3 Tesla Zero TE Imaging of the Hip

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Disclosures

• David W. Stanley B.S.R.T. is employed by GE Healthcare

• Dan W. Rettmann B.S. is employed by GE Healthcare

• PSD is a works in progress; exams performed under IRB approved research protocol
Objectives

• Review cross sectional and 3D applications in the structural evaluation of the hip
• Discuss zero echo time (ZTE) bone imaging of the pelvis and hip
• Discuss the basics of 3D rendering
Introduction

Background

• Structural hip abnormalities have become a major focus in orthopedic surgery.

• Hip dysplasia has long been known to contribute to accelerated osteoarthritis of the hip.

• More recently, femoroacetabular impingement has been implicated as a mechanism for the development of osteoarthritis in non-dysplastic hips.

Introduction
Femoroacetabular Impingement

• Cam-type FAI
  • Caused by an aspherical femoral head
  • Decreased femoral head-neck offset
  • Anterolateral osseous bump results in “pistol grip” finding on radiographs
Introduction

Femoroacetabular Impingement

• Cam-type FAI
  • The alpha angle on CT and MRI is an indicator of cam morphology
  • Normal alpha angle on CT and MRI on axial oblique plane is <55°

Alpha Angle Measured on a Pelvic CT Performed for the Evaluation of FAI
Introduction
Femoroacetabular Impingement

- Pincer type impingement
  - Acetabular over coverage
- General
  - Coxa profunda
  - Acetabular retroversion
- Focal
  - Anterior
  - Posterior
Introduction
Femoroacetabular Impingement

• Pincer type impingement
  • Various measurements reported on cross sectional imaging studies

Acetabular Anteversion Measured on a Pelvic CT Performed for the Evaluation of FAI
Introduction
Femoroacetabular Impingement

• The most common FAI type is mixed from cam and pincer morphology and the abnormalities can be complex

• Patients often undergo CT for:
  • Confirmation of structural abnormalities that may be difficult to appreciate on radiographs
  • Creation of 3D images to aid in surgical planning

• Although some measurements can be made on standard MR sequences, the 3D models cannot

Zero Echo Time Bone Imaging
3D Imaging Processing

• CT is optimal for the creation of 3D images of osseous anatomy:
  • High spatial resolution
  • Rapid acquisition and availability
  • High contrast between bone and soft tissues

Zero Echo Time Bone Imaging
3D Imaging Processing

• Generation of 3D model from CT requires little time and technologist training.

• The drawback of CT is the radiation exposure in the young and typically healthy population with hip pain.

Zero Echo Time Bone Imaging

• Challenges in MR of cortical bone
  • Cortical bone has a low proton density (15-20% free water by volume)
  • Cortical bone has a fast decay time (T2* of 390 µS at 3T)
  • High resolution, isometric voxels are required for 3D rendering

Zero Echo Time Bone Imaging

• ZTE Pulse sequence
  • Nonselective pulse excitation
  • 3D center out radial sampling
  • Gradients are not ramped down between repetitions
  • Encoding starts immediately at the time of excitation, TE=8µs

Zero Echo Time Bone Imaging

Parameters

- Imaging was performed on 3.0T Discovery MR750W (GE Healthcare, Waukesha, WI, USA)
- 32 channel body array
- 40 cm
- TR ~ 400ms
- Matrix 320 x 320
- Nex = 4
- BW 62.5 kHz
- Resolution 1.3-1.6 mm
- Scan time ~ 4-6 minutes
ZTE image prior to logarithmic rescaling of the normalized image intensities
Zero Echo Time Bone Imaging

• The intrinsic properties of ZTE creates two histogram intensity peaks:
  1. Lower Peak:
     • Cortical Bone
     • Gas
  2. Upper Peak:
     • All other tissues (muscle, fat, tendons, ligaments, fluid)

Zero Echo Time Bone Imaging

• Automatic Post Processing:
  • A histogram-based intensity correction algorithm is applied as described by Wiesinger et al.
  • A logarithmic rescaling is used to enhance cortical bone
  • This aids in threshold segmentation

• Non-rescaled axial ZTE image of the pelvis
  • Slice Thickness 1.3mm
  • Acquisition time 6:11

• Logarithmic rescaled image with greyscale inversion
• Non-rescaled axial ZTE image of the pelvis
  • Slice Thickness 1.6mm to shorten time and increase SNR
  • Acquisition time 3:58

• Logarithmic rescaled image with greyscale inversion
Standard Cross Sectional Measurements Performed on 2D reformatted ZTE images

Acetabular Anteversion 19.5°

Alpha Angle 55.8°
2D ZTE Femoral Neck Radial Reformats for Head/Neck Morphology
Zero Echo Time Bone Imaging
3D Imaging Processing

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3D Generated Models
Maximum Intensity Projections

• Requires minimal processing time
• Lack detail of 3D models created from CT

ZTE MIP
Zero Echo Time Bone Imaging
3D Imaging Processing

• Segmentation:
  • Refers to the process of converting pixels from a 2D image set into a 3D object
• Requires:
  • Isometric voxels
  • High resolution
  • High contrast between the bones and soft tissues
Zero Echo Time Bone Imaging

3D Imaging Processing

• Threshold:
  • Accepting or rejecting the pixels within a dataset based on greyscale pixel value
  • Limited in standard MR techniques
  • Starting point for ZTE bone segmentation

Raw threshold of the hemipelvis from ZTE
3D Image of the Pelvis and Hips Generated from a 1.3 mm ZTE Acquisition

Created with Materialise 3-Matic® and Mimics ® (Materialise, Leuven, Belgium)
3D Image of the Pelvis Generated from a 1.3 mm ZTE Acquisition

3D Generated Model with Wrapping and Smoothing

3D Generated Model with Overlying Mesh

Created with Materialise 3-Matic® and Mimics ® (Materialise, Leuven, Belgium)
3D Image of the Proximal Femur
Generated from a 1.3 mm ZTE Acquisition

Created with Materialise 3-Matic® and Mimics ® (Materialise, Leuven, Belgium)
Zero Echo Time Bone Imaging
3D Imaging Processing Limitations

- Fascial Plane Artifacts:
  - Occur at muscle interfaces and fascial planes
  - Artifact is easy to remove in post processing as it is remote from cortex
Zero Echo Time Bone Imaging
3D Imaging Processing Limitations

• False Positive Bone Voxels:
  • Occurs at the surface of the cortex
  • Difficult to remove in 3D post processing
  • 3D smoothing and wrapping algorithms are helpful, but lead to artifactual bone contours

Artifact at 1.3 mm
Artifact at 1.6 mm
Zero Echo Time Bone Imaging
3D Imaging Processing Limitations

• Thin Cortical Bone:
  • Some areas of thin cortical bone are not detected
  • This results in cortical defects in 3D models

Thin Cortex of Posterior Femoral Head
Conclusion

• This ePoster reviews our initial experience with ZTE in osseous evaluation of the pelvis and hips
• As this has only been attempted in several volunteers, further evaluation is required
References


