MAGNETIC RESONANCE MYELOGRAPHY IN BRACHIAL PLEXUS INJURY

TOSHIYASU NAKAMURA, YUTAKA YABE, YUKIO HORIUCHI, SHINICHIROU TAKAYAMA

From Keio University, Tokyo, Japan

We used magnetic resonance (MR) myelography in ten patients with injuries to the brachial plexus and compared the findings with those obtained by conventional myelography and postmyelographic CT (CTM). In the presence of complete nerve-root avulsion (seven cases), a post-traumatic meningocele was detected by MR myelography. Injuries to the upper roots (three cases) MR myelography showed abnormal findings with a high signal intensity in the nerve root, obliteration of the damaged nerve root, or enlargement and obliteration of the root sleeve. No pseudomeningoceles were detected in these upper-root injuries by MR myelography and CTM. The overall accuracy of detection of damaged nerve roots or root sleeves was better with MR myelography than with conventional myelography and was similar to that of CTM.

MR myelography is non-invasive, relatively quick, requires no contrast medium, provides imaging in multiple projections, and is comparable in diagnostic ability to the more invasive, time-consuming techniques of conventional myelography and CTM.

PATIENTS AND METHODS

Between 1993 and 1996, we studied ten patients with brachial plexus injuries who had had surgical exploration. There were nine men and one woman, with a mean age of 22 years (16 to 38). In six patients, the injury was on the right side and in four on the left; all had occurred during motorcycle accidents. The damaged nerve roots were C5 to C8 in five patients, C5 to T1 in two, C5 to C7 in two and C5 and C6 in one (Table I).

In the last five years, a new MR technique utilising three-dimensional fast spin-echo volume acquisition with maximum intensity projection (MIP) has been developed.1-6 It provides T2-weighted images in which the CSF in the thecal sac is very bright. The MIP algorithm then creates a three-dimensional myelogram-like image (MR myelogram). Background vessel signal is suppressed by a T2-weighted fast spin-echo pulse sequence with a long echo time, and the fat signal obliterated by a presaturation pulse for fat suppression.

Preoperative imaging of brachial plexus injuries has previously been by conventional myelography,7-11 and postmyelographic CT (CTM).12-15 Both, however, involve considerable exposure to radiation, a possible reaction to the contrast material, and the surgical risk of lumbar puncture. Although recent MR studies have been useful in assessing brachial plexus injury,16-18 these were not superior to conventional imaging.19,20 We have now evaluated patients with brachial plexus injuries by MR myelography, conventional cervical myelography, and with CTM to compare the three techniques.

Received 10 February 1997; Accepted after revision 1 April 1997

In the last five years, a new MR technique utilising three-dimensional fast spin-echo volume acquisition with maximum intensity projection (MIP) has been developed.1-6 It provides T2-weighted images in which the CSF in the thecal sac is very bright. The MIP algorithm then creates a three-dimensional myelogram-like image (MR myelogram). Background vessel signal is suppressed by a T2-weighted fast spin-echo pulse sequence with a long echo time, and the fat signal obliterated by a presaturation pulse for fat suppression.

Preoperative imaging of brachial plexus injuries has previously been by conventional myelography,7-11 and postmyelographic CT (CTM).12-15 Both, however, involve considerable exposure to radiation, a possible reaction to the contrast material, and the surgical risk of lumbar puncture. Although recent MR studies have been useful in assessing brachial plexus injury,16-18 these were not superior to conventional imaging.19,20 We have now evaluated patients with brachial plexus injuries by MR myelography, conventional cervical myelography, and with CTM to compare the three techniques.

PATIENTS AND METHODS

Between 1993 and 1996, we studied ten patients with brachial plexus injuries who had had surgical exploration. There were nine men and one woman, with a mean age of 22 years (16 to 38). In six patients, the injury was on the right side and in four on the left; all had occurred during motorcycle accidents. The damaged nerve roots were C5 to C8 in five patients, C5 to T1 in two, C5 to C7 in two and C5 and C6 in one (Table I).

