Role of MRI Zero Echo Time in the Evaluation of Bone Lesions

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ABSTRACT:
BACKGROUND:
Assessment of bone tumors needs more than one imaging modality. Zero echo time (ZTE) MRI is a high-resolution and rapid sequence. It gives an enhanced bone contrast in MR imaging and may obviate further need for CT and its attendant ionizing radiation
OBJECTIVE:
To evaluate clinical applicability of zero time echo magnetic resonance imaging in the assessment and evaluation of bone lesions (tumors and tumor like conditions) in comparison with CT.
PATIENTS AND METHODS:
21 patients (7 males and 14 females) were included. ZTE MRI was done for all patients included in the study. Quality assessment of bone findings was performed between ZTE and CT using a 5 point grading scale. The findings were considered significance with $P < 0.05$. Agreement was assessed between the raters and Weight Kappa statistics were used. Interpretation of agreement was based on published standards: 0.00–0.20Indicated slight; 0.21–0.40, fair; 0.41–0.60, moderate; 0.61–0.80, substantial; and 0.81–1, perfect agreement.
RESULTS:
In this study, 6 types of bone tumors and tumor-like lesions. The image quality between ZTE and CT imaging showed good agreement between the 2 raters (K = 0.93, K = 0.81) in the bone tumors. ZTE-MR XIII and CT had similar displays in assessment of lesion boundary, periosteal reaction, bone sclerosis, bone destructions, calcifications, and soft tissues.
CONCLUSION:
ZTE is radiation-free bone imaging and provides image contrast similar to that CT. ZTE-MR can meet the diagnostic requirements of bone assessment, but also presented better tumor boundary and extra or intraosseous soft tissue components in some cases. ZTE-MR can be used as an alternative to CT.
KEYWORDS: Zero time echo, Bone lesions, Magnetic resonance.

INTRODUCTION:
Bone tumors and tumor-like conditions require that extensive radiological imaging assessment [1]. The evaluation often requires > 1 imaging modality (including x-ray, bone scan, CT, MRI and PET). Conventional x-ray is usually the initial step in the assessment process, and is an essential tool in assessment of lesion aggressiveness and assesses response. CT is very useful in conditions affecting complex bones (e.g., the spine or pelvis), where conventional x-ray fail due to limited contrast resolution, complex anatomy and/or superposition of skeletal elements. It is more sensitive than

conventional MRI for visualization of fine bony details or small foci of calcifications. CT is the best modality in detecting and assessing cortical alteration, periosteal reaction and matrix calcifications [2].
MRI is considered as the best imaging investigation used for the assessment of bone tumors of the appendicular skeleton and is used for assessment of the origin, anatomic extent and accurate detection of the margins of bone tumor [3]. MRI-based bone evaluation can provide valuable assessment of the surrounding tissues including tendons and muscles [4]. Conventional MRI pulse sequences detect cortical bone as signal void area because of short T2 relaxation time of cortical bone [5].

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The advent and refinement of Zero time echo (ZTE) MRI techniques, it is now possible to directly visualize and quantitatively characterize these tissues [6, 7]. It provides a near-zero-time interval between the end of the radiofrequency (RF) excitation and the beginning of data acquisition. Unlike the conventional MRI RF pulse sequences, the ZTE begins data acquisition immediately after the RF pulse, giving the possibility of visualization of tissue with short T2 relaxation such as cortical bone [8].

ZTE is a rapid and high-resolution sequence and [9] provides good bone contrast in MR imaging and may obviate the need of CT and its adverse ionizing radiation [10]. Signals are acquired directly after the application of the RF pulse, the echo time is 8ms [1]. Inverse-logarithmic rescaling of ZTE images gives us contrast between soft tissues and cortical bone producing images comparable to that of CT. (the cortical bones show high signals similar to that in CT image) [11]. In order to increase image contrast, inversion recovery technique has been used which suppress long-T2 signal [12].

AIMS OF STUDY:

To demonstrate the clinical applicability ZTE magnetic resonance imaging sequence in the assessment of bone tumors and tumor-like lesions in comparison with CT.

PATIENTS AND METHODS:

Twenty one patients presenting with bone tumors or tumor-like lesions were included in this cross sectional analytic study, which was done in Al-Imamian Al-Kadhymiian Medical City/ Baghdad/ Iraq during the period from June 2020 to January 2021, 7 were males and 14 were females.

Inclusion criteria: patients with bone tumor and tumor like lesions evident on CT exam. Exclusion criteria: patients with general contraindication to MRI.

Ethical consideration: the study was approved by scientific committee of the Iraqi Board of diagnostic radiology. An oral informed consent was obtained from all participants.

CT date acquisitions: CT was conducted using Somatome definition AS (Siemens medical system, Germany). Section thickness was 1mm. FOV 290mm, pixel size 0.273-0.559mm, matrix 256x256.

