Assessment of Spectral Attenuated Inversion Recovery (SPAIR) MR Imaging: Normal and Osteomyelitis in the Mandible

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Abstract
To describe signal characteristics of normal structures in the mandibular region using spectral attenuated inversion recovery (SPAIR) magnetic resonance (MR) imaging and evaluate the usefulness of SPAIR MR images in mandibular osteomyelitis compared with T1- and T2-weighted spin echo (SE) images. SPAIR MR images of 212 normal subjects and T1- and T2-weighted SE images of 21 subjects of mandibular osteomyelitis were evaluated. T1- and T2-weighted images were obtained in all patients. MR images were evaluated in terms of signal characteristics of normal and abnormal mandibular bone marrow, and surrounding soft tissue. In normal subjects, the mandibular bone marrow demonstrated low signal intensities (100%) and cortical bone showed no signal intensities (100%) on SPAIR images. In surrounding soft tissue of normal subjects, the submandibular glands demonstrated high signal intensities (100%), the parotid glands showed intermediate to high signal intensities (100%), the sublingual glands showed high (92%) and intermediate to high (8%) signal intensities, the lymph nodes showed high signal intensities (100%), and the masseter muscles showed intermediate signal intensities (100%) on SPAIR images. The lesions in mandibular bone marrow were low (86%) and low to intermediate (14%) signal intensities on T1-weighted images and high (52%), intermediate to high (33%), and intermediate to high (15%) signal intensities on T2-weighted images. On SPAIR images, the signal intensities resulted in high (86%), and intermediate to high (14%). The use of SPAIR imaging is useful for evaluating normal mandibular bone marrow and detecting osteomyelitis in the mandible and identifying the spread of inflammation to soft tissue.

Keywords:
SPAIR, MRI, mandible, osteomyelitis

Introduction
Recently, magnetic resonance (MR) imaging has been applied to oral and maxillofacial regions, enabling direct visualization of the mandibular bone marrow which is difficult to be visualized through conventional radiological modalities (1, 2). It has also been reported that MR imaging is useful in diagnosing mandibular osteomyelitis (1). Most MR examinations of the mandible entail T1- and T2-weighted spin echo (SE) imaging, with contrast-enhanced T1-weighted imaging performed as needed. However, there is abundant fat in the oral and maxillofacial regions (2). Therefore, it is difficult in many clinical cases to detect lesions using T1- and T2-weighted SE imaging alone. Fat suppression techniques are particularly effective in MR examination of the mandibular bone marrow, providing clear discrimination between normal and diseased marrow. However, it is difficult to discriminate diseased marrow from red marrow because red marrow appears less hypointense in relatively with its lower fat (3–5). The principal MR examination techniques used for fat suppression are 1) short inversion time inversion recovery (STIR) technique, shortening of inversion time (TI) during inversion recovery, and 2) techniques utilizing the frequency difference between the...
signals of water and fat, as represented by chemical shift techniques as spectral attenuated inversion recovery (SPAIR) MR imaging. Many studies have shown the utility of fat suppression techniques in systemic bone marrow diseases (3-11). However, its utility for SPAIR MR imaging in the mandible has received little attention. The purpose of this study was to describe signal characteristics of normal structures in the dento-maxillofacial region using SPAIR MR imaging and to evaluate the usefulness of these images in mandibular osteomyelitis compared with conventional T1- and T2-weighted SE images.

**Subjects and Methods**

*Normal SPAIR images of mandible and surrounding soft tissue*

The subjects consisted of 212 patients with no abnormal findings on panoramic radiographs and MR images, no history of radiotherapy, and no systemic diseases. Subjects were selected from 428 patients who underwent MRI as outpatients in our department, the Hospital of Nihon University School of Dentistry at Matsudo between July 2006 and April 2007. Subjects (92 men, 120 women) ranged from 20 to 75 years (mean, 38.8 years) of age. The SPAIR imaging technique consisted of scanning transverse to the axis of the mandibular body. MR imaging was performed with a 1.5-Tesla superconductive MR unit (Intera Achiba 1.5T Nova, Philips Medical Systems, in Best, the Netherlands) by using a head coil. Other conditions were 3 mm slice thickness, 256×256 matrix, 220×220 mm field of view, one acquisition and 90 flip angle. Repetition time (TR)/Echo time (TE)/delay time were 2961/60/70msec. All MR images were evaluated by two dental radiologists with a minimum professional experience of five years, and the evaluation of made on the mandibular bone marrow, mandibular cortical bone, and surrounding soft tissues (submandibular glands, sublingual glands, parotid glands, lymph nodes, and masseter muscles) in the planes. Final decisions were reached by means of consensus. Baseline structures adopted for the evaluation of MR signal intensity were cerebrospinal fluid (high signal intensity), muscle (intermediate signal intensity), and fat (low signal intensity) (2).