We performed conventional myelography in all patients by lumbar puncture using a water-soluble contrast medium and CT of the cervical spine within two hours of myelography. The CT images were obtained at each nerve root from C4 to T1 with three slices and a slice gap of 3 mm. A 1.5 Tesla Signa MR system (GE Medical, Milwaukee, Wisconsin) and a cervical surface coil were used for acquisition of the MRI. After localisation using T2-weighted images in the sagittal and axial planes, we obtained the MR myelogram using a three-dimensional fast spin-echo sequence (TR 2000 ms; TE 200 ms; slice thickness 2 to 5 mm; field of view 24 cm; 256 × 256 matrix; no slice gap). Thirty to forty slices were produced in six to eight minutes, and were then projected into a MR myelogram using the MIP algorithm. The MR myelograms were performed 1 to 30 months after the injury.

The three techniques were compared for their ability to
detect a traumatic pseudomeningocele, an injured nerve root and an abnormal nerve-root sleeve, and then checked with the findings at operation and intraoperative measurement of somatosensory evoked potentials (SEP) for each injured nerve root. The corresponding nerve roots on the uninjured side were used for comparison. We calculated the sensitivity (true-positive cases/true-positive cases + false-negative cases), specificity (true-negative cases/true-negative cases + false-positive cases), and accuracy (true-positive cases + true-negative cases/total cases) for the detection of traumatic pseudomeningocele and of injury to the nerve root.

### RESULTS

Table II gives the results for all three techniques for each nerve root (C5 to T1) for all ten patients. For definition of abbreviations see footnote below.
two, conventional myelograms did not show a pseudomeningocele (Fig. 2). CTM clearly showed pseudomeningoceles of the C7 and C8 roots in these same seven patients and in two of the patients with C5 to T1 lesions also in the T1 root. A pseudomeningocele of a C6 nerve root was also demonstrated, but its presence was not confirmed at operation (false-positive). No traumatic pseudomeningoceles were detected by any of the techniques in lesions of the upper plexus. Taking the findings at operation as correct the sensitivity, specificity and accuracy for MR myelography in detecting pseudomeningoceles were 88%, 100% and 98%; for conventional myelography 56%, 100% and 93%; and for CTM 100%, 98% and 99% (Table III).

<table>
<thead>
<tr>
<th>Table III. Comparison of diagnostic accuracy in detecting pseudomeningocele and avulsion of the nerve root by MR myelography, myelography and CTM compared with surgical findings and SEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical findings and SEP</td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>MR myelography</td>
</tr>
<tr>
<td>Pseudomeningocele (+)</td>
</tr>
<tr>
<td>Pseudomeningocele (-)</td>
</tr>
<tr>
<td>Avulsion</td>
</tr>
<tr>
<td>Normal</td>
</tr>
<tr>
<td>Myelography</td>
</tr>
<tr>
<td>Pseudomeningocele (+)</td>
</tr>
<tr>
<td>Pseudomeningocele (-)</td>
</tr>
<tr>
<td>Avulsion</td>
</tr>
<tr>
<td>Normal</td>
</tr>
<tr>
<td>CT myelography</td>
</tr>
<tr>
<td>Pseudomeningocele (+)</td>
</tr>
<tr>
<td>Pseudomeningocele (-)</td>
</tr>
<tr>
<td>Avulsion</td>
</tr>
<tr>
<td>Normal</td>
</tr>
</tbody>
</table>

Detection of abnormal nerve roots and nerve-root sleeves. MR myelography showed a high signal intensity at the C5 and C6 nerve roots, obliteration of the tip of the root sleeve with no identifiable root or a defect of the root sleeve in all seven patients with C5 to C8 and C5 to T1 lesions. Conventional myelography showed avulsion of the C5 and C6 nerve roots only in three patients with C5 to C8 roots. 

