Magnetic resonance neurography studies of the median nerve before and after carpal tunnel decompression


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Object. Recently developed novel MR protocols called MR neurography, which feature conspicuity for nerve, have been shown to demonstrate signal change and altered median nerve configuration in patients with median nerve compression. The postoperative course following median nerve decompression can be problematic, with persistent symptoms and abnormal results on electrophysiological studies for some months, despite successful surgical decompression. The authors undertook a prospective study in patients with carpal tunnel syndrome, correlating the clinical, electrophysiological, and MR neurography findings before and after 3 months after surgery.

Methods. Thirty patients and eight control volunteers were recruited to the study. The MR neurography consisted of axial and sagittal images (TR = 2000 msec, TE = 60 msec) obtained using a temporomandibular surface coil, fat saturation, and flow suppression. Maximum intensity projection images were used to follow the median nerve through the carpal tunnel in the sagittal plane.

Magnetic resonance neurography in patients with carpal tunnel syndrome demonstrated proximal swelling (p < 0.001) and high signal change in the nerve, together with increased flattening ratios (p < 0.001) and loss of nerve signal in the distal carpal tunnel (p < 0.05). Sagittal images were very effective in precisely demonstrating the site and severity of nerve compression. After surgery, division of the flexor retinaculum could be demonstrated in all cases. Changes in nerve configuration, including increased cross-sectional area, and reduced flattening ratios (p < 0.001) were seen in all patients. In many cases restoration of the T1 signal intensity toward that of controls was seen in the median nerve in the distal carpal tunnel. Sagittal images were excellent in demonstrating expansion of the nerve at the site of surgical decompression.

Conclusions. In this study the authors suggest that MR neurography is an effective means of both confirming compression of the median nerve and its successful surgical decompression in patients with carpal tunnel syndrome. This modality may prove useful in the assessment of unconfirmed or complex cases of carpal tunnel syndrome both before and after surgery.

KEY WORDS • magnetic resonance neurography • carpal tunnel syndrome • outcome
obtained, with focal areas of compression seen in patients with carpal tunnel syndrome.\textsuperscript{15} This was then further investigated in a larger study, in which MR neurography findings were correlated with clinical, electrophysiological, and operative findings, and abnormalities of the nerve were found in 100\% of patients with carpal tunnel syndrome.\textsuperscript{4}

A problem that has not yet been addressed is the confirmation of successful median nerve decompression, and how changes on MR neurography seen before and after surgery might help predict clinical and electrophysiological outcome. We conducted a prospective study in which MR neurography was used both pre- and postoperatively in patients with carpal tunnel syndrome and in which the clinical outcome was correlated with electrophysiological and MR neurography findings.

**Clinical Material and Methods**

*Patient Population*

A prospective study was conducted with protocols and consent forms approved by the local ethics and research committee. Thirty patients with electrophysiological evidence of carpal tunnel syndrome in whom conservative measures of treatment had failed and who thus were scheduled for carpal tunnel decompression were recruited; eight age-matched control volunteers were also studied.

The patients included in this study had a mean age of 56 years (control volunteers had a mean age of 49 years); 17 patients were female and 13 were male. Initially, 35 patients were recruited into the study; however, data in five patients were excluded because of motion artifacts. These five patients were female and 13 were male. Initially, 35 patients were scheduled for carpal tunnel decompression were recruited; eight age-matched control volunteers were also studied.

As shown in Table 1, no patient included in the study had Gelberman Stage 1 disease (mild), 23 patients had Stage 2 disease (intermediate), and seven had Stage 3 disease (advanced). To summarize, these included proximal nerve swelling at the level of the pisiform and distal radius bones in 28 of 30 wrists (p < 0.0001), increased signal change in proximal nerves in 27 of 30 (p < 0.001), increased flattening of the distal median nerve in 28 of 30 (p < 0.003), and loss of nerve signal in distal carpal tunnel in 26 of 30 (p < 0.05) (Fig. 1). Most striking was the fact that sagittally reconstructed images enabled us to identify both nerve compression in the carpal tunnel in 27 of 30 patients and prestenotic swelling and hyperintensity (Fig. 2) in comparison with controls (p < 0.0001).

