Magnetic resonance imaging guided biopsy of musculoskeletal lesions

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Abstract

Background: Minimally invasive interventional biopsy procedures have the advantages of accurate localization, small incisions, and rapid recovery. The purpose of this study was to clinically test and evaluate the efficacy of the magnetic resonance imaging (MRI)-guidance techniques for obtaining musculoskeletal biopsies using the appropriate imaging modalities and instruments.

Methods: We used MRI-compatible biopsy needles from the Invivo Bone Biopsy Set (Daum, Germany), and a 1.5-T closed-magnet MRI scanner was used to perform the MRI-guided biopsy. The pulse sequences included fast spin echo T1- and T2-weighted imaging and gradient echo imaging. The inclusion criteria included the presence of bone or soft tissue masses, infectious disease, and other nonspecific lesions that required tissue confirmation. Lesions that could not be visualized by computed tomography (CT) or other imaging modalities were preferred.

Results: From January 2005 through December 2009, 23 patients (12 males and 11 females, aged 11–82 years) underwent musculoskeletal MRI-guided biopsy. The biopsy locations were as follow: spine (n = 12), tibia (n = 3), pelvis (n = 1), femur (n = 2), scapula (n = 1), humerus (n = 1), ulna (n = 1), clavicle (n = 1), and soft tissue mass of the shoulder (n = 1). The final diagnoses included bone metastasis (n = 7), spinal osteomyelitis and discitis (n = 5), osteonecrosis after chemotherapy (n = 4), bone marrow change or benign lesion without malignancy (n = 3), insufficiency fracture (n = 1), long bone osteomyelitis (n = 1), soft tissue metastasis (n = 1), and perineural ganglion cyst (n = 1). In 10 of the 23 cases, the lesions were barely visualized or invisible on CT guidance. Pathologic analysis and laboratory culturing revealed that the lesions were successfully accessed by MRI-guided biopsy in 100% (23/23) of cases. No obvious complications developed during or after the procedures.

Conclusion: Biopsy under MRI guidance is especially valuable for the localization of bone marrow lesions, viable tumors (after chemotherapy or radiation), and lesions that cannot be visualized using CT. It is both accurate and safe, is a good alternative biopsy method, and may be a good adjunctive technique for the localization of bone lesions for radiofrequency ablation or other interventional procedures.

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Keywords: biopsy; intervention; magnetic resonance imaging; magnetic resonance imaging guidance; musculoskeletal

1. Introduction

Minimally invasive procedures for either the diagnosis or treatment of diseases have become increasingly popular because they only require a small incision, demonstrate reduced morbidity and pain, and require shorter hospital stays. However, these procedures require specialized instruments and precise imaging guidance.

Biopsy procedures for deep-seated structures can be performed using small-gauge needles and imaging guidance without creating a large wound. Computed tomography (CT), fluoroscopy, or ultrasound have been traditionally used for imaging-guided procedures. CT-guided biopsy of the spine
using a small-caliber biopsy needle has been widely accepted since 1981. The overall accuracy of percutaneous spinal biopsy using modern techniques ranges between 61–100%. Ultrasound guidance has limited applications for bone or spinal lesions. CT and fluoroscopy are less sensitive than magnetic resonance imaging (MRI) in terms of bone marrow and soft tissue contrast. Moreover, CT and fluoroscopy have the inherent disadvantage of emitting ionizing radiation.

Compared with ultrasound and CT, MRI offers better bone and soft tissue contrast as well as multiplanar imaging capabilities. MRI is especially useful for lesions that are difficult or impossible to visualize using other imaging modalities. MRI is also useful in cases when it is impossible to obtain a biopsy result using other imaging guidance techniques. Consequently, MRI is a potential imaging tool for guiding invasive procedures. In addition, MRI is radiation-free, which benefits both the physician and patient. Nevertheless, safely performing procedures under MRI guidance requires the instruments to be MRI-compatible and that the MRI pulse sequences be optimized for fast scanning. In addition, more time is required to perform MRI guidance than CT- or ultrasound-guided biopsies.

