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Adjustment and malfunction of a programmable valve after exposure to toy magnets

Case report

RICHARD C. E. ANDERSON, M.D., MARION L. WALKER, M.D., JOHN M. VINER, PH.D., AND JOHN R. W. KESTLE, M.D., M.SC.

Division of Pediatric Neurosurgery, Primary Children's Medical Center, and Department of Physics, University of Utah, Salt Lake City, Utah

Inadvertent adjustments and malfunctions of programmable valves have been reported in cases in which patients have encountered powerful electromagnetic fields such as those involved in magnetic resonance imaging, but the effects of small magnetic fields are not well known. The authors present a case in which a child playing with a collection of commercially available toy magnets altered the pressure setting of an implanted valve and may have caused its permanent malfunction.

KEY WORDS • **shunt malfunction** • **programmable valve** • **electromagnetic field** • **pediatric neurosurgery**

DURING the last 30 years, recognition of the challenges of CSF shunt therapy has led to the development of a variety of valve designs including differential-pressure, siphon-control, and flow-regulated valves. More recently, shunt systems incorporating a valve that allows for adjustment of the initially set pressure have been developed; these enable the surgeon to make noninvasive alterations to the flow characteristics of the valve as the patient's clinical course changes.[2,4,9,10,13,15] Such systems may be advantageous in patients with normal-pressure hydrocephalus, arachnoid cysts, or complications such as subdural hygromas, chronic subdural hematomas, and the slit-ventricle syndrome that are caused by acute or chronic overdrainage.[7] In pediatric patients, closure of the sutures, attainment of erect posture, growth, and aging are all additional situations in which the opening pressure of the valve might require adjustment.[15] Although a randomized clinical trial did not indicate any survival benefit of programmable compared with standard valves,[8] some neurosurgeons believe that the ability to adjust the valve pressure noninvasively, and thus potentially minimize subsequent operative manipulations of the shunt system, warrants the increased expense and complexity of the programmable system.[2,8,15,16]

Programmable valves may be percutaneously adjusted using an external magnet or a special programming tool that works via a magnetic field;[12] however, unexpected pressure changes in programmable valves can also be caused by external magnetic fields. Alterations of valve settings are common after exposure to strong magnetic fields such as those involved in MR imaging, and the need for readjustment of the valve setting after MR imaging has been emphasized in the neurosurgical and neuroradiological literature.[3,7,12] Accidental resetting by an external magnetic field other than that created by MR imaging, however, has been reported to be extremely rare.[15,16]

An unwanted change in the valve setting could cause either increased ICP or overdrainage, each with serious clinical sequelae. We present a case in which a 4-year-old boy playing with a collection of commercially available toy magnets (four pieces) altered the pressure of an implanted shunt valve and may have caused its permanent malfunction. We subsequently report on the effects of such toy magnets, their magnetic properties, and their potential to alter the pressure settings of several Codman (Codman, Raynham, MA) and Strata (Medtronics, Inc., Minneapolis, MN) programmable valves.

Case Report

History and Examination. This patient presented at 2 years of age with dragging of his right foot. Magentic resonance imaging revealed a large left frontal and third ventricle choroid plexus tumor and associated hydrocephalus. The boy underwent a gross-total resection and his tumor

Abbreviations used in this paper: CSF = cerebrospinal fluid; ICP = intracranial pressure; MR = magnetic resonance.

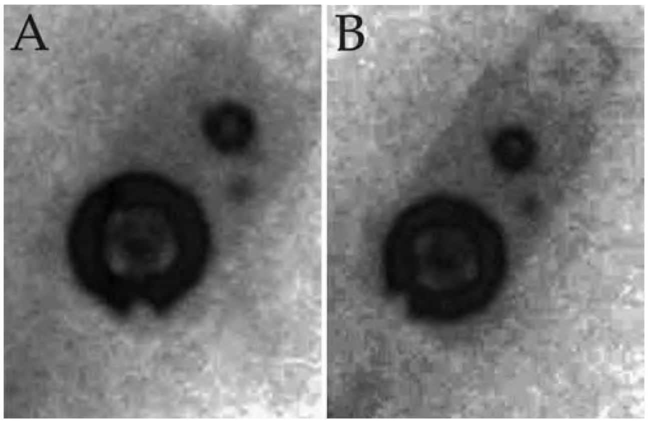

FIG. 1. Radiographs demonstrating the Codman programmable valve before (A) and after (B) the patient's exposure to the toy magnets. The initial valve setting (A) was 70 cm H_2O and the adjusted setting (B) was 110 cm H_2O.

