Diagnostic Value of Fluid-Attenuated Inversion Recovery Magnetic Resonance Imaging for Multilocular Ameloblastoma

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Abstract: Contrast-enhanced (CE)-MR image is useful to distinguish cystic and solid portions on multilocular lesion, however, the CE-MR examination is contraindicated in patients with kidney disease. Fluid-attenuated inversion recovery (FLAIR) image is one of methods which signal of fluid is suppressed. This study investigated qualitatively and quantitative whether FLAIR images were useful for detecting and differentiating cystic and solid portions of multilocular ameloblastomas. We retrospectively reviewed 11 cases of multilocular ameloblastoma. FLAIR and short T1 inversion recovery (STIR) sequences were performed in all cases, CE-MR images in 10 cases, and T1-weighted images (T1WI) in 7 cases. FLAIR, STIR, CE-MR, and T1WI images were visually evaluated (qualitative analysis). Signal-to-noise ratio (SNR) of cystic and solid portions were measured and compared among the images of all sequences (quantitative analysis). FLAIR imaging could detect cystic portions with very low SI in all cases because cystic fluid was well suppressed on the images, and the solid portion showed intermediate SI. On some STIR images, the solid portion was masked by the markedly high SI of the cystic fluid. CE-T1WI and CE-FLAIR images showed no enhancement of the cystic portion but enhancement of the solid portion. On FLAIR image, SNR of solid was higher than cystic portion (p < 0.05). Cystic and solid portions of a lesion could be detected and distinguished on FLAIR imaging. FLAIR images are thus useful for diagnosing multilocular ameloblastoma when CE-MR cannot be performed.

Key words: Ameloblastoma, Contrast-enhanced MRI, Diagnostic imaging, FLAIR, MRI

Introduction

Ameloblastoma is one of the most common tumors in the jawbone7, with multilocular ameloblastoma the most typical. Multilocular lesions in the jawbone are including cystic and tumorous lesions (e.g., odontogenic keratocysts, aneurysmal bone cysts, odontogenic myxomas), we should distinguish cystic from tumorous lesions before treatment because they might require different treatment. This is especially true for ameloblastomas. It has been reported that detecting the solid portion of a lesion is indispensable for distinguishing tumors from cystic lesions. Computed tomography (CT) could be useful for confirming the shape and size of a lesion, but it would not be helpful for identifying the solid portion even with contrast-enhanced CT (CE-CT)5. Magnetic resonance imaging (MRI) provides adequate information about soft tissue conditions and has been used for differential diagnoses of oral and maxillofacial lesions4,5, which are often divided into cystic and solid portions on the basis of their contrasting signal intensities (SIs)3. We previously showed that contrast-enhanced MRI (CE-MRI) is useful for detecting the solid portion and distinguishing between cystic and solid portions5. A gadolinium (Gd)-based contrast agent—the most common contrast agent used with MRI—could be used to improve various tissue imaging with low toxicity. In patients with kidney disease, however, the Gd-based contrast agent could cause nephrogenic systemic fibrosis, a chronic, incurable disorder associated with high morbidity and mortality7,8. Also, in those with asthma, the Gd-based contrast agent could induce a mild-to-severe breakthrough reaction9. Thus, the use of CE-MRI is limited for these reasons as well as its additional cost.

Fluid-attenuated inversion recovery (FLAIR) imaging is an inversion recovery technique that suppresses the signal of pure water by setting the inversion time to the time at which the magnetization of pure water equals zero. FLAIR, an MRI sequence, has important roles in brain imaging10,11 and has recently been used to examine pathological areas in the eye12. There are few reports, however, of the potential use of FLAIR in the oral and maxillofacial region13,14. In the present retrospective study, we qualitatively and quantitatively evaluated MRI sequences, including FLAIR, for their value in identifying multilocular ameloblastoma. We also wanted to assess whether FLAIR images could provide additional diagnostic information for distinguishing cystic from solid portions.
Materials and Methods

Subjects

We retrospectively examined 19 patients with histopathologically diagnosed ameloblastomas who underwent MRI, including FLAIR sequences in our university hospital between January 2012 and December 2016. Eight patients, including four with infected lesions, two with very small lesions, and two with unilocular lesions, were excluded from the study. Finally, 11 patients with multilocular ameloblastoma were enrolled in the study. There were nine men and two women (mean age 42.6 years, range 13–78 years). Our institutional review board approved the study protocol (No. 1711-040).

