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Usefulness of Magnetic Resonance Imaging/Ultrasound Fusion Imaging and Intraoperative Magnetic Resonance Imaging for Malignant Soft Tissue Tumor: A Case Report

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Abstract

Purpose: Achieving a balance between wide resection and function preservation is important when treating malignant soft tissue tumors; thus, tumor invasiveness must be determined precisely. This determination is typically evaluated by palpation with reference to Magnetic Resonance Imaging (MRI) and computed tomography images. However, this procedure cannot be performed in real time. Therefore, we paid attention to the combination of MRI/Ultrasound Fusion Imaging (M/UFI) and intraoperative MRI (iMRI) to evaluate tumor invasiveness precisely.

Methods: A 46-year-old woman presented with dermatofibrosarcoma protuberans on her left ankle. To facilitate initial alignment in M/UFI, we injected a titanium marker into the tumor and performed iMRI under anesthesia preoperatively. iMRI images were uploaded on an ultrasound device, and the initial alignment in M/UFI was performed based on the marker.

We marked tumor margin evaluated on palpation with reference to Magnetic Resonance Imaging (MRI) as ① and tumor margin evaluated on M/UFI as ②. Tumor resection was performed at a width of 2.5 cm and height of 3 cm from ①.

Results: After tumor resection, tumor slices were obtained and evaluated macroscopically. ② depicted precise tumor margin more accurately than ①.

Conclusion: M/UFI combined with iMRI enabled visual evaluation of tumor margin in reference to the latest MRI images, and it may help prevention of recurrence and limited operation.

Keywords: Magnetic resonance imaging/ultrasound fusion imaging; Intraoperative magnetic resonance imaging; Malignant soft tissue tumor; Tumor margin

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Introduction

Achieving an optimal balance between wider resection and better function is important in the field of malignant bone and soft tissue tumor therapy. To avoid leaving malignant tissue, we should resect the tumor extensively to prevent tumor recurrence while preserving the patient's extremity function as much as possible. We generally decide the extent of tumor resection on palpation in reference to Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) images. In the case of malignant soft tissue tumor in the surface layer, the resection margin is determined by palpation, approximately 3 cm from the tumor margin. It is sometimes observed that tumor invasion exceeds the predicted extent, with tumor cells being remarkably close to the resection margin because of two possible reasons. First, tumor margin can be examined upon palpation and measurement in reference to MRI images but not visually. Second, although surgery is often planned within 2 weeks from MRI examination, tumor may increase in size until then. As a solution to evaluate tumor visually, we focused on MRI/Ultrasound Fusion Imaging (M/UFI), which combines MRI with ultrasound images so both can be evaluated simultaneously. We found some reports referring to M/UFI, but most had targeted areas, such as the prostate gland or liver [1,2]. As far as we found, there was only one report targeting bone and soft tissue tumors [3]. Until now, we have performed M/UFI alone for malignant bone tumors. Because there are some landmarks such as the patella

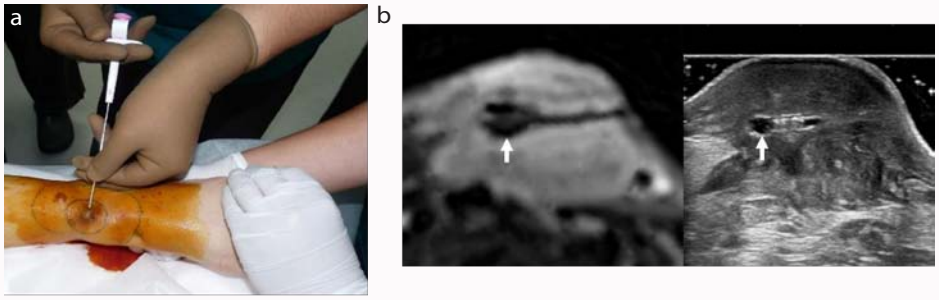

Figure 1: (a). A titanium marker into the tumor of her left ankle was injected under general anesthesia. (b). Left, T2-weighted image and right, ultrasonogram after injection of a titanium marker.

