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The Quality of Magnetic Resonance Imaging, as Affected by the Composition of the Halo Orthosis

A BRIEF NOTE*†
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Magnetic resonance imaging is emerging as a valuable tool in the diagnosis of musculoskeletal disorders, particularly in the evaluation of the spinal cord and associated soft tissues. Two important advantages of magnetic resonance imaging as compared with conventional and computer-assisted tomography are that it does not involve ionizing radiation and that it is completely non-invasive.

Patients who sustain an injury to the cervical spine are frequently treated with halo immobilization early in their hospitalization. Magnetic resonance imaging of the cervical spine obviously would be useful in these patients to more precisely define the nature and extent of the injury to the spinal cord, to follow the course of the lesion during recovery, and to evaluate the spinal cord if changes develop. However, the metal in most commercially available halo orthoses may compromise the quality of the magnetic-resonance imaging scan.

Previous reports in the radiological literature have focused on the effects of implanted metallic objects§¶, however, there have been no published reports, to our knowledge, on the utility of magnetic resonance imaging in orthopaedic patients who are immobilized in a metallic external-fixation device. The objective of this study was to determine how the properties of the materials of the halo orthosis affect the quality of magnetic resonance imaging of the cervical spine.

Materials and Methods

Six halo orthoses of various constructions (Table I) were obtained from six manufacturers and were applied to normal volunteers. The pins were threaded through the halo ring and were carefully padded but were not inserted in the skull.

Magnetic resonance-imaging scans of the cervical spine were made using a General Electric magnetic resonance-imaging scanner (General Electric, Milwaukee, Wisconsin) with a 1.5-tesla Oxford magnet. T1-weighted images were produced by applying a surface coil to the back of each subject’s neck. The relaxation time for each sequence was 600 milliseconds and the time to echo was twenty-five milliseconds.

The resulting images were evaluated independently by two of us (P. C. H. and S. R. G.), who were unaware of the type of halo that had been applied. Each image was ranked according to the visibility of the cervical spinal cord from the occiput to the first thoracic level and according to the amount of artefact that was present.

<table>
<thead>
<tr>
<th>Quality of Image*</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ring</td>
</tr>
<tr>
<td>1</td>
<td>Graphite</td>
</tr>
<tr>
<td>2</td>
<td>Titanium</td>
</tr>
<tr>
<td>3</td>
<td>Aluminum</td>
</tr>
<tr>
<td>4</td>
<td>Aluminum</td>
</tr>
<tr>
<td>5</td>
<td>Stainless steel</td>
</tr>
<tr>
<td>6</td>
<td>Stainless steel</td>
</tr>
</tbody>
</table>

* Subjective evaluations, based on the independent judgments of two examiners. Poorest = 6 and best = 1.

Results

The quality of the image of the cervical spine varied greatly according to the composition of the halo orthosis (Table I). These variations ranged from large areas of low signal intensity that obscured the entire cervical area to mild, wave-type artefacts covering non-essential regions of the image. The poorest image resulted from using a halo orthosis that was fabricated entirely from stainless-steel components (Fig. 1). The quality of the image was minimally improved by substituting aluminum uprights for stainless-steel up-
The poorest image, made of a subject who was immobilized in a halo orthosis that was constructed entirely of stainless-steel components. A large area of low signal intensity is obscuring the anatomical landmarks.

The best image, made using graphite-alloy uprights, a graphite-alloy ring, and titanium pins. A small band of low signal intensity persists over the lower cervical region.
rights and by retaining the stainless-steel ring and pins. Using aluminum uprights, aluminum rings, and titanium pins eliminated the area of low signal intensity in the region of the ring; however, a wave artefact was created in this area and over the lower cervical spine.

A halo orthosis that was composed of aluminum uprights, aluminum rings, and stainless-steel pins appreciably reduced the amount of wave artefact. The quality of the image was further improved by using a titanium ring and titanium pins, while retaining the aluminum uprights; however, the anatomical detail of the lower cervical region was compromised by low signal intensity (Fig. 2).

The best image was provided by a halo system consisting of graphite-alloy uprights, a graphite-alloy ring, and titanium pins (Fig. 2). This combination yielded the clearest visualization of the spinal cord and the associated structures, from the occiput to the seventh cervical level. The band of low signal intensity over the lower cervical region was smaller than that of the other orthoses that were tested.

Discussion

Our results demonstrate that the quality of the magnetic resonance image in subjects who were immobilized in a halo orthosis depended strongly on the type of material that was used to construct the halo ring and uprights. Visualization improved progressively with the construction materials in this order: stainless steel, aluminum, titanium, and graphite. In contrast, the type of pin did not appreciably affect the quality of the image of the cervical spine.

Both ferromagnetic and non-ferromagnetic materials have been shown to cause artefacts in the magnetic resonance image. These materials cause a local distortion in the magnetic field of the scanner, producing a low signal-intensity artefact on the resulting image. The magnitude of the artefact is related to the degree of magnetization of the ferromagnetic material and to its mass. Of the materials that were used in this study, stainless steel is the most ferromagnetic, followed by aluminum and titanium. Graphite is only weakly ferromagnetic.

Non-ferromagnetic materials may also produce artefacts on the magnetic resonance image if the materials are electrically conductive. The changing magnetic fields of the magnetic resonance-imaging scanner induce currents to flow in the conductive material. These currents generate a second magnetic field, which locally distorts the magnetic field of the scanner, again resulting in a low signal-intensity artefact, which may obscure the underlying anatomical detail.

According to Faraday's law of electromagnetic induction, a current is induced in a closed-loop conductor when the loop moves through a magnetic field. This phenomenon raises a potentially important safety consideration. The closed-loop configuration and metallic composition of most currently available halo orthoses may allow induction of an electrical current in the ring as the ring moves along the gantry of the magnetic resonance-imaging scanner. This current could potentially be transmitted through the halo pins to the skull, and possibly to the neighboring structures of the central nervous system. Because the short and long-term effects of this current in such close proximity to the human central nervous system are not known, they must be presumed to be potentially hazardous. It must be emphasized, however, that this is a theoretical concern.

The potential safety problem can be easily avoided in one of two ways. Producing halo components that are electrically and magnetically inert would eliminate the possibility of induction of electromagnetic current and would improve the quality of the image, according to the principles that have been outlined. The design of the halo ring could also be modified to interrupt the closed-loop configuration by adding small, non-conductive spacers at one or more points on the ring. This would prevent the flow of the current around the ring and would thereby eliminate the theoretical safety hazard.
References