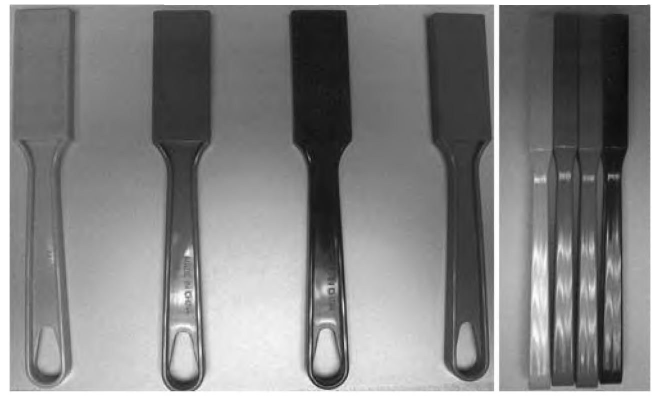

FIG. 2. Photograph of the four toy magnets used by our patient and then investigated in our study. They can be used individually or in combination. Each toy magnet measures 8 × 1 × 0.5 in.

has not recurred. Three months postoperatively he developed a symptomatic subdural collection of CSF, which was treated by placement of a low-pressure shunt. The shunt was removed 4 months later owing to overdrainage and a sunken bone flap. Two weeks later, he presented with signs and symptoms of increased ICP, and computerized tomography scanning demonstrated increased ventricle size. He underwent placement of a ventriculoperitoneal shunt that included a Codman programmable valve with an antisiphon guard set at 70 cm H_2O (Fig. 1).

The patient did well for 16 months and then experienced worsening headaches, nausea, and vomiting for 2 days. Head computerized tomography scanning demonstrated marginally increased ventricles and shunt series measured the valve pressure at 110 cm H_2O (Fig. 1). The valve was reprogrammed to 70 cm H_2O, but no clinical improvement resulted. The patient was taken to the operating room where brisk pressure flow was obtained from the ventricular catheter. No flow could be forced through the valve, but after the valve was removed, flow through the peritoneal tubing was excellent. A new Codman valve was inserted and set at a pressure of 70 cm H_2O. He improved clinically and was discharged home without complications. Extensive questioning of the parents revealed that the patient had been playing with a set of four new toy magnets prior to symptom development (Fig. 2).

Investigation. The magnetic properties of the toy magnets were examined and the magnetic flux densities for the magnets were determined individually and in combination. To calculate the effect of a single magnet over distance, the magnetic flux density was directly measured using a calibrated Hall probe at 31 different positions between 0 and 100 cm from the magnet. The Codman and Strata programmable valves were then tested to determine the effects of the toy magnets on each valve type. A single toy magnet (lowest-strength magnet) was passed (by hand) three times over each valve. The magnet was passed a distance of 12 in within a horizontal plane 2 cm above the valve at a rate of approximately 1 ft per second. Both the highest and lowest initial settings were used for each valve. During each test, the direction and degree of change for each valve were determined using real-time fluoroscopy. Three of each type of valve (Codman and Strata) were tested.

Results. The four magnet pieces together measured 180 milliteslas; each piece individually measured between 67 and 82 milliteslas (Table 1). A plot of the magnetic flux density compared with distance for a single toy magnet (82 milliteslas) indicated a strength of 10.4 milliteslas at 2 cm from the valve (Fig. 3). The four magnets appear identical, except for color, but their densities were slightly different when tested.