Case 3. A 21-year-old man with a right brachial plexus injury (C5 to C8). Pseudomeningoceles are clearly observed at the C7 and C8 roots on the conventional myelogram (a), CTM (b) and MR myelogram (c) (arrows). Enlargement of the C5 nerve-root sleeve (star) and obliteration of the C6 root (arrowhead) are seen on the conventional myelogram (a) and MR myelogram (c). The intraoperative SEP findings showed a postganglionic injury or a normal C5 root and preganglionic injuries on the C6, C7 and C8 roots. The surgical findings were rupture, not avulsion, of the C5 root, avulsion of the C6 root and pseudomeningoceles of both the C7 and C8 roots.
injury, while in the other four it did not delineate abnormal findings in the upper nerve roots. Obliteration of the tip of the root sleeve with no identifiable root and/or enlargement of the root sleeve on both injured nerve roots (Figs 3 and 4) were shown by all three techniques in one patient with a C5 to C7 injury (case 10), while in the other patient with a C5 to C7 injury (case 9), avulsion of the C7 root was detected only by CTM and avulsion of the C5 and C6 nerve roots only was seen. In one patient with a C5 to C6 injury, a clear MR myelogram was not obtained because of a motion artefact. CTM showed nine of the C5 and nine of the C6 roots which were avulsed. Intraoperative SEP findings showed that the lesions in the C5 nerve root in three patients and in the C6 nerve root in two were post-ganglionic. Compared with the surgical and SEP findings, the sensitivity, specificity and accuracy of detection of total nerve-root injury for MR myelography were 91%, 92% and 92%; for conventional myelography 54%, 94% and 81%; and for CTM 94%, 91% and 92% (Table III).

DISCUSSION

Myelography and CTM have been used for imaging both preganglionic and postganglionic injury to the brachial plexus. One advantage of myelography is its ability to delineate the entire injury. Both techniques, however,
involve considerable exposure to radiation and the possibility of reaction to the contrast medium. Myelography is reported to be unreliable at the level of the C5 and C6 nerve roots. CTM is superior to conventional myelography in visualising the nerve rootlets because of axial imaging, but it is difficult to detect the entire extent of the injuries. Vielvoye and Hoffmann concluded that detection of partial or complete cervical root damage was not fully reliable in either myelography or CTM. Recently, the usefulness of MRI as a non-invasive diagnostic tool for injury to the brachial plexus has been reported, but the acquisition time for conventional MRI is long, and the injury is not always clearly visible. Furthermore, it is difficult to determine the entire extent of the injury with single axial MRI, as in CTM, and thus combinations of multiple slices or multiple planes are needed. This requires further acqui-
position time and is difficult for the patients. A combination of conventional myelography and CTM has thus been the standard imaging technique for injury to the brachial plexus.  

MR myelography is a new method for generating myelo-
gram-like images of the CSF by MRI. Recent reports of MR myelography have been limited to the lumbar spine.  

Previous results with cervical MR myelography have been poor, but we were able to obtain nine excellent cervical MR myelograms by using a cervical surface coil, heavy T2-weighting and thin slices with no slice gap on the three-dimensional volume scan. Although the vertebral arteries and spinal venous plexus were shown by myelography, the bony landmarks were not, but this made little difference diagnostically when compared with conventional myelography.  

MR myelography demonstrated pseudomeningoceles better than myelography, because in the latter technique detection is affected by the quantity of intrathecal contrast medium injected. CTM does not delineate the full extent of injuries because it uses only axial images. MRI depends only on the presence of CSF and the appropriate imaging parameters to create a myelographic-like image. The image of a pseudomeningocele is also emphasised by superpositioning the multiple images by three-dimensional reconstruction on MR myelography. Slow flow of CSF in the meningocele is also emphasised in MR myelography because there is no flow void artefact. Abnormal nerve roots and root sleeves were shown equally well by MR myelography as by CTM. Myelography did not outline damaged nerve roots and root sleeves as well as CTM and MR myelography.  

MR myelography has several advantages over conventional and CT myelography. It is a non-invasive technique with a relatively short imaging time. No contrast medium is required, but excellent images of the thecal sac are provided. It can be used in the acute phase of injury to the brachial plexus whereas in such patients lumbar puncture and the use of contrast medium carry a slight risk. When carrying out MR myelography the patient is placed in a comfortable, supine position and does not have to move about because the multiple projection is produced by three-dimensional reconstruction (Fig. 4). The disadvantages of MR myelography include artefacts due to CSF pulsation and movement by the patient, and inclusion of the vertebral arteries and spinal venous plexus. It is also quite difficult to determine the exact level of injury since no bony landmarks are included on the images. It is able, however, to provide results similar to CTM in a non-invasive manner.

We wish to thank T. Asakura for his help with producing MR myelograms and K. Yamanaka, MD, PhD, for his help with the surgical and intrathecal SEP findings. Part of this study was supported by the clinical funds of the Marine and Fire Insurance Association of Japan.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

REFERENCES
22. de Verdier HJ, Colletti PM, Terek MR. MRI of the brachial plexus: a review of 51 cases. Comput Med Imaging Graph 1993;17:45-50.