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بكالوريوس الطب والجراحة العامة كلية الطب جامعة عين شمس

تحت اشراف

أ.د/ حنان محمود عرفة

أستاذ الاشعة التشخيصية كلية الطب جامعة عين شمس

د/.شيماء عبد الستار عبد السميع

مدرس الاشعة التشخيصية كلية الطب جامعة عين شمس

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Role of MRI in imaging of pediatric bone marrow infiltrative neoplastic disorders.

Essay

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In Radiodiagnosis by

Enas Arafa Anwar

M.B,B.CH

Supervised by

PROF.Dr. Hanan Mahmoud Arafa

Professor of Radiodiagnosis

Faculty of Medicine Ain- shams University

DR. Shaimaa Abdelsattar Abdelsamea

Lecturer of Radiodiagnosis

Faculty of Medicine Ain- shams University

Faculty of Medicine

Ain-Shams University

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INTRODUCTION

Bone marrow is one of the largest organs by weight in the human body. It consists of a trabecular framework surrounding fat and hematopoietic cells, supported by reticulum cells, nerves, and vessels. Hematopoietically active red marrow is involved in the production of RBCs, WBCs, and platelets. Yellow marrow is composed of fat cells and is considered hematopoietically inactive **(Maximilian F et.al, 2011).**

The normal bone marrow undergoes age-related changes of its cellular content with increasing age of the patient. In adults, the normal bone marrow is characterized by a partial or complete fatty conversion and low cellularity it consists of 80% fat ,15% water and 5% protein. In children, the normal bone marrow is highly cellular 40% fat,40% water and 20% protein , which leads to have a low signal intensity on plain T1-weighted images and high signal intensity on STIR or fat saturated T2-weighted MR images. With increasing age, a conversion from this highly cellular marrow in children to fatty marrow in adults occurs with a gradual increase of the bone marrow signal on T1-weighted MR images and a gradual decline of the bone marrow signal on STIR- or fat saturated T2-weighted MR images over time. This conversion also follows a particular distribution

pattern within the skeleton: it starts in the peripheral skeleton and progresses centrally Within long bones **(Heike E. et.al ,2006).**

Disorders that affect marrow production can be divided to reconversion , infiltrative hyperplasia, replacement, depletion ,and myelofibrosis which rarely occurs in children It is usually the result of radiation or chemotherapy, but it can be a primary disorder, Neoplastic disorders are under the category of infiltrative disorders (**Justin et.al, 2011).**

Neoplastic infiltration of the bone marrow in MR images results in a replacement of the fatty converted marrow by neoplastic cells including leukemia, lymphoma, multiple myeloma, and metastases as in neuroblastoma, it may be focal ,multifocal or diffuse , Leukemia tends to be in a diffuse form while metastasis tend to be focal. The detection of neoplastic bone marrow infiltrations with MR imaging depends on the quantity and distribution of cellular infiltration **(Guillerman R. et.al, 2011).**

On T1-weighted images, marrow infiltration causes signal intensity lower than that of muscle. On T2-weighted images, the signal intensity increases and lesion detection is improved on fat-suppressed images. On STIR and fat-saturatedT2-weighted

images, tumor infiltration typically produces a high signal intensity that is greater than that of red or yellow metastases usually enhance post contrast (**Guillerman R. et. al, 2011).**

Magnetic resonance imaging ,an imaging test that uses magnets and radio waves to create pictures of the body unlike X-rays,ct and pet ct which use radiation to create images of the body, there are less side effects associated with MRI scans (**Maximilian F et.al, 2011**).

Biopsies are not always an accurate measure of how far cancer has spread, and they are painful for the patient. They can also be inconvenient, as sometimes multiple biopsies are required if the first sample is not good enough for analysis(***Montazel JL. et al, 2010*****).**

With its high contrast resolution and ability to differentiate hematopoietic and fatty marrow, MRI is an important technique to evaluate the bone marrow non invasively**(Siegle M J., 2006).**

MR imaging may be more sensitive than all other current imaging modalities in demonstrating bone marrow infiltration and may be superior to blind bone marrow biopsy in detecting early disease **(Brix G. et.al,2013).**

AIM OF THE WORK

Aim of the work , is to highlight the role of MRI in imaging the changes that occur in pediatric bone marrow infiltrative neoplastic disorders .