The MRI-guided technique has been used in interventional biopsy procedures of the breast, prostate, liver, and musculoskeletal system. The MRI-guided technique has mostly been applied to the musculoskeletal system using low-Tesla (<1.5 T) open MRI scanners. In this preliminary study that was performed in Taiwan, an MRI-guided intervention technique was applied to obtain a musculoskeletal biopsy using a 1.5-T closed system. We evaluated the feasibility and efficacy of this procedure as well as its diagnostic accuracy.

2. Methods

2.1. Biopsy needles and instruments

This study was performed using the Invivo Bone Biopsy Set (Daum, Germany), which contains four instruments made of an MRI-compatible titanium alloy: a trocar, a stylet, a drill, and an ejector (model number: 15110, 15100, 15120) (Fig. 1). The drill was inserted into the lesion in order to obtain a pathological specimen. Other instruments used included a semiautomatic biopsy gun (Daum, Germany, model number: 11515) and coaxial needles (Daum, Germany, model number: 12608). Glycerine balls were used as the grid.

2.2. Patient selection

After obtaining informed consent, patients who were willing to cooperate throughout the imaging process were eligible for participation in this study. The inclusion criteria of patients were lesions necessary for tissue proof. Indications included bone and soft tissue masses, infection (osteomyelitis and discitis), and lesions that could not be visualized using CT or other imaging modalities. The exclusion criteria included bleeding diathesis, presence of a cardiac pacemaker, incompatible surgical clips, claustrophobia, inaccessible lesions, and patients who were unwilling to cooperate during the procedure.

From January 2005 through December 2009, we performed spinal and bone biopsy procedures on 24 patients. One case failed because the patient could not tolerate the procedure. Consequently, only 23 cases were included (12 males and 11 females, aged 11–82 years). The time between the MRI-guided biopsy procedure and previous CT or MRI examination ranged from 1–42 days.

2.3. Imaging

MRI-guided biopsy was performed using a 1.5-T closed MRI scanner. All of the MR images were obtained using a clinical MRI machine (Excite HD; GE Medical Systems, Milwaukee, WI, USA) using an 8-channel cardiac array coil. The pulse sequences included fast spin echo (FSE), T1- (TR/TE = 300–667/10–20) and T2-weighted imaging, both without/with fat saturation (TR/TE = 1700–3900/34–99), proton-density (TR/TE = 1967–2050/8.3–12), and gradient echo (GRE) (TR/TE = 150/2.5), which were accomplished using different MRI parameters in order to keep the scanning time of each pulse sequence to no more than 60 seconds (band width: 97–122; slice thickness: 5–6 mm; echo train length: 3–12). An in-room display monitor provided near real-time imaging throughout the procedure.

2.4. Biopsy technique

The self-referenced guidance method was performed by using glycerine balls on the skin as markers. With the aid of a grid marker, we determined the entry site and path of the needle. Following the administration of a local anesthetic, the MRI-compatible needles were percutaneously introduced, step by
3. Results

The biopsy locations were as follows: spine (n = 12), tibia (n = 3), pelvis (n = 1), femur (n = 2), scapula (n = 1), humerus (n = 1), ulna (n = 1), and the soft tissue of the shoulder (n = 1) (Table 1). The final diagnoses based on pathological analysis of the obtained specimens included bone metastasis (n = 7) (Fig. 2), spinal osteomyelitis and discitis (n = 5) (Fig. 3), osteonecrosis after chemotherapy (n = 4) (Fig. 4), bone marrow change or benign lesion without malignancy (n = 3), insufficiency fracture (n = 1), long bone osteomyelitis (n = 1), soft tissue metastasis (n = 1), and perineural ganglion cyst (n = 1) (Fig. 5) (Table 1). In 10 of the 23 cases, the lesions were barely visualized or impossible to visualize on CT guidance, including four cases of osteonecrosis after chemotherapy (Fig. 4), three cases of bone marrow change, two cases of bone metastasis (Fig. 2), and one case of perineural ganglion cyst (Fig. 5). Three cases underwent CT-guided biopsy before MRI-guided biopsy, yielding indefinite pathological diagnoses (Table 1). Bacterial culturing was performed using specimens from all patients clinically suspected of osteomyelitis (n = 6). Pathological specimens were obtained from all cases (n = 23).

