The Value of CT and MRI for Determining Thymoma in Patients With Myasthenia Gravis

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Abstract
The aim of the study was to evaluate the usefulness of computed tomography (CT) and magnetic resonance imaging (MRI) for differentiating thymoma from nonthymoma abnormalities in patients with myasthenia gravis (MG). A cross-sectional study of 53 patients with MG, who had undergone surgical thymectomy, was conducted at 103 Hospital (Hanoi, Vietnam) and Cho Ray Hospital (Ho Chi Minh City, Vietnam) during August 2014 and January 2017. The CT and MRI images of patients with MG were qualitatively and quantitatively (radiodensity and chemical shift ratio [CSR]) analyzed to determine and compare their ability to distinguish thymoma from nonthymoma abnormalities. Logistic regression was used to identify the association between imaging parameters (eg, CSR) and the thymoma status. The receiver operating curve (ROC) analysis was used to determine the differentiating ability of CSR and radiodensity. As results, of the 53 patients with MG, 33 were with thymoma and 20 were with nonthymoma abnormalities. At qualitative assessment, MRI had significantly higher accuracy than did CT in differentiating thymoma from nonthymoma abnormalities (94.3% vs 83%). At quantitative assessment, both the radiodensity and CSR were significantly higher for thymoma compared with nonthymoma groups ($P < .001$). The ROC analysis showed that CSR had significantly higher sensitivity (Se) and specificity (Sp) than radiodensity in discriminating between the 2 groups (CSR: Se 100%, Sp 95% vs radiodensity: Se 90.9%, Sp 70%). When combining both qualitative and quantitative parameters, MRI had even higher accuracy than did CT in thymoma diagnosis ($P = .031$). In conclusion, chemical shift MRI was more accurate than CT for differentiating thymoma from nonthymoma in patients with MG.

Keywords
thymoma, myasthenia gravis, MRI, CT, CSR

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Introduction
Myasthenia gravis (MG) is a relatively uncommon disease. The thymus plays an important role in the pathogenesis of MG. Approximately 90% of patients with MG displayed thymic abnormalities, such as hyperplasia (70%) and thymoma (20%). The differentiation of thymoma from thymic lymphoid hyperplasia is critical in the evaluation for surgical treatment. Thymectomy is strongly recommended in all thymoma cases.

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whereas the surgical indication in hyperplasia cases should be only considered when conservative treatments are ineffective. The anatomical distinction is based on morphological assessments on computed tomography (CT). Thymoma is seen as a focal soft tissue mass, whereas thymic hyperplasia shows a diffuse symmetric enlargement gland. However, it is difficult to differentiate the 2 conditions on CT because of high interrater variation. Thymic lymphoid hyperplasia may display as a focal soft tissue mass; in contrast, thymoma may demonstrate diffuse enlargement in both lobes. In these cases, CT results in indeterminate findings, whereas chemical shift magnetic resonance imaging (MRI) may differentiate pathologies by detecting fat in tissue, showing signal intensity (SI) loss on opposed-phase imaging compared to in-phase imaging. In Vietnam, there are very few publications on thymoma as well as on the use of CT and MRI in the diagnosis of this tumor. The aim of this study was to evaluate the usefulness of CT and MRI for differentiating thymoma from nonthymoma abnormalities in patients with MG.

**Methods**

**Participants and Study Design**

A cross-sectional study of 53 participants was conducted in Hanoi and Ho Chi Minh City, Vietnam, during August 2014 and January 2017. Participants were patients with MG who had undergone surgical thymectomy at 103 Hospital (Hanoi) and Cho Ray Hospital (Ho Chi Minh City), which are the 2 referral hospitals in Vietnam for the diagnosis and treatment of MG. The inclusion criteria were: (1) new onset of generalized MG, (2) definitive diagnosis based on postresection histological findings, and (3) being naive to neoadjuvant chemoradiotherapeutic treatment. As generalized MG was not a common disease in Vietnam, all eligible patients with MG were consecutively enrolled, except those who were under 16 years.

**Data Collection**

The information on demographic and clinical characteristics of the patients was extracted from the participants’ medical records, while the information on imaging assessment (CT and MRI) of the patients was collected according to the imaging protocols given below. The data collection was performed by 2 experienced radiologists, using a unique protocol, with supervision of the first author of the present manuscript (principle investigator).

