RECENT ADVANCES IN IMAGING OF PEDIATRIC MUSCULOSKELETAL TUMORS

Essay
Submitted for partial fulfillment of the Msc. Degree in Diagnostic Radiology

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2008

ACKNOWLEDGEMENT

*First and foremost I thank **Allah** the most merciful who indebted me with his countless blessings.*

I would like to express my special thanks and deep gratitude to Prof. Dr. Esam El-Shiekh, professor of diagnostic radiology, Faculty of medicine-Cairo University-for the science that he has been delivering to candidates over years. For his sincere help, guidance and for the time spent on this essay.

My gratitude to my mentor and professor Prof. Dr. Maha Helal, professor of diagnostic radiology, National Cancer Institute-Cairo University-for for her unfailing patience, tolerance and generosity. For her outstanding humbleness that parallels her invaluable knowledge. For the delightful work atmosphere she creates and the kindest patronage.

I would like to express my deep gratitude to my professors, my colleagues and co workers who aids me to finish this work.

DEDICATION

*To my **parents**, sister, brother and of course my wife and kids for the unconditioned love and support.*

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LIST OF ABBREVIATIONS

ACR	American College of Radiology
ADC	Apparent Diffusion Coefficient
AT	Acquisition time
BC	Bone cyst
CB	Chondroblastoma
CCH-E	Children's Cancer Hospital-Egypt
Cho	Choline
CNR	Contrast to Noise Ratio
CS	Chondrosarcoma
CT	Computed Tomography
DCE-MRI	Dynamic contrast material-enhanced MR
DWI	Diffusion weighted MRI
EC	Enchondroma
ES	Ewing's sarcoma
FD	Fibrous dysplasia
FDG	2-[fluorine 18]-fluoro-2-deoxy-D-glucose
FFE	Fast-Field-Echo
FOV	Field of view
FSE	Fast Spin Echo
FSPGR	Fast spoiled
GCT	Giant cell tumor
Gd	Gadolinium
GRASS	Gradient-recalled echo in the steady state
GRE	Gradient Recalled Echo
HA	Hemangioma
HIS	Hospital Information System
IVIM	Intra Voxel Incoherent Motion
LCH	Langerhans cell histiocytosis
mAs	milliampere-second
MDCT	Multi Detector Computed Tomography
MIBG	Iodine-131-meta-iodobenzylguanidine
ML	Malignant lymphoma
MPR	Multiplanar reconstruction
MPR	Multiplaner reformatting images
MR	Magnetic Resonance
MRS	Magnetic Resonance Spectroscopy
MRSI	Multivoxel Spectroscopic imaging
MSK	Musculoskeletal system
NOF	Nonossifying fibroma
OC	Osteochondroma
OO	Osteoid osteoma
OSA	Osteosarcoma
PACS	Picture Archiving and Communication System
PD	Proton Density
PET	Positron emission tomography
RF-FAST	Radio Frequency Spoiled Fourier-acquired steady-state technique

RIS	Radiology Information System
ROI	Region of Interest
SA	Sarcoidosis
SE	Spin echo
SI	Signal Intensity
SNR	Signal to Noise Ratio
SPECT	Single Photon Emission Computed Tomography
SP-GR	Spoiled gradient echo
SSD	Shaded Surface Display
STIR	Short tau Inversion Recovery
SUV	Standardized uptake value
SV	Single voxel
T	Tesla
T1-W	T1-weighted
T2-W	T2-weighted
TBR	Tumor to background ratio
TSE	Turbo-spin-echo
VIBE	Volumetric Interpolated Breath hold Examination
VR	Volume rendering
3D	Three dimensional

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ABSTRACT

The development of more effective chemotherapeutic agents as well as improvement in limb salvage surgery and advances in radiotherapy assisted by novel technologies of the imaging techniques have improved staging and ultimate outcome in pediatric patients with musculoskeletal tumors.

The role of medical imaging in diagnosis, staging and eventual follow up of these patients has expanded; in particular the recent applications of MRI specially the functional imaging, as well as the PET/CT and MDCT technologies trying to reach the best way for management of such tumors in that age .

Key words: pediatric, musculoskeletal, tumors, MDCT, DWI, DCE-MRI, MRS, PET/CT.

INTRODUCTION

Pediatric musculoskeletal tumors are uncommon, and when they occur, are usually benign. Early detection of a malignant musculoskeletal tumor may not only make the difference between life and death, but also may allow for successful limb salvage surgery rather than amputation of the limb. ***(Erol et al. 2004)***

Before the development of adjuvant/neoadjuvant chemotherapy, even localized potentially curable bone tumors had a greater than 80% mortality rate. Multi-agent chemotherapy has resulted in cures for a significant percentage of patients but there are still failures (~30–50%) ***(Domb et al. 2004)***. In addition, chemotherapy is associated both with the development of drug-resistant types and with toxicity. An early predictor of response to chemotherapy would be extremely valuable, allowing the oncologist to intervene with alternative therapies. ***(Teo et al. 2007)***