Testing of the Codman and Strata programmable valves revealed significant alterations of pressure settings after exposure to the toy magnets (Table 2). Exposure of the Codman valve to the magnet caused the pressure setting to change in both directions, regardless of the initial setting. The Strata valve consistently changed to a higher pressure setting when the initial setting was low. The Strata valve setting did not change when the initial setting was at the highest level (2.5).

Discussion

The value of using an adjustable shunt valve in the treatment of patients with hydrocephalus has previously been described.[2,9–11,14,15] Nevertheless, programmable valves are expensive, they add to the complexity of the valve, and there is considerable inconvenience associated with reprogramming the valve.[8]

Ex vivo and studies in humans have indicated that the opening pressure of adjustable-valve shunts is susceptible to accidental resetting.[3,6,12] The authors of several studies have established that MR imaging can alter the valve settings on programmable valves regardless of their initial setting.[6,7] Accidental resetting induced by an external magnetic field other than those associated with MR imaging has been reported to be extremely rare.[15,16] Schneider and colleagues,[12] however, conducted a study of an ex vivo Codman valve and a Sophysa valve to determine the weakest magnetic field that could change the valve pressure setting. They found that in nonhomogeneous magnetic fields, the Sophysa valve was affected at 25 milliteslas, and the Codman valve at 15 milliteslas. They concluded that pro-

TABLE 1

Summary of the magnetic flux densities for the toy magnets individually and in combination

Toy Magnet	Magnetic Flux Density (milliteslas)
magnet no.	
1	82
2	80
3	67
4	67
1 & 2*	130
1–4*	180

* Multiple magnets tested together.

grammable valve alterations can be produced by magnetic impulses during everyday living, such as those from telephone loudspeakers, headphones, and hairdryers.[12] For these reasons, some authors have recommended that pressure settings of programmable valves be constantly checked.[6]

In the present case a permanent malfunction of a programmable valve occurred after the patient played with commercially available toy magnets (Fig. 2). We do not think the malfunction was coincidental for the following reasons. 1) Symptoms of increased ICP developed soon after exposure to the magnets. 2) The parents witnessed the child placing the magnets near his head and shunt valve. 3) The magnetic properties of the magnets (range 67 milliteslas individual to 180 milliteslas combined [Table 1]) are of sufficient strength to alter programmable valves.[12] 4) Further testing of identical magnets with several different valves induced significant alterations of valve settings (Table 2).

We cannot be certain what caused the valve malfunction in this case. It is possible that exposure to the toy magnets caused a permanent malfunction of the Codman antisiphon programmable valve. Despite the valve having been readjusted to 70 cm H_2O and the pressure confirmed by radiography, CSF could not be forced through the valve at the time of surgery. When the explanted valve was sent to the manufacturer to be investigated, no mechanical reason for the malfunction could be identified. In a previous clinical series in which authors investigated the Codman programmable valve, a small number of valves had to be replaced because the opening pressure at time of surgery was discordant with the valve setting.[15] It is not clear, however, whether this was due to exposure to MR imaging, other magnetic fields, or other factors. It is known that the Codman valve ex vivo can be demagnetized with strong magnetic fields (after four exposures to 1.5 teslas from MR imaging or exposure to a 4-tesla magnet), but such alteration was thought not to be possible after exposure to common magnetic fields.[1,2,7] Our findings are unique; the toy magnets in this case may have induced a permanent malfunction of the valve with a comparatively low-strength magnetic field (maximum combined strength of the magnets 180 milliteslas). Magnetically induced total shunt failure has not been observed by the manufacturer, nor, to our knowledge, has it been reported.

Most investigators have shown that the direction and magnitude of the changes in the valve pressure setting resulting from exposure to external magnetic fields cannot be predicted.[7,12] In some instances, remarkable changes from high to low pressures, which could lead to rapid and excessive drainage of CSF, slitlike ventricles, or subdural hematomas, were observed.[6,7] Alternatively, a rapid increase in valve pressure could precipitate signs and symptoms of increased ICP. We found that the direction and magnitude of change of the valve setting could not be predicted. Regardless of the initial valve setting, exposure of the Codman valve to the toy magnets caused bidirectional changes (Table 2). Exposure of the Strata valve at a low initial setting to the toy magnets caused both small and large changes in the valve setting, but only in one direction (higher).