Table 1. Patient characteristic and image findings

<table>
<thead>
<tr>
<th>No</th>
<th>Age</th>
<th>Sex</th>
<th>T1-WI</th>
<th>STIR</th>
<th>FLAIR</th>
<th>CE-T1WI</th>
<th>CE-FLAIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>32</td>
<td>F</td>
<td>Homogeneous intermediate</td>
<td>Heterogeneous high to markedly high</td>
<td>Homogenous low in the center, thick marginal intermediate</td>
<td>Thick rim enhancement</td>
<td>NP</td>
</tr>
<tr>
<td>2</td>
<td>35</td>
<td>M</td>
<td>Homogeneous markedly high</td>
<td>Homogeneous low to intermediate</td>
<td>NP</td>
<td>Heterogeneous strongly enhanced</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>66</td>
<td>M</td>
<td>Homogeneous high to markedly high</td>
<td>Heterogeneous very low to intermediate</td>
<td>NP</td>
<td>Enhancement on margin and some area in the centre</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>F</td>
<td>Homogeneous intermediate</td>
<td>Homogeneous markedly high</td>
<td>Heterogeneous low signal</td>
<td>NP</td>
<td>Rim enhancement and enhancement some area</td>
</tr>
<tr>
<td>5</td>
<td>22</td>
<td>M</td>
<td>Homogeneous intermediate to slightly high on margin</td>
<td>Homogeneous markedly high</td>
<td>Heterogeneous low to intermediate</td>
<td>Rim and enhancement on some area</td>
<td>NP</td>
</tr>
<tr>
<td>6</td>
<td>78</td>
<td>M</td>
<td>Homogeneous intermediate</td>
<td>Heterogeneous high to markedly high</td>
<td>Heterogeneous low and intermediate</td>
<td>Strong enhancement and rim enhancement</td>
<td>NP</td>
</tr>
<tr>
<td>7</td>
<td>13</td>
<td>M</td>
<td>Heterogeneous intermediate</td>
<td>Heterogeneous slightly to high</td>
<td>Heterogeneous to intermediate</td>
<td>NP</td>
<td>NP</td>
</tr>
<tr>
<td>8</td>
<td>66</td>
<td>M</td>
<td>Homogeneous intermediate</td>
<td>Heterogeneous slightly to markedly high</td>
<td>Heterogeneous low to intermediate</td>
<td>Strong enhancement</td>
<td>NP</td>
</tr>
<tr>
<td>9</td>
<td>17</td>
<td>M</td>
<td>NP</td>
<td>Heterogeneous intermediate to high</td>
<td>Heterogeneous intermediate</td>
<td>NP</td>
<td>Heterogeneous strongly enhanced</td>
</tr>
<tr>
<td>10</td>
<td>64</td>
<td>M</td>
<td>NP</td>
<td>Heterogeneous high</td>
<td>Heterogeneous low to intermediate</td>
<td>NP</td>
<td>Rim enhancement</td>
</tr>
<tr>
<td>11</td>
<td>24</td>
<td>M</td>
<td>Homogeneous intermediate</td>
<td>Homogeneous markedly high and intermediate to high in few area</td>
<td>Heterogeneous low to intermediate</td>
<td>Rim enhancement and enhancement in some area</td>
<td>NP</td>
</tr>
</tbody>
</table>

*NP: Not performed

Figure 1. Quantitative analysis: measurement of signal intensities. Regions of interest (ROI) were drawn on the larger parts of the cystic portion (dashed line), the solid portion (solid line) and image background (circle dash line) on a contrast-enhanced fluid-attenuated inversion recovery (CE-FLAIR) image (a). The same ROI was set within the same area on a FLAIR image (b), a short T1 inversion recovery (STIR) image (c) and T1-weighted image (T1WI) (d).
The quantitative analysis was performed for 10 patients who had undergone STIR and FLAIR, five patients with CE-T1WI, and five patients with CE-FLAIR and seven patients with T1WI. We used signal-to-noise ratio (SNR) as an index. To determine SNR, we used the region of interest (ROI) of each sequence with using formula:

$$SNR = \frac{mean\ SI\ of\ ROI\ of\ solid\ or\ cystic}{standard\ deviation\ of\ background\ image}$$

The ROI of cystic, solid portions and image background was drawn on same size and position in greatest part of each portion (Fig. 1) on each CE-FLAIR, FLAIR, STIR, and T1WI. The ROIs were taken 5 times on each sequence and measured using ImageJ software (NIH, Bethesda, MD, USA). The SNR of cystic and solid portion of each sequence was measured using the formula and result of SNR measurement was analyzed using SPSS statistics Based 24.0 (Tokyo, Japan). The mean of SNR of cystic and solid portions of all sequences were analyzed to determine significant differences of SNR using the Mann–Whitney U test.

**Results**

**Qualitative analysis**

The MRI features and clinical findings for the 11 patients are shown in Table 1. All tumors were diagnosed histopathologically as ameloblastomas. All T1WI images showed homogeneous, intermediate to slightly high SI. All STIR images revealed heterogeneous, high to markedly high SI. On STIR images, the cystic portion had high to markedly high SI, and the solid portion showed slightly high to high SI. In addition, in five patients, the solid portion was masked by the cystic portion signal (Patients no. 1, 3-6). On FLAIR images, in all 11 patients, the cystic area had low SI, and the solid portion had low to intermediate SI. In only one patient (Patient no.3), the solid portion had very low SI, and the solid portion was difficult to identify. FLAIR images in 7 patients (Patients no. 1, 4-6, 8, 9, 11) showed shapes and outlines of the cystic and solid portions that were similar to those on the CE-MR images (Fig. 2). CE-T1WI images (5 patients) and CE-FLAIR images (5 patients) showed no enhancement in the cystic portion but strong enhancement in the solid portion. An unenhanced area showed low to intermediate SI, and an enhanced area showed high SI. CE-T1WI and CE-FLAIR images showed the cystic and solid portions clearly. One patient (Patient no.10) showed intermediate to slightly high SI on CE-FLAIR images and either thin rim enhancement or no enhancement in the inner part of the lesion.