Pathologic analysis and laboratory culturing revealed that MRI-guided biopsy successfully accessed the lesions in all 23 cases (100%). The total procedure time was about 2 hours. No obvious complications developed during or after the procedures.

<table>
<thead>
<tr>
<th>Case</th>
<th>Sex</th>
<th>Age (y)</th>
<th>Location</th>
<th>Pathological diagnosis</th>
<th>Original clinical impression</th>
<th>Nonvisualization on CT</th>
<th>Bacterial culture</th>
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<tr>
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<td>M</td>
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<td>Acetabulum</td>
<td>Bone metastasis</td>
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<tr>
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<td>F</td>
<td>76</td>
<td>Spine (L1)</td>
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<tr>
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<td>M</td>
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<tr>
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<tr>
<td>10</td>
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<tr>
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<td>Spine (L4-5)</td>
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<tr>
<td>19</td>
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<td>Discitis, osteomyelitis</td>
<td>+</td>
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<td>Femur</td>
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<td>Suspected viable tumor (osteosarcoma)</td>
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<td>Fibrosis after chemotherapy, lymphoma</td>
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<td>Osteonecrosis after chemotherapy, radiation therapy</td>
<td>Suspected bone metastasis, synovial sarcoma</td>
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<td></td>
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<tr>
<td>23</td>
<td>M</td>
<td>69</td>
<td>Tibia</td>
<td>Osteonecrosis after chemotherapy</td>
<td>Myelofibrosis, suspected leukemia</td>
<td>+</td>
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</tr>
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</table>

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

4. Discussion

Biopsy is an important diagnostic procedure that precedes clinical treatment. Image guidance is a growing trend among minimally invasive procedures. Percutaneous spinal biopsy was first performed in the mid-1930s by Robertson and Ball.22 It has been refined over the years with the development of increasingly sophisticated biopsy needles and imaging techniques.23 It was first performed using an open method with a large-bore needle. Since 1949, fluoroscopically-guided needle biopsy has been in use. CT-guided biopsy of the spine using a small-caliber biopsy needle became widely accepted after 1981.1,2 The overall accuracy of percutaneous spinal biopsy ranges from 61–100%.3–11 However, CT has the disadvantages of radiation and beam-hardening artifacts, which may obscure the target during scanning.

In comparison, MRI offers superior bone and tissue contrast, multiplanar imaging capabilities, and the absence of beam-hardening artifacts and ionizing radiation.24–27 For these reasons, MRI is particularly valuable as a guidance modality.14 Common applications include lesions that cannot be visualized by CT or ultrasound, suspicion of a viable tumor after chemotherapy or radiotherapy, intra-articular or synovial soft tissue lesions adjacent to surgical hardware, and obtaining a biopsy from pregnant or pediatric patients.13,14 Moreover, new advances in hardware and software have made real-time or near real-time procedural guidance possible.16,24–27
Previous reports on the use of MRI-guided biopsy in the musculoskeletal system generally involved low-Tesla (< 1.5 T), open-magnet MRI. This is a convenient biopsy procedure, requires less time and yields less susceptibility artifacts compared with the closed 1.5-T system used in this system. However, the 1.5-T system provides better resolution and a better signal-to-noise ratio (SNR). This is especially advantageous for accurate localization of the lesion. However, the efficacy of MRI-guided biopsy has not been evaluated as thoroughly as that of CT-guided biopsy.

In this preliminary study, we successfully applied MRI-guided biopsy to the musculoskeletal system of 23 patients. In our study, MRI guidance was especially valuable for lesions that could not be visualized using other imaging modalities, such as a bone marrow lesion suspected of being a viable tumor after chemotherapy or radiotherapy. In our study group, 10 cases were hardly visualized or were impossible to visualize by CT scan. Three cases had received CT-guided biopsy before MRI guidance. In one patient (case 2), CT-guided biopsy was able to diagnose discitis and osteomyelitis of the lumbar spine; the clinician wanted to obtain another biopsy and aspirate the abscess. In two cases (cases 17 and 19), biopsy under CT guidance was performed, but there was no definite pathological diagnosis. MRI guidance was then performed to diagnose metastasis (case 17) and osteomyelitis and discitis (case 19). Determining the correct location of the lesion is important in order to avoid nondiagnostic or misleading results. MRI-guided biopsy has been shown to be effective for obtaining accurate pathological specimens. Previous reports on the diagnostic accuracy of MRI guidance range between 91–95%. Our study showed pathological diagnosis and accuracy in 100% of cases.

