ADVANCED MAGNETIC RESONANCE IMAGING (MRI) OF SOFT TISSUE TUMORS: TECHNIQUES AND APPLICATIONS.

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Abstract: Imaging evaluation of soft tissue tumors is important for the diagnosis, staging, and follow-up. Magnetic resonance imaging (MRI) is the preferred imaging modality due to its multiplanarity and optimal tissue contrast resolution. However, standard morphological sequences are often not sufficient to characterize the exact nature of the lesion, addressing the patient to an invasive bioptic examination for the definitive diagnosis.

Keywords: IVIM-DWI, DCE-MRI, iAUC,

The purpose of this article is to review technical aspects of each of these advanced MR imaging techniques, with a particular focus on their clinical application in the characterization, differentiation of benign from malignant lesions and the assessment of response to treatment in soft tissue tumors.

Diffusion weighted imaging (DWI)

DWI is a functional MRI technique that provides information about tissue cellularity and cell membrane integrity, evaluating the diffusivity of water molecules (Brownian motion).

Technique

The DWI signal is given by the degree of movement of water molecules in cellular spaces (extracellular, intracellular, transcellular, and intravascular), in an inversely proportional manner. The movement of water molecules is restricted in high-cellularity tissues, intact cell membranes, and reduced extracellular spaces. On the contrary, in tissues with low cellularity and considerable extracellular spaces, the movement of the water molecules is facilitated. It is important to take into account the contribution to the DWI signal of the intravascular movement of water molecules since in very vascularized lesions it can be significant.

Applications

The DWI signal and the ADC values reflect the cellularity of the tissues, so even if there are no normal cutoff values, DWI can characterize the biological activity of the tissues. In the study of musculoskeletal soft tissue tumors, this means that, as a general rule, benign tumors with a low degree of biological activity will have a loss of ADC signal as the b values increase, while malignant tumors (in which the water has greater restriction in movement) will show high intensity at high b values. The results of the use of DWI in the characterization of the nature of the lesions are numerous in the literature. Pekcevik et al. found that the mean ADC values of benign and malignant soft tissue tumors were statistically different, with values of 2.31 ± 1.29 and 0.90 ± 0.70, respectively. The authors found the highest values in benign cystic tumors and the lowest values in giant cell tumors of tendon sheaths (maybe due to their spindle-shaped stromal cells' and multinucleated giant cells' histological composition). Joung et al. using conventional MRI and DWI sequences together, obtained values of sensitivity, specificity, and accuracy of 96%, 85.7%, and 90%, respectively. The authors confirmed the persistence of high signal intensity with increasing b values in all malignant lesions (muscular metastases, myxoid liposarcoma, etc.) on the qualitative evaluation, with low ADC values on quantitative analysis with increasing b values, although with differences among the various histological types. They also found that higher b values (more than 800 s/mm2) are useful to increase the contrast between benign and malignant lesions and thus reduce the number of equivocal cases. All benign myxoid lesions showed loss of high signal intensity with increasing b values (e.g., schwannoma). Some authors suggested that in highly necrotic lesions the surrounding edema may contaminate tumor tissue and increase the diffusion coefficient.

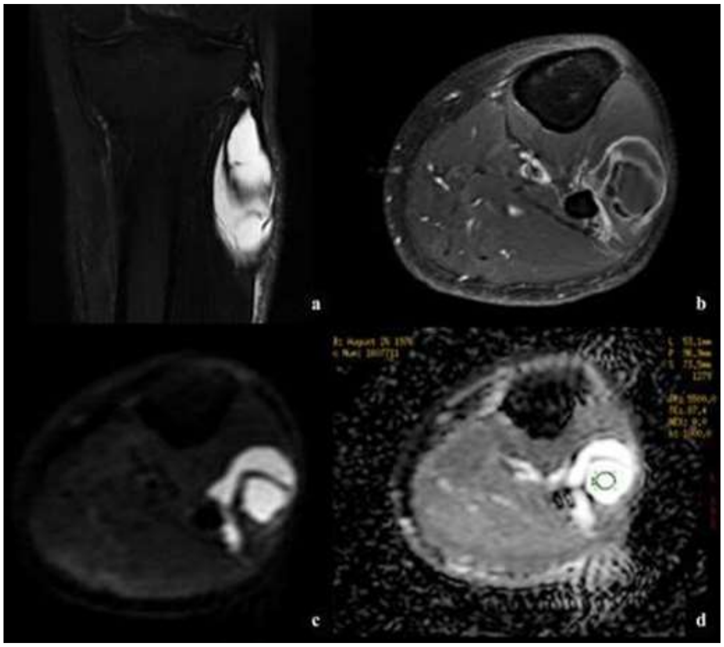

Fig. 1 Coronal and axial MR images of a cystic soft tissue lesion at the level of the proximal leg. The lesion shows homogeneous internal fluid signal intensity with peripheral contrast enhancement, features suggestive for a perineural ganglion cyst of the common peroneal nerve. DWI sequences show values of 2.75 × 10−3 mm2/s (b value = 1000) on ADC map, confirming the benign cystic nature of the lesion.

In another study, mean ADC of desmoid tumors was found to be significantly higher than that of malignant soft tissue tumors without overlap in the minimum ADC values. DWI has proved very useful also in the assessment of treatment response to chemotherapy in soft tissue tumors. In fact, changes in tumor size with standard MRI imaging are not a useful criterion as in other solid tumors. Similarly, the evaluation of enhancement patterns can be challenging, as both granulation and scar tissues (aspecific tissue changes after chemo/radiotherapy) are enhancing after contrast administration, and the differentiation from the viable tumor is not always direct. DWI demonstrated to improve this discrimination earlier than conventional imaging, as solid tumors are characterized by high cellularity with intact cell membranes, while tissues after cytotoxic treatment show lower cellularity and membrane damage. DWI implements standard morphological sequences also in the evaluation of postsurgical follow-up, aiding to detect residual/recurrent tumor tissue.