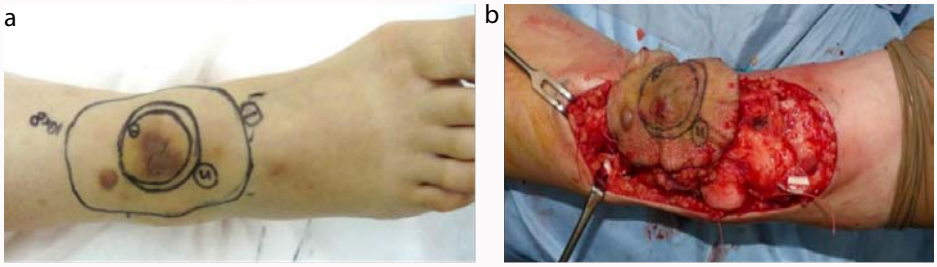

Figure 2: (a). Mark ① indicates the tumor margin found upon palpation and measurement in reference to MRI images, and mark ②indicates the tumor margin found on M/UFI. Mark ①' indicates the resection line (2.5 cm in width, 3 cm in height from mark ①). (b). Tumor resection was performed at mark ①'.

and joint surface, we can adjust positions of MRI and ultrasound images and it is possible to perform initial alignment of both imaging modalities. On the other hand, because soft tissue tumors do not have landmark unlike bone tumors, the initial alignment is exceedingly difficult. Therefore, as a solution for not performing the latest MRI examination and absence of landmarks, we focused on intraoperative MRI (iMRI). iMRI may enable obtaining the latest preoperative MRI images and set up a landmark by injecting a marker in soft tissue tumor under anesthesia. We found studies referring to intraoperative MRI (iMRI) in the area of neurosurgery that had found iMRI helped reduce the residual tumor and was associated with a lower recurrence rate [4-6]. To the best of our knowledge, there are only two studies referring to iMRI in relation to bone and soft tissue tumors [7,8]. We report, for the first time, a useful strategy for estimating tumor margin using M/UFI combined with iMRI.

Materials and Methods

The patient was a 46-year-old woman with dermatofibrosarcoma protuberans on her left lower leg. Although she had been aware of a raised lesion on her left lower leg for two years, she considered it a ganglion and monitored it. After two years, she visited a dermatology clinic and underwent a biopsy. She was diagnosed as having dermatofibrosarcoma protuberans by pathological findings. It was a malignant tumor located on the dermal surface layer, and two metastatic left lung nodules were detected on CT. Therefore, she was referred to our department and received two courses of preoperative chemotherapy with eribulin mesylate. After two courses of chemotherapy, the two metastatic left lung nodules did not aggravate and new metastases were not observed on CT. We planned to performed resection surgery. To decide the extent of tumor resection properly, we equipped an ultrasound device with an M/UFI system (ALOKA ARIETTA 850, Hitachi Medical Co.), a 0.4T intraoperative MRI system (AIRIS, Hitachi Medical Co.), and a titanium marker (HydroMARK; Devicor Medical Japan Inc.). We evaluated the extent of tumor margin using these systems and performed tumor resection and free flap from her left groin.

Results

After a titanium marker was injected into the tumor under general anesthesia, iMRI examination was performed (Figure 1a). These iMRI images were imported into an ultrasound device to obtain M/UFI images, and M/UFI images were harmonized using the injected marker as a landmark and the initial adjustment was completed (Figure 1b). We marked the tumor margin found upon palpation and measurement in reference to MRI images as ① and marked the tumor margin found on M/UFI as ② (Figure 2a). We performed tumor resection at ①' (2.5 cm in width, 3 cm in height from ①) (Figure 2b). The resected tumor was fixed by formalin and attached by needles to prevent shrinkage (Figure 3a). After tumor resection, specimen slices were prepared and the marking on the resected tissue was checked. It was found that tumor margin evaluation was more precise at ② by M/UFI combined with iMRI than at mark ① by palpation and measurement in reference to MRI images (Figure 3b).

