the others had aseptic thrombosis. All patients were treated with heparin for 4 weeks, followed by oral anticoagulants for about 6 months. However, in 2 of the 4 patients included retrospectively, diagnosis was initially missed, and treatment was delayed.

In 21 patients, MRI was performed with a 1.5-T imager (Magnetom, Siemens), and 2 patients were examined with a 0.5-T imager (Gyrosan T5, Philips). The initial examination includes spin-echo sequences in at least two different slice orientations (usually coronal and axial). The follow-up examinations were performed using the coronal orientation. Additionally, T2-weighted sequences were acquired. Contrast medium was not applied. A total of 61 spin-echo examinations on 23 patients were obtained.

In 10 patients, fast low-angle shot (FLASH) sequences (flip angle, 40°; repetition time [TR], 20 msec; echo time [TE], 8 msec) were acquired a total 14 times.

Subtraction three-dimensional FISP angiography (flip angle, 20 degrees; TR, 50 msec; TE, 23 msec) was acquired 27 times in 14 patients.

Two experienced neuroradiologists graded the signal intensity of the intraluminal thrombus in relation to normal brain tissue on a scale from grade 1 to 5 (1, strongly hypointense; 2, slightly hypointense; 3, isointense; 4, slightly hyperintense; and 5, strongly hyperintense). If a thrombus showed two different signal characteristics (seen in three patients), the part of the thrombus with the maximum volume was classified.

The observed signal intensities were related to a time axis. For practical use, we defined the clinical onset as day 1 of the thrombosis (see Figs 1a through 1c).

Additionally, the structure of the thrombus was analyzed. A rating scale from R0 to R3 was established (R0, strongly homogeneous; R1, slightly inhomogeneous; R2, strongly inhomogeneous; and R3, complete recanalization with total

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signal intensity $T_1w$ signal intensity $SD$ signal intensity $T_2w$ signal pattern homogenous-inhomogenous

Fig 1. a through c: Signal intensity of the thrombus, graded from 1 (strongly hypointense) to 5 (strongly hyperintense); 3 indicates isointense compared to normal brain tissue signal. Every square demonstrates the signal intensity in relation to the age of the thrombus, starting at day 1, clinical onset. The number corresponds to the number of cases with identical findings, a, $T_1$-weighted ($T_1w$) signal intensities; b, spin-density ($SD$) signal intensities, and c, $T_2$-weighted ($T_2w$) signal intensities. See explanation in the text for the three cases marked with arrows. d: Thrombus homogeneity. Grading of 0 indicates strongly homogeneous; 1, slightly inhomogeneous; 2, strongly inhomogeneous; 3, signal void, related to time after clinical onset.

Results

The results of the spin-echo examinations are listed in Fig 1.

Days 1 to 5

In all 8 patients examined during the first 5 days, the intraluminal thrombus was strongly hypointense on $T_2$-weighted and isointense on $T_1$-weighted images (Figs 2a and 2b). A slight hypointensity or isointensity was seen on the spin-density images. The thrombus signal was always homogeneous, and the sinus itself appeared expanded. Flow-sensitive sequences, obtained in 6 of these 8 patients, demonstrated the absence of flow (Figs 2c and 2d).

Days 6 to 15

Between days 6 and 15, 7 new patients entered the study. They showed a markedly increased thrombus signal regardless of the sequence used ($T_1$- and $T_2$-weighted or spin density) (Figs 3a and 3c). On day 9, a so-called target sign (peripheral hyperintensity or central isointensity) was visible in 3 of these cases. Three patients who had already been examined in the first 5 days had a follow-up examination in this second period. In these patients, the thrombus signal intensity in $T_1$-weighted sequences was isointense to hypointense only (Fig 1c, arrows), whereas signal intensities on $T_1$-weighted and spin density images were similar to the findings in the other cases.

