Adjustable shunt valve–induced magnetic resonance imaging artifact: a comparative study

Clinical article


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Object. In this paper, the authors’ goal was to compare the artifact induced by implanted (in vivo) adjustable shunt valves in spin echo, diffusion weighted (DW), and gradient echo MR imaging pulse sequences.

Methods. The MR images obtained in 8 patients with proGAV and 6 patients with Strata II adjustable shunt valves were assessed for artifact areas in different planes as well as the total volume for different pulse sequences.

Results. Artifacts induced by the Strata II valve were significantly larger than those induced by proGAV valve in spin echo MR imaging pulse sequence (29,761 vs 2450 mm$^3$ on T2-weighted fast spin echo, $p = 0.003$) and DW images (100,138 vs 38,955 mm$^3$, $p = 0.025$). Artifacts were more marked on DW MR images than on spin echo pulse sequence for both valve types.

Conclusions. Adjustable valve–induced artifacts can conceal brain pathology on MR images. This should influence the choice of valve implantation site and the type of valve used. The effect of artifacts on DW images should be highlighted pending the development of less MR imaging artifact–inducing adjustable shunt valves.

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Key Words • hydrocephalus • adjustable valve • programmable valve • cerebrospinal fluid shunt • artifact • magnetic resonance imaging

Adjustable shunt valves, with their advantage of noninvasive adjustment of the opening pressure setting, are being increasingly used as the shunt valve of choice in the treatment of different types of hydrocephalus, particularly normal-pressure hydrocephalus. Magnetic resonance imaging is increasingly being used in examining patients with hydrocephalus. In addition, patients with an implanted shunt valve might need MR imaging with different pulse sequences (such as DW imaging or gradient echo sequences) to investigate a separate or associated brain condition.

Most of the adjustable shunt valves rely on intrinsic magnetic components, the position of which can be noninvasively altered using an external adjustment magnetic device. Inevitably, the shunt valve induces artifacts on MR images; this has been studied as part of the assessment of shunt valve MR imaging safety, mainly ex vivo.1–3,5,7,9,11,12

To our knowledge, no previous studies have been done in which the artifacts of different types of adjustable shunt valves have been compared on postoperative MR images. In this study, we compare the in vivo MR imaging artifact induced by 2 types of adjustable shunt valves: the proGAV valve (Miethke GMBH & Co. KG) and the Medtronic Strata II shunt valve (Medtronic, Inc.).

Methods

We retrospectively reviewed all MR images obtained between 2006 and 2007 at our institution in patients with an implanted proGAV or Medtronic Strata II adjustable shunt valve. The shunt valves had been placed for different clinical indications. The proGAV valve is composed of 2 units: an adjustable unit and a nonadjustable gravitational shunt assistant. Both units have titanium shells. The adjustable unit uses a ball-in-cone valve system. The standard valve has pressures ranging from 0 to 20 cm H$_2$O for the adjustable unit. The Medtronic PS Medical Strata II Valve incorporates a ball-in-cone valve in series with a siphon control mechanism (Delta chamber). It has 5 performance levels (0.5–2.5). A 1.5-T MR imaging unit (GE Signa EchoSpeed, General Electric Medical Systems) was used to obtain all the images; routine brain MR imaging parameters were used.

One author (A.K.T.) measured the maximum surface area of the intracranial artifact on axial, coronal, and...
Adjustable shunt valve–induced MR imaging artifact

The intracranial artifact ellipsoid volume on T1-weighted, T2-weighted, DW, and gradient echo pulse sequence images was calculated by measuring the axis radii of the width, length, and height and by using the following equation: $\frac{4}{3} \pi \times \text{axis radius width} \times \text{axis radius length} \times \text{axis radius height}$.

The median and interquartile range of the 2 groups of data were analyzed, and probability values were calculated using the Mann-Whitney test.

