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## Case Report

# Black Holes on MR Images of the Brain of Patients with Björk-Shiley Heart Valves: Additional Observation in Three Cases

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**Summary:** We report the cases of three patients with Björk-Shiley convexo-concave heart valves with unusual black holes shown on cerebral MR images. For two patients, these findings were associated with fracture of the Björk-Shiley convexo-concave heart valve, and for the third, with worn surfaces on the heart valve. Susceptibility changes shown by MR imaging suggest the possibility that these black holes may be associated with microscopic metallic particles, although, the exact cause of these black holes remains undetermined.

A few case reports have addressed typical black holes on MR images of the brain of patients with prosthetic heart valves (1, 2). Although various potential causes have been discussed, the frequency and origin of these black holes is still unknown. We report the cases of three patients with prosthetic heart valves with similar MR findings on T2\*-weighted gradient-echo sequences, all of whom had a history of a Björk-Shiley convexo-concave heart valve explantation.

## Case Reports

### Case 1

A 41-year-old man was admitted to the hospital for the investigation of suspected brain hemorrhage. MR imaging of the brain, performed with a 1.5-T MR imaging unit, revealed a hemorrhage located in the left posterior lobe. In addition, the T2\*-weighted gradient-echo sequence showed multiple black holes. Unenhanced CT revealed no signs of calcifications in those regions. The patient's medical history included a prosthetic valve implantation with a Björk-Shiley convexo-concave mitral valve (Shiley, Inc., Irvine, CA), which had been replaced 13 years later with another prosthetic heart valve because of progressive paravalvular leakage. Examination of the explanted

valve revealed the presence of a single leg fracture of the outlet strut.

### Case 2

A 51-year-old woman, who received a 60-degree Björk-Shiley convexo-concave valve in aortic position in 1982 at age 33 years because of aortic stenosis and insufficiency, was invited to the hospital to undergo MR imaging of the brain. The T2\*-weighted gradient-echo technique revealed several black holes that were diffusely spread throughout the brain (Fig 1A). The black holes were also visible on the spin-echo images, smaller but with typical white halos (Fig 1B). One year after the first MR images were obtained, we invited her to undergo repeat imaging of the brain. All black holes that were present on the first set of images were unchanged, and no additional abnormalities were discovered. The patient's medical history reported that she had suffered a complete fracture of the outlet strut of the valve in 1988 and had undergone emergency valve replacement.

### Case 3

A 63-year-old man, who had a 60-degree Björk-Shiley convexo-concave valve implanted in mitral position in 1980 at age 43 years because of rheumatic combined mitral valve disease, was invited to the hospital to undergo MR imaging of the brain. A small silent cortical infarction on the right parietal lobe was seen; however, no black holes could be detected on the T2\*-weighted gradient-echo sequence (Fig 2A). Because of the high risk Björk-Shiley convexo-concave mitral valve and concomitant aortic valve insufficiency, a double heart valve replacement was planned for 1 week later. Five months after the successful double valve replacement operation, the patient underwent repeat MR imaging of the brain. At that time, two black holes, similar to those we had seen earlier, were clearly visible on the T2\*-weighted gradient-echo sequence (Fig 2B). Scanning electron microscopy research revealed no fractures or cracks in the explanted Björk-Shiley convexo-concave valve, although valve wear was visible on the outlet strut.

## Discussion

These three patients had black holes shown by MR imaging of the brain that were similar to those described in earlier reports (1, 2). The reports suggested that the MR imaging artifacts were due to microscopic embolic metal fragments, most likely from mechanical heart valve prostheses. Our cases support the suggestion that black holes shown on MR images of the brain may be related to Björk-Shiley convexo-concave heart valves or prosthetic valve surgery.