ZTE MRI date acquisitions: MRI was performed using a 3T MR system (Achieva, Philips medical system, Netherland). The following parameters were used: TE, 3.3ms, TR, 25ms; FOV 160x160mm; slice thickness 1mm; flip angle less than 2 degree, matrix size 276x276; image voxel resolution 0.58×0.58, Scanning time 6min.

Imaging interpretation: patients were the above mentioned in the inclusion criteria, full history and demographic data were taken. In most of the patients ZTE- MR and CT imaging examinations were performed on the same day. ZTE image were co-registered to CT to ensure similar image planes and to minimize variance from multi-planar reformatting in the assessment and scorning the feature. The CT and ZTE images were randomly reviewed using 5 point grading system: 1.Very poor: no clear anatomic details, not sufficient for diagnosis: 2. Poor: no clear anatomic detail, anatomic structures are not sufficiently detectable: 3. Fair: most anatomic structures are sufficient for diagnosis, but some picture are inadequate for evaluation: 4. Good: anatomic structures and details are present in a level that allows proper but not excellent evaluation of the images: and 5. Excellent: distinct anatomic detail leading to clear and easy evaluation. The imaging characteristics such as lesions boundary, periosteal reaction, bone sclerosis, bone destruction, calcification and soft tissue were compared between CT and ZTE-MR.

Imaging analysis: 3D mFFE (multi-echo fast field echo sequence) which is summation of T2*weighted multi-echo images give a high SNR and good contrast between cartilage and synovial fluid. T2* relaxation is the decay of transverse magnetization produced the combination of spin-spin relaxation and magnetic field inhomogeneity. T2* relaxation is seen only with gradient-echo (GRE) imaging because transverse relaxation produced by magnetic field in homogeneities is eliminated by the 180° pulse at spin-echo imaging. The values of T2* are always shorter than the underlying T2 values. The minimal gradient switching between repetitions decreases eddy currents to a negligible level and minimizes acoustic noise level. The imaging encoding starts directly after the end of the RF excitation to fill the center of the *k*-space. The RF duration must be short (about 3.3mm), and the flip angle is limited in ZTE to decrease the delay between the RF pulse and the transmit-to-receive switching time. In addition, the excitation bandwidth is limited.

As a result, 4 images in each slice with different echo time (TE). After that algorithm was used in the setting called imaging Algabera, this images undergo summation to get a new imaging with good quality. The final dataset of image ere further post processed and applying inversion logarithmic image rescaling, the final resultant image reveals excellent cortical bone delineation.

Statistical analysis: the data were analyzed using SPSS (statistical package for social sciences) version 25. The data were categorized as mean, standard deviation and ranges. Categorical data presented by frequencies and percentages. Independent t-test (two tailed) was used to compare continuous variables accordingly. Chi square test was used in order to assess the comparison in image characteristics between both methods of examination, while fisher exact test was used instead when the expected frequency was less than 5. The level of P value less than 0.05 was stated as significant.

RESULTS:

The studied patients were 21. All of them were presented with bone tumor and tumor like lesion.

Age and gender: Study patients' age was ranging from 14 – 59 years (mean 35.33±15.8 years). The highest number of study patients was aged < 40 years (52.4%).

Regarding gender, the number of females was higher than males (66.7% versus 33.3%), male to female ratio of 1:2.

Diagnosis: Table 1 demonstrates the distribution of studied patients by diagnosis. The most common findings were osteochondroma and metastatic lesions (28.6% for each one).

Table 1: Distribution of study patients by diagnosis.

Diagnosis	No. (n= 21)	Percentage (%)
Osteochondroma	6	28.6
Metastasis	6	28.6
Bony destructive TB	3	14.3
Non ossifying fibroma	2	9.5
Stress fracture (Bone like lesion)	2	9.5
Enchondroma	2	9.5

CT scan and ZTE MRI examination consistency analysis: The comparison between the 2 radiologists regarding consistency of each method of examination is shown in table (2). We noticed that no significant differences in consistency analysis between the 2 radiologists regarding both methods and degree of agreements for CT-scan and ZTE MRI examination were (93% and 81% respectively)

Table 2: Comparison between the 2 radiologists regarding consistency of each method of examination.

Consistency analysis	Radiologist 1 (Mean ± SD)	Radiologist 2 (Mean ± SD)	Kappa Value
CT scan	4.94 ± 0.21	4.91 ± 0.2	0.93
Zero echo time MRI	4.89 ± 0.33	4.83 ± 0.29	0.81

Findings: In this study, there were no statistically significant differences (P ≥ 0.05) detected between CT scan and ZTE MRI regarding all characteristics of the images. These findings were demonstrated in table 3.

Table 3: Comparison in image characteristics between ZTE and CT.

