Title
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Potential of FLAIR in identification of temporomandibular joint effusion in comparison with T2-weighted images

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Abstract

Objective. The purpose of this study was to determine the potential of fluid attenuated inversion recovery (FLAIR) sequence images in the identification of joint effusion (JE) in comparison with T2-weighted images.

Study design. A total of 31 joints (28 patients) with JE were investigated by magnetic resonance imaging. Regions of interest were placed over JE, cerebrospinal fluid (CSF) and gray matter (GM) on T2-weighted and FLAIR images and their signal intensities compared. The signal intensity ratios (SIRs) of JE and CSF were calculated used GM as the reference point. The Pearson product-moment correlation coefficient was used for the statistical analysis.

Result. The SIR of JE showed a strong correlation between T2-weighted and FLAIR images. However, no correlation was observed for CSF. The average suppression ratio for JE was lower than that for CSF.

Conclusion. MRI using FLAIR sequences revealed that JE was not only water content, but a fluid accumulation containing elements, such as protein. Further studies are needed and FLAIR sequences could be useful for the diagnosis of pain and symptoms of the TMJ.
Magnetic resonance imaging (MRI) can be used for visualization of the temporomandibular joint (TMJ). Earlier studies have used it to investigate disk morphology and position, osseous change in the condyle and joint effusion (JE). High signal intensity from the upper and lower joint spaces on T2-weighted images is considered to indicate JE. Joint effusion in the TMJ on MRI was first investigated by Harms et al., followed by a number of subsequent studies aimed at clarifying its association with TMJ pain and symptoms and intra-articular pathosis. While some studies have suggested a correlation between JE and TMJ pain, others have found no such correlation. From a biochemical perspective, it has been suggested that JE is related to inflammatory changes seen in patients with disorders of the TMJ. Furthermore, microscopic investigation revealed that JE may reflect synovitis. Gynther et al. found that the inflammatory changes brought about by synovitis in the TMJ induced hyperplasia of the synovial cell layer. Segami et al. suggested that there was a strong correlation between hyperplastic synovial tissue and amount of JE. Inflammation of synovial tissue may result in an increase in its signal intensity to a level almost equal to that obtained with JE on T2-weighted images. It is possible that JE indicates inflammation of the synovial membrane tissue itself. Although much research has been carried out on JE, its detection by MRI remains problematic, and identification by T2-weighted images alone is difficult. In this study, we investigated the potential of fluid attenuated inversion recovery (FLAIR) sequence images to demonstrate JE in comparison with T2-weighted images. Employing T2-weighted images, FLAIR is often used to suppress cerebrospinal fluid (CSF), allowing differentiation between CSF and
brain lesions.\textsuperscript{18} We hypothesized that the signal intensity of JE would be lower on FLAIR images, provided that JE comprised mainly fluid, as does CSF. A signal intensity on FLAIR may be depending on amount of protein in the JE. Our another hypothesis is that more TMJ pain a patient has, more protein JE has. As a result, a TMJ with more pain would show increased signal on FLAIR images. Based on this hypothesis, we compared the signal intensities of JE obtained from T2-weighted and FLAIR images and investigated the relationship between them retrospectively.
Materials and methods

Magnetic resonance images were obtained from patients referred to our department at Tokyo Dental College Chiba Hospital in 2004, 2005 and 2008. Informed consent was obtained from all patients and the study protocol was approved by the Ethical Review Board of our institution (No.139). This study was based on 232 joints of 116 patients. According to the inclusion and exclusion criteria (Table I), 201 joints were excluded from this study. A total of 31 joints of 28 patients were studied. There were 4 males and 24 females. The mean age of the patients was 39.9 years with an age range of 13 to 76 years.

All images were obtained with the 1.5 Tesla MR Imager (Magnetom Symphony, Siemens, Erlangen, Germany), using a double loop array coil. Using a fast-spin echo sequence, T2-weighted and FLAIR sagittal images were obtained at the closed-mouth position (Figure 1). Table II shows the parameters employed for both sets of images. Echo times (TE) of 122 ms and 168 ms were used for the FLAIR images. During our study, TE was changed to TE 168 ms to improve attempt the contrast as a result of the examination of FLAIR images with TE 122 ms images obtained with 2004-05. Images were obtained with a TE of 122 and 168 ms in 15 and 13 patients, respectively.