**Computed tomography examination.** Computed tomography examination was carried out using a 2-section CT system (Somatom Spirit; Siemens, Munich, Germany) in a single breath hold at end-inspiration. Technical parameters were set at 120 kVp, 180 mAs, pitch of 1, section thickness of 5 mm, contiguous section interval, and 512 × 512 matrix without contrast agent intravenous injection. Observation was performed on soft tissue window W350, L100 HU.

**Magnetic resonance imaging examination.** Magnetic resonance imaging examination was carried out using a 1.5 T MRI unit (Intera; Philips Healthcare, Best, the Netherlands) with phased-array surface coil (Torso coil with 8 channels) from the thoracic inlet to the cardiophrenic angle. All patients underwent transverse gradient-echo T1-weighted in- and opposed-phase imaging using an anterior-to-posterior phase-encoding direction. In 49 patients, dual-echo technique in single breath hold was performed. In 4 patients, non-dual-echo technique in separated breath holds was performed. Axial T1-weighted, T2-weighted and sagittal T2-weighted with fat suppression and black blood technique were added. Axial T1-weighted, T2-weighted and sagittal T2-weighted with fat suppression and black blood technique were added. Imaging parameters are listed in Table 1. Imaging assessment. Two radiologists, with 20 and 23 years of experience, and without knowledge of patients’ diagnosis, independently analyzed the imaging data to retrieve qualitative and quantitative data. In cases of discrepancies, consensus between the 2 radiologists was used to determine the imaging data.

The collected qualitative data were location; shape and position of the gland/tumor; level of necrosis; attenuation; SI on T1-weighted, T2-weighted, and T2-weighted with fat suppression; and SI loss on the opposed-phase relative to the in-phase image. The gland shape was divided into 2 forms: bilateral gland (triangle, arrow) and soft tissue mass. The gland SI on T1-weighted and T2-weighted was divided into 2 levels as equal or higher than muscle but lower than fat and other. Necrotic or cystic component was presumed to be present when an area of low SI was seen on T1-weighted images, and high SI was seen on T2-weighted or Short TI Inversion Recovery images.

The collected quantitative data were the radiodensity, for CT, and chemical shift ratio (CSR), for MRI. In order to measure the radiodensity, region of interest (ROI) was manually drawn at the level where the thymus appeared largest on the cross-sectional image, with exclusion of peripheral areas, calcifications, cystic, or necrotic components as well as beam-hardening artefacts. The SI measurements within the thymus and chest wall muscle were obtained by using ROI (area, 0.5-1 cm² for the thymus gland and 1-2 cm² for the chest wall muscle), then were used for calculation of CSR. The selection

| Table 1. Thymic MRI Protocol. |
|-----------------------------|
| Pulse Sequence | TR  | TE  | Thickness |
|----------------|-----|-----|-----------|
| Axial double IR T1-weighted imaging with CG | 1000 | 10  | 6         |
| Axial double IR T2-weighted imaging with CG | 2000 | 60  | 6         |
| Sagittal double IR T2-weighted imaging with CG and fat saturation | 2000 | 60  | 6         |
| Axial in-phase and opposed-phase T1-weighted fast incoherent gradient-echo imaging | 150  | 4.6 | 2.3       | 5         |

Abbreviations: CG, cardiac gating; IR, inversion recovery; MRI, magnetic resonance imaging; TE, echo time; TR, recovery time.
Diagnosis of thymoma, at least one of the following:

- Focal soft tissue mass with heterogeneous morphology and irregular shape
- Nodular lesion with size of nodule ≥1 cm
- Presence of calcifications and/or cystic/necrotic components regardless of morphology
- No signal intensity loss on opposed-phase images relative to in-phase images

Diagnosis of nonthymoma, at least one of the following:

- Normal gland thymus shape (triangle, arrowhead) regardless of attenuation and margins
- Micronodularity (<1 cm) of parenchyma in the anterior mediastinal fat
- Focal mass with clear entire fat attenuation
- Homogeneous signal intensity decrease on opposed-phase images relative to in-phase images

The CSR was determined by comparing the SI of the thymus gland (tSI) with that of the paraspinal muscle (mSI) on both in-phase (in) and opposed-phase (op) images. The CSR was calculated by using the following equation: CSR = (tSIop/mSIop)/(tSIin/mSIin).

Criteria for thymoma diagnosis based on CT and MRI data. Pironti et al. showed the morphological criteria on CT to differentiate thymoma from hyperplasia. On MRI, in addition to the same qualitative parameters found on CT and MRI, the most frequent quantitative parameters of thymoma were at lateral position, in mass shape, absence of SI loss on the opposed-phase image relative to the in-phase image, high SI in T2-weighted with fat suppression, and having attenuated soft or mixed tissue. Meanwhile, nonthymoma showed opposite imaging parameters (Table 2).