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Comparison of the preoperative and 3-month postoperative MR neurography images of the median nerve yielded the results summarized in Table 2. In all 30 patients studied, the median nerve configuration changed after surgery.
Changes in the previously described prestenotic nerve included a return toward normal nerve signal in 25 of 30 patients (p < 0.05) and a reduction in size of the nerve toward control values in 24 of 30 (p < 0.05). In the distal portion of the carpal tunnel, where the median nerve was seen to be most compressed, the reverse change was seen with a significant increase in both cross-sectional area of the nerve in all 30 patients (p < 0.001) and an increase in nerve signal in 23 of 30 (p < 0.05) after surgery. Marked changes were seen in the reconstructed sagittal images, with confirmation of division of the flexor retinaculum (Fig. 3) and enlargement of the nerve at the previous site of compression in all patients. Additional features seen on axial imaging that were not formally scored were a low signal halo appearing around the decompressed median nerve, which may represent restoration of the normal fat plane (Fig. 4); the ability to see individual nerve fascicles postoperatively that were not seen before decompression; and clear division of the flexor retinaculum.

These results of median nerve MR neurography indicate that when there is evidence of median nerve compression, this is associated with a good or excellent outcome after surgery (83%). Only one patient in our series had a poor outcome at 3 months; in this case only mild compression was seen on MR imaging, and there was clinical evidence of severe carpal tunnel syndrome with thenar wasting. An individual feature of preoperative median nerve imaging directly associated with outcome was low signal in the distal nerve (p < 0.007); a low T2 signal in this nerve was associated with a worse outcome. No feature of the postoperative imaging taken by itself was correlated with outcome; however, in all cases decompression of the median nerve could be confirmed. The strongest factor correlating with clinical outcome at 3 months was the Gelberman stage (p < 0.01 according to the Pearson correlation).

Results of Electrophysiological Studies

In all patients, abnormalities on their electrophysiological studies were strongly suggestive of carpal tunnel syn-

<table>
<thead>
<tr>
<th>Preop Stage</th>
<th>Excellent</th>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
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<tr>
<td>1</td>
<td>14</td>
<td>7</td>
<td>2</td>
<td></td>
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<tr>
<td>2</td>
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<tr>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
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<tr>
<td>total</td>
<td>14</td>
<td>10</td>
<td>5</td>
<td>1</td>
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TABLE 1
Outcome after carpal tunnel decompression in 30 patients at 3-month follow-up review according to the Gelberman stage of carpal tunnel syndrome.
drome before surgery; however, none of these individual variables could be significantly correlated with outcome or the changes seen on MR neurography. Comparison of the mean electrophysiological values before and after surgery revealed an improvement in motor latency, but not back to normal levels (Fig. 5). Thus, many patients in the study who had minor residual symptoms (15 with good or fair outcome) also had persistent abnormalities in their electrophysiological parameters, including motor amplitude and sensory velocity and amplitude in all 15 patients in this subgroup.

**Discussion**

The patients selected for this study had clinical and electrophysiological evidence of carpal tunnel syndrome, and for them either conservative treatment had failed or they had chosen to have surgical treatment. Thus, the patients studied generally represented those with worse Gelberman grades and more severe electrophysiological changes.

The preoperative data generally support the work of Britz, et al., with MR neurography providing both sensitivity and specificity in the diagnosis of carpal tunnel syndrome. Again, similar to findings in their study, no correlation was seen between the severity of carpal tunnel syndrome, electrophysiological changes, and quantitative parameters measured on the MR neurography studies of the median nerve. As in our study, imaging of the carpal tunnel in control volunteers demonstrated that the cross-sectional area of the median nerve was larger just before it entered the carpal tunnel and that flattening of the nerve within the carpal tunnel was normal. This and other studies have revealed that the median nerve signal remains constant through the carpal tunnel in normal nerves.2,16

Many of the changes in both the size of the nerve and signal intensity in carpal tunnel syndrome are thought to be caused by changes in the blood supply and venous drainage of the nerve. Experimental models show that nerve compression results in early reduction in epineural blood flow, with resultant perineural edema; eventually axonal blood flow is affected, with a subsequent reduction in intraneuronal blood flow and associated edema. The intrashaving edema eventually produced by this process would almost certainly manifest on the MR neurography images as nerve swelling and hyperintensity due to increased T₂ signal. The prestenotic swelling and signal change of the nerve at

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**TABLE 2**

Comparison of quantitative MR neurography data obtained in the median nerve before and 3 months after surgical decompression