Amount of TMJ fluid on the T2-weighted images was determined by the method of Larheim et al.19 Accordingly, fluid content in the joints was categorized as moderate, marked, or extensive.

Images were saved as DICOM files. Signal intensity was determined using the public domain image analysis software ImageJ 1.37j (NIH, USA). Measurements of signal intensity were performed on both the T2-weighted and FLAIR images by one of the
authors. The decision as to which images were suitable for ROI selection for each area by two sequences was made by a consensus of two oral and maxillofacial radiologists.

The signal intensity of gray matter (GM) was taken as the reference point. Regions of interest (ROI) were placed over the GM, CSF and JE. The size of the ROI and its position on the CSF and GM were determined according to the method of Yajima et al. A 6.25 mm$^2$ for TE of 122ms or a 6.86 mm$^2$ for TE of 168 ms as ROI were defined. The maximal area of JE on the T2-weighted images was defined as the ROI for JE (Figure 2). An average area were 3.45 mm$^2$ (ranging from 1.29 – 9.09 mm$^2$) for TE of 122ms and 7.15 mm$^2$ (ranging from 1.80 – 18.45 mm$^2$) for TE of 168ms. A 0.25 mm$^2$ for TE of 122ms or a 0.34 mm$^2$ for TE of 168 ms as ROI were defined and placed over CSF. They were placed closest to the mandibular condyle on a line perpendicular to the top of the condyle.

The signal intensity ratio (SIR)s of JE and CSF were calculated as follows: SIR = the signal intensity of JE or CSF/the signal intensity of GM. In the FLAIR sequence images, the patients were divided into Group A (TE, 122 ms) and Group B (TE, 168 ms) for the statistical analysis. The Pearson product-moment correlation coefficient was used to assess the correlation between the SIRs on the T2-weighted and FLAIR images of both JE and CSF. A probability of less than 0.05 was considered statistically significant. The suppression ratios of the signal intensities in FLAIR imaging were also compared according to the following equation: (SIR of T2-weighted images – SIR of FLAIR images)/SIR of T2-weighted images × 100 (Figure 3).
Results

The SIRs obtained for JE and CSF on T2-weighted and FLAIR images are shown in Table III. The average SIR of JE was higher than that of CSF on both T2-weighted and FLAIR images in both Groups A and B.

A strong correlation between T2-weighted images and FLAIR images was obtained for JE in both groups. The correlation coefficient was 0.81 in Group A and 0.94 in Group B (Figures 4 and 5). On the other hand, no correlation was found between the two sets of images for CSF (0.09 in Group A, -0.33 in Group B).

The average suppression ratio for the signal intensity of JE by FLAIR imaging was 36.9% in Group A and 16.3% in Group B. The ratio for CSF was 75.6% in Group A and 71.7% in Group B (Table IV). The signal intensity of CSF was suppressed more markedly than that of JE.
Discussion

Joint effusion is considered to be a pathological collection of joint fluid that can only be observed on T2-weighted images. Hitherto, the only way to determine the presence of JE has been by amount of fluid present in the joint. We hypothesized that the FLAIR technique would provide additional information for clarification of JE.

In this study, a strong correlation was found between T2-weighted images and FLAIR images in both groups for JE. On the other hand, no such correlation was found for CSF.

A reduction in signal intensity was observed for JE on FLAIR sequence images. However, the average suppression ratio for JE was lower than that for CSF. If JE comprised liquid components similar to those of CSF, the suppression ratio for JE would not have differed from that for CSF. This indicates that the liquid content of JE differs somewhat to that of CSF, and that some element in JE induces a shortened T1 relaxation time in MRI.

