Automatic Determination of the Imaging plane in Lumbar MRI

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ABSTRACT

In this paper we describe a method for assisting radiological technologists in their routine work to automatically determine the imaging plane in lumbar MRI. The method is first to recognize the spinal cord and the intervertebral disk (ID) from the lumbar vertebra 3-plane localizer image, and then the imaging plane is automatically determined according to the recognition results. To determine the imaging plane, the spinal cord and the ID are automatically recognized from the lumbar vertebra 3-plane localizer image with a series of image processing techniques. The proposed method consists of three major steps. First, after removing the air and fat regions from the 3-plane localizer image by use of histogram analysis, the rachis region is specified with Sobel edge detection filter. Second, the spinal cord and the ID were respectively extracted from the specified rachis region making use of global thresholding and the line detection filter. Finally, the imaging plane is determined by finding the straight line between the spinal cord and the ID with the Hough transform. Image data of 10 healthy volunteers were used for investigation. To validate the usefulness of our proposed method, manual determination of the imaging plane was also conducted by five experienced radiological technologists. Our experimental results showed that the concordance rate between the manual setting and automatic determination reached to 90%. Moreover, a remarkable reduction in execution time for imaging-plane determination was also achieved.

Keywords: MRI, Lumbar, Image recognition, automatic setting

1. INTRODUCTION

Since its introduction into clinical practice in the early 1980s, magnetic resonance imaging (MRI) technology has improved rapidly. One advantage of MRI is its capability to produce images in any desired plane. MRI provides the maximum amount of information when evaluating patients with suspected spinal disorders [1, 2]. Therefore MRI is used as the optimal imaging investigation for nearly all lumbar spine lesions, such as low back pain [3-8]. Lumbar MRI provides high-resolution, multi-axial, multi-planar views that have high contrast between soft tissues. However, determination of an anatomically accurate imaging plane by an operator needs experience and expertise. In particular, the determination of the imaging plane by an inexpert may result in the increase of not only unnecessary scanning but also constraint time given to the patients.

In this paper we describe a method for assisting radiological technologists in their routine work to automatically determine the imaging plane in lumbar MRI. The method is first to recognize the spinal cord and the intervertebral disk (ID) from the lumbar vertebra 3-plane localizer image, and then the imaging plane is automatically determined according to the recognition results. To determine the imaging plane, the spinal cord and the ID are automatically recognized from the lumbar vertebra 3-plane localizer image with a series of image processing techniques. The proposed method consists of three major steps. First, after removing the air and fat regions from the 3-plane localizer image by use of histogram analysis, the rachis region is specified with Sobel edge detection filter. Second, the spinal cord and the ID were respectively extracted from the specified rachis region making use of global thresholding and the line detection filter. Finally, the imaging plane is determined by finding the straight line between the spinal cord and the ID with the Hough transform. Image data of 10 healthy volunteers were used for investigation. To validate the usefulness of our proposed method, manual determination of the imaging plane was also conducted by five experienced radiological technologists for comparison.

Medical Imaging 2006: Image Processing, edited by Joseph M. Reinhardt, Josien P. W. Pluim,
Proc. of SPIE Vol. 6144, 61443X, (2006) · 0277-786X/06/$15 · doi: 10.1117/12.652908

2. MATERIALS AND METHODS

2.1 Background

Conventional MRI examination was performed according to the following procedures: (a) to let a patient lie down on the bed of the MR scanner; (b) to determine the imaging plane in sagittal section based on the image been obtained beforehand for positioning. For an experienced radiological technologist, it needs approximately 10-30 seconds to determine the imaging plane. If the optimal imaging plane for lumbar MR imaging can be automatically determined, the decrease in scanning time and in constraint time given to the patients can be achieved. Consequently the rate of operation of the MR scanner can be improved. An overview of the conventional, manual operation and the automatic operation for determination of the imaging plane in lumbar MRI, as we would expect, is given in Fig. 1(a) and (b), respectively.

