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Osteosarcoma subtypes: Magnetic resonance and quantitative diffusion weighted imaging criteria

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ABSTRACT

Introduction: Osteosarcoma (OS) is a primary bone malignancy, characterized by spindle cells producing osteoid. The objective of this study is to describe the magnetic resonance imaging (MRI) features of different OS subtypes, record their attenuation diffusion coefficient (ADC) values and to point to the relation of their pathologic base and their corresponding ADC value.

Patients and methods: We performed a retrospective observational lesion-based analysis for 31 pathologically proven osteosarcoma subtypes: osteoblastic (n = 9), fibroblastic (n = 8), chondroblastic (n = 6), para-osteal (n = 3), periosteal (n = 1), telangiectatic (n = 2), small cell (n = 1) and extra-skeletal (n = 1). On conventional images we recorded: bone of origin, epicenter, intra-articular extension, and invasion of articulating bones, skip lesions, distant metastases, pathological fractures, ossified matrix, hemorrhage and necrosis. We measured the mean ADC value for each lesion.

Results: Among the included OS lesions, 51.6% originated at the femur, 29% showed intra-articular extension, 16% invaded neighboring bone, 9% were associated with pathological fracture and 25.8% were associated with distant metastases. On MRI, all lesions showed ossified matrix, 35.5% showed hemorrhage and 58% showed necrosis. The mean ADC values for OS lesions ranged from 0.74×10^{-3} mm^2/s (recorded for conventional osteoblastic OS) to 1.50×10^{-3} mm^2/s (recorded for telangiectatic OS) with an average value of $1.16 \pm 0.18 \times 10^{-3}$ mm^2/s. Conventional chondroblastic OS recorded higher values compared to the other two conventional subtypes.

Conclusion: Osteosarcoma has different pathologic subtypes which correspondingly vary in their imaging criteria and their ADC values.

Introduction

Osteosarcoma (OS) is a primary bone malignancy, characterized by spindle cells producing osteoid. Its peak of incidence lies in the second and third decades, paralleling the growth spurt of bones, mostly arising from the metaphyses of long bones around the knee [1–5].

The World Health Organization classification of OS includes: low-grade central, conventional (chondroblastic, fibroblastic, osteoblastic), telangiectatic, small cell, secondary, para-osteal, periosteal, high-grade surface OS [6].

Pathologically, conventional OS is a mesodermal malignancy that produces osteoid and can variably produce cartilage and fibrous tissue. The pathological subtype of conventional OS points to a greater than 50% predominance of one type of matrix, yet the presence of osteoid matrix remains the ultimate diagnostic feature of OS, regardless the amount of cartilage or fibrous tissue matrix present [4].

Conventional OS is defined on imaging as an aggressive osseous intra medullary lesion with the characteristic osteoid formation. The non-conventional OS subtypes are less common and may mimic other bone tumors on imaging. Magnetic resonance imaging (MRI) is primarily indicated for local staging of the tumor, while diffusion weighted images (DWI) is an additional tool that depends on Brownian motion of protons. It provides an idea about the degree of tumor cellularity through measuring the apparent diffusion coefficient (ADC) value. The value of DWI and ADC measure-

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ment has been studied in various musculoskeletal tumors and proved it valuable in many instances [7–11].

The presentation, prognosis, therapeutic options may differ among OS subtypes. Hence, this study is dedicated to describe the MRI features of different OS subtypes and record their ADC values. Our purpose is to raise the knowledge and attention of radiologists to the imaging criteria of the less common and less popular OS subtypes and to point to the relation of their pathologic base and their corresponding ADC value.

Patients and methods

Patients

We performed a retrospective observational lesion-based analysis for different pathological subtypes of osteosarcoma. The study has been approved by the "Ethical Committee of Faculty of Medicine, Cairo University", in compliance with Helsinki Declaration. The study was performed at the National Cancer Institute in Egypt. We reviewed the data bases from December 2015 till June 2016 to for all patients. We selected OS patients to record their medical history, tumor staging and pathology results. The study included 31 patients (18 male and 13 female patients) who had pathologically proven OS; their ages ranged from: 7 to 46 years, mean age: 19 years. We excluded patients whose pathology results data were not available. The included OS pathologic subtypes are: osteoblastic (n = 9), fibroblastic (n = 8), chondroblastic (n = 6), para-osteal (n = 3), periosteal (n = 1), telangiectatic (n = 2), small cell (n = 1) and extra-skeletal (n = 1).