MRI ANATOMY OF BONE MARROW

MRI is the imaging modality of choice for the investigation of bone marrow disorders. Accurate interpretation of MR examinations of bone marrow requires an understanding of the anatomy, physiology, distribution, and conversion patterns of bone marrow. Technical factors of the MR examination are also important**(Wang S. et.al, 2011) .**

Marrow distribution in different ages

infantile marrow: Normal marrow in late fetal and early infant life is characterized by a high concentration of red marrow throughout the axial and appendicular skeleton. Thus, the diaphyses and metaphyses of long bones on MRI have low T1 signal, while unossified epiphyses and apophyses composed predominantly of cartilage exhibit intermediate signal on T1 weighted images (figs. 1.1& and 1.2) Later, when epiphyses and apophyses ossify, yellow marrow becomes evident within the ossification centers as areas of hyperintense T1 signal**(Wang S. et.al, 2011)** .

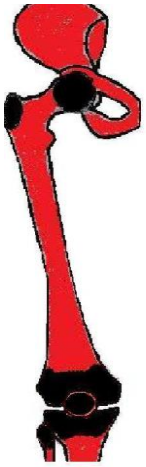


Figure 1. 1: Schematic diagram of the infantile marrow (just after birth) showing global distribution of red marrow . (Red areas represent red marrow and black areas represent cartilage)quoted from**(Wang S. et.al, 2011)** .

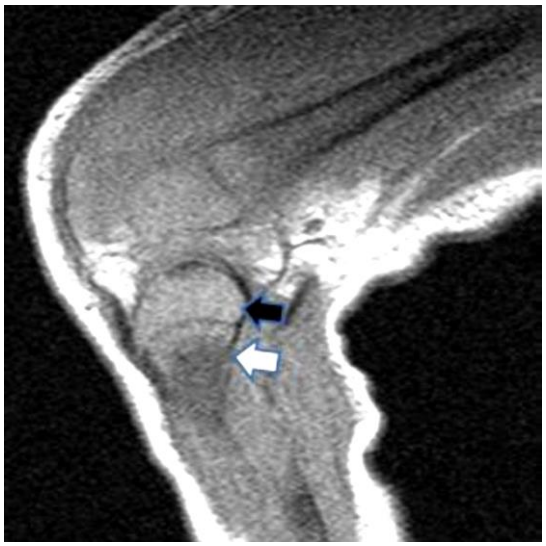


fig **1.** 2: .Sagittal T1 weighted image of the knee in a 18 day old male (A) shows hypointense red marrow in the proximal tibial (and distal femoral) metadiaphyses (white arrow) and intermediate signal (isointense to muscle) in the cartilaginous epiphyses (black arrow)quoted from (**Vanel D., 2004).** .

Childhood marrow (one year to 10 years): Near the end of the first year of life, marrow conversion begins in the phalanges of the hands and feet and is complete by 1 year of age. Additionally, marrow conversion in the femoral diaphyses commences by 12 months of age, sometimes seen as early as 3 months of age.10 After the first year of life, yellow marrow replaces red marrow in the diaphyses, while red marrow remains within the metaphyses. This results in relatively hyperintense signal in the diaphyses and low to intermediate signal intensity in the metaphyses on T1 weighted sequences (figs**1.**3&1.4) **(Wang D. et.al, 2011)** .

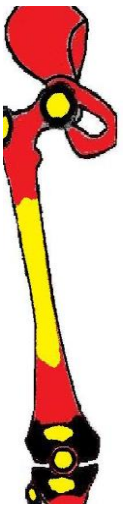


Figure 1. 3: . Schematic diagram of childhood marrow (1-10 years) showing yellow marrow distributed in apophyses, epiphyses, and the diaphysis and red marrow situated in the proximal and distal metaphyses. (Red areas denote red marrow, yellow areas denote yellow marrow, and black areas denote cartilage quoted from**(Wang S. et al, 2011)** .

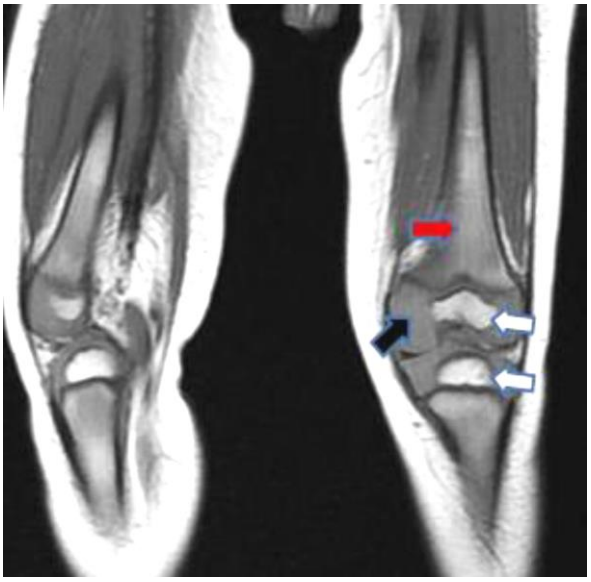


fig **1.**4: Coronal T1 weighted image of the pelvis in a 20 month old male. Note hyperintense yellow marrow within the ossification centers of the femoral and tibial epiphyses (white arrows), intermediate to hypointense signal of the unossified cartilaginous epiphyses (black arrow), and the intermediate to low marrow signal of red marrow in the metaphyses (red arrow) quoted from (**Vanel D., 2004).**