### Statistical Analysis

The radiodensity and CSR were expressed as mean values ± standard deviations (all data were normally distributed, based on the Shapiro-Wilk test results); χ² test and Fisher exact test were used for comparison of qualitative imaging characteristics between the 2 groups of thymoma and nonthymoma, while t test was used for comparison of the radiodensity and CSR between the 2 groups. Logistic multivariate regression was performed by both predictive qualitative and quantitative variables to estimate the probability that patients had thymoma.

The diagnostic ability of radiodensity and CSR for thymoma diagnosis was evaluated using the area under the receiver operating characteristic curve (AUROC). The optimal cutoff points were identified based on Youden index, then were used for calculating the sensitivity (Se), specificity (Sp), and accuracy (Acc) of both CT and MRI. McNemar test was used to compare the diagnostic performance of CT versus MRI. A P value of <.05 was considered indicative of a statistically significant difference for all statistical analyses. SPSS 20.0 was used.

### Results

#### Sample Characteristics

A total of 53 patients with MG were included in the statistical analysis. The mean age of men was 40.9 ± 11.6 years, which was not different from that of women (43.9 ± 14.8, P = .43). Of these patients, 45.3% were males and 54.7% were females. Histopathological examination resulted in 33 thymoma and 20 nonthymoma. The mean age of patients with thymoma was significantly higher than that of nonthymoma patients (47.9 ± 11.3 years vs 33.6 ± 11.8 years, P < .0001).

#### Comparison of Imaging Parameters Between Thymoma and Nonthymoma Groups

There was a significant difference between thymoma and nonthymoma groups regarding the counts of imaging qualitative parameters found on CT and MRI. The difference was observed in almost all assessed parameters, except for SI T1-weighted and SI T2-weighted. On both CT and MRI, the most frequent qualitative parameters of thymoma were at lateral position, in mass shape, absence of SI loss on the opposed-phase image relative to the in-phase image, high SI in T2-weighted with fat suppression, and having attenuated soft or mixed tissue. Meanwhile, nonthymoma showed opposite imaging parameters (Table 3).

The mean CSR was higher in the thymoma group than in the nonthymoma group (1.021 ± 0.068 vs 0.648 ± 0.109, P < .001; Figure 1A). The mean radiodensity was also higher in the thymoma group than in the nonthymoma group (34.45 ± 21.1 vs −4.65 ± 41.85, P < .001; Figure 1B). Despite the significant difference between CT and MRI regarding the frequency of qualitative imaging characteristics (Table 3), logistic regression analyses showed no association between these parameters with the thymoma diagnosis probability, except for CSR at MRI and the shape at CT. The respective odds ratio (95% confidence interval [95% CI]) for CSR and the shape was 8.80 (95% CI: 1.359-56.93) and 11.723 (95% CI: 1.332-103.202), respectively (Table 4).
Table 3. Qualitative Characteristics of Thymoma and Nonthymoma Patients Based on CT and MR Images.

| Characteristic  | Thymoma (n = 33) | Nonthymoma (n = 20) | P     |
|----------------|------------------|---------------------|-------|
| Location b     | Superior         | 17 (51.5%)          | 19 (95.0%) | .001 a |
|                | Inferior         | 16 (48.5%)          | 1 (5.0%)  |       |
| Position b     | Middle           | 10 (30.3%)          | 15 (75.0%) | .002 a |
|                | Right, left      | 23 (69.7%)          | 5 (25.0%)  |       |
| Shape b        | Gland            | 3 (9.1%)            | 15 (75.0%) | <.001 a |
|                | Mass             | 30 (90.9%)          | 5 (25.0%)  |       |
| SI loss c      | Yes              | 1 (3.0%)            | 18 (90.0%) | <.001 a |
|                | No               | 32 (97.0%)          | 2 (10.0%)  |       |
| SI T1 c        | > Muscle SI, < fat SI | 31 (93.9%) | 17 (85.0%) | .271 f |
|                | Other            | 2 (6.1%)            | 3 (15.0%)  |       |
| SI T2 c        | > Muscle SI, < fat SI | 31 (93.9%) | 17 (85.0%) | .271 f |
|                | Other            | 2 (6.1%)            | 3 (15.0%)  |       |
| SI T2 fat suppression c | Low | 32 (97.0%) | 12 (60.0%) | .001 f |
| Necrosis, cyst d | Yes | 14 (42.4%) | 0 (0.0%) | <.001 a |
| Necrosis, cyst d | No | 19 (57.6%) | 20 (100.0%) |       |
| Attenuation d  | Fat              | 1 (3.0%)            | 8 (40.0%)  | .001 a |
|                | Soft tissue or mixed | 32 (97.0%) | 12 (60.0%) |       |

Abbreviations: CT, computed tomography; MR, magnetic resonance; SI, signal intensity.