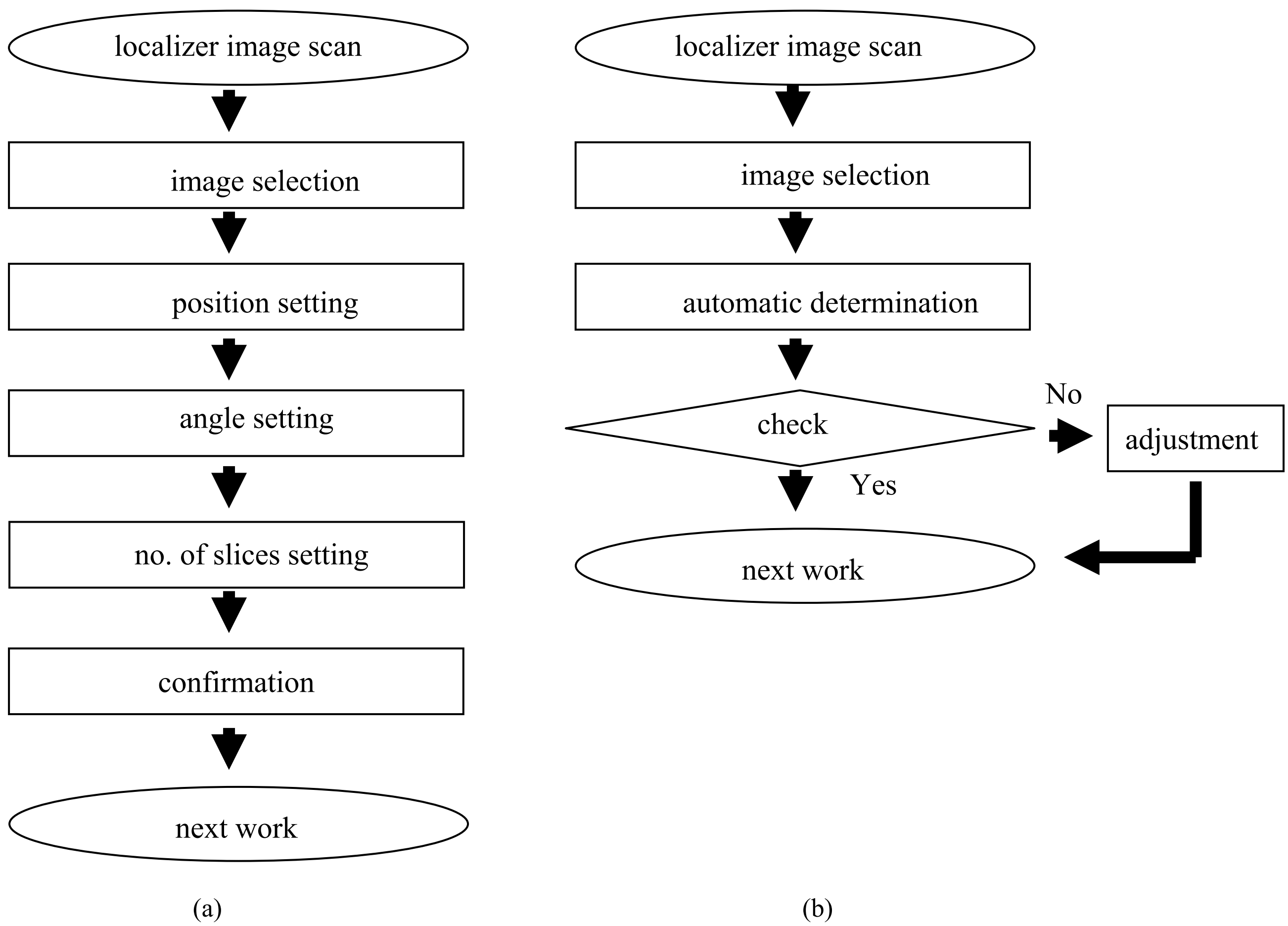


Fig.1 Flowchart of MRI operation on the basis of the mouse click. (a) manual operation. (b) automatic operation.

2.2 Proposed algorithm

To automatically determine the imaging plane for MR imaging of the lumbar spine in patients, we propose a simple and effective algorithm. The algorithm consists of three major steps shown in Fig.2. In the first step, we remove both the air and subcutaneous fat regions by applying histogram analysis, binarization, and morphological filter. In the second step, we extract the lumbar vertebra region by applying Sobel filter, binarization, and edge accumulation analysis. In the third step, we determine the slice lines in sagittal section for lumbar imaging by applying binarization, area masking filter, and Hough transform.