Adolescent marrow (10 years to 25 years): In the second decade of life, continued conversion of predominantly red marrow to predominantly yellow marrow in the diaphyses of long bones is accompanied by recession of red marrow from the distal metaphyses. Thus, there is a slightly greater proportion of yellow marrow in the distal metaphyses, resulting in progressively increasing hyperintense signal on T1 weighted images (figs1.5 &1. 6) **(Wang S. et al, 2011)** .

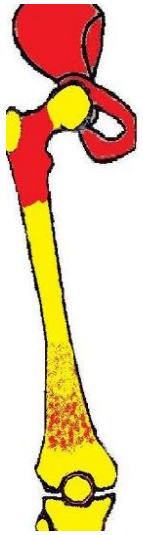


Fig **1.5**. Schematic diagram of adolescent marrow (10-20 years) showing recession of red marrow from the distal metaphysis and replacement of yellow marrow in the diaphysis and distal metaphysis. (Red areas denote regions of red marrow and yellow areas denote regions of yellow marrow**(Wang S. et al, 2011)** .

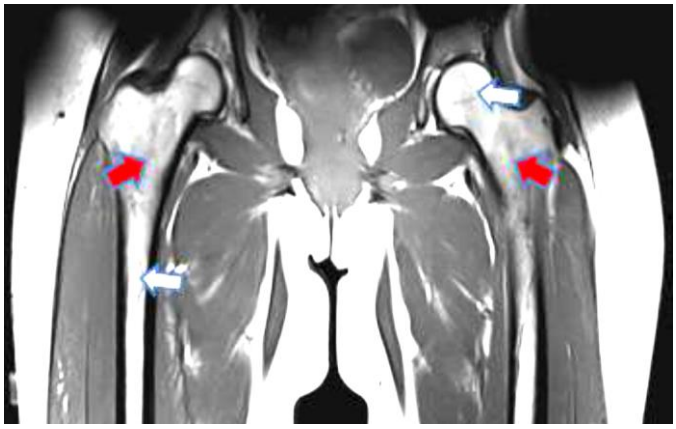


Fig **1.6**. Coronal T1 weighted image of the pelvis in an 18-year-old female. Note hyperintense yellow marrow within the femoral epiphyses and diaphyses (white arrows) and intermediate to low marrow signal of red marrow in the proximal femoral metaphysis quoted from **(Wang S. et.al, 2011)** .

Mri Anatomy Of Bone Marrow

Bone marrow conversion is an age dependant process in which red marrow is progressively replaced by yellow marrow in the peripheral skeleton ,mean while the proportion of fat cells with in the axial bone marrow progressively increases. By the age of 25 red and yellow marrow have reached their final adult distribution (red marrow in skull, axial skeleton, ribs sternum, pelvis and proximal femoral and humeral metaphysis). This fundamental process explain the distribution of most marrow lesions in the body **(Van Berg, 2005).**

Conversion from red to yellow marrow proceeds from the extremities to the axial skeleton, occurring in the distal bones of the extremities (feet and hands) first, and progressing finally to the proximal bones (humeri and femora), (Fig. 1.7). This process occurs in a roughly symmetric manner on each side in a given individual **(Wang S. et.al, 2011)** .

