Restricted Diffusion in the Optic Nerve and Retina Demonstrated by MRI in Rhino-Orbital Mucormycosis

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Abstract: A 29-year-old man developed vision loss in the right eye due to ophthalmic artery, cavernous sinus, and superior ophthalmic vein occlusion in mucormycosis. Diffusion MRI obtained within 2 days of symptom onset showed that the apparent diffusion coefficient values of the optic nerve and retina were remarkably decreased on the affected compared with the unaffected side. A follow-up MRI study 21 days after symptom onset revealed the anticipated disappearance of these signal changes, confirming that they were a true reflection of ischemia in the optic nerve and retina. This report adds to an accumulating body of literature on restricted diffusion in these tissues in conditions producing severe ischemia.


Diffusion imaging has been used to diagnose acute brain ischemia. Because early diagnosis is important to salvage the penumbral zone (1), this new sequence has been widely applied. Its use in spinal cord and optic nerve ischemia has only recently been reported (2–6). In this report, we demonstrate restricted diffusion not only in the optic nerve but also in the retina.

CASE REPORT

A 29-year-old man presented with complete vision loss in the preceding 3 hours. He also noted restricted movement and proptosis of his right eye for 3 days and eyelid swelling and pain for 1 day. He had been treated with oral corticosteroids for idiopathic thrombocytopenic purpura in the last month.

Ophthalmologic examination on admission showed no light perception in the right eye. Proptosis, hyperemic and chemotic conjunctiva, and eyelid swelling of the right eye and restricted right eye movement in all directions were confirmed. The right pupil was dilated and unreactive to direct light. The right optic disc was edematous. The left eye was normal. He had a right lower motor neuron seventh cranial nerve palsy. Results of the rest of the neuro-ophthalmologic examination were normal.

The white blood cell count was 12100/mL. Brain CT showed mucosal thickening compatible with inflammation involving the right frontal, bilateral maxillary, sphenoid, and ethmoid sinuses.

Brain MRI was obtained 22 hours after admission. All images were acquired on a 1.5-T instrument (Excite; GE Medical Systems, Milwaukee, Wisconsin). The gradient capacity was 33 mT/m. The following sequences were obtained: precontrast and postcontrast spin echo T1 [time to recovery (TR): 700 ms, time to echo (TE): 8.8 ms, slice thickness 5 mm, interslice gap 1.5 mm, matrix 288 3 256] and fast spin echo T2 (TR: 4,440 ms, TE: 99.8 ms, slice thickness 5 mm, interslice gap 1.5 mm, matrix 352 3 192) and fluid attenuated inversion recovery (FLAIR) (TR: 8,402 ms, TE: 101.6 ms, time to inversion [TI]: 2,100, slice thickness 5 mm, interslice gap 1.5 mm, matrix 288 3 160). A contrast agent (0.2 mL/kg gadolinium) was administered intravenously. The diffusion sequence (TR: 8,000 ms, TE: 80.8 ms, slice thickness 4 mm, interslice gap 1 mm, matrix 128 3 128) was performed with echo planar single shot spin echo imaging with b values of 0 and 1,000 s/mm². Diffusion gradients were applied in three orthogonal directions to generate three sets of diffusion images (x, y, and z axes). Apparent diffusion coefficient (ADC) values were calculated automatically. A standardized region of interest (ROI) of 2 mm² was used for the measurements. ADC values were calculated from the ROIs by dividing the signal intensity by 1,000 to give values in terms of ADC 10⁻³ mm²/s. The measurements were from three separate locations on both optic nerves. The mean value was calculated.

The routine MRI sequences were normal. The right optic nerve appeared hyperintense on diffusion imaging and hypointense on the ADC map (Fig. 1A–B). The mean ADC value was 0.471 10⁻³ mm²/s for the right optic nerve and 1,663 10⁻³ mm²/s for the left optic nerve. The mean diffusion signal value was 315 in the right optic nerve.
FIG. 1. MRI performed 25 hours after vision loss in the right eye. A. Diffusion imaging demonstrates marked diffusion restriction in the right optic nerve (large arrow) and retina (small arrow). B. The apparent diffusion coefficient map shows a corresponding hypointense signal change. C. Postcontrast T1 coronal MRI shows reduced enhancement of the right cavernous sinus (arrows), consistent with thrombosis.

and 133 in the left optic nerve. The mean ADC value was $1.84 \times 10^{-3} \text{mm}^2/\text{s}$ on the right retina and $2.60 \times 10^{-3} \text{mm}^2/\text{s}$ on the left retina. The mean diffusion signal value was 320 on the right retina and 193 on the left retina. The right optic nerve appeared normal on FLAIR and pre- and postcontrast T1 and T2 images. There was right cavernous sinus thrombosis (Fig. 1C). The right superior ophthalmic vein was dilated with heterogeneous intraluminal signal intensity on T2 images. Cerebral magnetic resonance venography showed a normal left superior ophthalmic vein.