*Investigation of SPAIR images of mandibular osteomyelitis*

The subjects consisted of 21 patients at the same department of radiology, between April 1999 and December 2001, who had been diagnosed with mandibular osteomyelitis from clinical observation, radiographic findings, and pathological examinations. Criteria for inclusion into this study were recurrent pain and swelling, and sclerotic radiodense abnormalities on panoramic radiographs. In addition, all patients had inflammatory changes with osteoblastic reaction and no malignant or benign tumor documented at histopathology. They included 10 men and 11 women, whose age were ranged from 20 to 70 years (mean, 48.6 years) of age. They were examined by the same MR machine and coil as the normal subjects. T1-weighted images were obtained using the SE sequence with the following parameters: TR/TE=435-715/15 msec, 6 mm slice thickness, 256×256 matrix, 220×220 mm field of view, two acquisitions. Conventional T2-weighted images were obtained in 19 patients using the SE sequence of 2500-3750/120 msec (TR/TE). In the remaining two patients, fast spin echo (FSE) T2-weighted sequences were used with 4000-4800/120 msec (TR/TE), 6 mm slice thickness, 224×256 matrix, 220×220 mm field of view, four acquisitions. Other parameters were the same as those used for T1-weighted imaging. Additional T1-weighted images were acquired in the coronal (19/21) and sagittal (3/21) planes. SPAIR imaging sequences of 1692/60/70 msec (TR/TE/delay time), 90 flip angle were scanned in all cases, in addition to T1- and T2-weighted imaging. MR images were evaluated independently by two dental radiologists in terms of signal characteristics of bone marrow and spread of inflammation to surrounding soft tissue without knowledge of the exact site of the osteomyelitis in the mandible. Final decisions were reached by means of consensus. Baseline structures adopted for the evaluation of MR signal intensity were cerebrospinal fluid (high signal intensity), mus-
cle (intermediate signal intensity), and fat (low signal intensity).

Results

Normal SPAIR images of mandible and peripheral soft tissue

a) Mandible

The mandibular bone marrow demonstrated low signal intensities on SPAIR images in 212/212 (100%) subjects. Mandibular cortical bone showed no signal intensities on SPAIR images in 212/212 (100%) subjects (Fig. 1).

b) Surrounding soft tissue

On SPAIR images, the submandibular glands demonstrated high signal intensities in all subjects 212/212 (100%) (Fig. 2). The sublingual glands showed high signal intensities in 195/212 (92%) subjects, and intermediate to high signal intensities in 17/212 (8%) subjects (Fig. 2). In all patients, the parotid glands showed intermediate to high signal intensities, the lymph nodes showed high signal intensities and the masseter muscles showed intermediate signal intensities 212/212 (100%), respectively (Fig. 3).

Investigation of SPAIR images of mandibular osteomyelitis

The lesions in mandibular bone marrow were low 18/21 (86%) and low to intermediate 3/21 (14%) signal intensities on T1-weighted images and high 10/21 (48%), intermediate to high 8/21 (38%), and intermediate 3/21 (14%) signal intensities on T2-weighted images (Figs. 4, 5). On SPAIR images, the signal intensities resulted in high 18/21 (86%), and intermediate to high 3/21 (14%) in the mandibular bone marrow (Fig. 6). SPAIR images were superior to abnormal bone marrow in high signal intensities than that of T2-weighted images (Fig. 7). There is a significant difference between SPAIR and T2-weighted images (p<0.05, Mann–Whitney’s U-test). In cases where inflammation extended to the surrounding soft tissue, signal changes to high signal intensities were demonstrated on T2-weighted images and SPAIR images.
Fig. 3. Parotid gland shows intermediate to high signal intensities (arrow) due to higher content of fat than submandibular gland. Masseter muscle shows intermediate signal intensity (arrow heads).

Fig. 4. Osteomyelitis in right side of the mandible. T1-weighted image shows a low signal intensity area in bone marrow at the right molar region (arrow). Spread of inflammation to surrounding soft tissue is not observed.

Fig. 5. T2-weighted image shows a hyperintense area at the same area (arrow). However, margins between normal and abnormal bone marrow are not distinct. Spread of inflammation to surrounding soft tissue is not observed.