Joint effusion is believed to represent not only exudation from inflamed tissue, but also hypertrophic synovium in the joint. Hypertrophic synovium is a characteristic of synovitis seen in the patients with internal derangement. Synovitis has been observed arthroscopically and studied to clarify histological changes in disorders of the TMJ. Synovial hyperplasia, vascularity and an increase in inflammatory cells are all characteristic changes brought about by synovitis. In an arthroscopic study, Segami et al. investigated whether JE indicated the presence of synovitis by comparing amounts of JE and degree of synovitis. They found that joints with effusion had more pronounced synovitis than joints with no effusion, and, moreover, amount of
JE increased according to severity of synovitis. It is possible that JE indicates morphological changes brought about by synovitis such as hyperplastic synovium, as the signal intensity for such inflammatory synovial tissues would not be suppressed, unlike that for CSF. However, synovitis was predominantly observed in the posterior disk attachment in arthroscopic studies. Joint effusion is usually located in the anterior recess of the upper joint space. In this study, too, the maximal area of JE was always observed in the anterior recess of the upper joint space, and this is where the ROI was placed. To our knowledge, this is the first study to report that hyperplastic synovium was observed predominantly in the anterior recess of the upper joint space. These results strongly suggest that JE indicates morphological change in synovial tissue.

There are several different contents in JE, such as protein or polysaccharide. In a study on the relationship between joint effusion, joint pain and protein levels in joint lavage fluid obtained from patients with internal derangement or osteoarthritis of the TMJ, Takahashi et al. found that painful joints were more likely to show joint effusion on MRI and that protein levels in joint lavage fluid recovered from those joints was higher than that obtained from pain-free joints. In another study on the relationship between amount of JE and levels of total protein and proinflammatory cytokines in synovial fluid from patients with internal derangement or osteoarthritis of the TMJ, Segami et al. found that synovial fluid in TMJs with internal derangement or osteoarthritis and JE contained higher concentrations of total protein and proinflammatory cytokines IL-6 and IL-8 than did synovial fluid in TMJs without JE.

These two earlier studies indicated that JE contains a high level of protein derived
from inflammatory synovial tissues. Protein can induce a shortening of T1 relaxation
time.\textsuperscript{30} This suggests that the average suppression ratio of signal intensity for JE was
lower than that for CSF in this study because higher amounts of proteins were present
in the JE, which would be consistent with the results of these earlier studies.

If JE contains secondary products produced by inflamed synovium, the signal
intensity of joint fluid in asymptomatic TMJs and its suppression ratio on FLAIR
images would differ from those for JE. Further study investigating joint fluid from
volunteers with no TMJ symptoms is needed to clarify this point, however.

Takahashi et al.\textsuperscript{7} found that mean protein concentration in pain-free joints with JE
was higher than that in pain-free joints without JE, although the difference was not
statistically significant. On the other hand, mean protein concentration in painful,
JE-free joints was significantly higher than that in JE-free joints that were not painful.
Therefore, they suggested that elevated protein levels may be correlated with joint pain
rather than JE. Joint pain, a representative symptom of TMJ disorders, may be
correlated with signal intensity in joint fluid, including JE, on FLAIR images. Further
study is needed to clarify the clinical significance of JE in joint pain, however.

Although the average suppression ratio of signal intensity for JE by FLAIR imaging
with a TE of 122 ms was higher than that with a TE of 168 ms in this study, this may be
considered to be within the margin of error, as the standard deviation of the average
suppression ratio of signal intensity for JE was relatively high (Table IV).

In conclusion, MRI using FLAIR sequences revealed that JE was not only water
content, but a fluid accumulation containing protein elements. However, we do not
know whether this fluid accumulation containing protein elements can be specialized in
only JE yet. The further study, which investigates the content of small amount of joint fluid using FLAIR image is needed. Moreover, the correlation between the suppression ratio of signal intensity for JE by FLAIR imaging and clinical symptom should be analyzed. Depending on further studies, FLAIR sequences could be useful for the diagnosis of pain and symptoms of the TMJ.
References


8. Schellhas KP, Wilkes CH. Temporomandibular joint inflammation: comparison of


15. Segami N, Nishimura M, Kaneyama K, Miyamaru M, Sato J, Murakami K. Does joint effusion on T2 magnetic resonance images reflect synovitis? Comparison of


**Legends**

Figure 1. T2-weighted (a) and FLAIR (b) sagittal MR images of the TMJ. Joint effusion (arrow) is demonstrated in upper joint space on both images.