[a] n = 33.
[b] On both MRI and CT.
[c] On MRI.
[d] On CT.
[e] P value from χ² test.
[f] P value from Fisher exact test.

Discussion

Qualitative Assessment

Generally, CT is the first choice modality for discriminating between thymomas and thymic lymphoid hyperplasia. On CT, thymomas usually present as sharply demarcated round or oval soft tissue masses in the anterior mediastinum compartment. This typical appearance is highly suggestive of the diagnosis. However, many hyperplasia cases presented with large soft tissue masses, which were easily detected on chest radiograph, were found misdiagnosed as thymoma. In patients with MG, Nicolaou et al. found thymic lymphoid hyperplasia can exhibit variable morphologies and sizes as it may appear normal (45% of cases), triangular-shaped diffusely enlargement with smooth margin (35%), or as a focal thymic mass (20%). This mass could not be differentiated with thymoma (Figure 2). Pirronta et al found in patients with MG, CT is a sensitive, specific, and efficient modality for detecting thymoma but is less so for detecting thymic hyperplasias. In Pirronta et al’s study, the Se of CT for detecting hyperplasia was only 36%. For MRI, since 1987, Batra et al demonstrated that MRI examination added no clinically important information to results obtained by CT in patients with MG. However, at that time, MRI protocol included only T1-weighted and T2-weighted sequences. With technical development, chemical shift MRI was introduced and used for the discrimination of thymoma from nonthymoma abnormalities not only based on morphologic assessments but also based on finding microscopic fat in soft tissue. Today, chemical shift is the first choice in MRI protocol to evaluate thymic lesion. The normal thymus and hyperplasia contains various amounts of fat tissue, depending on age, with nearly 20% in the first decade of life and increases to reach 40% in the second decade. Chemical shift imaging is much more sensitive to detect this fat by showing the SI loss in the opposed-phase image relative to the in-phase image. Conversely, thymomas have no fat and lack of SI loss. In the general radiology practice, visual assessment of the SI loss is a commonly used method to characterize thymoma as well as adrenal adenoma and liver steatosis. Nevertheless, using visual analysis, the SI loss is not always obvious in tissues containing microscopic fat and should be performed with quantitative assessments. In this study, only 2 hyperplasia cases had no SI loss at visual assessment. One small thymoma embedded in triangular-shaped fatty infiltrated thymus was also not detected. Such high reliability of chemical shift MRI in detecting fat in tissue and discriminating thymoma from nonthymoma in this study is similar to that of several studies.

Quantitative Assessment

The advantage of quantitative assessment is to use a threshold value for differentiating the lesions. At CT, the optimal cutoff point of 18 HU was used to differentiate thymoma from nonthymoma with Se, Sp, and Acc of 90.9%, 70%, 83%, respectively. However, the AUROC of 0.798 was moderate; in addition, the logistic multivariate regression showed that only shape on CT was significant for distinguishing the 2 groups. Priola et al showed that only shape and unenhanced CT attenuation were significant for discrimination between groups, with probability of 2% and 7.3% of being normal thymus or thymic hyperplasia if the findings had focal shape and heterogeneous attenuation at unenhanced CT, respectively. De Kraker et al found that the evaluation by CT is a highly subjective process. Experience has been reported as an important influencing factor in observation errors.

The SI loss can be assessed qualitatively by direct observation and can be assessed quantitatively by calculating the index of CSR or SI index (SI1). Many studies have shown that quantitative assessment is more accurate than qualitative one. For adrenal adenomas, Israel et al have reported such discordance...
in 7% (3 of 42) of cases in which the quantitative parameters have characterized a lipid-rich adenoma (CSR = 0.41-0.67 and SII = 36%-58%), but the qualitative analysis did not yield SI loss. Park et al also found the SI loss directly be observed was not sensitive than CSR measurement. In addition, for the assessment of hepatic steatosis, the studies have reported a lipid

Figure 1. Box-and-whisker plots show the CSR (A) and radiodensity (in HU) (B) values for all cases in the thymoma and nonthymoma groups. The boxes represent data from the 25th to the 75th percentile. The horizontal line inside the boxes is the median value. The vertical lines and whiskers indicate 10th and 90th percentiles. The values outside this range are displayed as individual point. P value from t test. CSR indicates chemical shift ratio; non-CECT, noncontrast enhancement computed tomography.

