Apparent Diffusion Coefficient (ADC) Map for the Assessment in Reactive Zone of Soft-Tissue Sarcomas: pathological correlative analysis

Shuji Nagata[1], Koji Hiraoka[2], Tetsuya Hamada[2], Takanori Shoda[2], Hiroshi Nishimura[3], Masayoshi Kage[4], Kimberly K Amrami[5], and Naofumi Hayabuchi[1]
[1]*Radiology, Kurume University Hospital, Kurume, Fukuoka, Japan,* [2]*Orthopedic Surgery, Kurume University Hospital,* [3]*Radiology, Saiseikai Futsukaichi Hospital,* [4]*Pathology, Kurume University Hospital,* [5]*Radiology, Mayo Clinic*

Introduction: Limb-sparing surgery has become the standard method of care for patients with soft-tissue sarcoma. In preoperative planning, magnetic resonance imaging (MRI) is important tool to achieve negative surgical margins with surgery by identifying the extent of tumor pre-operatively. Although T2-weighted images (T2WI), short tau inversion recovery (STIR), and contrast-enhanced T1-weighted images (CE-T1WI) have been used to assess tumor extent, these techniques have limitations [1, 2]. A reactive zone composed of mainly edema and inflammatory cells is frequently present in the soft tissues surrounding soft-tissue sarcomas which is, like tumor, characterized by high signal intensity on T2WI or STIR [3, 4]. Soft-tissue sarcomas tend to have lower true diffusion measurements due to increased tumor cell packing, resulting in restricted Brownian motion in the extracellular space [5]. On the other hand, the reactive zone shows higher true diffusion measurements. In this study, we aim to evaluate the utility of apparent diffusion coefficient (ADC) map for depicting of margin of soft-tissue sarcomas and to compare the differences between tumor and the surrounding reactive zone based on histological analysis.

Methods: Experiment- Thirteen patients (28-73 years old, average age 59 years) with histologically proven soft-tissue sarcoma underwent diffusion-weighted image (DWI) in addition to fat-suppressed T2WI (FS-T2WI), CE-T1WI at 1.5T MRI (MAGNETOM Symphony Maestro Class; Siemens). The sequence parameters for DWI were as follows: single-shot, spin-echo type, EPI with CHESS, TR/TE=2200-4000/ 90-120 ms, matrix=256 x 512, FOV=120 to 360 mm, and slice thickness 4mm with gap of 2 mm. DWI was acquired with two b-factors (b = 0 and 1000 s/mm^2). The ADC maps were determined using the two b factors with the following formula: ADC = ln (SI_0 / SI_{1000}) / (b_{1000} – b_0), where SI_0 and SI_{1000} was the signal intensity of DWI corresponding to the b value of 0 and 1000 s/mm^2, respectively.
Image Evaluation- Two experienced radiologists reviewed whether a reactive zone was present or not and assessed the conspicuity of tumor margin using a 4-point scale on each of FS-T2WI and CE-T1WI and ADC map. The conspicuity of tumor margins was rated as follows: 1, tumor could not be identified; 2, tumor was identified, but margin was not defined; 3, tumor was identified, and margin was partially defined; and 4, whole tumor margin was well defined. We also analyzed the median ADC value in both tumor and reactive zone. This was compared with the number of cells such as tumor, inflammatory, and fibroblastic cells, as measured by a pathologist. The Spearman correlation coefficient was used to evaluate the strength of the correlation between cellularity and ADC value.

Result: A reactive zone was present in 9 of 13 patients with soft tissue sarcomas. Scores for tumor margin conspicuity were significantly improved using the ADC map (3.4 ± 0.5), compared with FS-T2WI (2.6 ± 0.9), and contrast-enhanced T1WI (2.7 ± 0.9) (p < 0.001). The mean cell count of tumor and reactive zone was 678 ± 322 and 195 ± 199, respectively. There was a significant difference between them (p < 0.001). The mean ADC value of tumor and reactive zone was 1.53 ± 0.51x10^{-3} mm^2/s and 2.08 ± 0.35x10^{-3} mm^2/s, respectively, which was also significantly different (p < 0.001) (Fig. 1). There was a significant inverse correlation of ADC value with cell count at the tumor and reactive zones (r = -0.57, p < 0.001, Fig. 2)

Conclusion: ADC map gives more reliable information for the assessment of the true extent of the soft-tissue sarcoma compared with FS-T2WI and CE-T1WI.

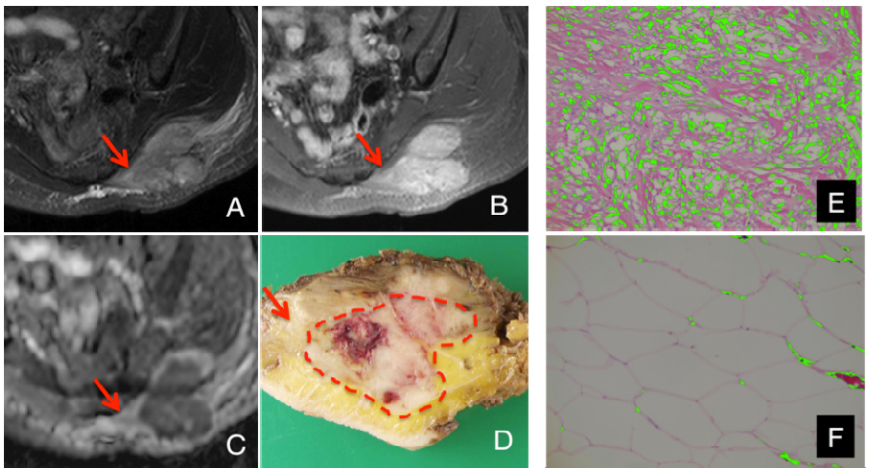

Fig. 1 A 58-year-old woman with a malignant giant cell tumor of the left buttock.
It is difficult to distinguish tumor from reactive zone (arrow) on FS-T2WI (A) and CE-T1WI (B). However, the periphery of the tumor, correlating with the reactive zone, was markedly brighter than tumor on ADC map (C). The mean ADC value of tumor and reactive zone (arrow) was 1.12 x10^{-3} mm^2/s and 2.42 x10^{-3} mm^2/s, respectively. The cut surface of the tumor revealed whitish solid tissue (dotted line) with several hemorrhagic spaces. Photomicrograph of tumor (E) shows hypercellularity, on the other hand, reactive zone (F) shows hypocellularity with no tumor cells but rather scattered spindle cells set edematous background.

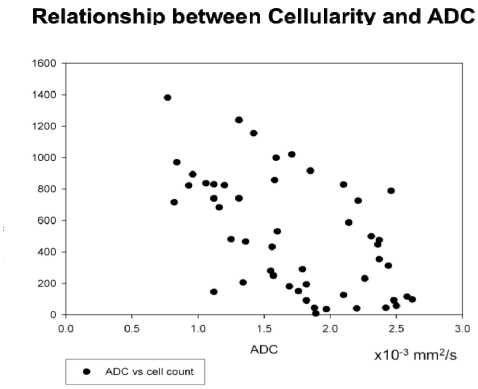

Fig. 2
There was a significant inverse correlation of ADC value with cell count at tumor and reactive zone (r = -0.57, p < 0.001).

Reference: [1] Lang P et al. Radiology, 1995; 197: 831-39. [2] Seeger LL et al. AJR, 1991; 157: 347-51. [3] Beltran J et al. Radiology, 1987; 162: 251-55. [4] Hann SL et al. J Magn Reson Imaging, 1991; 1: 441-49. [5] van Rijswijk CS et al. J Magn Reson Imaging, 2002; 15: 302-7.