Discussion

Properly determining the extent of tumor resection when we treat a malignant bone and soft tissue tumors is important. How to treat the malignant tumor while balancing wide resection and good function has been discussed. Generally, MRI, CT, and echo would be used equally as the devices to evaluate tumor margin; now, MRIs are used most frequently. However, MRI findings are only an indication of tumor size; thus, even if tumor can be palpated and tumor size can be measured in reference to MRI images, these images cannot be used for real-time navigation. On the other hand, ultrasound images enable evaluation of tumor size and character immediately, but the precise tumor margin cannot be determined by ultrasound images only because ultrasound images cannot show invasion of malignant tumors, unlike MRI images. Therefore, we considered the use of M/

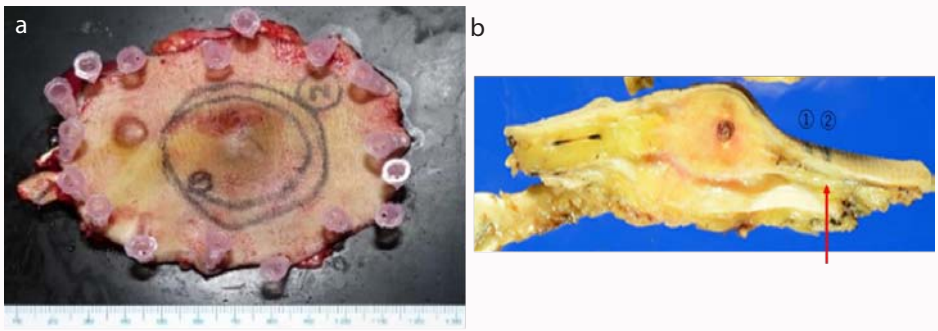

Figure 3: (a) The resected tumor was attached by needles to prevent shrinkage. (b) It was sliced at the titanium marker level, and the red arrow indicates malignant soft tissue tumor margin.

UFI to evaluate malignant tumor margin precisely. M/UFI combines MRI with ultrasound images so both can be evaluated simultaneously. As far as we found, there is only one report targeting bone and soft tissue tumors [3]. However, M/UFI has two disadvantages. One, the malignant soft tissue tumor margin is evaluated in reference to MRI images, but MRI examination was often performed within 2 weeks of surgery; therefore, the tumor may increase in size until then. Second, because malignant soft tissue tumors do not have landmarks, unlike bone tumors, the initial alignment with MRI and ultrasound images is exceedingly difficult. Furthermore, as a solution for the difficulty in performing the latest MRI examination and lack of landmark, we focused on iMRI, which enables obtaining the latest preoperative MRI images and set up landmark by injecting a marker in a malignant soft tissue tumor under anesthesia. We found studies referring to iMRI in the area of neurosurgery [4-6]. However, to the best of our knowledge, there are only two studies referring to iMRI in relation to bone and soft tissue tumors [7,8]. After a titanium marker was injected into the tumor and iMRI was performed under anesthesia, initial alignment was performed (Figure 1a, 1b). The marker functioned as the landmark and enabled initial alignment of M/UFI for soft tissue tumor. In this study, tumor margin evaluation was more precise at ② by M/UFI combined with iMRI than at ① by palpation and measurement in reference to MRI images (Figure 3b). Generally, the surgical margin of malignant soft tissue tumors in the surface layer is approximately 2 cm from the tumor when the rate of positive margin is said to be 7% to 13% [9]. Therefore, we attempted to resect malignant tumor with a margin of 2.5 cm to 3 cm from the tumor. In virtue of confirmation that the tumor margin entered within the extent of resection using M/UFI combined with iMRI, tumor resection could be efficiently performed. One of the limitations of this study was the difficulty in matching the MRI and ultrasound images perfectly. Drawing a perfectly matched view requires great skill; thus, it would be best for this process to be performed automatically, for example, using Artificial Intelligence technology.

Conclusion

M/UFI combined with iMRI can help evaluate malignant soft tissue tumor margin visually in reference to latest MRI images and may help prevent recurrence and limited operation.

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Compliance with Ethical Standards

Ethical approval Ethical approval was obtained from the institutional review board of Hiroshima University (No. E-911).

Informed Consent

Given this patient information, the institutional review board waived the requirement for informed consent. We took the opt-out method. To protect patient privacy, we removed all identifiers from our records upon completion of our analyses.

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