Table 4. Odds Ratio and Associated 95% Confident Intervals of Thymoma Diagnostic Probability According to Imaging Parameters.

| Qualitative parameter                           | MRI               |               | CT               |               |
|------------------------------------------------|-------------------|---------------|------------------|---------------|
| Shape (gland vs mass)                           | 41.43             | 0.07-2542.00  | 11.72            | 1.33-103.20   |
| Location (superior vs inferior)                 | 10.11             | 0.00-536.00   | -                | -             |
| Position (middle vs right, left)                | 1.15              | 0.00-334.49   | 3.69             | 0.70-19.46    |
| Necrosis, cyst (no vs yes)                      | -                 | -             | -                | -             |
| SI T2 fat suppression (low vs high)             | -                 | -             | -                | -             |
| SI loss (yes vs no)                             | -                 | -             | -                | -             |
| CSR (per 0.1)                                   | 8.80              | 1.36-56.93    | -                | -             |
| Attenuation (fat soft tissue, mixed)            | -                 | -             | 1.73             | 0.66-4.50     |
| Radiodensity (per 10 HU)                        | -                 | -             | 1.07             | 0.82-1.40     |

Abbreviations: CI, confidence interval; CSR, chemical shift ratio; CT, computed tomography; MRI, magnetic resonance imaging; OR, odds ratio; SI, signal intensity.

Table 5. Ability of Qualitative, Quantitative, and Both Analyses for MRI in Differentiating Thymoma and Nonthymoma Groups.a

| Technique | Sensitivity, % (n) | P   | Specificity, % (n) | P     | Accuracy, % (n) | P     |
|-----------|--------------------|-----|--------------------|-------|-----------------|-------|
| Qualitative |                   |     |                    |       |                 |       |
| CT        | 93.9 (31/33)       | .00 | 65.0 (13/20)       | .062  | 83.0 (44/53)    | .031  |
| MRI       | 97.0 (32/33)       |     | 90.0 (18/20)       |       | 94.3 (50/53)    |       |
| Quantitative |                |     |                    |       |                 |       |
| CT        | 90.9 (30/33)       | .25 | 70.0 (14/20)       | .062  | 83.0 (44/53)    | .008  |
| MRI       | 100.0 (33/33)      |     | 95.0 (19/20)       |       | 98.1 (52/53)    |       |
| Both      |                    |     |                    |       |                 |       |
| CT        | 93.9 (31/33)       | .50 | 75.0 (15/20)       | .125  | 86.8 (46/53)    | .031  |
| MRI       | 100.0 (33/33)      |     | 95.0 (19/20)       |       | 98.1 (52/53)    |       |

Abbreviations: CT, computed tomography; MRI, magnetic resonance imaging. 

aP value from McNemar test.
concentration threshold greater than 10% or 15% for detecting SI loss on the opposed-phase image relative to the in-phase image at visual assessment.\textsuperscript{23,24} Priola et al have reported 2 hyperplasia cases with the absence of SI loss, but SII was 7.8\% and 12.7\%, respectively.\textsuperscript{18} In this study, CSR was an important, independent criterion for differentiating thymoma from nonthymoma with an AUROC of 0.981. With the optimal cutoff point 0.75, CSR had the Se, the Sp, and the Acc of 100\%, 95\%, and 98.1\%, respectively. In addition, although many signs differed significantly between the 2 groups, the logistic

