Programmable Shunt Valves: In Vitro Assessment of Safety of the Magnetic Field Generated by a Portable Game Machine

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Abstract

Cerebrospinal fluid (CSF) shunts are frequently used to treat hydrocephalus. The use of a programmable shunt valve allows physicians to easily change the opening pressure. Since patients with adjustable CSF shunt valves may use portable game machines, the permanent magnets in these machines may alter the shunt valve programmed settings or permanently damage the device. This study investigated the risk of unintentional valve adjustment associated with the use of game machines in patients with programmable CSF shunt valves. Four adjustable valves from 4 different manufacturers, Sophysa Polaris model SPV (Polaris valve), Miethke proGAV (proGAV), Codman Hakim programmable valve (CHPV), and Strata II small valve (Strata valve), were evaluated. Magnetic field interactions were determined using the portable game machine, Nintendo DS Lite (DS). The maximum distance between the valve and the DS that affected the valve pressure setting was measured by x-ray cinematography. The Polaris valve and proGAV were immune to unintentional reprogramming by the DS. However, the settings of the CHPV and Strata valves were randomly altered by the DS. Patients with an implanted shunt valve should be made aware of the risks posed by the magnetic fields associated with portable game machines and commonly used home electronics.

Key words: hydrocephalus, magnetic field, shunt valve, safety, portable game machine

Introduction

Cerebrospinal fluid (CSF) shunts are frequently used to treat hydrocephalus. Shunt systems with programmable valves include an adjustable, programmable CSF valve for the management of hydrocephalus. Programmable CSF valves allow the physician to noninvasively change the opening pressure with a special magnetic tool after shunt surgery. The shunt systems with programmable valves have gained wide acceptance for the treatment of hydrocephalus. Programmable valves in the shunt system are adjusted using an externally applied programmer tool that magnetically activates the adjustable components of these devices. However, exposure to an external magnetic field can alter the programmed settings or permanently damage the valve. Alterations in valve settings are common after exposure to strong magnetic fields, such as those used for magnetic resonance (MR) imaging. However, accidental resetting induced by an external magnetic field other than those associated with MR imaging has been reported to be rare.11)

The use of the Nintendo DS series (Nintendo Co., Ltd., Kyoto) portable game machine has become increasingly common worldwide. However, the potential effects of magnetic fields produced by this portable game machine on programmable valves are not known. Portable game machines typically contain permanent magnets which are used to vibrate the speaker and air in front of the speaker to create audible sound waves.

The present study investigated whether the pressure settings of programmable valves could be altered by the use of this portable game machine.
Materials and Methods

This study determined the interaction between a portable game machine and programmable shunt valves in vitro. Four adjustable, commercially-available valves from 4 different manufacturers were evaluated: Sophysa Polaris model SPV (Polaris valve; Sophysa SA, Orsay, France), Miethke proGAV (proGAV; Christoph Miethke GmbH & Co. KG, Potsdam, Germany), Codman Hakim programmable valve (CHPV; Codman & Shurtleff, Raynham, Massachusetts, USA), and Strata II small valve (Strata valve; Medtronic Inc., Minneapolis, Minnesota, USA). Normal function of each programmable shunt valve was verified with the programmer tool before testing.

The experiments were performed with a Nintendo DS Lite (DS; Nintendo Co., Ltd.), which is a commercially-available, portable game machine. We assumed that the highest flux density associated with the DS occurred at the speakers on each side of the screen, because the speakers contain permanent magnets. To calculate the effect of the DS over a distance, the magnetic flux density of the DS in the POWER ON (with music playing) was measured using a calibrated Gauss/Tesla-Meter (F. W. Bell, Inc., Milwaukee, Oregon, USA) at five different positions between 0 and 50 mm (0, 5, 10, 15, and 20 mm).

The distances that led to alteration of the adjustable valve settings were measured with x-ray cinematography performed with an Integris (Royal Philips Electronics, Eindhoven, the Netherlands) angiography machine. The DS was opened at a right angle and placed on the panel of the angiography machine in the POWER ON (with music playing) mode. Each programmable valve was placed 10 cm from the speaker of the DS and was slowly advanced closer to the speaker in a random direction under x-ray cinematography (30 frames per second) (Fig. 1A). The distance was measured with a ruler that was suitable for x-ray cinematography (Fig. 1B). The maximal distance that led to alteration of the valve setting was determined by decreasing the distance between the DS and valve, and this measurement was repeated 10 times with each valve under the same conditions. After all testing was completed, normal function of each programmable valve was verified with the programmer tool.