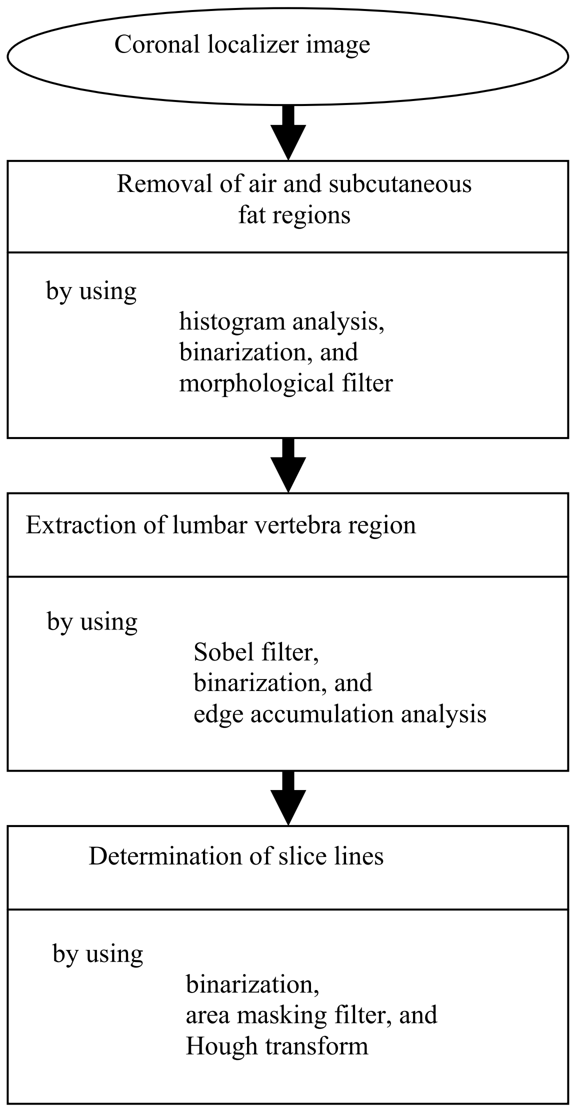


Fig. 2 Flowchart of our proposed algorithm.