<table>
<thead>
<tr>
<th>Variable</th>
<th>Controls</th>
<th>Preop</th>
<th>Postop</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Value (mean ± standard deviation)</td>
<td></td>
<td></td>
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<tr>
<td>distal radial level</td>
<td>area (mm²)</td>
<td>13.38 ± 1.52</td>
<td>19.38 ± 7.47</td>
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<td></td>
<td>signal (ratio)</td>
<td>2.07 ± 0.41</td>
<td>1.88 ± 0.43</td>
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<td>flattening (ratio)</td>
<td>2.6 ± 1.41</td>
<td>2.37 ± 0.78</td>
</tr>
<tr>
<td>pisiform level</td>
<td>area (mm²)</td>
<td>11.51 ± 2.81</td>
<td>18.64 ± 6.46</td>
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<tr>
<td></td>
<td>signal (ratio)</td>
<td>2.41 ± 0.19</td>
<td>1.92 ± 0.38</td>
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<td>flattening (ratio)</td>
<td>2.31 ± 0.42</td>
<td>2.52 ± 0.67</td>
</tr>
<tr>
<td>hamate level</td>
<td>area (mm²)</td>
<td>12.9 ± 2.04</td>
<td>11.0 ± 3.42</td>
</tr>
<tr>
<td></td>
<td>signal (ratio)</td>
<td>1.36 ± 0.31</td>
<td>1.38 ± 0.34</td>
</tr>
<tr>
<td></td>
<td>flattening (ratio)</td>
<td>2.58 ± 1.31</td>
<td>4.91 ± 2.38</td>
</tr>
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</table>

* Significant at p < 0.05, independent samples t-test.
† Significant at p < 0.001, independent samples t-test.
‡ Range 1 to 4 (most severe to no compression) on a qualitative scale.

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**FIG. 2.*** Upper: Sagittal MR neurography image through carpal tunnel in a patient with carpal tunnel syndrome, demonstrating proximal nerve swelling (right arrow) and nerve compression in distal carpal tunnel (left arrow). Lower: Sagittal MR neurography image through carpal tunnel in a control volunteer, demonstrating normal course and size of the median nerve (arrow) in carpal tunnel.

**FIG. 3.*** Sagittal MR neurography image through carpal tunnel in a patient with carpal tunnel syndrome after decompression, demonstrating expansion of the nerve at the operative site.
the level of the pisiform bone is most likely a result of the proximal spread of edema. Other mechanisms proposed to account for the changes in nerve configuration include alterations in axoplasmic flow, with accumulation of axoplasm causing the changes demonstrated on MR neurography. The most significant feature on preoperative imaging that was associated with outcome was signal intensity in the distal median nerve (Pearson correlation, \( p < 0.007 \)). This indicates that if the T2-weighted signal was markedly reduced in the distal (hamate) portion of the median nerve, there may have been permanent damage to the nerve, perhaps caused by long-standing compression. In this study we found sagittal images to be excellent for identifying the site of compression and proximal hyperintensity. This was particularly useful in one patient with persistent carpal tunnel syndrome in whom decompression was performed at another center. By using MR neurography in this patient, we were able to confirm that residual flexor retinaculum was causing nerve compression; the patient’s median nerve was successfully reexplored, and the flexor retinaculum was divided completely. Despite this finding, the grade of sagittal compression was not significantly associated with outcome; interestingly, in the one patient with a poor outcome only mild nerve compression was observed on sagittal imaging.

Magnetic resonance neurography of the median nerve after surgery confirmed its decompression, with a significant reduction in both nerve T1 signal and in proximal swelling. Again, on sagittal images we were clearly able to confirm division of the flexor retinaculum and the associated expansion of the nerve into the operative site in all patients. The electrophysiological parameters improved to some degree in almost all patients, although the readings remained abnormal 3 months postsurgery. This is in contrast to MR neurography, which clearly demonstrates successful nerve decompression at 3 months. Because many patients remain symptomatic to some degree at 3 months, MR neurography may be used to confirm successful median nerve decompression before clinical and electrophysiological testing.

**Conclusions**

The findings in this study indicate that MR neurography of the median nerve is an accurate means of assessing patients with carpal tunnel syndrome, providing good sensitivity and specificity. After surgical decompression of the median nerve this modality can be used to confirm a successful result and to demonstrate changes in the nerve’s signal intensity and dimensions. Although specialized MR imaging of the median nerve in carpal tunnel syndrome may not be indicated as part of the routine assessment of patients in whom this condition is suspected, this method may be of use in the investigation of unconfirmed or complex cases and in cases in which surgical treatment has failed to improve the outcome.

**References**


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