Combined Use of Magnetic Resonance Imaging and Fine-Needle Aspiration Cytology for Diagnosis of Soft-Tissue Tumors

Yasuyuki Kitagawa¹, Ryu Tsunoda¹, Mitsuhiro Nanno², Satoru Arai³ and Shinro Takai¹

¹Department of Orthopaedic Surgery, Nippon Medical School, Tokyo, Japan
²Department of Orthopaedic Surgery, Nippon Medical School Tama Nagayama Hospital, Tokyo, Japan
³Department of Pathology, Nippon Medical School Tama Nagayama Hospital, Tokyo, Japan

Background: Magnetic resonance imaging (MRI) and fine-needle aspiration cytology (FNAC) are useful in the diagnosis of soft-tissue tumors and can be performed on outpatients. These modalities are complementary: MRI examines a large area, while FNAC assesses a highly specific region; MRI displays only signal intensities, while FNAC visualizes actual tumor cells. We investigated the combined use of these methods for differentiating malignant and benign tumors.

Methods: 148 patients (153 lesions: 137 benign, 16 malignant) underwent preoperative MRI and FNAC. A diagnosis was judged to be correct if one or both diagnoses were correct, incorrect if at least one diagnosis was incorrect, and indeterminate if both diagnoses were indeterminate or if MRI was indeterminate and the FNAC sample was insufficient.

Results: The diagnostic yields for MRI only, FNAC only, and their combination were 81.7%, 84.3%, and 92.2%, respectively, indicating that the diagnostic performance of MRI and FNAC was significantly improved when the methods were combined.

Conclusions: As compared with either modality used alone, combined preoperative use of MRI and FNAC improved diagnosis of soft-tissue tumors. (J Nippon Med Sch 2020; 87: 54–59)

Key words: cytology, fine-needle aspiration, magnetic resonance imaging, soft-tissue tumor

Introduction

Soft-tissue tumors are difficult to diagnose on the basis of patient history and physical examination. Therefore, modalities such as magnetic resonance imaging (MRI) and fine-needle aspiration cytology (FNAC) are often used to assist in the evaluation of soft-tissue tumors. MRI can detect and differentiate benign and malignant lesions, enables specific histological diagnosis, and facilitates surgical planning. MRI-informed diagnoses are reinforced by FNAC, a technique that is easily administered to outpatients and often favored over a needle biopsy, especially for small lesions.

Although MRI can detect lesion signals and the relationship of the lesion to adjacent tissues, the lack of specificity of signals indicating lesions makes most MRI-based diagnoses speculative. In contrast, FNAC allows visualization of actual tumor cells, can differentiate benign and malignant lesions when an adequate sample volume is collected, and yields specific diagnoses. However, FNAC can only evaluate a section of a lesion. We investigated the potential for combined use of MRI and FNAC to improve diagnosis of soft-tissue tumors. To our knowledge, few published studies have examined this subject.

Materials and Methods

This retrospective study was approved by the Institutional Review Board of Nippon Medical School Tama Nagayama Hospital (No. 2013-341) and was conducted in accordance with the principles of the Declaration of Hel-
MRI and Cytology for Soft-Tissue Tumors

Table 1 Summary of lesion types

| Soft-tissue tumors          | No. of lesions |
|-----------------------------|---------------|
| Benign tumors               | 137           |
| Lipoma                      | 34            |
| Epidermoid cyst             | 11            |
| Tenosynovial giant cell tumor| 11            |
| Nodular fascitis            | 10            |
| Ganglion cyst               | 10            |
| Schwannoma                  | 8             |
| Hemangioma                  | 7             |
| Others                      | 46            |
| Malignant tumors            | 16            |
| UPS                         | 5             |
| Malignant lymphoma          | 4             |
| Myxofibrosarcoma            | 2             |
| Liposarcoma                 | 1             |
| Soft-tissue metastasis      | 2             |
| Rhabdomyosarcoma            | 1             |
| Malignant melanoma          | 1             |

UPS: Undifferentiated pleomorphic sarcoma

Table 2 Summary of initial diagnoses, by diagnostic method, and final diagnoses

| Diagnostic method | Initial diagnosis | Final diagnosis |
|-------------------|-------------------|-----------------|
|                   | Malignant         | Benign          | Total |
| MRI               | Malignant         | 15              | 1    |
|                   | Benign            | 0               | 110  |
|                   | Indeterminate     | 1               | 26   |
| FNAC              | Malignant         | 12              | 2    |
|                   | Benign            | 1               | 117  |
|                   | Indeterminate     | 2               | 11   |
|                   | Insufficient sample | 1        | 7    |
| MRI + FNAC        | Malignant         | 14              | 3    |
|                   | Benign            | 1               | 127  |
|                   | Indeterminate     | 1               | 7    |