However, even if malignant lesions typically demonstrate rapid early arterial enhancement and higher slopes of enhancement compared with benign lesions, the patterns may show some degree of overlap secondary to highly vascularized benign lesions and poorly vascularized or necrotic malignant lesions.

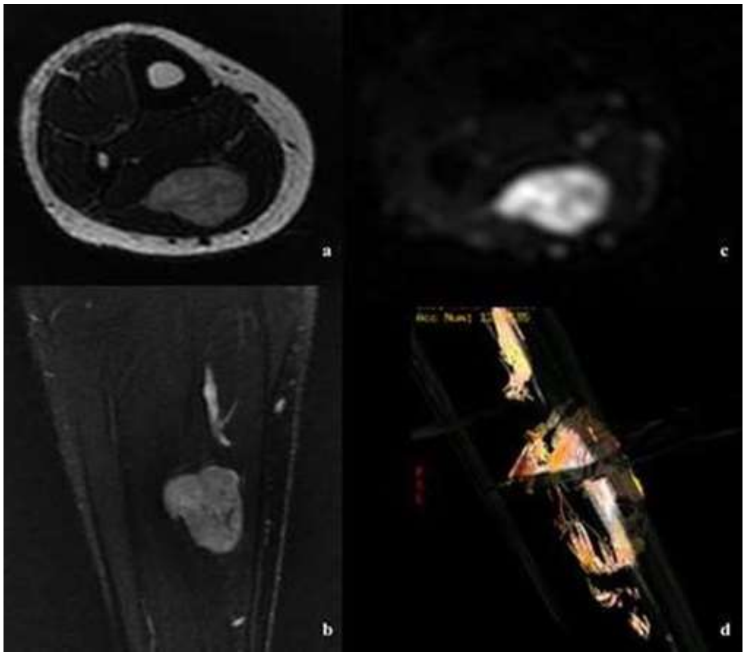

Fig. 2 Axial (a) an coronal (b) MR images of a rounded fusiform lesion at the level of the posterior compartment of the leg (within the soleus muscle) showing intense, homogeneous contrast enhancement. Axial DTI sequence (c) with fiber track reconstruction (d) demonlimiting it in another, the so-called anisotropy. In peripheral nerves, due to the presence of nerve fiber fascicles, water molecules tend to move in the direction of the axons ("anisotropic diffusion"). The differences in anisotropic characteristics of different tissues allow DTI to image nerve tracts and surrounding tissues. At our institution, we perform DTT using a 3 Tesla MRI scanner (EPI sequence, three diffusion directions, b value of 1000 s/mm2).

The diffusion is quantified by the apparent diffusion coefficient (ADC), and fractional anisotropy maps with diffusion directions are color coded. High-resolution images are also acquired using morphological sequences. Images are evaluated for image quality, ADC of the lesion, tractography, and fractional anisotropy of nerves. strates the growth of the lesion within the nerve fibers and its relationship to them. The imaging features are consistent with the diagnosis of schwannoma. Applications. In musculoskeletal imaging clinical practice, DTI and tractography are mainly used to evaluate peripheral nerve tumors and soft tissue tumors arising around nerve structures. This approach is of paramount importance not only for the diagnosis when there is often great difficulty in correctly delineating the tumor from healthy nerve structures, but also for the preoperative planning, as the preservation of unaffected nerve fascicles is important to maintain neuromuscular function after surgery. The assessment of peripheral nerve involvement by STTs, based on conventional structural MR sequences alone, is limited by subjective interpretation. Moreover, correlation of “d” sectional images with surgical findings, particularly in anatomically complex regions, can be challenging. DTI and tractography have radically changed the ability to visualize tissue anatomy in a threedimensional, noninvasive manner. Using tractography, the topographical relationship between the peripheral nerve and the tumor can be clearly depicted, even in the presence of regional anatomy derangement. In schwannomas, in which the tumor originates from the sheath of a single fascicle, leaving the main trunk of the peripheral nerve attached to the mass, DTI and tractography imaging are helpful in the differential diagnosis with neurofibromas, clearly depicting the eccentric and separate tumor growth relative to the involved nerve. Moreover, in addition to the morphological T2 sequence, discontinuity and abrupt thinning are signs that may indicate nerve invasion. Also, the literature results report a tendency toward lower FA and higher ADC values for adjacent nerve segments in malignant STTs than in benign STTs. These findings could be explained by the presence of greater regional nerve edema associated with aggressive tumor behavior or by true tumoral infiltration. In our experience, DTT was found to be capable of properly visualizing intact nerve fascicles and correctly delineating healthy nerve tissue and tumors across the vast majority of PNST patients with good intraoperative correlation between the DTT scans and surgical anatomy with 95.8% sensitivity, 66.8% specificity, and 89% positive predictive value (Fig. 4).

Conclusions

Functional and metabolic MRI techniques have expanded the role of MRI in the evaluation of soft tissue tumors. The added information obtained from these sequences, either alone or integrated, may improve multiparametric evaluations of soft tissue tumors that result in more accurate diagnosis, appropriate treatment planning, and monitoring of treatment efficacy. It is important to further implement these techniques to be able to use them on a routine clinical basis and to standardize furtherly acquisition protocols.

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