Image Characteristics		Method of Examination		P - Value
		CT no (%)	ZTE MRI no (%)	
Lesion's boundary	Well defined	13 (61.9)	15 (71.4)	0.512
	Ill Defined	4 (19.0)	6 (28.6)	0.468
Soft Tissue		3 (14.3)	5 (23.8)	0.431
Periosteal Reaction		2 (9.5)	1 (4.8)	0.549
Bone destruction		3 (14.3)	3 (14.3)	<1.0
Bone sclerosis		3 (14.3)	2 (9.5)	0.633
Calcification		1 (4.8)	1 (4.8)	<1.0

Bone structures were clearly demonstrated on the ZTE MR images and matched well with the images obtained by CT. Figure 1 shows images of some patients included in the study

Fig.1Aand B: 27years old male presented with pain and lumping in the LT leg, ZTE-MR (a) and co-registered coronal CT (b) images of the same patient show exostosis. Fig.1 C and D: 6-year-old male presented with RT thigh pain .ZTE-MR (a) and co-registered CT (b) images non-ossifying fibroma of the right lower femur

DISCUSSION:

Bone tumors accounted for 2-3% of body tumors [13]. With advancement of diagnostic imaging, bone tumors detection rate has significantly increased. ZTE is the newest technique with short-TE, and can successfully image short-T2/T2* structures (cortical bone, meninges, cartilage, tendons, ligaments, calcium, airway, and lungs) [14]. The addition of ZTE bone sequence would enable highly efficient and radiation-free evaluation in several pediatric neuroimaging, head/neck imaging, and musculoskeletal imaging scenarios. Inversion recovery techniques can also give T1-weighted ZTE images which are beneficial for assessing brain and spinal cord myelination, pituitary imaging, vessels, and airways [8]. Compared with conventional T1, T2 and proton density imaging, ZTE imaging is another breakthrough in MR field. It is constantly developing, and is incentive methods and reconstruction algorithms are also constantly improving [5].

In the current study, ZTE MRI yielded acceptable image quality with substantial interobserver agreement. There was no statistically significant difference, though the mean ZTE MR can meet the needs of clinical diagnosis [15]. The consistency analysis between the 2 reviewers in MRI and CT groups demonstrate a good consistency between ZTE-MRI and CT (K = 0.93, K = 0.81) as seen in (Table 3.2). Agreement interpretation was based on published standards (0.00–0.20 indicated slight; 0.21– 0.40 fair; 0.41–0.60 moderate; 0.61–0.80 substantial; and 0.81–1 perfect agreement) in comparison with previous study [1]. ZTE was used to investigate patients with bone tumors and tumor like lesions, and well showed the destructions of bone cortex in bone tumors in 2/2 patients (<1.0%). In addition, ZTE MRI provided added information about soft tissues extension and architecture of tumor. Soft tissue extension was seen in 3/5 patients (0.431%), ZTE MRI still stains good soft tissue resolution like conventional MRI, and good inter-observer agreement in comparison to a previously reported study [1]. Also assessment of the lesions boundary (well define and ill define), periosteal reaction, bony sclerosis and calcification

showing good agreement in comparison to CT images, these finding were similar to the results of previously reported studies [1, 10]. ZTE- MR imaging could produce bone images close to that of CT and suggest that it could be a valid alternative to CT for bone imaging in different clinical situations. Furthermore, these findings also support that reported in previous studies [1, 10, 14, 15] that suggested possible technical applications to develop attenuation correction algorithms. MRI examination can not only show the cortex of the patients with bone tumors and tumor like lesion, but also show the soft tissue manifestation of these conditions [1].

For all 21 patients, ZTE MRI was successfully acquired, and bone tumors and tumor like lesions were depicted as clearly on the ZTE MRI as on the CT. The findings of the current study for detecting bone abnormalities were identical to those reported in a recent study done by Breighner RE et al [16], which showed acceptable agreement for evaluating bony lesions in the shoulder between raters and modalities. In the present study, the CT like image with positive contrast for the bone lesions obtained by post processing allowed more intuitive interpretation for assessing the bone and it is in agreement with the previous study, despite differences in the applied anatomic sites.

The findings in the current study confirm that ZTE MRI gives an accurate imaging of bone architecture with similar image contrast to CT that is not possible with the conventional MR sequences. This is more useful for young patients with benign lesions, as multiple long term follow up examination may be required for lesions monitoring and cumulative substantial radiation exposure. Overall, MRI could provide accurate evaluation of soft tissue and bone structure in any bone lesions within single examination [17].

CONCLUSION:
ZTE is a good technique and radiation-free bone imaging. It provides image contrast similar to that CT. ZTE-MR can meet the diagnostic requirements of bone instruction with good tumor boundary and extra or intraosseous soft tissue component in some cases. In case of bone tumors or tumor like lesions, ZTE-MR can be used as an alternative to CT.

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