MRI: Magnetic resonance imaging, FNAC: Fine-needle aspiration cytology

The most common final diagnoses were lipoma, epidermoid cyst, tenosynovial giant cell tumor, nodular fasciitis, ganglion cyst, and undifferentiated pleomorphic sarcoma (Table 1). Diagnostic results for MRI alone, FNAC alone, and their combination are shown in Table 2, and diagnostic rates are shown in Table 3, 4. While there was little difference among the diagnostic accuracies of MRI alone, FNAC alone, and their combined use, combined use of MRI and FNAC significantly improved diagnostic yield. The number of lesions that could not be diagnosed...
with combined MRI and FNAC was less than half that which could not be diagnosed with MRI or FNAC alone. Of the 27 lesions classified as indeterminate by MRI, 16 were correctly diagnosed by FNAC (Table 5). Of the 21 lesions classified as indeterminate or unevaluable by MRI, 12 were correctly diagnosed with MRI (Table 6). Twelve lesions were unsuccessfully diagnosed by combined MRI and FNAC (Table 7). MRI yielded only one instance of a false-positive lesion, which was later identified as a vascular eccrine spi-
radenoma. This lesion was a subcutaneous spherical tumor (approximately 7 cm in diameter) that pressed against the forearm muscles; it had a low signal intensity on T1-weighted images and a heterogeneously high signal intensity on T2-weighted images. FNAC yielded two false-positive lesions: a desmoid tumor and nodular fasciitis. Smears of the desmoid tumor showed numerous small spindle cells with enlarged nuclei. Smears of the nodular fasciitis showed spindle cells with enlarged nuclei, as well as large cells with double nuclei and conspicuous nucleoli. The FNAC false-negative lesion was a well-differentiated liposarcoma. A subsequent smear revealed only mature fat cells. Various lesion types could not be diagnosed with MRI or FNAC. In multiple cases, FNAC: Fine-needle aspiration cytology, Unevaluable: Could not be evaluated because of insufficient sample volume, MRI: Magnetic resonance imaging, UPS: Undifferentiated pleomorphic sarcoma

Table 6  Lesions that were diagnostically indeterminate or unevaluable by FNAC but correctly diagnosed with MRI

| Lesions                | Indeterminate in FNAC | Unevaluable by FNAC | Correct in MRI |
|------------------------|-----------------------|---------------------|----------------|
| Nodular fasciitis      | 2                     | 1                   | 2              |
| Schwannoma             | 2                     | 1                   | 1              |
| Hemangioma             | 1                     | 1                   | 1              |
| Myxofibrosarcoma       | 1                     | 0                   | 1              |
| UPS                    | 0                     | 1                   | 1              |
| Tenosynovial giant cell tumor | 1               | 0                   | 1              |
| Lipoma                 | 0                     | 1                   | 1              |
| Intramuscular myxoma   | 1                     | 0                   | 1              |
| Ganglion cyst          | 1                     | 0                   | 1              |
| Dermatitis             | 1                     | 0                   | 1              |
| Tenosynovitis          | 0                     | 1                   | 1              |
| Desmoid tumor          | 0                     | 1                   | 0              |
| Malignant lymphoma     | 1                     | 0                   | 0              |
| Vascular eccrine spiradenoma | 0      | 1                   | 0              |
| Calcifying epithelioma | 1                     | 0                   | 0              |
| Lymphadenitis          | 1                     | 0                   | 0              |
| Total                  | 13                    | 8                   | 12             |

Table 7  Lesions that were not successfully diagnosed with combined MRI and FNAC

| Tumor                                              | No. | MRI             | FNAC               |
|----------------------------------------------------|-----|-----------------|--------------------|
| Lesions with false-positive diagnoses              |     |                 |                    |
| Vascular eccrine spiradenoma                       | 1   | Malignant       | Insufficient       |
| Desmoid tumor                                      | 1   | Indeterminate   | Malignant          |
| Lesions with false-negative diagnoses               |     |                 |                    |
| Nodular fasciitis                                  | 1   | Benign          | Malignant          |
| Liposarcoma (well differentiated)                 | 1   | Malignant       | Benign             |
| Lesions with undetermined diagnoses                 |     |                 |                    |
| Schwannoma                                         | 2   | Indeterminate   | Indeterminate      |
| Desmoid tumor                                      | 1   | Indeterminate   | Indeterminate      |
| Hemangioma                                         | 1   | Indeterminate   | Indeterminate      |
| Lymphadenitis                                      | 1   | Indeterminate   | Indeterminate      |
| Malignant lymphoma                                 | 1   | Indeterminate   | Indeterminate      |
| Calcifying epithelioma                             | 1   | Indeterminate   | Unevaluable        |
| Nodular fasciitis                                  | 1   | Indeterminate   | Indeterminate      |
| Total                                               | 12  |                 |                    |