Results

Maximal flux density of the DS was 49.6 mT at the minimum distance of 0 mm from the speaker. The magnetic flux densities at different distances are shown in Fig. 2. The Polaris valve and proGAV were immune to unintentional reprogramming by the portable game machine. However, the CHPV and Strata valves showed significant alterations in pres-

![Fig. 1 Radiographs showing position of the shunt valve and the Nintendo DS Lite (A), and measurement of the distance between the shunt valve and the Nintendo DS Lite affecting the valve settings (B).](image)

![Fig. 2 Graph showing the magnetic flux density compared with distance from the Nintendo DS Lite.](image)

![Fig. 3 Scatterplot showing the distance between the shunt valves and the Nintendo DS Lite affecting the valve settings. CHPV: Codman Hakim programmable valve, Strata: Strata II small valve.](image)
sure settings after exposure to the DS. Exposure of the CHPV and Strata valve to the speaker of the DS caused changes in the pressure settings, regardless of their initial settings and the direction in which the valve was advanced closer to the speaker. The maximal distance at which the pressure setting of the CHPV was changed varied from 6.05 mm to 7.73 mm (mean distance ± standard deviation [SD] 6.81 ± 0.61) (Fig. 3). A change in the pressure setting of the Strata valve was observed at a maximum distance that varied from 11.43 mm to 12.77 mm (mean distance ± SD 12.24 ± 0.36) (Fig. 3). The adjustable function of each shunt valve was normal after the test.

Discussion

The development of programmable shunt valves has dramatically improved the management of hydrocephalus. However, technological advances carry risk of unexpected adverse clinical effects, such as accidental interactions with external magnetic fields. \(^3\) An unintentional change in the programming of the opening pressure due to an external magnetic field is a common problem with the use of programmable valve with a hand held electromagnet \(^1\) ); a man who attempted suicide by deliberately altering his programmable valve with a hand held electromagnet \(^1\); and a 14-year-old girl with an in vivo alteration to the valve setting caused by a vagus nerve stimulator-activating magnet. \(^4\) A few studies showed that cell phones can cause programmable valve alterations. \(^5,6\) Some investigations found that the settings of the CHPV and Strata valves were randomly changed even by cell phones that induced the lowest-intensity fields (CHPV valve, 17.5–42 mT; Strata valve, 6.0–30 mT).

Common permanent magnets for household or office use are generally associated with low risk due to low magnetic field strength. However, rare earth magnets that generate a large magnetic flux despite a small mass have recently become available. Because of such high magnetic field strength and low production costs, rare earth magnets are increasingly being incorporated into various consumer items, for example, speakers, motors in cordless tools, hard disk drives, and magnetic fasteners. Pediatric patients are likely to be exposed to many toys that have magnets of different strength in daily life. In particular, portable game machines are very popular with children. Therefore, the present finding that the magnetic field of the DS is sufficient to alter the settings of CHPV and Strata programmable valves is very important. Whether or not the headphones were attached to the digital music player and whether or not the music player was POWER ON or OFF had no impact on the rate of magnetic interference. \(^9\) Importantly, the magnetic flux density of the DS is always "ON," whether or not the DS is POWER ON or OFF.

The settings of the Polaris valve and proGAV cannot be altered by any magnetic toy at any distance, due to their mechanical locking systems. A specific device is needed to unlock each system. From this point of view, the Polaris valve and proGAV seem to be superior to other commercially available models. Therefore, no radiographic confirmation of the settings of these models is required after exposure to an external magnetic field. The physician can easily confirm the setting with a handheld indicator.

The present investigation suggests that the family of a pediatric patient with a CHPV or Strata programmable valve should be warned to avoid approximating a portable game machine to the valve. In general, the magnetic flux density decreases in inverse proportion to the square of the distance from the magnetic pole. Shunt valves are implanted mainly behind the ear. Consequently, there is a low probability that the use of a portable game machine will affect any valve, but patients with an implanted shunt valve should be aware of the magnetic flux density of other portable game machines and commonly used home electronics.

The CHPV and proGAV are MR imaging-compatible in terms of minor \(T_1\)-generated artifacts, but the Polaris valve shows bigger artifact volumes. \(^9\) The Strata valve has intermediate compatibility with considerable \(T_2\) artifacts. Choice of a shunt valve must consider the different characteristics of the various shunt valves.

The primary limitation of this study is that the number of tested valves and the number of tests are insufficient for statistical analysis. Only four valves from four manufacturers were examined, so variability in the susceptibility of different speci-
moms of the same type of valves to magnetic fields cannot be excluded. Furthermore, our experiments are confined to laboratory findings measured ex vivo. The effect of magnetic fields on implanted valves has not yet been investigated.

The present study showed that the pressure settings of some programmable valves can be altered by close contact with a DS game machine. Therefore, patients with an implanted shunt valve should be made aware of the risks posed by the magnetic fields associated with portable game machines and commonly used home electronics.

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References


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