**Quantitative analysis**

The results of the quantitative analysis are shown in Fig. 3. The SNRs of CE-T1WI, CE-FLAIR and FLAIR were shown statistical significant differences between solid and cystic portion ($p < 0.05$). On CE-T1WI, the SNRs of solid and cystic portion were 1298.64±291.25 and 491.64±43.44, respectively ($p = 0.008$). On CE-FLAIR, they were 636.93±202.56 and 61.46±31.48, respectively ($p = 0.008$). On FLAIR, they were 141.61±38.22 and 47.23±19.31, respectively ($p = 0.000$). However, on STIR and T1WI, there were not statistical significant dif-
ferences of SNR between solid and cystic portion. On STIR, the SNRs of solid and cystic portion were 915.05±542.57 and 1046.42±566.02, respectively ($p = 0.353$). On T1WI, they were 649.08±234.71 and 598.57±194.66, respectively ($p = 0.589$).

**Discussion**

According to the 2017 World Health Organization’s histological classification of odontogenic tumors, ameloblastomas are divided into types: conventional, unicystic, extraosseous/peripheral, and metastasizing\(^1\). Conventional ameloblastomas contain solid tissue with some cystic areas\(^3,4\). We have reported that detecting a solid portion is indispensable for differentiating between cystic and tumorous lesions\(^3\). MR images, including CE-MR images, provide useful diagnostic information for oral and maxillofacial lesions. Gd-based contrast agents are usually those used for MRI. In patients with severe kidney disease, however, Gd may trigger the onset of nephrogenic systemic fibrosis, a fibrotic disorder that mostly involves skin but could also affect other organs, such as the lung, liver, heart, and skeletal muscle, leading to severe physical disability and death\(^8,9\). Gd-based contrast agents have been reported to induce nephropathy and other co-morbidities. Hypersensitive reactions particularly could occur in patients with a history of allergies or asthma\(^7\). In a previous MRI study, ameloblastomas showed low to intermediate SI on T1WI, markedly high SI on T2WI or STIR images, and enhancement in the solid portion but no enhancement in the cystic portion on CE-T1WI images\(^3\). Our present study revealed similar findings—that CE-T1WI and CE-FLAIR showed enhancement of the margins in the solid portion but no enhancement in the cystic portion on CE-T1WI images\(^5\). Our present study revealed similar findings—that CE-T1WI and CE-FLAIR showed enhancement of the margins in the solid area and no enhancement in the cystic area. Thus, cystic and solid portions could be clearly distinguished each other using either CE-T1WI or CE-FLAIR imaging.

In all cases, T1WI revealed homogeneous, intermediate to high SI, and so the cystic and solid portions could not be differentiated. STIR images showed heterogeneous, high to markedly high SI in most cases. In some cases, however, the SI of the cystic portion masked that of the solid portion. With the FLAIR sequence, the fluid signal is nullified and suppressed by the long TR and TI. On FLAIR images, the cystic area (a water-like area), showed low SI, and the solid portion showed intermediate SI, clearly contrasting the cystic and solid portions in most cases, although some showed only an unclear contrast between the two portions.

Fluid signal suppression could help increase the contrast between cystic and solid portions. Some studies have reported that FLAIR improved tissue contrast in the presence of degenerative disease of the cervical spine area and brain lesions\(^10,12\). It has also been reported that there is a potential use for FLAIR imaging in patients with vascular malformations and to assess condylar bone marrow changes in temporomandibular joint disorders\(^14,15\). The FLAIR sequence, however, has not come into common use in the oral and maxillofacial region. We tried to apply the FLAIR sequence to distinguish cystic from solid lesions in this study. We found that FLAIR has good potential for this use because of the contrasting SIs.

Quantitative analysis showed statistically that the SNR of cystic and solid portions were not significantly different on STIR and T1WI images. This lack of a difference might be because cystic and solid portions have similar appearance and similar SIs on T1WI, and the solid area was masked by the high SI of the cystic portion on STIR. In contrast, CE-T1WI, CE-FLAIR and FLAIR image clearly showed that SNR of solid portion substantially higher than cystic portion. In addition, there was a significant difference between cystic and solid portions on the FLAIR images. The FLAIR images could be useful for detecting solid portions without the need for contrast agents. FLAIR images could distinguish cystic and solid portions in multilocular ameloblastomas. Hence, FLAIR could provide valuable information when CE-MRI cannot be performed.

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**Conflict of Interest**

The authors have declared that no COI exists.

**References**