In our cases, blooming of signal intensity loss was seen on the gradient-echo images. The black holes

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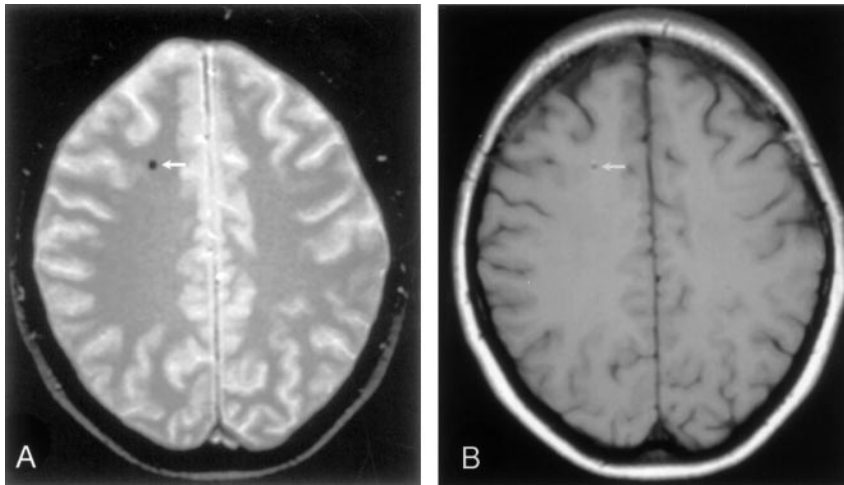


FIG 1. Patient 2.

A, Axial view T2\*-weighted gradient-echo image (710/27.6/2 [TR/TE/number of excitations]) shows a black hole (arrow). Repeat images obtained after 1 year appeared unchanged, with no increase in number or size of black holes (not shown).

B, Corresponding axial view T2-weighted spin-echo image (1380/60/2) shows the same black hole with a typical white halo (arrow).

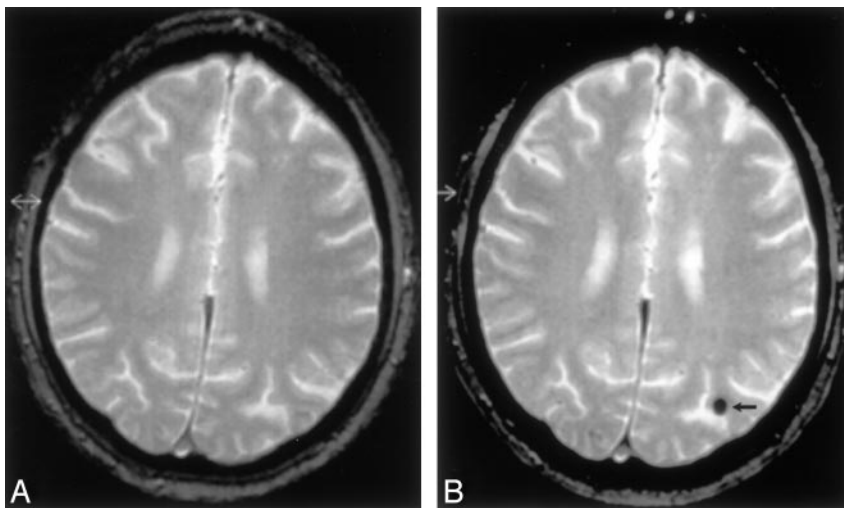


FIG 2. Patient 3.

A, Axial view T2\*-weighted gradient-echo image (710/27.6/2), obtained 1 week before double valve replacement, shows no apparent abnormalities.

B, Axial view T2\*-weighted gradient-echo image (710/27.6/2), obtained 5 months after successful double valve replacement, shows one of the two large black holes (arrow).

observed could therefore be characterized as *susceptibility artifacts*. Magnetic susceptibility is described as the extent to which a material becomes magnetized in a magnetic field (3). This effect can be found in particular when using the T2\*-weighted gradient-echo technique, which is highly sensitive for magnetic field inhomogeneities. Field distortions caused by material with high magnetic susceptibility (paramagnetic) induce signal intensity loss, resulting in typical signal intensity voids called *susceptibility artifacts*. Near the paramagnetic substance, MR signals are shifted to higher or lower frequencies, so the image is warped in the frequency-encoding direction, leaving a void with a bright crescent rim or white halo (4). This is clearly manifest when using the T2-weighted spin-echo technique.