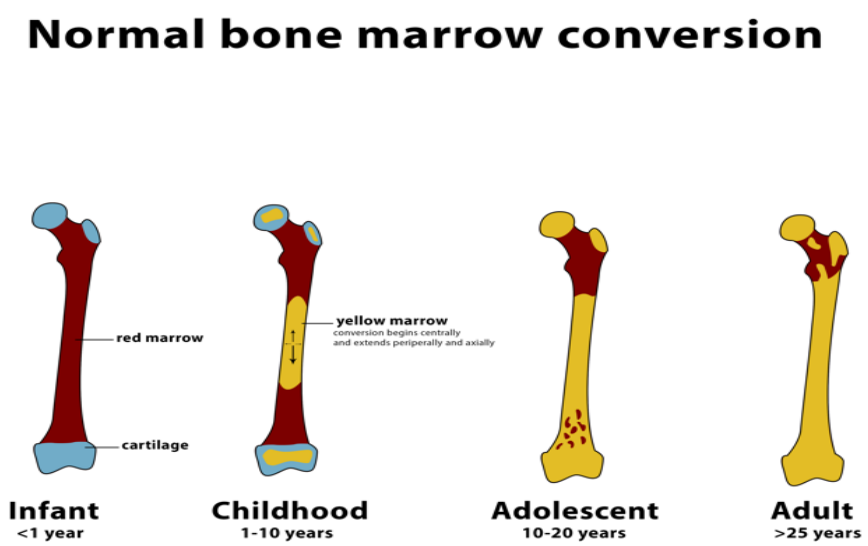


Fig 1. 7: a Progression of conversion from red to yellow marrow within an individual long bone occurs in the following sequence: epiphyses and apophasis first, then the diaphysis, followed by the distal metaphysis, and finally the proximal metaphysis. Conversion also occurs in a centri petal fashion within a bone with fat predominating centrally, whereas red marrow predominates at the outer margins or periphery (subcortical region) of the medullary space of flat bones, long bones, and vertebral bodies , quoted from (**Dennis J., 2008).**

MRI signal charecteristics of bone marrow in different pulse sequences

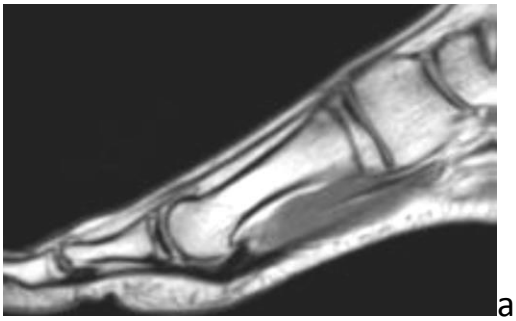
The MR signal depends on three parameters; inherent to specific tissue proton density, T1 relaxation time, and T2 relaxation time. By selecting the appropriate MR pulse sequence, we can enhance one of these tissue properities. Proton density images contribute little to the appearance of the bone marrow because proton densities of various tissues differ little. There are

many MR sequences with specific use in the study of the bone marrow (**Vanel D. et al, 2004).** .

T1-weighted images:

On T1 weighted images tissue contrast is determined primarily by T1 characters(fig**1.8)**. Fat has a short T1 relaxation time and is hyperintense (bright) on T1 weighted images. Fatty marrow because it is composed primarily of fat has a characteristic bright signal, similar to that of subcutaneous fat. Water, on the other hand, has a long T1 relaxation me and is hypointense (dark) on T1 weighted images. Tissues rich in water such as cerebrospinal fluid are dark on T1 weighted images (**Kellenberger C., 2004).**

Red marrow is composed of 40% water, 40% fat, and 20% protein. On T1 weighted images, red marrow is considerably darker than fatty marrow and has signal intensity similar to or slightly higher than `muscles. The bright signal of fatty marrow facilitates the detection of marrow lesion, the vast majority of which have a longer T1 relaxation time than fat. However marrow lesion may have similar T1 relaxation time to red marrow, and their detection on a background of hematopoietic marrow may be difficult with T1 weighted MR images alone (**Kellenberger C., 2004).**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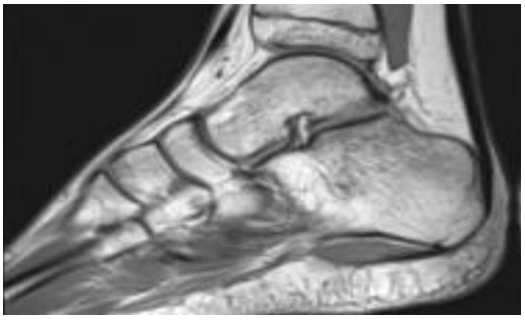
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Fig **1.8:** thirteen years old female: Normal foot T 1 Weighted image quoted from (**Vanel D., 2004).**

T2weighted images:

fat has a short T2 relaxation time, which means that, on T2 weighted images, in which T2 characters prevail, fat is less bright and the signal intensity of fatty marrow decreases. Water has a long T2 relaxation time and is bright on T2 weighted images. The appearance of red marrow on T2 weighted MR images vary slightly. It usually shows a small increase in signal becoming slightly brighter than muscle. The vertebral bodies on T2 weighted images are darker than the intervertebral discs, unless the discs are degenerated **(Moulopoulos, 1997).**