Results

We examined the MR images obtained in 8 patients with a proGAV valve and 6 patients with Strata II valve (Figs. 1–3). The artifact area induced by the Strata II valve on T2-weighted FSE axial imaging was larger than that induced by the proGAV valve (1275 vs 327 mm$^2$, $p = 0.003$). The same trend was found for T1-weighted FSE images in different planes (1403 vs 451 mm$^2$ for axial, 1607 vs 669 mm$^2$ for coronal, and 2925 vs 1052 mm$^2$ for sagittal; $p < 0.05$) (Table 1 and Fig. 4).

The artifact size for both valves was markedly larger on DW images (2524 vs 1014.5 mm$^2$, $p = 0.02$) and gradient echo pulse sequences than on T1- and T2-weighted spin echo sequences (Fig. 5).

The artifact volumes were markedly larger in all pulse sequences with the Strata II valve than with the proGAV valve (29,761 vs 2450 mm$^3$ for T2-weighted images, $p = 0.003$) (Fig. 6). The same applied for DW images (100,138 vs 38,955 mm$^3$, $p = 0.025$) and gradient echo pulse sequences. However, the artifact volume for both valves was markedly larger on DW images than on T1- and T2-weighted spin echo sequences (Fig. 7).

Only 3 patients with gradient echo pulse sequence images had a similar trend of larger artifact produced by...
the Strata II valve than the proGA V valve and markedly larger artifact than that on the T1- and T2-weighted images.

**Discussion**

Several types of adjustable shunt valves are currently available. Neurosurgeons base their shunt valve selection on a number of criteria such as reliability, ease of adjustment, and cost. This study highlights that valve-induced MR imaging artifact is an additional factor that should be taken into consideration. Both the Strata II and the proGA V adjustable shunt valves induced significant artifacts on MR images. The Strata II valve–induced artifact was significantly larger in terms of area and volume in all pulse sequences. The sequence with the least artifact was the T2-weighted FSE image. The magnitude of artifacts produced by both valves on DW images was extensive and could potentially interfere with diagnostic information near the area of interest, particularly in patients with the Strata II valve.

In our practice, we found that both the Strata II and proGA V are reliable programmable valves. The Strata II valve has the advantage of a painless and easily adjustable mechanism, but it has the disadvantage of an MR imaging–induced alteration of the valve setting. On the other hand, the proGA V valve has the advantage of being resistant to setting changes during MR imaging as well as the added flexibility of fine tuning the valve setting (1-cm H₂O adjustment). Readjustment of the proGA V valve is not difficult, but because it requires minimal direct pressure over the valve area, it can cause momentary discomfort particularly in the immediate postoperative period.

Most of the previous work on programmable shunt valves has focused on the other aspects of MR imaging safety and implants such as the torque, heating, and particularly change in valve setting and malfunction.⁷⁻¹⁰,¹³⁻¹⁸ No previous studies have been performed in which the artifact of different types of programmable shunt valves on postoperative MR images have been compared, and there has been no comparison of the artifact produced by the proGA V and Strata shunt valves.

An ex vivo study comparing the Codman-Medos and the Sophy Adjustable shunt valves (Sophysa) under 1.5-T MR imaging showed that the signal void on magnitude and phase images included a 6 × 6 × 12-cm ellipsoidal space around the Sophy and a 4 × 4 × 4-cm spherical space around the Medos valves.¹⁴ Using the ellipsoid volume calculation, these figures correspond to an artifact volume of 226 cm³ for the Sophy and 33.5 cm³ for the Codman-Medos valves.

Following the increasing clinical use of 3-T MR imaging units, various studies evaluating MR imaging safety of various adjustable shunt valves have been conducted.⁹⁻¹³⁻¹⁷⁻¹⁸ One study evaluated the artifact sizes at 3 T compared with 1.5 T, as well as the influence of imaging parameters with respect to artifact size on a 3-T MR imaging system in which 2 aneurysm clips and 5 shunt valves were examined using a water phantom module.¹³ Two versions of the Codman Hakim programmable valves were evaluated (a cylindrical valve with a prechamber and a Codman Hakim microvalve [Codman Sarl]). The authors found that the artifact sizes from implants increased when the magnetic field strength was increased from 1.5 to 3 T.