The substances that could be responsible for these susceptibility artifacts can be divided approximately into four different groups: air, calcium, microhemorrhages, and foreign metallic particles. Air can be ruled out because of expected resolution over time, which we did not observe on the second set of images obtained for patient 2 after 1 year. As for calcium deposits, these have slightly distinct appearances on MR images and lack the white halo, which was clearly visible on the T2-weighted spin-echo sequence of pa-

tient 2 (Fig 1B). In addition, the blooming of signal intensity loss on the T2\*-weighted gradient-echo sequence is not observed with calcium deposits.

Microhemorrhages can cause similar, small, round signal intensity losses on MR images of the brain, and the technical aspects of distinguishing small hemorrhages on T2\*-weighted gradient-echo images from other black holes can therefore be difficult (5). It should be noted, however, that microhemorrhages are often detected in patients with cerebral amyloid angiopathy, cavernous hemangiomas, primary intracerebral hemorrhage, and chronic hypertension with different types of microangiopathy as a common pathogenesis (6–9). In addition, these microhemorrhages are frequently located in regions with small perforating arteries where microangiopathy is likely to cause the first damage. The artifacts we observed are diffusely spread throughout the brain, following the pattern of circulatory distribution via the main cerebral arteries. However, the possibility that the black holes we observed were caused by microhemorrhages was not rejected because of insufficient imaging follow-up of the patients described.

Small particles of foreign metallic material can originate from biomedical implants, such as pros-

thetic heart valves. The Björk-Shiley convexo-concave heart valve consists of two main parts: the occluder, which is made of pyrolytic carbon, and the frame, which consists of Haynes 25, a chromium cobalt alloy that contains 4% ferrite. Both substances have a high magnetic susceptibility, strongly deviating from tissue. This implies that small quantities are able to produce local disturbances and can produce image distortion in the magnetic field of the MR imaging unit. Small particles resulting from abrasions of valve material should be easily detected when found in a region with no additional paramagnetic interference, such as the brain (10).

Because of manufacturing deficiencies, the outlet strut of the Björk-Shiley convexo-concave valve is subject to fracture at the welding points of both legs of the strut (11). Fracture of a single leg can eventually lead to fracture of the second strut, resulting in what is called an *outlet strut fracture*, which often is lethal. In most cases, a single leg fracture exists without apparent clinical symptoms (12). Scanning electron microscopy scans of explanted fractured Björk-Shiley convexo-concave valves often show smoothed surfaces caused by rubbing at both ends of the fracture (13).

Interestingly enough, the images of patient 3 showed artifacts after the Björk-Shiley convexo-concave valve explantation and not before. When valve wear or damage is considered for this patient, one would expect that the "exposure time" of the valve to the circulation was sufficient to cause some artifacts. In addition, no cracks or fractures were discovered with scanning electron microscopy research after valve removal, although common valve wear was obvious. Based on the postoperative changes seen on the MR images, it seems that surgery played a more important role in the formation of these artifacts. This could also be the case for the first two patients for whom we did not have MR images of the brain before explantation. If intensive cardiac surgery were to induce these artifacts, however (ie, by means of surgical instrumentation or cardiopulmonary bypass machines), one would expect to observe it more frequently in daily practice. This may be explained in part by considering that patients with prosthetic heart valves often are unjustly withheld from MR imaging investigation because of fear of valve failure being induced by the magnetic field (14). Moody et al (15) have reported extensively on microembolic phenomena associated with cardiopulmonary bypass, combining clinical presentations and histochemical staining. Unfortunately, in our cases, no pathologic or histochemical evidence is available. In general, detrimental effects on the brain after cardiopulmonary bypass

surgery are still not completely resolved and remain a challenging field of research.

## Conclusion

This case report describes three patients with multiple cerebral black holes on MR images. Although the origin remains unclear, we speculate that Björk-Shiley convexo-concave heart valves and valve explantation surgery might play a causative role. In addition, further studies are needed to assess whether these black holes can be used as markers for the detection of single leg fracture in Björk-Shiley convexo-concave heart valves or whether they can be used to quantify prosthetic valve wear in general.

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