Chemical Shift and Fat Suppression Magnetic Resonance Imaging of Thymus in Myasthenia Gravis

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Myasthenia gravis (MG) is an autoimmune neuromuscular disease leading to fluctuating muscle weakness. Approximately 70% of patients with MG have thymic hyperplasia, and 10–20% of them have thymoma. In MG patients without thymoma, thymectomy should be performed only in selected patients. In contrast, thymectomy should be performed in all patients with thymoma. In addition, thoracoscopic thymectomy can be used in non-thymomatous MG but not in MG with thymoma, since it has limited exposure. Therefore, it is essential to differentiate thymic hyperplasia from thymoma in MG patients so that physicians can determine the need for thymectomy together with the best approach. 

In most previous studies, imaging characteristics of thymic hyperplasia and thymoma overlapped considerably on both computed tomogram (CT) and conventional magnetic resonance imaging (MRI). However, by incorporating new sequences, MRI has shown recent promise. Inaoka et al. found that chemical shift MRI could reliably differentiate thymic hyperplasia from thymus gland tumors. Furthermore, Popa and colleagues confirmed the ability of chemical shift technique in differentiating thymic hyperplasia from thymoma in MG. In addition, Kuhnt et al. suggested that MRI with fat suppression sequences was superior to CT in thymic imaging.

Although the above studies are valuable for the application of MRI in MG, they did not use chemical shift and fat suppression techniques together and directly compare their performance. Moreover they did not consider the influence of age. The proportion of fat tissue in thymus changes significantly over a lifetime; after 40 years-of-age it is predominantly replaced by fat. On the other hand, chemical shift and fat suppression techniques performed differently according to the ratio of fat in the tissue. The performance of these MRI techniques on thymus imaging may change across different age groups as the ratio of fat in thymus changes. The purpose of this study was to assess the role of chemical shift and fat suppression MRI techniques in thymic imaging of patients with MG and to determine whether their performance changes with age.

METHODS

Subjects

The institutional review board of our hospital approved the study protocol. We retrospectively reviewed the medical records, CT and MRI images of consecutive MG patients treated at our hospital from 2009 to 2011, and found seven MG patients who had undergone both CT and MRI (including chemical shift and fat suppression MRI) studies of the thymus, with known histological results. The diagnosis of MG was based on their history, neurological examinations, neostigmine test and electrophysiological studies (including single fiber electromyography and repetitive nerve stimulation). A summary of their demographic and clinical characteristics is shown in the Table. Only Case 2 had received small dose corticosteroid treatment before the imaging studies; none of the other patients had received immunosuppressants, including corticosteroids, before CT and MRI scanning.

 Imaging Study

All MRI was performed using a 1.5 T unit (Signa; General Electric Medical Systems, Milwaukie, WI, USA) and a torso coil. Chemical shift images were obtained by using both in-phase and opposed-phase T1-weighted gradient-echo sequences in all subjects. These images were acquired using fast multiplanar spoiled gradient-echo sequences with a flip angle of 90°. 5 mm section thickness, 1 mm intersection gap, 340-380 mm field of view, 288×180 image matrix, one signal acquisition, and a bandwidth of ±62.5 kHz in a single breath-hold of 20 seconds. Repetition time (TR) was 220 msec on each image. Echo time (TE) for the in-phase image was 4.9 msec and that for the opposed-phase image was 2.3 msec. We also obtained T2-weighted spin-echo axial images with and without fat suppression in all subjects. The T2-weighted spin-echo imaging was obtained using a single shot fast spin-echo sequence with the following parameters: TR range/ TE range, 2000-2333.33/79.65-86.51; section thickness, 5 mm with a 1 mm intersection gap; and matrix, 288×180.