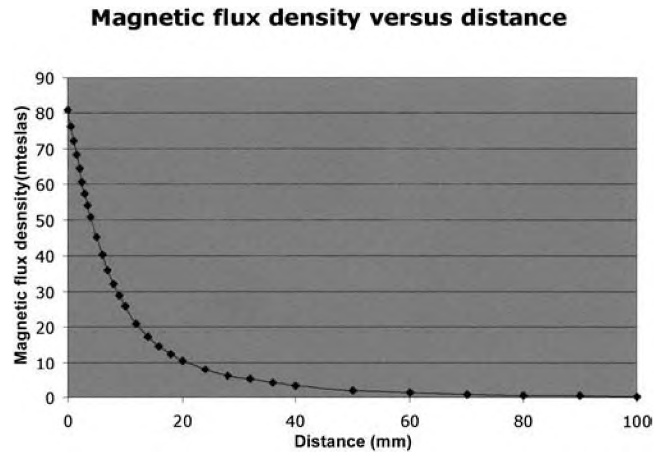

FIG. 3. Graph showing the magnetic flux density (in milliteslas) compared with distance (millimeters) for an individual toy magnet (82 milliteslas). Each *diamond* represents a distinct data point where the magnetic flux density was directly measured with a calibrated probe.

Because exposures to magnetic fields in everyday life cannot be controlled or accurately quantified, it is difficult to determine the incidence of unwanted alterations in valve settings or of valve malfunctions secondary to magnetic fields. In two large studies conducted to investigate Codman programmable valves, the valves malfunctioned and required replacement between 2[8] and 5%[15] of the time, respectively. Reasons for replacement included unexpectedly different opening pressures measured during revision and the inability to adjust the valve's pressure setting. It cannot be determined which, if any, of these malfunctions were induced by external magnetic fields.

The primary limitation of this report is that the number of tested valves and the number of tests are insufficient for statistical analysis. Because only three valves from each of two manufacturers were examined, variability in the susceptibility of different specimens of the same type of valves to magnetic fields cannot be ruled out. Furthermore, despite intraoperative investigation and analysis by the manufacturer, the precise cause of the valve malfunction in this case could not be determined. Nevertheless, this is the first report to describe alterations in pressure settings of programmable valves resulting from contact with commercially available children's toys. Moreover, there have been few studies conducted to investigate the efficacy and reliability of the new Strata valve,[5] and the effects of external magnetic fields on pressure settings have not been described.

TABLE 2

Summary of the initial and resulting pressure settings of three different Codman and Strata programmable valves

Valve Type	Settings*	
	Initial	Resulting†
Codman valve no.		
1	50	70
	120	140
2	50	50
	120	100
3	50	30
	120	100
Strata valve no.		
1	1.0	1.5
	2.5	2.5
2	1.0	2.5
	2.5	2.5
3	1.0	1.5
	2.5	2.5

* Measurements are only approximate estimates of actual pressure. The Codman valve has 18 programmable settings ranging from 30 (lowest pressure) to 200 (highest pressure). The Strata valve has five settings ranging from 0.5 (lowest) to 2.5 (highest).

† Resulting pressure after three passes of a toy magnet (67 milliteslas) 2 cm from the valve.

Conclusions

The pressure level of adjustable valves can be changed inadvertently by electromagnetic fields present in everyday life. Both Codman and Strata programmable valves revealed alterations of pressure settings after exposure to commercially available toy magnets. When children with programmable valves present with shunt malfunction, questions in the history should be included that may help identify magnetic toys so they can be removed from the environment. Surgeons should warn the families of patients with programmable valves to avoid toy magnets.

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Address reprint requests to: Richard C. E. Anderson, M.D., The Neurological Institute, 710 West 168th Street, Room 421, New York, NY 10032. email: rca24@columbia.edu.