The MRI-guidance technique can be a good adjunct to other interventional procedures. In addition to spinal biopsies, MRI-guided nucleotomy of the lumbar spine, intradural cyst drainage, and discography have been performed with favorable outcomes. One patient in our group (case 15) demonstrated a small perineural ganglion adjacent to the spine, which was causing painful sensations. Because it could not be identified by CT, aspiration and injection were performed under MRI guidance in order to promote cyst fibrosis and healing. Radiofrequency ablation (RFA) has been proven as an effective technique for the treatment of bone tumors. It is a minimally invasive therapy with very low morbidity and mortality rates. It induces coagulation necrosis by ionic agitation and the consequent heating of tissue. In the current study, one patient with an underlying lung carcinoma (case 8) showed positive uptake at the scapula on a bone scan, but the lesion could not be visualized by CT. MRI helped to localize the scapular lesion, which was then treated by RFA.

The scanning time of the MRI-guidance procedure depends on the adjusted parameters. During MRI guidance, a shorter TR would result in a shorter procedure time. However, lower spatial resolution or SNR may result. Consequently, it is practical to use a longer scanning time in order to obtain better imaging resolution and contrast.

We acknowledge the limitations of our study. MRI guidance has a variety of contraindications, including the presence of a cardiac pacemaker, incompatible surgical clips, bleeding diathesis, patient claustrophobia, and inaccessible lesion locations. Originally, we performed 24 cases of MRI-guided...
Fig. 3. A 52-year-old female underwent MRI-guided and, subsequently, CT-guided biopsy at the L1-2 spinal level; discitis was confirmed by MRI-guided biopsy. (A) Axial T2-weighted MRI image showing a low-signal needle (arrow) within the paraspinal abscess (arrowhead). (B) CT scan showing a high-density needle (arrow) in the soft tissue window with beam-hardening artifacts and less soft tissue contrast (arrowheads) compared with MRI (A).

Fig. 4. MRI-guided biopsy was performed on a 17-year-old male with osteosarcoma of the femur after limb-salvage surgery and chemotherapy for suspected skip bone metastasis. (A) Coronal short-tau inversion recovery (STIR) image demonstrating a high-signal lesion at the proximal femur (arrow) superior to the surgical site with metallic artifacts (arrowheads). (B, C) Axial and sagittal T1-weighted images showing the needle drill within the bone lesion (arrow). The multiplanar MRI technique accurately localized the lesion. Pathological analysis revealed osteonecrosis after chemotherapy without a viable tumor.
biopsy; however, one case failed because the patient could not tolerate the procedure. In addition, our study sample was small because of time limitations to the daily MRI examination procedures and the use of a closed MRI system.

In conclusion, biopsy under MRI guidance at 1.5 T with a closed magnet is especially valuable for the localization of active inflammation, bone marrow lesions, viable tumors (after chemotherapy or radiation), and lesions that cannot be visualized using CT. It is accurate, safe, and offers a good alternative biopsy method. The relatively higher cost and longer procedure time are the disadvantages of MRI guidance compared with CT guidance. Understanding the relationship between the susceptibility artifacts of the needle and the MRI parameters is essential so that the radiologist can adjust and optimize these parameters. MRI guidance may also be a good adjunct for the localization of bone lesions for RFA or other interventional procedures.

Acknowledgments

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References


Fig. 5. MRI-guided aspiration, biopsy, and injection were performed on a 30-year-old female with a perineural ganglion cyst. (A) Axial T2-weighted image of the spine showing a high-signal ganglion cyst (arrow), which was barely visible on CT. (B) Axial T2-weighted image demonstrating a coaxial needle penetrating the cyst (arrow). Following aspiration for pathological analysis, Tissucol was injected into the cyst to promote tissue growth.