MRI: Magnetic resonance imaging, FNAC: Fine-needle aspiration cytology, Unevaluable: Insufficient FNAC sample volume
schwannoma, nodular fasciitis, and desmoid tumor were difficult to diagnose, despite combined use of MRI and FNAC.

Discussion
The present study found that combined preoperative use of MRI and FNAC for diagnosis of soft-tissue tumors increased diagnostic yield, as compared with MRI or FNAC alone. This better performance may be attributable to the complementary relationship between the methods: while MRI can be used to assess a general area, the spatial scope of FNAC data is highly specific; moreover, MRI shows only the signal intensities of lesions, whereas FNAC can show individual tumor cells.

To our knowledge, few previous studies have explored the diagnostic performance of combined MRI and FNAC. In previous studies, MRI-informed diagnosis of soft-tissue tumors had a sensitivity of 78% to 94% and a specificity of 82% to 90%\(^3\), and FNAC-informed diagnosis had a sensitivity of 84.6% to 89.5% and a specificity of 88.4% to 90.6%, with an indeterminate rate of 5.5% to 8.1%\(^4\). Our findings indicate that MRI had a sensitivity of 100% and a specificity of 99.1%, both of which are considerably higher than previously reported values. However, the 27 present lesions with indeterminate diagnoses (17.6%) were excluded from this calculation. We found that FNAC had a sensitivity of 92.3% and a specificity of 98.3%, which were also higher than previously reported values. However, as compared with past studies, this study had a higher proportion of indeterminate and unevaluable lesions (13.7%).

A variety of histologic lesions, including nodular fasciitis, schwannoma, and desmoid tumor, are difficult to diagnose with MRI or FNAC alone, and diagnosis remains challenging even when these modalities are combined. MRI findings for nodular fasciitis are generally nonspecific and aggressive, such as transcompartmental spread\(^5\). The common cytological features of nodular fasciitis include large numbers of cells and inflammatory cells, and a tissue-culture appearance. However, it can be challenging to definitively determine whether such lesions are benign\(^6\). When using MRI to diagnose schwannomas without specific clinical features, such as an intramuscular schwannoma, the presence of target and split-fat signs is essential in differentiating the lesion from malignant peripheral nerve sheath tumors. Large tumor size, invasion of fat planes, heterogeneity, ill-defined margins, and edema surrounding the lesion are suggestive of malignant peripheral nerve sheath tumors\(^7\). Diagnostically important cytological findings of schwannoma include cohesive tissue fragments with fibrillary/fibrous stroma, intranuclear inclusions, marked nuclear pleomorphism, and absence of spindle cells with bipolar cytoplasmic processes\(^8\). However, pain at the time of puncture may suppress sufficient aspiration, thus preventing observation of these key features. Because of cellularity and collagen deposition, desmoid tumors exhibit low-to-intermediate signal intensity on T1-weighted images and intermediate-to-hyperintense signal intensity on T2-weighted images\(^9\). Diffusion-weighted imaging was useful in differentiating desmoid tumors from malignant soft-tissue tumors\(^10\).

Common cytological findings of desmoid tumor include predominance of bland spindle cells with long, fusiform nuclei and metachromatic matrix material. However, these features are nonspecific, and nuclear β-catenin staining may be required for specific diagnosis\(^11\).

This study had several limitations. First, it was a retrospective observational study that analyzed data from only a small number of patients and lesions. Second, the MRI diagnostic reports were completed by different doctors at various hospitals. Third, the actual process of diagnosing lesions with MRI and FNAC is likely more complex than the method modeled by the present study. Despite these limitations, our report has notable strengths. To our knowledge, this is the first study to investigate the diagnostic potential of combined use of MRI and FNAC.

Although our analysis included a variety of soft-tissue tumors, the characteristics that indicate whether each tumor is benign or malignant are specific to tumor histologic type; thus, the optimal method for combining MRI and FNAC for each histologic type should be investigated in a future study. In addition, future studies should assess the performance of this combination by applying the present diagnostic method to a larger number of samples, before it is used clinically.

Conflict of Interest: All authors declare that they have no conflict of interest related to this study.

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