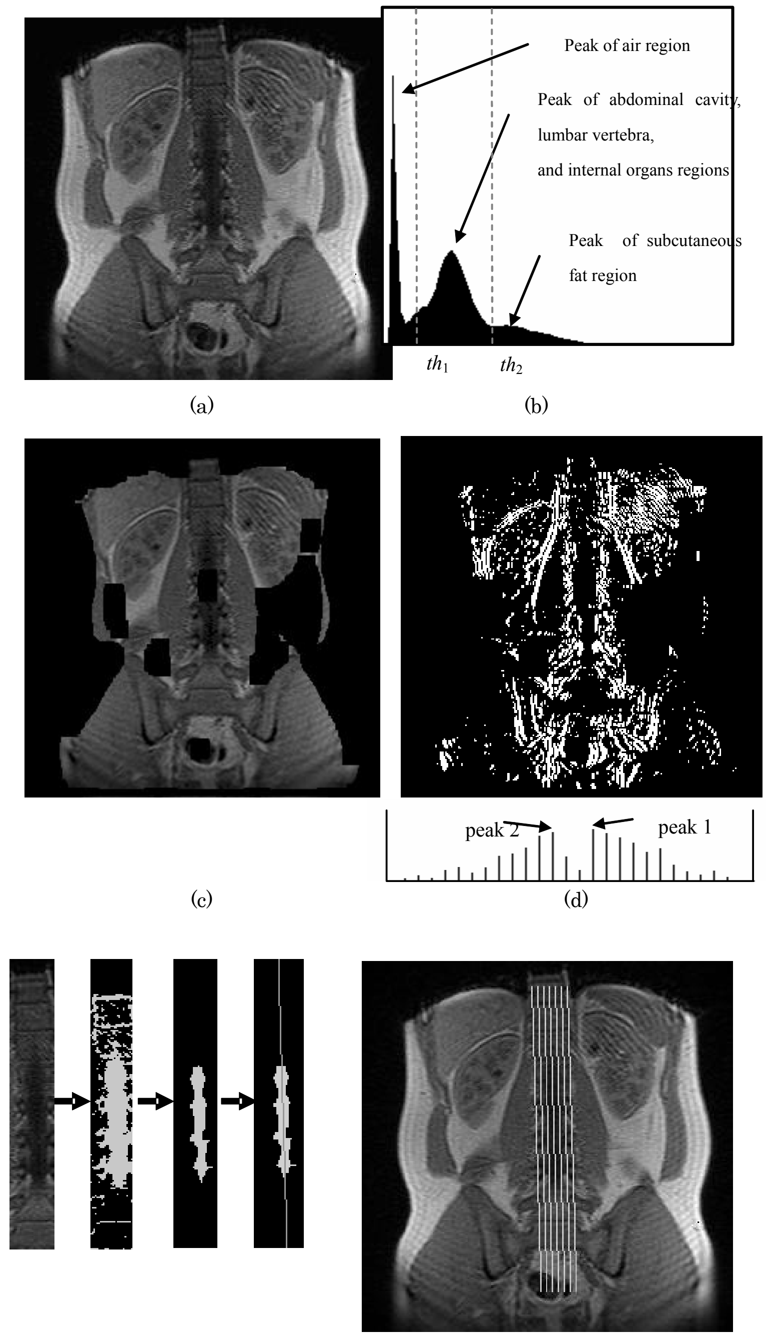


Fig. 3 Processed images corresponding to the flowchart. (a) Original image (Coronal localizer image). (b) Histogram of original image. Threshold values th_1 and th_2 for binarization are automatically determined by detecting valleys between peaks. (c) In-processed image obtained by eliminating air and subcutaneous fat regions after applying binarization and morphological filter of dilation and erosion. (d) Image obtained by applying Sobel masked to (c) and its accumulative distribution of vertical-direction edge component. (e) Lumbar vertebra region, binary image, spinal cord region detected by area masking, and a slice line obtained by Hough transform. (f) Automatically determined seven lines for sagittal slice.

Fig. 3 shows the various processed images corresponding to the flowchart given in Fig. 2. Fig. 3(a) shows an original image (coronal localizer image). Fig. 3(b) shows the histogram of the original image. There are three peaks and two valleys shown in the histogram. The three peaks are considered to represent the peaks of air region, abdominal cavity and lumbar vertebra region, and subcutaneous fat region, respectively. The threshold values th_1 and th_2 used for binarization are automatically determined by detecting the valleys between the two peaks. By applying binarization, the air region and the subcutaneous fat region can be removed. Further, by applying morphological filter of dilation and erosion, the in-processed image shown in Fig. 3(c). By applying the Sobel gradient mask in the *y* (vertical) direction, the accumulative distribution of vertical-direction edge component can be obtained after thresholding and is given in Fig.3 (d). Two peaks can be found from the accumulative distribution. The region between the two peaks is regarded as the lumbar vertebra area. By applying binarization, area masking filter and the Hough transform, a central slice line in sagittal section can be automatically determined (see Fig. 3(e)). Finally a total of 7 slice lines including the determined central slice line and 3 each parallel slice lines on the left and on the right of the central slice line are determined for MR imaging of the lumbar spine.

2.3 Image data acquisition

Ten (10) healthy volunteers (4 women and 6 men) participated in the present study. All of them were fully informed and explained the purpose of the study. A coronal localizer image showing the lumbar and the cavity of spinal cord, obtained from 3-plain localizer image, was selected from each volunteer. The image was regarded as an original image and was used for the experiment of automatic determination of the imaging plane in lumbar MRI.

The study was conducted on a Signa Profile 0.2T system (GE Yokogawa Medical). The MR acquisition utilizes a T_1 weighted sequence (TR/TE 115/7 msec, matrix 256×128, FOV 40 cm, flip angle 70˚, bandwidth 5.12 kH_Z, and slice thickness 5mm.