**TABLE 1: The artifact area in different MR imaging sequences**

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Area (mm²)</th>
<th>ProGA V Valve</th>
<th>Strata II Valve</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>axial T2-weighted</td>
<td>327 (271.5–460)</td>
<td>1275 (1157–1301)</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>axial T1-weighted</td>
<td>451 (436–556)</td>
<td>1403 (1133–2063)</td>
<td>0.025</td>
<td></td>
</tr>
<tr>
<td>coronal T1-weighted</td>
<td>669 (595.5–888)</td>
<td>1607 (1406–2234)</td>
<td>0.014</td>
<td></td>
</tr>
<tr>
<td>sagittal T1-weighted</td>
<td>1052 (787–1331)</td>
<td>2925 (2835–3556)</td>
<td>0.049</td>
<td></td>
</tr>
<tr>
<td>axial DW</td>
<td>1014.5 (921–1439)</td>
<td>2524 (2212–2725)</td>
<td>0.020</td>
<td></td>
</tr>
<tr>
<td>axial gradient echo</td>
<td>1886.5 (897–2876)</td>
<td>5548</td>
<td>0.003</td>
<td></td>
</tr>
</tbody>
</table>

* Values are presented as the median with the interquartile range in parentheses.

**Fig. 4**. The artifact area (in mm²) in different FSE MR imaging planes. The asterisk indicates a statistically significant difference.

**Fig. 5**. The artifact area (in mm²) in T2-weighted FSE and DW MR imaging sequences. The asterisk indicates a statistically significant difference.
3 T. Furthermore, they found that alterations of bandwidth on spin echo images and echo time on gradient echo images obtained using the 3-T head imager affected artifact size to a similar extent as the increase in field strength for most of the studied implants. The recommendation was that optimization of imaging parameters and the proper choice of pulse sequences is important to minimize artifacts from implants on high-field MR imaging systems. The artifact areas were 18 × 20 and 40 × 65 mm for the Codman Hakim micro- and cylindrical valves, respectively. Further studies to compare the artifact induced by Codman Hakim microvalves versus proGA V valves and cylindrical valves versus Strata II valves are needed.

The proGA V valve has been studied ex vivo under 3-T MR imaging, and the artifact has been measured using a saline-filled phantom module. The artifact areas on the T1-weighted spin echo pulse sequences were 1359 and 1165 mm² on the long and short axes, respectively. Under 3-T MR imaging, the Strata II valve artifact areas on the T1-weighted spin echo pulse sequence were 3516 and 3303 mm² (parallel and perpendicular to the valve, respectively). The long axis area artifacts of both the Strata II and proGA V in the aforementioned ex vivo studies are similar to that of the current study. However, the short axis area artifacts were approximately double the size of the axial image artifacts in the current study; this is most likely due to the fact that we delineated the (intracranial) artifact area only. Under 3-T MR imaging, the artifact areas of the Codman Hakim programmable valve on the T1-weighted spin echo pulse sequence were 1590 mm² (long axis) and 1022 mm² (short axis).

A recent case report of radiation-induced meningioma concealed by shunt component artifact highlights the risk of missing pathology in the area of programmable valve artifact.

Conclusions
With the increasing use of adjustable valves, more attention should be paid to the artifact it induces on different pulse sequences, and particular attention should be paid to the choice of programmable valve to be used and the implantation site in relation to an area of interest. Further work is essential to optimize imaging parameters and proper choice of pulse sequences for patients with programmable shunt valves.

Diffusion weighted imaging is being increasingly used in investigating cerebrovascular ischemic disease, abscess, and neurooncology. Gradient echo sequences are helpful in detecting blood and its products. Pending future development of less artifact-inducing programmable valves, neurologists and radiologists as well as neurosurgeons should bear in mind the artifact effect prior to arranging DW or gradient echo imaging to investigate cerebral ischemia, bleeding, or abscess.

Disclosure
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References
A. K. Toma et al.


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