A hyperintense thrombus signal first appeared on day 8 and was visible at least until day 15, but was observed up to day 26. The hyperintense signal was seen earlier and brighter on $T_1$-weighted and spin density images. On the $T_2$-weighted images it started later but disappeared earlier. If a thrombus appeared strongly hyperintense in the $T_1$-weighted sequence, it also appeared hyperintense in the two-dimensional FLASH sequences, simulating flow signal (Fig 3b). In contrast, the subtraction three-dimensional FISP angiography showed a good correlation to the results of the spin-echo sequences.

Day 16 to the End of the Third Month

Six new patients entered the study during this period, and in 12 patients with previous examinations, one to
Fig 2. Complete occlusion of the superior sagittal sinus on day 2, acute stage. a: On the T₂-weighted images the fresh thrombus appears strongly hypointense, simulating normal flow void. b: T₁-weighted sagittal magnetic resonance image. Homogeneous isointense thrombus signal (arrows). c: Magnetic resonance angiography of the same patient. There is no flow signal within the superior sagittal sinus, suggesting complete occlusion. d: The flow-sensitive gradient-echo sequence (two-dimensional fast low-angle shot) demonstrates clearly the absence of flow in the superior sagittal sinus.

three follow-up examinations were performed. In this third period the thrombus signal decreased in all sequences. This finding was first visible on T₂-weighted images. At the same time, the thrombus signal became more inhomogeneous. Corresponding to the degree of recanalization, the flow signals in three-dimensional angiograms increased (Fig 4). In this period, strongly hyperintense thrombus signals were seen in only 2 patients, who did not receive heparin up to that time because the diagnosis was not yet established.

Only 2 of 21 patients examined until the end of the third month showed return to completely normal MRI findings (spin-echo and gradient-echo sequences), suggesting complete recanalization (in 1 patient after only 4 weeks).

From the Fourth Month On

Only 2 new patients entered the study after the end of the third month. In 8 patients, long-term follow-up examinations (more than 6 months after clinical onset) were performed. In 3 of these 8 patients a persisting isointense intraluminal signal and missing flow signal in magnetic resonance angiography suggested permanent occlusion of a lateral sinus. In 2 of these patients thrombosis initially was more extensive, also including the superior sagittal sinus. Signs suggesting complete recanalization occurred in the other 5 patients with long-term follow-up, although in 3 the walls of the formerly thrombosed sinuses were irregular by sectors.

Discussion

A thrombosed dural sinus contains coagulated blood. With regard to the biochemical processes that take place in intracerebral hemorrhage, it can be assumed that the same changes occur in an occluding thrombus, because it consists mostly of red blood cells. Concerning the early stage of sinus thrombosis, our findings are in agreement with this hypothesis. During
the first days of a sinus thrombosis, the signal appearance in MRI corresponds to that of deoxyhemoglobin (strong hypointensity on T$_2$-weighted images; Figs 2a and 2b). The single use of T$_2$-weighted sequences may lead to the wrong assumption that flow is normal, because in spin-echo sequences laminar flow with high velocity and turbulent flow appear strongly hypointense (flow-related signal void). In our opinion, only the combined use of T$_1$-weighted, spin-density, and gradient-echo sequences allows the safe diagnosis of an acute dural sinus thrombosis.

The time-dependent increasing hyperintensity of a thrombus seen in spin-echo sequences is similar to the signal appearance of an intracerebral hemorrhage and corresponds to the release of extracellular Met-hemoglobin. It can be assumed that the signal changes develop from the periphery to the center of the thrombus, producing a typical target sign. Several authors observed a hyperintense thrombus signal on magnetic resonance images between the second and fourth week after clinical onset.5,7,9,11,15

During this second stage, diagnosis can be established using spin-echo sequences. Flow phenomena leading to false-positive results can be abolished by the acquisition of spin-echo sequences in two-slice orientations. Flow-sensitive sequences should be interpreted carefully because the bright thrombus signal in this stage can simulate flow.16 We used a three-dimensional FISP sequence in combination with a subtraction technique for dephased and rephased images. This method allows the differentiation between real flow and Met-hemoglobin artifacts. Phase imaging is thought to be another alternative.16,17

Because the signal pattern in three patients heparinized early differed from those in whom treatment was started later, one might speculate whether early treatment accelerates thrombus evolution. However, clinical onset is not necessarily identical with the commencement of the thrombosis.