2.4 Qualitative analysis

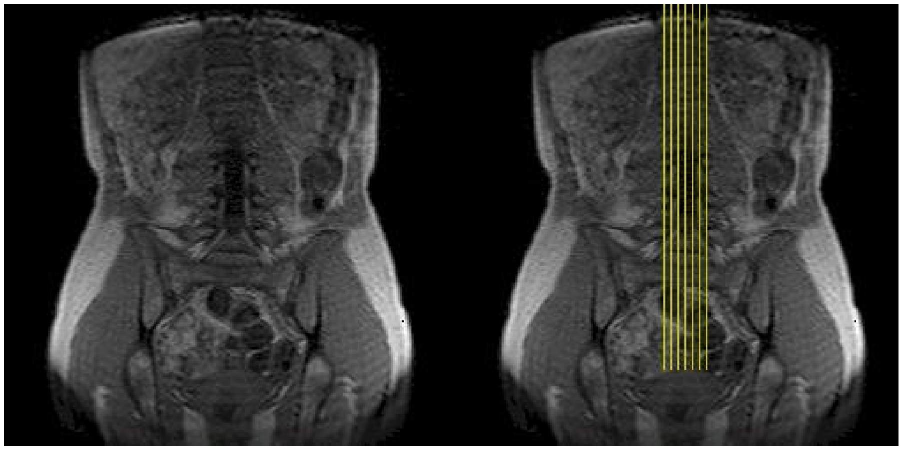
The automatically determined slice lines for MR imaging of the lumbar spine were visually evaluated by five radiological technologists with 2 to 8 years of experience. The readers were asked to rank the image on which the determined slice lines had been shown. The evaluation was based on the necessity of making further angle- or positioning-adjustment manually. The ranking was defined as: (A) automatically determined imaging plane can be used as is; (B) the angle of the automatically determined imaging plane needs to be manually adjusted; (C) the position of the automatically determined imaging plane needs to be further manually adjusted; (D) both the angle and position of the automatically determined imaging plane needs to be manually adjusted.

3. RESULTS AND DISCUSSION

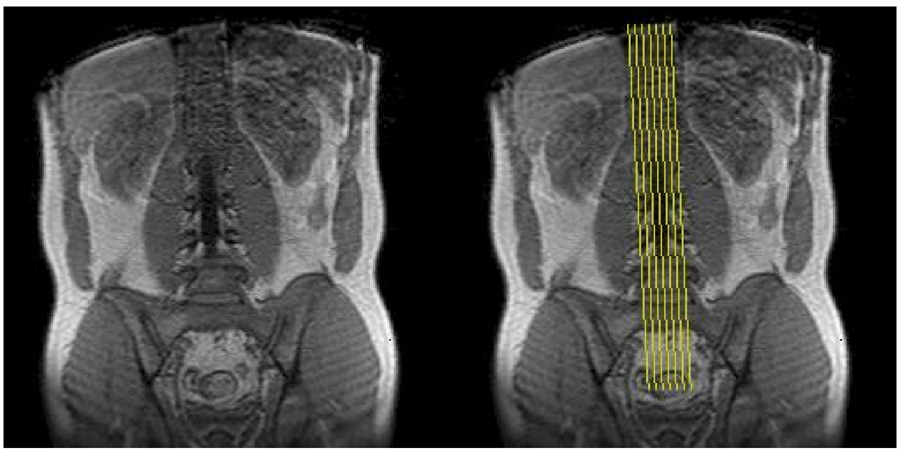
In 9 of 10 cases, all the reader ranked as A (automatically determined imaging plane can be used as is). The remaining one case was ranked as B (the angle of the automatically obtained imaging plane needs to be manually adjusted). This means that our experimental results showed that the concordance rate between the manual setting and automatic determination reached to 90%. Fig. 4 shows three A-ranked cases with automatically determined 7 slice lines superimposed on each image. The results demonstrate the usefulness of our proposed method. The only one B-ranked case is shown in Fig. 5. As shown in Fig. 5(a) and (b) that a fine adjustment of angle was required. The reason of the inconsistency in the direction of the slice lines was due to insufficient removal of noise at the step of extraction of lumbar-vertebra cavity. To overcome this issue, a design of an improved image processing technique is in progress. The average execution time for one examination with the automatic method and that with the manual method were 10 seconds/case and 5 minutes/case, respectively. A remarkable reduction in execution time for imaging-plane determination was achieved.

