MRI SEQUENCE EVALUATION FOR NON-INVASIVE BIOMETRY OF SPINAL STRUCTURES

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ABSTRACT

To determine clinical acquisition sequences allowing best visual identification of skin, fat, vertebrae and muscles, magnetic resonance images (MRI) of 81 scoliotic patients were reviewed. Three investigators rated the contrast of all images. Each sequence provided acceptable results for skin and subcutaneous fat. Fast spin echo sequence was found more appropriate for vertebrae and spin echo provided the best contrast between muscles. Subcutaneous fat thickness was found to influence the level of contrast in MRI of the back.

INTRODUCTION

In adolescent idiopathic scoliosis (AIS), abnormal curvature of the spine is usually accompanied by a larger electromyographic (EMG) signal on the convex side [1,2]. EMG asymmetry may also be attributed to imbalanced neural input [3]. Asymmetry can be observed in cross-sectional areas (CSA) of MRI along the scoliotic spine but good contrast between the anatomical structures of interest is required for reliable results [4]. Muscular information is also needed in biomechanical models of spinal deformities aimed at providing new understanding on the etiology of AIS [5].

The most important parameters of any MRI sequence are TE (echo time) and TR (repetition time). By varying their relative value, the contrasts of fat, water, and protons can be modified. MRI units are capable of numerous pulse sequences including partial saturation, and inversion recovery [6]. Many of these sequences are specific to the manufacturers.

Our purpose is to identify relevant parameters that influence the contrast of MRI in order to make the segmentation of muscles, skin, subcutaneous and infiltrated fat, and even the skeleton easier. This would facilitate the analysis of spinal deformities.

MATERIALS AND METHODS

From the picture archiving and communication system (PACS) of the hospital[1], MRI of 81 scoliotic patients were retrieved: 510 series (15 ± 8 slices each) from 34 boys (11.5 ± 4.6) and 47 girls (age 11.4 ± 5.1). The sequences used in this study are: gradient recalled echo imaging (GRE) as a localizer, spin echo (SE), turbo spin echo (TSE), and fast spin echo (FSE). Not designed specifically for muscular biometry nor for fat infiltration studies, those sequences are mostly used on scoliotic patients. From this databank bank, 35 patients whose series included the three sequences mentioned above were selected for evaluation.

Quality was assessed by 3 persons. Each of them spent approximately 30 hours to rate the contrast of fat (subcutaneous and infiltrated), muscle and skeleton. Ratings ranged from 1: blurred to 5: excellent.

RESULTS

Principal characteristics of the evaluated acquisition sequences are shown in Tab.1. GRE has the shortest TE while FSE has the largest one. In all 337 SE sequences, TE was fixed at 20 ms, and TR within a range from 450 ms up to 1 s. For each sequence, pixel dimensions are □1 mm, and slice thickness □ 4 mm.

Mean ratings of the 3 observers are presented in Tab.2. As illustrated, FSE sequence is more appropriate for bone imaging while GRE is not very good. SE sequence can be used for all structures; particularly a good contrast is obtained for subcutaneous fat and muscles, but satisfaction was reduced for infiltrated fat. TSE is not compared with the others, but gives excellent results with height series from only one patient.

Contrast was also assessed according to patients' sex, age, skin and subcutaneous fat. From our preliminary analysis, only subcutaneous fat is correlated with image contrast (Fig.1). In general, images of patients with larger subcutaneous fat thickness (i.e. >10 mm) showed improved contrast for identical sequence parameters (not illustrated). In this study, 6 patients who have the best contrasted images had in common a large skin thickness varying from 17.8 to 30.0 mm, while 12 patients with fat thickness ranging from 2.3 to 6.8 had blurred images.

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Table 1: Pulse sequences and acquisition parameters sorted according to pulse sequence name. GRE is a localizer (positioning sequence), while FSE, SE and TSE are the clinical sequences.

Pulse sequence	Sequence parameters				#series
	TR (msec)	TE (msec)	Pixel dim (mm)	Slice thickness (mm)	
FSE (Fast Spin Echo)	3500 - 4600	90 - 126	0.63 - 1.00	3-10	75
GRE (Gradient Recalled Echo)	25	5-5.27	1.87 - 1.88	9	90
SE (Spin Echo)	450 - 1000	20	0.75 - 1.00	1-10	337
*TSE (Turbo spin echo)	564-3200	14-124	0.49 - 0.78	4-5	8

*TSE is not compared with the other sequences for lack of data (8 series from 1 subject)

Table 2: Evaluation scores for 35 patients: mean ± SD (mode).

sequence	fat		muscle	skeleton
	subcutaneous	infiltrated		
FSE	**3.6 ± 1.1 (4)**	2.0 ± 0.8 (2)	1.9 ± 1.0 (1)	**3.9 ± 1.3 (5)**
GRE	2.5 ± 1.2 (3)	1.3 ± 0.5 (1)	1.9 ± 0.9 (1)	1.4 ± 0.6 (1)
SE	**4.4 ± 0.9 (5)**	**3.4 ± 1.4 (3)**	**3.7 ± 1.2 (5)**	**4.0 ± 1.1 (4)**

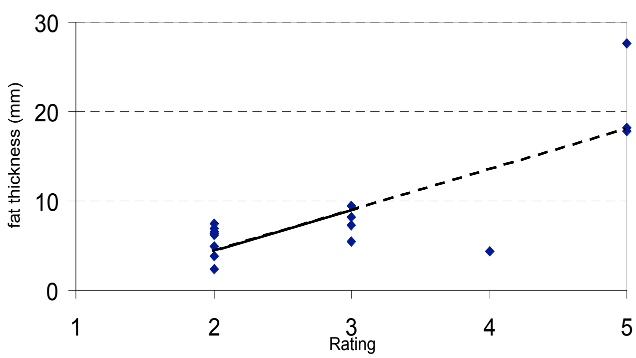

Figure 1: Correlation between fat thickness and MRI contrast ($p<0.001$, $r=0.81$). Larger subcutaneous fat thickness aims to better image contrast.

DISCUSSION

MRI sequences with scoliotic patients have been evaluated for the contrast they provided. For bone segmentation, FSE appears the most appropriated sequence while for muscle segmentation, SE is the best choice. As with SE, 8 TSE series from one patient showed a very good contrast for all structures. But more TSE series are needed to validate this result. One advantage of SE over a specific sequence such as FSE is its ability to image other anatomical structures of interest (skin, fat, bone) with a good contrast. One advantage of TSE is its shorter acquisition time due to a larger flip angle than FSE.

It thus seems that each structure has a MRI sequence by which best contrast can be obtained. With further studies, those sequences may be optimized in order to obtain more contrasted images. Therefore, (semi) automated segmentation could be used.

Attention should be paid to subcutaneous fat thickness to refine acquisition parameters.

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