

Effect of high field magnetic resonance scanner on four kinds of pressure programmable shunt valves

T. Inoue¹, Y. Kuzu¹, K. Ogasawara¹, A. Ogawa¹

¹Neurosurgery, Iwate Medical University, Morioka, Iwate, Japan

Introduction

Pressure programmable shunt valves permit noninvasive readjustment of the opening pressure in an implanted shunt to respond to changes in cerebrospinal fluid hydrodynamics. However, the magnetically adjustable valve setting may need readjustment after exposure to the intense magnetic fields used in magnetic resonance (MR) imaging. Changes in the valve pressure setting of pressure programmable shunt valves have occurred after 0.4 and 1.5 Tesla MR imaging. MR scanners with higher field strengths of 3.0 Tesla are now under development at many institutions. The present study investigated effect of exposure to a 3.0 Tesla magnetic field on the valve pressure setting of several types of magnetically pressure programmable valves, which are widely used in the neurosurgical field.

Materials and Methods

Valve Characteristics

The following four types of pressure programmable shunt valves were tested: Sophy PolarisTM (Sophysa, Orsay, France) (n = 5), Sophy SM8TM (Sophysa) (n = 5), Codman HakimTM (Codman & Shurtleff, Raynham, MA) (n = 5), and Medtronic StrataTM (Medtronic, Minneapolis, MN) (n = 5).

The Sophy PolarisTM is a spring ball valve. Noninvasive adjustment involves using a magnet to rotate a pressure bar containing two cobalt-samarium micromagnets to change the force exerted on the ball by a semicircular spring attached to the extremities of the bar. The pressure bar is immobilized by a second spring in five positions. This valve has a self-locking system. The immobilizing spring is fixed to an H-shaped rotor which can pivot within the body of the valve around the central ruby axis. Two mobile shuttles can slide along the H-shaped rotor. Each shuttle contains a polarized micro-magnet to permanently attract the opposite shuttle. Each shuttle is equipped with a lug, designed to lock the rotor-shuttle system in indexing notches located on the wall of the valve body. The rotor-shuttle system can be unlocked by attracting the shuttles in opposite directions simultaneously. In contrast, a static magnetic field attracts the shuttles in the same direction and the rotor-shuttle system cannot be unlocked. The Sophy SM8TM, the Codman HakimTM programmable valve and the Medtronic StrataTM valve are not provided with the self-locking system.

Experimental Protocol

All experiments were performed using a Signa VH/i 3.0 T MR imaging system (GE Medical Systems, Milwaukee, WI) and standard head coil. The tests were performed at room temperature. None of the valves was filled with fluid. All four valves were new at the time of testing.

The effect of exposure to the static magnetic field was tested. Each valve was taped to the MR phantom with the long axis of the valve parallel to the main magnetic field. Then the phantom was advanced toward the center of the magnet. A few minutes later, the phantom was taken out from the magnet without scanning. Changes of the pressure setting were determined by visual inspection with a compass or by radiography. The procedure was repeated three times for each valve at the following pressure settings: Sophy PolarisTM at 30, 110, and 200 mm H₂O; Sophy SM8TM at 30, 110, and 200 mm H₂O; Codman HakimTM at 30, 100, and 200 mm H₂O; and Medtronic StrataTM at 50, 100, and 150 mm H₂O.

The changes of pressure setting after exposure to the radiofrequency magnetic field during scanning were tested. Valves showing no changes in pressure setting in the first experimental setup were scanned. The image protocol consisted of three-dimensional spoiled gradient recalled acquisition in the steady-state T1-weighted, two-dimensional fast spin echo T2-weighted, and echo planar imaging diffusion-weighted images. Sequence-specific parameters were as follows: for the T1-weighted sequences, repetition time (TR) 7.8 msec, echo time (TE) 1.8 msec, field of view (FOV) 200 mm, and 256 matrix; for the T2-weighted sequences, TR 5000 msec, TE 97.8 msec, FOV 240 mm, and 256 matrix; for the diffusion-weighted sequences, TR 9000 msec, TE 79.4 msec, FOV 240 mm, and 256 matrix. Each scan was repeated three times for each sequence at the low-, middle-, and high-pressure settings. After each scanning, the changes of the pressure setting were determined by visual inspection with compass or radiography.

Results

The pressure setting of all Sophy PolarisTM was unchanged at all pressure settings in all three tests. The pressure setting of all Sophy MS8TM was unchanged at 30 mm H₂O, but was changed from 110 or 200 mm H₂O to 30 mm H₂O in all three tests. The pressure setting of all Codman HakimTM was unchanged at 100 mm H₂O, but was changed from 30 or 200 mm H₂O to 100 mm H₂O in all three tests. The pressure setting of all Medtronic StrataTM was unchanged at 100 mm H₂O, but was changed from 50 or 150 mm H₂O to 100 mm H₂O in all three tests.

The second experiment was performed only with the Sophy PolarisTM. All pressure settings studied were unchanged after T1-, T2-, and diffusion-weighted MR imaging.

Discussion

The present study tested the compatibility of four types of pressure programmable valves, Sophy PolarisTM, Sophy MS8TM, Codman HakimTM, and Medtronic StrataTM with a 3.0 Tesla magnetic field, and demonstrated that only the Sophy PolarisTM maintained its pressure settings after exposure to the 3.0 Tesla static and radiofrequency magnetic fields.

The static magnetic field caused changes in the pressure settings of the Sophy MS8TM, Codman HakimTM, and Medtronic StrataTM valves. The pressure setting of the Sophy MS8TM was changed to 30 mm H₂O, the lowest pressure of the valve, in all three tests. The pressure setting of the Codman HakimTM and Medtronic StrataTM valves were changed to 100 mm H₂O, the middle pressure of these valves, in all three tests. These findings suggest that the direction and degree of change is predictable in a 3.0 Tesla magnetic field.

The pressure setting did not change in the Sophy PolarisTM under any conditions studied. This valve has a self-locking system which presumably prevented any change in the pressure setting during 3.0 Tesla MR imaging. Changes in the intracranial pressure may affect patients during and after MR imaging. Patients with slit ventricle syndrome can develop symptoms such as headache or loss of consciousness within a few hours. Therefore, the Sophy PolarisTM, in which the pressure setting does not change during 3.0 Tesla MR imaging, may benefit such patients. However, the pressure setting should still be checked after exposure to the intense magnetic field of the MR scanner.

Conclusion

The present study demonstrated that only the Sophy PolarisTM retained the pressure settings after exposure to 3.0 Tesla static and radiofrequency magnetic fields. This valve may be beneficial for shunt-dependent patients who need a programmable valve and will undergo 3.0 Tesla MR imaging.