\begin{figure}
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\includegraphics[width=\textwidth]{figure2}
\caption{The ROC curves indicate the sensitivity, specificity, and optimal cutoff value of CSR (A) and radiodensity-based (B) differentiation in thymoma and nonthymoma groups. CSR indicates chemical shift ratio; ROC, receiver operating curve.}
\end{figure}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure3}
\caption{A 21-year-old woman with TLH. The CT findings showed the large mass with density of soft tissue (40 HU). Chemical shift MRI demonstrated no signal intensity loss on the opposed-phase images relative to the in-phase images, suggesting the absence of fat component. The CSR was 0.68. CSR indicates chemical shift ratio; CT, computed tomography; MRI, magnetic resonance imaging; TLH, thymic lymphoid hyperplasia.}
\end{figure}
multivariate regression showed only CSR was significant for differentiation between thymoma and nonthymoma. One hyperplasia case with absence of SI loss was correctly interpreted by CSR 0.68 (Figure 3). Only 1 hyperplasia case, a 22-year-old woman (Figure 4), with absence of SI loss and CSR 1.0 was misdiagnosed in this study. In this case, postoperative histopathological findings showed only a few fat cells, which was not sufficient to detect the SI loss on chemical shift MRI. Some normal or hyperplasia cases with no SI loss have been recently reported in the literature. 3,25,26 With thymic hyperplasia cases without fat (Figure 5), Priola suggested that diffusion-weighted MRI could be valuable by demonstrating restricted diffusion and low apparent diffusion coefficient (ADC) values. His study showed with the cutoff ADC of $1.625 \times 10^{-3}$ mm$^2$/s, diffusion-weighted MRI could differentiate thymic tumor from nonthymic lesions with Se 96.8% and Sp 79.2%. 27 However, until now this has been the only study using diffusion-weighted MRI to distinguish thymic tumor from normal and hyperplasia thymus. Studies of Ahmed Abdel Khalek, 28 Razek et al, 29 Usuda et al, 30 Seki et al, 31 and

Figure 4. A 22-year-old woman with TLH. Both CT and MRI showed a bilobed shaped soft tissue homogeneous gland with straight margins without the signal intensity loss in the opposed-phase image relative to the in-phase image. The CSR value was 1.0. A histopathologic image exhibits preserved architecture of the thymus, consisting of cortex, medulla, and Hassall corpuscles with lymphoid follicles and minimally fatty infiltrated thymic tissue. CSR indicates chemical shift ratio; CT, computed tomography; MRI, magnetic resonance imaging; TLH, thymic lymphoid hyperplasia.
Gumustas et al\textsuperscript{32} often use diffusion-weighted MRI to distinguish benign versus malignant tumors. Therefore, the matter should be further studied.

Magnetic resonance imaging is not the favored modality of choice for the assessment of thymic abnormalities. Usually, CT is the first choice. After detecting a mass anterior to the compartment, diagnosticians could use PET-CT to differentiate thymic neoplasm from normal and hyperplastic tissues. Neoplasm manifests increased metabolic activity with high standard uptake value (SUV) value. PET-CT used to be considered as a highly sensitive and specific imaging technique, especially for patients with lymphoma. However, the studies show that the increased fluorodeoxyglucose uptake could be found in normal, thymic lymphoid hyperplasia or rebound thymic hyperplasia.\textsuperscript{2,33,34} Due to the overlap of the SUV of neoplasm with non-neoplasm, SUV value cannot reliably distinguish between these lesions.\textsuperscript{35} In this setting, chemical shift MRI could be helpful to distinguish neoplasm from non-neoplasm based on threshold value of CSR.

Although SII can be used for the quantification of fat tissue, especially in dual-echo technique, the use of this index is not as common as the CSR. This may be because the reference tissue may contain determined amount of fat and therefore may be incorrect.\textsuperscript{17} In a study of Priola,\textsuperscript{18} SII had both Se and Sp of 100\% (at cutoff point 8.92), while CSR had the respective Se 100\% and Sp 96.7\% (at cutoff point 0.85). No overlap in SII values was found between the 2 groups, while CSR values overlapped in some cases. However, this difference was negligible.\textsuperscript{5} Both Inaoka\textsuperscript{5} and Popa et al\textsuperscript{19} used CSR for studying despite one with non-dual-echo technique and one with dual-echo. In our study, CST was applied because the non-dual-echo technique was used in four cases.

Despite strengths in study design, the findings of the present study should be interpreted with some precaution. This is because only patients who underwent surgery were included and the present findings may not be generalizable to wider population with MG. In addition, non-dual-echo techniques were performed in 4 patients. Because of the in-phase and opposed-phase images obtained in different times from 2 radio-frequency excitations, the misregistration could mislead the observation of SI loss.

**Conclusion**

Chemical shift MRI was more accurate than CT and more helpful for differentiating thymoma from nonthymoma in patients with MG.

**Authors’ Note**

The present study was approved by the Ethical Review Committee of Hanoi Medical University (No 164B/HDDDHYHN, December 10, 2014). All participants provided written consent forms.

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