Also there has been an unprecedented improvement in the survival outcome of children with extremity sarcoma as well as a corresponding increase in percentage of limb-sparing surgeries being performed over the past many decades. This has been, in part, due to the improved imaging modalities, newer surgical techniques, and advances in neoadjuvant chemotherapy. ***(Conrad et al. 2007)***

Plain radiography is the initial imaging modality in the evaluation of bone tumors. Improvement in the treatment and outcome of patients with bone and soft-tissue tumors requires the development of diagnostic tools that can help differentiate between benign, malignant and malignant mimicking lesions in a noninvasive and reliable manner. The current

challenge for imaging is to define new treatment response criteria and to identify new prognostic factors. ***(Gregory et al. 2006)***

Some of the developing modalities in this field are multidetector computed tomography (MDCT), dynamic contrast material-enhanced MR (DCE-MRI), diffusion weighted MRI (DWI), MR spectroscopy (MRS) and 18-fluorodeoxyglucose positron emission tomography (18 FDG-PET/CT).

The introduction of multidetector CT is especially valuable in the pediatric patient on a number of levels. First, the tremendous speed of image acquisition with multidetector CT enables the successful completion of most studies in less than 10 seconds is particularly advantageous compared with performing magnetic resonance (MR) imaging in the pediatric patient. Second, with multidetector CT, isotropic volume image data are acquired and the ability to retrospectively reconstruct multiple high-resolution image sets from the original raw data is possible, thereby requiring only one acquisition for production of three-dimensional (3D) CT images in numerous planes. Finally, when used correctly, 3D CT volume imaging can help minimize the radiation dose to the pediatric patient. ***(El-Khoury et al 2004)***

Use of multidetector CT has specific advantages that include the ability to combine volume acquisitions with CT angiography for better definition of tumor vascularity and to define involvement of adjacent structures, including blood vessels and muscle. Also its ability to distinguish true neoplasms from processes that mimic tumors, such as osteomyelitis, myositis ossificans, and fractures. Multidetector CT with postprocessing of the data set by using multiplaner reformatting images (MPR) and 3D volume rendering (VR) is valuable in the postoperative

patient with orthopedic hardware in place, as it is capable of potentially eradicating streak artifact associated with metal devices ***(Mori et al. 2005)***.

Multidetector CT can be used to evaluate the success of intervention as well as determine the etiology of any new symptoms or complaints. Multidetector CT really has unique imaging capabilities that are advantageous in the pediatric population. ***(Mahesh 2002)***

The effectiveness of magnetic resonance (MR) imaging in accurate characterization of musculoskeletal tumors has not gone unquestioned ***(Jaarmello & Laor 2008)***. During the past few years, differentiation between benign and malignant masses on unenhanced MR images has been based mainly on the evaluation of morphologic parameters such as size, demarcation of margins, involvement of adjacent vital structures, signal homogeneity, and measurements of relaxation times ***(Chapman et al. 2004***). Contrast-enhanced magnetic resonance imaging (MRI) has proven to be the method of choice for a proper estimation of the extent of bone tumors. (***Varich et al. 2000)***

Contrast-enhanced MR imaging, however, does not allow an optimal estimation of the response to preoperative chemotherapy in the case of osteo- or Ewing's sarcoma, as this technique is unable to visualize small, scattered foci of residual tumor. ***(Pui et al. 2005)***

Dynamic contrast-enhanced MR imaging using an intravenous contrast tracer is a sensitive indicator for the presence of remnants of viable tumor in patients with high-grade musculoskeletal tumors ***(Verstraete et al. 2005).*** In dynamic gradient-echo MR studies, this technique provides clinically useful information by depicting tissue

vascularization and perfusion, capillary permeability, and composition of interstitial space. ***(Brisse et al. 2004)***

In addition to imaging features, information regarding the cellular chemistry obtainable from hydrogen 1 (1H) nuclear MR spectroscopy and DWI may help characterize suspicious lesions and assess treatment response. ***(Madhu et al. 2006)***

Positron emission tomography (PET) was developed in the 1960s. In recent years, it has been increasingly used in some centers for the detection and staging of malignancy. PET can be used to image tumor metabolism because of the detection of photons emitted from tissue after the intravenous injection of a pharmaceutical such as 2-[fluorine 18]-fluoro-2-deoxy-D-glucose (FDG). ***(Aoki et al. 2003)***

PET has been shown to have sensitivity similar to that of serial CT and MR for detecting lesions and for distinguishing post surgical scarring from tumor recurrence. However, the specificity of PET is higher than that of serial CT or MRI. In evaluating musculoskeletal sarcomas, FDG image higher sensitivity, specificity, positive and negative predictive values for detecting recurrent tumor compared with iodine-131-meta-iodobenzylguanidine (MIBG) scans. ***(Hawkins et al. 2005)***

PET appears to be better than CT and MRI in depicting residual or recurrent tumor after treatment. The main disadvantage of PET is the high cost of the equipment, which limits its wide availability. ***(Biswal et al. 2007)***

The purpose of this study is to review the role of the recent updated imaging modalities used in evaluating the pediatric musculoskeletal tumors and how they can improve the outcome and add new prognostic values by helping in finding a non-invasive trustable method to