Fig. 6. In the SPAIR image, the lesion shows a hyperintense area (arrow). Slight signal elevation is observed adjacent to masseter muscle and superficial fat.
Fig. 7. Detection of abnormal bone marrow using SPAIR and T2-weighted images. There is a significant difference between SPAIR and T2-weighted images (p<0.05, Mann-Whitney’s U-test).

Discussion

MR imaging has clinically been applied to the imaging of bone marrow status in recent years as a non-invasive technique. Imaging of suppresses of the fat signal within bone marrow and enhances small amounts of water, making the fat suppression technique extremely useful for bone marrow imaging (4, 5, 7, 8). Since Bydder et al (9), first reported the clinical application of fat suppression sequence such as STIR imaging to the central nervous system and other areas in 1985, there have been many reports about its usefulness in bone marrow lesions throughout the body (5–11, 12). However, there has been no report concerning the usefulness of SPAIR imaging in mandibular osteomyelitis.

Normal bone marrow consists of a matrix that includes red marrow, yellow marrow, vasculature, and reticular tissue, and such tissues are rich in water and fat (2–4, 13). Bone marrow composition varies by site and with age (3, 13), and according to the report of Kaneda et al (2), all of the mandibular bone marrow are red marrow at birth. As aging occurs, yellow marrow increases from the incisor region to the molar region toward the mandibular ramus, and by age 20 years nearly all of the mandibular bone marrow have been converted to yellow marrow. Changes attributable to this physiological conversion from red marrow to yellow marrow can be reflected in MR imaging of normal bone marrow.

In the present study, SPAIR images of normal bone marrow showed low signal intensities. These findings indicate that yellow marrow occupied a high proportion of the mandibular bone marrow in our subjects, who were aged 20–75 years, and that fat suppression techniques suppressed the signal from fat so that mandibular yellow marrow demonstrated low signal intensities. The present study is unable to investigate signal intensities of red marrow, which has been reported to be low in signal intensity on T1- and T2-weighted images and high under fat suppression techniques (3–5), because our patient population was of adult age.

Mandibular osteomyelitis, a disease frequently encountered in the clinical setting, may be a sequela of dental infection. In some instances, it occurs subsequent to radiotherapy or follows systemic diseases that weaken resistance. Until now, conventional radiography, CT and bone scintigraphy have been the primary techniques used in the diagnostic imaging of mandibular osteomyelitis. However, such techniques depict bone reactions caused by inflammation of the bone marrow, not bone marrow inflammation itself. Changes in early-stage osteomyelitis are particularly difficult to detect using conventional radiography and CT (1). Depiction of the spread of inflammation to soft tissue around inflamed bone marrow by these modalities is also problematic (5, 8). Consequently, MR imaging, with its direct depiction of bone marrow inflammation and surrounding soft tissue changes, is extremely useful in the diagnosis of early-stage osteomyelitis. MR findings of osteomyelitis, which show low signal intensities on T1-weighted images, high signal intensities on T2-weighted images, and high signal intensities on SPAIR images are considered to indicate the decrease of fat component and increase of water component in bone marrow. The increase in water component is in turn considered to reflect hyperemia and/or edema (8). The contrast between normal bone
marrow and diseased bone marrow is also distinct on T1-weighted images, and such changes also may indicate simple osteosclerosis or fibrosis. However, to detect inflammatory activity, diagnosis by T1-weighted images alone is difficult. The combination of T1-weighted and SPAIR images is highly effective for the evaluation of bone marrow lesions (4). These images are also more effective for diagnosis in identifying focal areas or the spread of inflammation to soft tissue. On T2-weighted images, lesions present high signal intensity, and normal bone marrow and superficial fat also present high signal intensity, therefore elevation of signal due to inflammation was somewhat difficult to detect in clinical situations. In addition, it has been previously reported that tissue contrast for the detection of bone marrow lesions on conventional T2-weighted images is less than that provided by fat suppression sequences (7, 14). Contrast between diseased bone marrow and normal bone marrow was also indistinct, as was the spread of inflammation to soft tissue. The abovementioned results suggest that SPAIR is a useful imaging technique for detecting osteomyelitis in the mandible.

In conclusion, in mandibular osteomyelitis, the use of SPAIR imaging is useful for detecting osteomyelitis, identifying the extent of inflammation, investigating the spread of inflammation to soft tissue, and also depicting postoperative recurrence. This suggests that the augmentation of conventional T1- and T2-weighted SE imaging with SPAIR imaging is effective in diagnosing mandibular osteomyelitis.

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