4. CONCLUSIONS

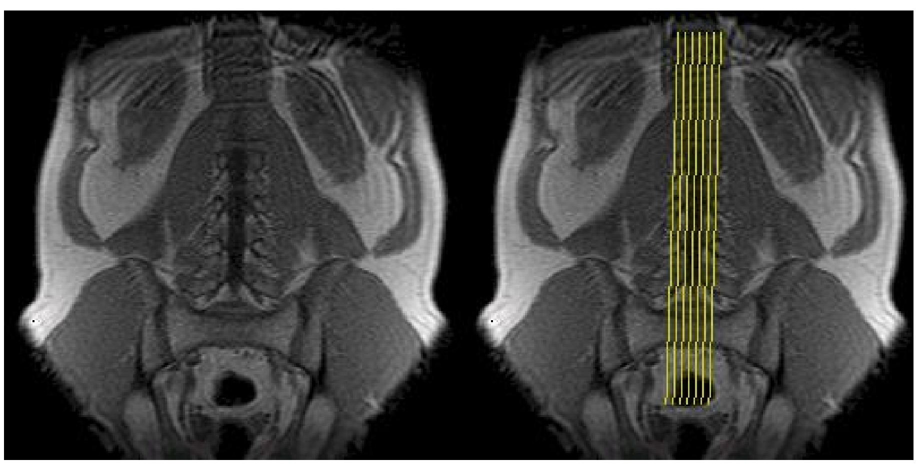
We have proposed a method for automatic determination of the imaging plane from the lumbar vertebra 3-plane localizer image in lumbar MRI. The agreement between the automatic and manual determination is strong. Our preliminary



(a)



(b)



(c)

Fig. 4 Three examples of automatic determination of the imaging plane in lumbar MRI: (a) volunteer 1 (female), (b) volunteer 2 (male), and (c) volunteer 3 (male).

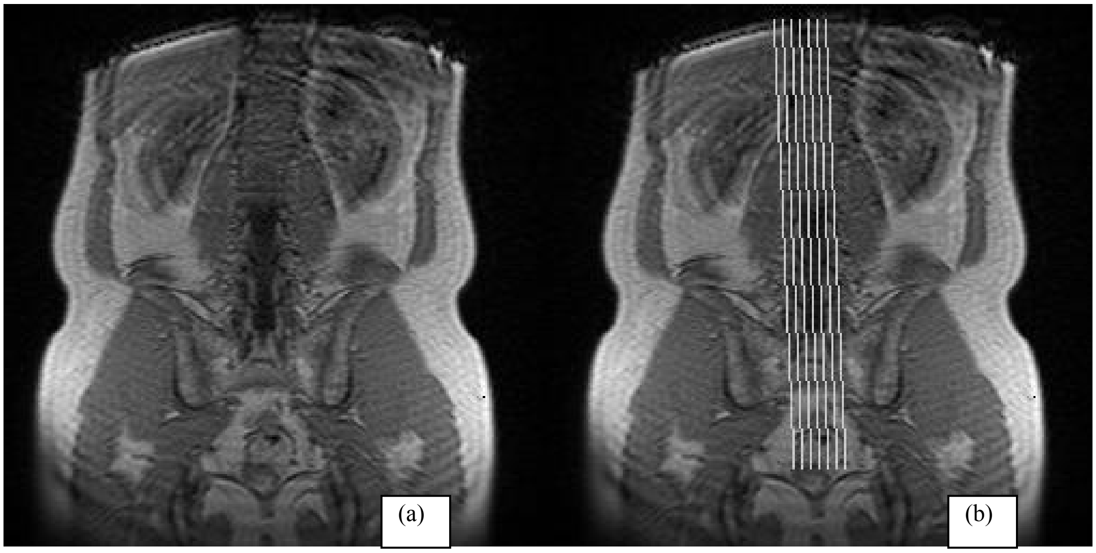


Fig. 5 The case that the adjustment of angle was required.

results have demonstrated the usefulness and advantages of the proposed method for assisting radiological technologists in their routine work to automatically determine the imaging plane in lumbar MRI. Further, the averaged operation time for one case has been reduced to 10 seconds from 5 minutes. The proposed algorithm has a potential for applying to other imaging regions.

ACKNOWLEDGMENT

The authors wish to thank the radiological technologists from Nakajo Central Hospital for their support in conducting the performance evaluation of this work.

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