Bone marrow in the proximal femur: Creation of a method to get reproducible values of MRI signal intensity by using standardized regions of interest

N. A. Ghanem[1], D. Schmitz[2], C. Altehoefer[2], H. Sturzenecker[2], M. Büchert[2], M. Langer[2]

[1]Dept. of Diagnostic Radiology, University Hospital Freiburg, Freiburg, Germany, [2]Dept of Diagnostic Radiology, University Hospital Freiburg, Freiburg, Germany

Abstract

Observation of bone marrow in the proximal femur enables the detection and control of changes of bone marrow. The purpose of this study was to show the reproducibility of signal intensity measurements in MRI.

Repetitive measurements were taken to validate reproducibility within one observer. In three regions the relative error was lower than 10%. The results of two observers were compared to look for hints onto reproducibility within different observers. The comparison of three different regions for normalization showed that from this selection the adductor muscle is best suited. Normalized signal intensities in the metaphysis of competitive athletes determined with this method correlate with some hematological data.

Introduction

Examination of bone marrow by MRI to find out changes in its activity is a highly sensitive process in radiological diagnostics[2]. It provides valuable diagnostic information about the alterations due to marrow infiltration, application of hematopoietic growth factors and bone marrow hyperplasia. In order to detect small changes in signal intensities it is necessary to apply a quantitative analysis[1-3]. The femur is a typical region for reconversion of red to yellow bone marrow[4].

Methods

For the measurements of the proximal femur in a sagittal plane with a slice thickness of 4 mm there was used a 1,5 tesla tomograph (Magnetom Symphony, Siemens, Erlangen, Germany) with a body coil for signal reception. The following echo sequences and parameters were selected: T1 weighted SE (TR 500/TE 15), TIRM (TR 4500/TE 60/TI 150), Opposed phase (OPP) (TR 250/TE 6,8), Subtract (IP-OP) (TR 250/TE 4,6).

To register signal intensity in the bone marrow of the proximal femur four different regions of interest (ROI) were set (ROI 1 = metaphysis, ROI 2 = proximal diaphysis, ROI 3 = distal diaphysis, ROI 4 = femur, including metaphysis and diaphysis). To normalize the signal intensities and to compare quantitative assessments of bone marrow signals three different circular reference regions were set in the same slice (ROI 5 = greater trochanter, ROI 6 = adductor muscle and ROI 7 = the specific noise between the legs of the proband) (Fig 1a + b).

For validation fifteen healthy male volunteers (mean age 22 years, range: 19-24) were included in this prospective study and were examined by two observers independently. The results of the measurements of one observer and the ratios (ROI 1-4 / ROI 5-7) were compared by computing the relative error. Furthermore the averaged measurements of the two examiners were compared for all test persons to look for hints onto reproducibility within different observers. This was done using a two population t-test for paired values. P-values < 0,05 were considered to represent significant differences.

As a first application of the method twelve healthy competitive athletes (mean age 23 years, range: 18-30) examined by one observer were included in the study to compare the normalized signal intensities with hematological data (erythrocytes, hemoglobin, hematocrit, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), reticulocytes, leucocytes, ferritin) via linear regression.

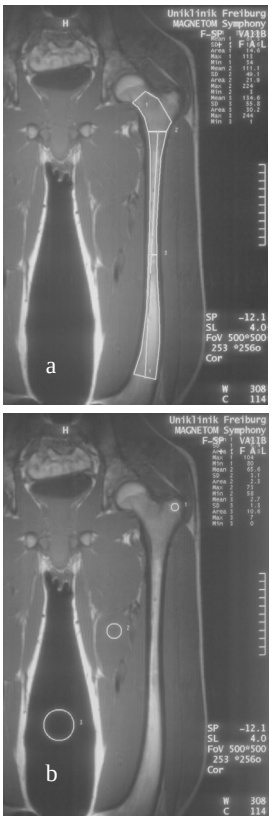

Fig. 1: T1 sequence demonstrating (a) ROI 1 to 4 (b) ROI 5 to 7

Results

The investigation of the reproducibility within one observer showed relative errors in one or more than one sequence higher than 10 % for ROI 2 (proximal diaphysis), ROI 5 (major trochanter) and ROI 7 (specific noise). An error lower than 5 % for both observers in the same sequence only was found in T1 (ROI 1), IP-OPP (ROI 1) and TIRM (ROI 4). Most often ROI 1, 4 and 6 belonged to the regions with the lowest error (OPP, T1 and IP-OPP). The signal intensities, that were normalized with the ROI 6 (adductor muscle), showed in every sequence the lowest relative errors (Table 1). Comparing the signal intensities of ROI 1, 4 and 6 between the two examiners there was a significant difference in each sequence. Normalized signal intensities and hematological data showed a linear correlation only in OPP for MCH (r=0,56, p=0,05) and MCHC (r=0,57, p=0,05) (Table 2).

Discussion

The bone marrow of the femur is a typical region to look for changes like decrease or increase of red bone marrow or lots of bone marrow disorders[2]. To detect changes of red bone marrow MRI is a highly sensitive method [1]. Next to visual analysis there are also used quantitative analysis for the measurement of signal intensity [3]. In this context our method is the next logical step. By defining standardized regions of interest and computing signal intensities for them we are able to compare different images. This requires reproducibility of the data. We have shown reproducibility within one observer for the same picture with a relative error for the metaphysis smaller than 5%. Normalization debases these results but we still get an error mostly smaller than 10% (adductor muscle). Up to now the method is not exact enough to make the results of different observers comparable. A more detailed description of the definition of the ROI seems to be necessary.

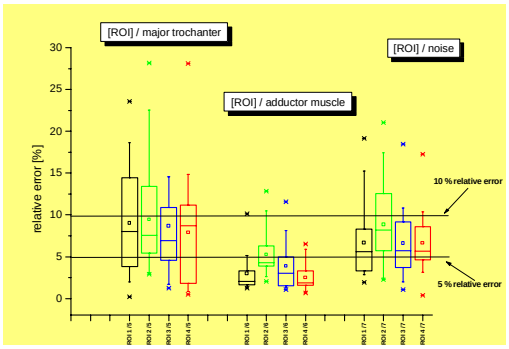

Table 1:Example for results of relative error in nSI OPP sequence

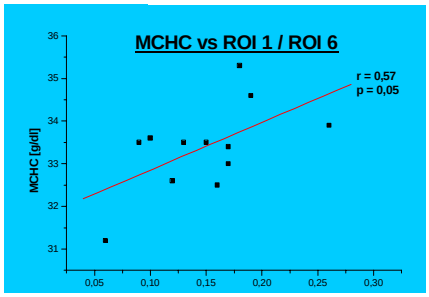

Table 2: indicating a significant correlation between MCHC and nSI in OPP-sequences in athletes

In conclusion we found a correlation between normalized signal intensities in the metaphysis and hematological as it was shown in results of former studies[3]. In agreement to the published data the correlation was found in the opposed phase gradient echo sequence [4].

References

1. Altehoefer C. et al., *J Magn Reson Imaging* 14, 141, 2001.
2. Vogler J B et al., *Radiology* 168: 679, 1988.
3. Ghanem N. et al., *Proc Intl Soc Mag Reso Med* 10, 2002.
4. Lang P et al., *Fortschr Röntgenstr*, 156, 89, 1992.