Academic Radiology
Available online 13 May 2021
In Press, Corrected Proof

Original Investigation

Bone Marrow Fat Distribution in Patients With β-Thalassemia: A Study Using Chemical Shift-Based Water-Fat MRI

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https://doi.org/10.1016/j.acra.2021.03.028

Rationale and Objectives

Molecular studies have shown the changes in bone marrow fat in relation to altered hematopoiesis. This study aims to investigate the changes in the bone marrow fat in patients affected by β-thalassemia by using chemical shift-encoded (CSE)–MRI.

Materials and Methods

Twenty-three subjects, comprising of six healthy (17-31 years old) and 17 β-thalassemia subjects (19-39 years old), were scanned using a multiecho fast low angle shot sequence ($0.94\times0.94\times3.00$ mm^3) and a stimulated echo acquisition mode sequence using 3T MRI. Bone marrow proton density fat fraction (PDFF) was quantified in the left femur of each subject. Regression and Bland-Altman analysis were used to analyze agreement between CSE-MRI and 1H-MRS. PDFF distribution was analyzed using Hartigan's dip test and the computed Wasserstein distances. Jonckheere-Terpstra trend analysis was performed to evaluate the effect of disease severity on PDFF distribution.

Results

An excellent agreement was found between PDFF measured using CSE-MRI with ^{1}H-MRS (R^2=0.91; bias =-1.41%). Healthy subjects showed left-skewed or bimodal PDFF distribution while β-thalassemia subjects showed bimodal, normal or right-skewed distribution. Jonckheere-Terpstra test shows that PDFF distribution was increasingly different from the norm as disease severity increased (T_{JT}=166.0, z=3.806, p < 0.05). Increase in variability of PDFF distribution within each subject group was also seen with increasing disease severity (T_{JT}=169.0, z=3.971, p < 0.05).

Conclusion

CSE-MRI is a promising tool to demonstrate spatial changes and variability in marrow fat distribution, resulting from ineffective erythropoiesis.

KEY WORDS

Bone marrow; Ineffective erythropoiesis; Chemical shift-encoded MRI; β-thalassemia; Hematopoiesis

Abbreviations: CSE, Chemical Shift-Encoded; cMAT, Constitutive Marrow Adipose Tissue; EMD, Earth-Mover's Distance; TE, Echo Time; ECDF, Empirical Cumulative Distribution Function; FLASH, Fast Low Angle Shot; FOV, Field Of View; FA, Flip Angle; GRAPPA, Generalized Autocalibrating Partially Parallel Acquisitions; HSD, Hartigan's Dip Statistic; HPLC, High Performance Liquid Chromatography; IE, Ineffective Erythropoiesis; MRI, Magnetic Resonance Imaging; MRS, Magnetic Resonance Spectroscopy; MSC, Mesenchymal Stem Cells; NAFLD, Non-Alcoholic Fatty Liver Disease; PDFF, Proton Density Fat Fraction; QPBO, Quadratic Pseudo-Boolean Optimization; rMAT, Regulated Marrow Adipose Tissue; TR, Repetition Time; SD, Standard Deviation

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