By the beginning of the third week the signal development of an intraluminal thrombus was different from that of an intracerebral hemorrhage. The signal intensity and the volume decreased, and the appearance was more inhomogeneous. The initially enlarged sinuses returned gradually to normal size.
We interpreted these phenomena as signs of increasing organization and recanalization. Simultaneously, we observed reappearance of flow with the three-dimensional angiography (Fig 4a through 4d). The latter excludes that strongly hypointense parts are hemosiderin deposits.

In this third stage MRI-based diagnosis can be difficult or impossible. A thrombosis that is incompletely recanalized may be proven by MRI in some cases, but often there is neither a clear thrombus signal nor clear absence of blood flow. If the analysis of the magnetic resonance images gives no sufficient information and an older thrombosis is suspected, intra-arterial angiography should be performed.

In a considerable number of patients in other studies, persistent abnormalities can be observed in the late stage.18 Permanent occlusions and irregularities of the signal of the formerly affected sinus and its walls occurred in our patients, also. These changes were accentuated in the transverse sinus, possibly because the contralateral transverse sinus may compensate unilateral occlusion.

Flow phenomena complicate the diagnosis of dural sinus thrombosis in MRI. A paradoxical signal increase can occur in the entry slices caused by the inflow of unsaturated protons. The same phenomenon may appear if a discontinuous slice selection mode is used.19 This paradoxical enhancement can be abolished by the use of nonselective presaturation.11 Another phenomenon of laminar flow is observed in the second echo of a symmetric double-echo sequence—the so-called “even echo rephasing,” which indicates laminar flow.19 Extremely low laminar flow can also cause a paradoxical intraluminal signal. The appearance of this flow artifact depends on the flow rate related to the used sequence parameters. It decreases by increasing TR and TE.16
Flow phenomena are influenced by the ratio of slice orientation to flow direction. The variation of slice orientation with constant sequence parameters eliminates the flow artifact. A thrombus shows identical signal appearance in all slice orientations.11,15,19

Two- and three-dimensional flow-sensitive sequences allow identification of flow phenomena, which may be misleading in the spin-echo sequences. Absence of flow in flow-sensitive sequences can be differentiated from a hypoplasia of a sinus by use of spin-echo sequences.7,20

The three-dimensional angiography and the single-slice two-dimensional FLASH sequences are useful in demonstration of the flow reappearance. However, three-dimensional angiography provides better information about the global extent of actual recanalization. It is an excellent tool for follow-up examinations.21

To this end we recommend the following diagnostic management:

1. Acquisition of coronal T2-weighted and spin-density images, sagittal T1-weighted images, and single-slice two-dimensional flow-sensitive sequences (oriented 90° to flow direction). Acute or subacute dural sinus thrombosis is excluded if these images are normal.

2. An abnormal finding in the coronal double echo requires a control acquisition, showing a similar signal pattern in a second slice orientation in case of thrombosis. Additionally, flow-sensitive sequences must be performed. A lack of flow signal also suggests thrombosis. Based on the combination of signal characteristics, it is possible to determine the stage of the thrombosis.

3. The hyperintensity of the sinus lumen in two different orientations indicates subacute dural sinus thrombosis. The use of flow-sensitive sequences is unnecessary.

Conclusion

The present study should also demonstrate the difficulties of MRI-based diagnosis of dural sinus thrombosis. The use of MRI and magnetic resonance angiography in the diagnosis of venous sinus thrombosis demands knowledge of the different stages and pitfalls. In our opinion, certain diagnosis can be made only in the first two stages. An older thrombus as well as the occlusion of cortical veins still requires intra-arterial angiography.

References

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