Figure 2. Measurement of region of interest (ROI) on sagittal T2-weighted images in closed-mouth position. ROIs were placed over gray matter (GM) (black arrow) and cerebrospinal fluid (CSF) (white arrow) close to top of condyle. Joint effusion (JE) (arrow heads) in this case shows extensive fluid, and ROI for JE was placed over maximal area in upper joint space.

Figure 3. Schematic drawing of equation for the suppression ratio.

Figure 4. Signal intensity ratio (SIR) for joint effusion (JE) in group A. Strong correlation observed between T2-weighted and FLAIR images for JE. Correlation coefficient was 0.81 ($P < .001$) with Pearson product-moment correlation.

Figure 5. Signal intensity ratio (SIR) for joint effusion (JE) in Group B. A strong correlation was observed between T2-weighted images and FLAIR images. Correlation coefficient was 0.94 ($P < .001$) with Pearson product-moment correlation.

**Table I.** Inclusion and exclusion criteria.

**Table II.** MR imaging parameters.

**Table III.** Average signal intensity ratios from joint effusion (JE) and cerebrospinal fluid (CSF).

**Table IV.** Average suppression ratio for signal intensity from joint effusion (JE) and cerebrospinal fluid (CSF) by FLAIR.
Figure. 3

/ SIR of T2-weighted images × 100.
**Table I.** Inclusion and exclusion criteria

**Inclusion Criteria:**

- Temporomandibular joint with evidence of disk derangement.

- Temporomandibular joint with amount of joint fluid categorized as “moderate”, “marked” or “extensive” by Larheim and the others\(^\text{19}\).

**Exclusion Criteria:**

- **History of trauma or surgery, systematic inflammatory disease, mandibular growth disturbances, or TMJ tumors.**

- Temporomandibular joint with amount of joint fluid categorized as “no fluid” or “minimal” by Larheim and the others\(^\text{19}\).
**Table II.** MR imaging parameters.

<table>
<thead>
<tr>
<th>Index</th>
<th>T2-weighted images</th>
<th>FLAIR images</th>
</tr>
</thead>
<tbody>
<tr>
<td>TI (ms)</td>
<td></td>
<td>2,500</td>
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<td>TR (ms)</td>
<td>3,300</td>
<td>9,000</td>
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<tr>
<td>TE (ms)</td>
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<td>122 or 168</td>
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<td>FOV (mm)</td>
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<td>150×150</td>
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<td>Section thickness (mm)</td>
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<td>3</td>
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<tr>
<td>Slice gap (mm)</td>
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<td>0.3</td>
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<tr>
<td>Matrix</td>
<td>256×256 or 512×512</td>
<td>256×256</td>
</tr>
</tbody>
</table>
**Table III.** Average signal intensity ratios from joint effusion (JE) and cerebrospinal fluid (CSF).

<table>
<thead>
<tr>
<th></th>
<th>JE</th>
<th>CSF</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group A</strong></td>
<td></td>
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<tr>
<td>T2-weighted images</td>
<td>1.71 ± 0.64</td>
<td>1.44 ± 0.23</td>
</tr>
<tr>
<td>FLAIR images</td>
<td>1.15 ± 0.86</td>
<td>0.34 ± 0.22</td>
</tr>
<tr>
<td><strong>Group B</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T2-weighted images</td>
<td>1.81 ± 0.67</td>
<td>1.36 ± 0.33</td>
</tr>
<tr>
<td>FLAIR images</td>
<td>1.52 ± 0.61</td>
<td>0.35 ± 0.16</td>
</tr>
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</table>

Mean ± SD (%)
**Table IV.** Average suppression ratio for signal intensity from joint effusion (JE) and cerebrospinal fluid (CSF) by FLAIR.

<table>
<thead>
<tr>
<th>Echo Time (ms)</th>
<th>JE</th>
<th>CSF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>122</td>
<td>122</td>
</tr>
<tr>
<td>MEAN ± SD (%)</td>
<td>36.9 ± 25.3</td>
<td>75.6 ± 17.1</td>
</tr>
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<td>168</td>
<td>16.3 ± 13.5</td>
<td>71.7 ± 14.5</td>
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