On the basis of the clinical and MRI findings, a diagnosis of orbital cellulitis, cavernous sinus thrombosis, and ischemic ocular syndrome was rendered. The patient underwent sinus surgery involving a right maxillary antrostomy, ethmoidectomy, and orbital decompression. There was extensive necrosis and a fungal mass was extracted from the right maxillary sinus. After histopathologic evaluation, the diagnosis was rhino-orbital mucormycosis. Treatment with an antifungal agent along with broad-spectrum antibiotics was started.

On follow-up examination 3 weeks later, left hemiplegia had developed. Brain MRI obtained 20 days after the admission study demonstrated abscesses in the right frontal region (Fig. 2A), prepontine cistern, and corpus callosum

FIG. 2. MRI performed 20 days after the initial study. A. Postcontrast T1 sagittal MRI shows ring enhancement in the frontal lobe (vertical arrow) and frontal and sphenoid sinuses, as well as diffuse enhancement of the genu and body of the corpus callosum (oblique arrow). B. Diffusion imaging shows extensive diffusion restriction in the right cerebral hemisphere, consistent with infarction due to occlusion in the right internal carotid artery. C. Diffusion imaging no longer shows restricted diffusion in the right optic nerve and retina.
and along the tentorium, in addition to extensive right cerebral ischemia due to thrombosis of the right internal carotid artery (Fig. 2B). The restricted diffusion of the right optic nerve and retina had disappeared (Fig. 2C). The patient died 4 weeks after the onset of his illness.

**DISCUSSION**

At 25 hours after vision loss, our patient had a normal MRI on standard pulse sequences but showed diffusion restriction in the affected optic nerve and retina, as evidenced by a relatively reduced ADC value and diffusion signal intensity. We attribute the restricted diffusion to ischemia caused by occlusion of ophthalmic and central retinal arteries, superior ophthalmic vein, and cavernous sinus due to mucormycosis.

There are some previous reports regarding diffusion imaging in ocular or orbital conditions. The first report (3) was of a 61-year-old patient who experienced bilateral perioperative hypotensive posterior ischemic optic neuropathy after cardiac bypass surgery. The patient was scanned on the fourth day after the onset of symptoms. All sequences except diffusion imaging and FLAIR were normal.

The second report (4) involved a 56-year-old woman with vision loss having features of anterior and posterior ischemic optic neuropathy. Scanned 6 days after vision loss, the patient showed a decrease in ADC value in the diseased optic nerve compared with the unaffected optic nerve.

The third report (5) involved a 44-year-old man who developed bilateral vision loss due to bilateral cavernous sinus and superior ophthalmic vein thrombosis. The proximal ophthalmic arteries were normal on CT. Diffusion imaging demonstrated bilateral optic nerve ischemia. The patient had presented to the hospital 11 days after symptom onset, but there was no information on the timing of the MRI scan. That report was the first to note subtle diffusion restriction in the retina, but the authors did not provide a corroborative retinal ADC value or a follow-up study showing the expected disappearance of restricted diffusion, as we have shown in our patient.

The fourth report (6) involved a 60-year-old woman who developed vision loss due to mucormycosis and subsequent right cavernous sinus thrombophlebitis 15 days after admission (6). The first MRI, performed soon after admission, was normal. The second MRI, performed 6 days after the onset of vision loss in the right eye, revealed subtle diffusion imaging signal abnormality in the affected optic nerve. The diffusion restriction was obvious on the third MRI, performed 15 days after the second study. Other MRI sequences revealed no abnormality. Unlike our very similar patient, there was no mention of diffusion restriction in the retina.

In contrast with the reduced ADC value shown in ischemic optic neuropathy, an increased ADC value has been shown in optic neuritis (7), suggesting that this sequence might be useful in differentiating these two entities.

There are technical limitations to our study. The optic nerve ischemia detected on diffusion images was incidentally depicted on MRI images. Therefore, the image slice was 5 mm and not tailored for the optic nerves. In the future, we recommend using thinner sections (3 mm slice thickness instead of 5 mm) for this purpose. We did not perform coronal or sagittal diffusion imaging because of the unstable condition of the patient. Diffusion imaging near the orbits and skull base tends to show extensive susceptibility artifacts. We tried to overcome this problem by increasing the number of excitations. Although magnetic resonance venography demonstrated the dilatation and heterogeneous signal intensity in the superior ophthalmic vein on the right side, we did not perform CT or MRA to accurately define the arterial supply of the orbital region.

**REFERENCES**