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

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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[1]. 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[2].

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-

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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 fasciitis	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		Total
		Malignant	Benign	
MRI	Malignant	15	1	16
	Benign	0	110	110
	Indeterminate	1	26	27
FNAC	Malignant	12	2	14
	Benign	1	117	118
	Indeterminate	2	11	13
	Insufficient sample	1	7	8
MRI + FNAC	Malignant	14	3	17
	Benign	1	127	128
	Indeterminate	1	7	8

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

sinki. Informed consent was obtained from the participants by following the retrospective observational research information disclosure procedure (opt-out) of the hospital. This study was conducted in the orthopedics department of a single university hospital.

The department evaluated 312 patients with soft-tissue tumors during the period from 1 October 2005 to 31 December 2008. Of these patients, 148 (total lesions, 153; benign, 137; malignant, 16) underwent both preoperative MRI and FNAC and ultimately received a diagnosis of soft-tissue tumor or tumorous conditions, as indicated by histological assessment or clinical course. Histological diagnosis was performed on 119 lesions. The remaining 35 lesions were diagnosed as benign because they resolved spontaneously or remained nearly unchanged during the clinical course after the examination; these included ganglion cyst (n = 7), lipoma (n = 5), bursitis (n = 4), nodular fasciitis (n = 3), and others (n = 16). MRI and FNAC findings were ascertained from patients' examination reports and medical records. MRI was performed at multiple hospitals and clinics, while FNAC examination reports were obtained from a single hospital. In our department, MRI was principally performed when a lesion was suspected to be malignant or required surgical treatment. FNAC was additionally performed when a lesion was suspected to be malignant, except when lesions were located in areas that adversely affected the accuracy of the procedure. MRI and FNAC diagnostic results were classified as benign, malignant, or indeterminate, based on the examination reports. Diagnosis based on the combination of MRI and FNAC was performed in the following manner. A correct diagnosis was defined as a case in which (1) either the MRI- or FNAC-informed diagnosis was correct, while the other was indeterminate or, in the case of FNAC, when diagnosis was impossible because of inadequate sample volume or (2) when both MRI- and FNAC-informed diagnoses were correct. An incorrect diagnosis was defined as a case in which at least one of the diagnoses was incorrect. An indeterminate diagnosis was defined as a case in which both diagnoses were indeterminate or, in the case of FNAC, when diagnosis was impossible because of inadequate sample volume.

Statistical Analysis

The sensitivities, specificities, accuracies, and diagnostic yields of MRI alone, FNAC alone, and their combination were analyzed. Diagnostic yield was defined as the number proportion of all correctly diagnosed lesions. All metrics were compared among the three diagnostic methods by using the chi-square test. A P-value of <0.05 was considered statistically significant.

Results

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

Table 3 Diagnoses for combined MRI and FNAC

MRI + FNAC	MRI	FNAC	No.	Total
Correct	Correct	Correct	111	141
	Correct	Indeterminate or insufficient sample	12	
	Indeterminate	Correct	18	
Incorrect	Incorrect	Any	1	4
	Any	Incorrect	3	
Indeterminate	Indeterminate	Indeterminate or insufficient sample	8	8
Total			153	153

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

Table 4 Diagnostic characteristics of MRI, FNAC, and their combination

	Sensitivity	Specificity	Accuracy	Indeterminate/ insufficient sample	Diagnostic yield
MRI	100.0%	99.1%	99.2%	27 lesions	81.7% (125/153) *
FNAC	92.3%	98.3%	97.7%	21 lesions	84.3% (129/153) **
MRI + FNAC	93.3%	97.7%	97.2%	8 lesions	92.2% (141/153) *,**

MRI: Magnetic resonance imaging, FNAC: Fine-needle aspiration cytology
*P = 0.01, **P = 0.03

Table 5 Lesions that were diagnostically indeterminate on MRI but correctly diagnosed by FNAC

Lesions	Indeterminate on MRI	Correctly diagnosed by FNAC
Lipoma	4	2
Nodular fasciitis	3	2
Epidermoid cyst	2	2
Desmoids tumor	3	1
Schwannoma	3	1
Hemangioma	2	1
Tenosynovial giant cell tumor	1	1
Intravascular papillary endothelial hyperplasia	1	1
Vascular leiomyoma	1	1
Subcutaneous endometriosis	1	1
Amyloidoma	1	1
Sarcoidosis	1	1
Bursitis with calcification	1	1
Malignant lymphoma	1	0
Calcifying epithelioma	1	0
Lymphadenitis	1	0
Total	27	16

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

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 FNAC, 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-

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

FNAC: Fine-needle aspiration cytology, Unevaluable: Could not be evaluated because of insufficient sample volume, MRI: Magnetic resonance imaging, UPS: Undifferentiated pleomorphic sarcoma

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

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, 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%[3–5], 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%[6–8]. 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[9]. 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[10]. 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[11]. 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[12]. 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[13]. Diffusion-weighted imaging was useful in differentiating desmoid tumors from malignant soft-tissue tumors[14]. 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[15].

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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