All patients underwent CT scan using a 16-slice scanner (Brightspeed; General Electric Medical Systems, Milwaukie, WI) without contrast. Helical CT was performed from the lung apices to the middle portion of both kidneys with 4-mm collimation and a pitch of 1.3. The image data were reconstructed using 5-mm thickness. Scanning parameters were 120 kVp and auto-mA by keeping...
the noise index below 11. The lung (window width, 1500 Hounsfield units (HU); window level, -600 HU) and mediastinal (window width, 400 HU; window level, 35 HU) windows were reconstructed using the bone algorithm and soft tissue algorithm, respectively.

Image Analysis

The CT and MRI images were independently assessed by two professional radiologists, who were blinded to patients’ clinical information. Final decisions were reached by consensus.

Both the CT and MRI images were assessed for the shape of the thymuses, their relationship with adjacent structures and the signal homogeneity; the CT attenuation value and MRI signal intensity of the thymuses (or thymoma) were evaluated on CT and MRI, respectively. The chemical shift ratio (CSR) was determined by comparing the relative change of the signal intensity of the thymic tissue (or thymoma) (tSI) to that of the paraspinal muscle (mSI) for the in (in) and opposed (op) phases. A circular region of interest (ROI) was placed within the thymus (or thymoma) and the paraspinal muscle at a slice level of the maximum axial surface of the thymus (or thymoma) when the lesion was homogeneous. If the lesion had heterogeneous signal intensity, its signal intensity was determined by the dominant signal intensity. The CT attenuation values of the thymus (or thymoma) were measured on the way similar to MRI signal intensity measurements. The area of the ROI ranged from 66 to 194 mm². The following equation was adopted: CSR = (tSI_{op}/mSI_{op})/(tSI_{in}/mSI_{in}).³

Thymectomy and Pathologic Examination

Thymectomy was performed through median sternotomy in all patients by thoracic surgeons in our hospital. Operation records were reviewed. Thymic pathology was determined by clinical pathologists in our hospital. The diagnosis of thymic hyperplasia was established by the presence of several lymphoid follicles with germinal centers. Thymoma was diagnosed and classified according to the latest World Health Organization classification.

RESULTS

Thymic hyperplasia Group

The findings of CT and MRI are summarized in the Table. There was no compression to surrounding structures by the thymuses on both imaging modalities. In Case 1 and Case 2, the thymuses were soft tissue density structures on CT. On MRI examination, the thymuses of these two cases were of intermediate signal intensity on T1 and T2. After fat suppression, their signal intensity was slightly reduced and was higher than both muscle and subcutaneous fat. However, on chemical shift imaging, there was no signal loss on the opposed-phase image; its CSR was 1.02. In Case 3, an elderly patient, there were few micronodularities and linear strands in the thymus on both CT and MRI (Figure 2). The thymus showed predominant fat attenuation on CT, while on MRI the signal intensity of the thymus was similar to subcutaneous fat and much higher than muscle on T1 and T2. After fat suppression, its signal intensity was significantly reduced, which was similar to subcutaneous fat. However, on chemical shift imaging, there was no signal loss on the opposed-phase image; its CSR was 1.02.