Magnetic resonance imaging

The patients had their MRI done on high field system (1.5 Tesla) closed magnet unit (Phillips Achieva XR) using the optimal surface coil to cover the examined area for each patient.

Imaging protocol

Conventional MR images. Pre-contrast imaging included T1-weighted images (T1WIs), T2-weighted images (T2WIs) and short tau inversion recovery (STIR). Contrast-enhanced study was performed after bolus injection of 0.1 mmol/kg body weight of Gadolinium flushed with 20 ml of sterile 0.9% saline solution at a rate of 2 ml/s using an automatic injector. Contrast-enhanced MR imaging using T1WIs and THRIVE (T1 High Resolution Isotropic Volume Excitation) techniques was performed.

Diffusion-weighted MR images. Images were acquired for the OS lesions in the axial plane using a fat-suppressed single-shot spin-echo echo planar imaging (EPI) sequence with tri-directional diffusion gradients and four b values (0, 50, 400 and 800 s/mm^2) to increase the sensitivity to cellular packing. The ADC value was automatically generated for each pixel of the DWI in the form of parametric maps on the operating console or on the workstation.

Images interpretation and analysis

For analysis, all images were transferred to a workstation using the Digital Imaging and Communications in Medicine (DICOM) format. Two consultant radiologists, one specialized in musculoskeletal and the other in oncology imaging, reviewed the conventional and diffusion weighted MR images while being blind to the pathology data.

Conventional images analysis

The following criteria are assessed for all studied OS lesions subtypes and recorded: bone of origin, epicenter, intraarticular extension, invasion of articulating bones, skip lesions, distant

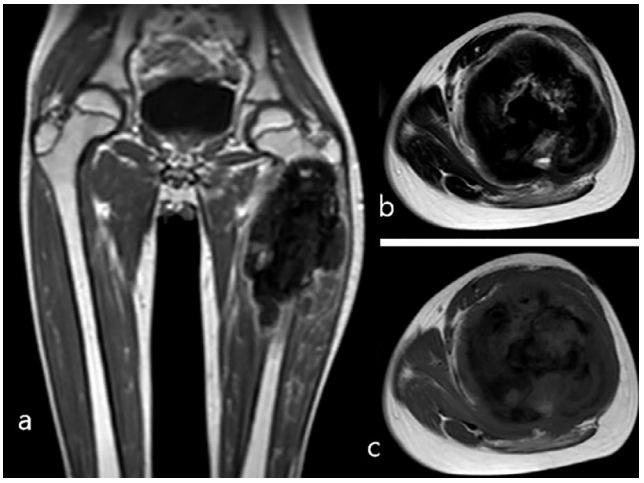

Fig. 1. Conventional osteoblastic OS presenting in a 14-year-old male patient; (a) coronal postcontrast T1, (b) axial T2 and (c) axial T1 showing a large aggressive osseous lesion arising at the proximal metadiaphyses of the left femur. Osteoblastic matrix demonstrates hypo-intense signal on T1 and T2 images, which predominates the tumor's matrix forming a large conglomerate mass.

Table 1
Conventional MR images criteria of OS pathologic subtypes.

	Number of lesions	Bone of origin		Long bone epicenter	Intra articular extension	Invading neighbor bone	Pathological fracture	Distant metastases
		Long bone	Flat bone					
Conventional OS								
Osteoblastic	9	4F 2T 1H	1 maxilla 1 calvicle	Medulla	3	2	0	2 lung 2 lung & bone 1 bone & nodal
Fibroblastic	8	4H 2F 1T	1 rib	Medulla	1	1	2	1 lung
Chondroblastic	6	3F	1 maxilla 2iliac	Medulla	4	2	0	1 lung & bone
Non-conventional OS								
Para-osteal	3	3F	0	Surface	0	0	0	1 lung
Peri-osteal	1	1F	0	Surface	0	0	0	0
Telangiectatic	2	2F	0	Medulla	1	0	1	0
Small cell	1	1F	0	Medulla	0	0	0	0
Extra skeletal	1	–	–	–	–	–	–	0
Total	31	25	6	–	9	5	3	8

Notes: F: femur, T: tibia, H: humerus.