Table: Summary of demographic, clinical, CT, and MR characteristics

<table>
<thead>
<tr>
<th>Case</th>
<th>Gender</th>
<th>Age</th>
<th>Osserman grading</th>
<th>Muscle groups involved</th>
<th>Thymic histology</th>
<th>Shape on CT</th>
<th>CT attenuation value (HU)</th>
<th>Shape on MRI</th>
<th>Opposed-phase imaging</th>
<th>CSR</th>
<th>Fat suppression</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Female</td>
<td>30</td>
<td>IIa</td>
<td>Ocular and limbs</td>
<td>LFH</td>
<td>Triangular</td>
<td>27</td>
<td>Convex</td>
<td>Signal decreased</td>
<td>0.16</td>
<td>Signal decreased</td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>30</td>
<td>IIb</td>
<td>Ocular, facial, axial and limbs</td>
<td>LFH</td>
<td>Convex</td>
<td>9</td>
<td>Convex</td>
<td>Signal decreased</td>
<td>0.78</td>
<td>Signal decreased</td>
</tr>
<tr>
<td>3</td>
<td>Female</td>
<td>60</td>
<td>IIa</td>
<td>Ocular, facial, axial and limbs</td>
<td>LFH</td>
<td>Irregular</td>
<td>−107</td>
<td>Irregular</td>
<td>Signal decreased</td>
<td>0.36</td>
<td>No change</td>
</tr>
<tr>
<td>4</td>
<td>Female</td>
<td>34</td>
<td>IIa</td>
<td>Ocular, facial, axial and limbs</td>
<td>Type B1 thymoma</td>
<td>Circular 36</td>
<td>29</td>
<td>Round</td>
<td>Signal decreased</td>
<td>1.12</td>
<td>No change</td>
</tr>
<tr>
<td>5</td>
<td>Male</td>
<td>32</td>
<td>IIa</td>
<td>Ocular, facial, axial and limbs</td>
<td>Type B2 thymoma</td>
<td>Circular 33</td>
<td>26</td>
<td>Irregular</td>
<td>No change</td>
<td>1.06</td>
<td>No change</td>
</tr>
<tr>
<td>6</td>
<td>Female</td>
<td>33</td>
<td>IIa</td>
<td>Ocular, facial, axial and limbs</td>
<td>Type B1 thymoma</td>
<td>Circular 33</td>
<td>26</td>
<td>Irregular</td>
<td>No change</td>
<td>1.06</td>
<td>No change</td>
</tr>
<tr>
<td>7</td>
<td>Female</td>
<td>51</td>
<td>IV</td>
<td>Ocular, facial, axial and limbs, and respiratory</td>
<td>Type B2 thymoma</td>
<td>Irregular 26</td>
<td>31</td>
<td>Round</td>
<td>No change</td>
<td>1.06</td>
<td>No change</td>
</tr>
</tbody>
</table>

CSR = chemical shift ratio; LFH = lymphoid follicular hyperplasia.
There was compression to the surrounding structures in Case 7 but not in other patients. All the thymomas showed soft tissue density on CT and homogenous signal intensity between that of muscle and less than that of fat. After fat suppression, there was no significant signal intensity loss of the tumors and the signal intensity of these thymomas also showed no reduction in the opposed-phase image when compared with the in-phase image. The CSR ranged from 0.96 to 1.12 (mean 1.03).

Compared with other MRI sequences and CT, the performance for delineating the margin of the tumors and their relationship with surrounding tissues was better on chemical shift imaging in Case 4, 5 and 6 (Figure 3 for Case 4), while was better on fat suppression imaging in Case 7, who was much older (Figure 4).

**DISCUSSION**

In the present study, by incorporating chemical shift and fat suppression techniques, MRI could demonstrate the composition...
of the thymuses, thus differentiating thymic hyperplasia from thymoma. In addition, these techniques helped delineate the margin of thymoma and its relationship with surrounding tissues. Furthermore, chemical shift and fat suppression MRI performed differently in young and older patients. Chemical shift imaging is based on the resonance frequency differences of protons in water and fat and is best suited for tissue mixed with fat and water. It has been widely used in radiological diagnosis of adrenal adenoma and fatty liver. Fat suppression techniques such as fat saturation and inversion-recovery imaging were based on the
Chemical shift and fat suppression MRI have remarkable advantages in differentiating thymic hyperplasia and thymoma in MG. In clinical practice and future research, attention should be paid to the age of the patients in thymus imaging. In young patients, chemical shift MRI is better than CT, conventional MRI sequences, and fat suppression in both differentiating thymus hyperplasia from thymoma, and depicting the tumor margin and its relationship with surrounding tissues in thymoma. In elderly patients, fat suppression should be preferred, especially in patients with thymoma, for it proved better than CT and other MRI sequences in our study in depicting tumor margin and its relationship with surrounding tissue. These results show promise and warrant further investigation.

**STATEMENT OF AUTHORSHIP**

Kai Li and Da-Wei Yang contributed equally to this study.

**DISCLOSURES**

The study was not funded by any grant. Hai-Bo Chen does not have anything to disclose.

**REFERENCES**