Liver texture analysis: robustness of measurement in cirrhotic patients and healthy volunteers

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Introduction

Established imaging techniques are limited at detecting and quantifying hepatic fibrosis and liver biopsy is routinely performed to diagnose and stage hepatic cirrhosis from a wide range of causes. Although MRI has proven valuable for quantifying other diffuse liver diseases such as steatosis and haemochromatosis [1,2] there has been limited progress regarding cirrhosis, except when advanced disease leads to morphological changes such as lobar atrophy, nodularity of the capsular margin and indirect markers of portal hypertension such as splenomegaly. "Heterogeneity" on T2w imaging has been noted previously in cirrhosis [3] but few attempts made to quantify this. In recent years high spatial resolution T2w images can be routinely acquired using RARE based imaging with respiratory triggering. This work investigates which if any image features using an established texture analysis approach might be used to discriminate between cirrhotic and healthy livers, with the aim of evaluating these features in the future to quantify mild and moderate degrees of cirrhosis. Ideally any such method would be applied to routinely acquired imaging and relatively simple to perform.

Methods

13 healthy volunteers (8 male, 5 female, age range 23-56), with no history of liver disease and 5 patients with biopsy proven advanced cirrhosis (etiology: 1 HCV, 2 EtOH and 2 EtOH/NASH) undergoing routine clinical MRI were recruited: informed written consent was obtained. Examinations were performed on a 1.5T whole body MRI (Excite, GEHT, Milwaukee) with an 8-channel body array and a fast-recovery fast spin echo sequence (TE 68 ms, matrix 512 x 380, echo train 13, section thickness 8mm, intersection gap 2mm, FOV 34cm, tailored RF pulse, RBW 62.5 kHz). Respiratory triggering was used with a TR of at least 4.8 seconds (TR range 4.8-10.9 seconds) giving an acquisition time of 6-12 minutes. Image textures were quantified using the Mazda texture analysis programme (v 3.2 [4]). Circular regions of interest (3000 pixels) were selected within the liver, avoiding the major vessels. The Mazda programme was then used to calculate texture parameters. The following tests were performed: (1) identification of the most significant parameters distinguishing healthy volunteers and cirrhotic patients. (2) within the group of healthy volunteers, we tested for any correlation between the texture measures and age or gender. The discriminating statistics were identified by calculating the Fisher statistic, which is the ratio of the between-group variance to the within-class variance.

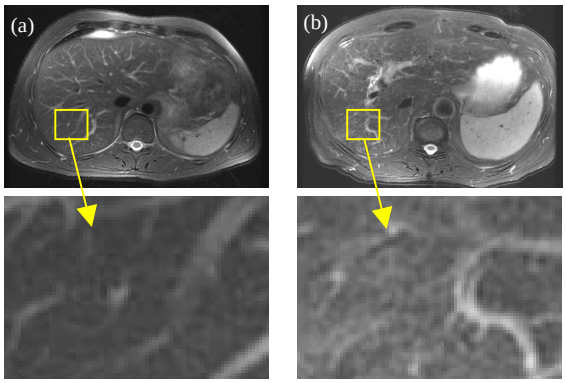

Figure 1 : Typical images from (a) a healthy volunteer and (b) a cirrhotic patient with a magnified area of liver tissue shown underneath.

Results

The five best discriminatory texture measures were identified (table 1). Using these measures it was possible to correctly classify 85% of all the regions of interest studied. If the ROIs for each measures were averaged for each individual the classification had 100% sensitivity and specificity. Figure 2 shows the pooled data for the healthy volunteers and the cirrhotic patients for three of the measures. It was found that the entropy (figure 2a) measures provide the most distinct classification of healthy volunteers and cirrhotic patients, followed by the gradient non-zeroes (figure 2b) measure: these two measures have the added benefit of allowing the possibility of classifying intermediate stages of fibrosis. This hypothesis will be tested in future work. The horizontal non-uniformity measure (figure 2c) was capable of achieving 100% classification between healthy and cirrhotic individuals, but given the large spread and overlap of results, accurate classification of intermediate stages of fibrosis would be unlikely. Among the healthy volunteers, there was no evidence of a correlation between volunteer age and any of the texture measures (correlation coefficient = 0.16, figure 3). Also, there was no significant difference in texture measures between the male and female healthy volunteers ($p = 0.28$).

Texture Parameter	F-value	Short description of texture parameter
S(2,0) Entropy	2.24	Entropy (natural logarithm of co-occurrence matrix) for a 2-pixel spacing
S(3,0) Entropy	2.18	Entropy (natural logarithm of the co-occurrence matrix) for a 3-pixel spacing
Horizontal Non-Uniformity	2.14	Inverse measure of the lengths of runs of identical intensity values
S(1,0) Entropy	2.12	Entropy (natural logarithm of co-occurrence matrix) for adjacent pixels
Gradient Non-Zeroes	1.98	Percentage of pixels with a non-zero gradient (representing 'smoothness')

Table 1 : F-values for texture parameters and short descriptions

Conclusions

It has been shown that texture analysis of high spatial resolution T2w liver images can provide 100% sensitivity and specificity between healthy volunteers and patients with advanced cirrhosis, with the potential therefore to classify intermediate states of fibrosis. A larger number of cirrhotic patients is being studied to confirm these findings and in the future the ability of these measures to discriminate intermediate stages of cirrhosis will be evaluated in a larger population with direct histological feature correlation, cirrhosis grade and etiology.

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[3] Ohtomo *et al.*, *Radiology* **189**, 871-874 (1993)
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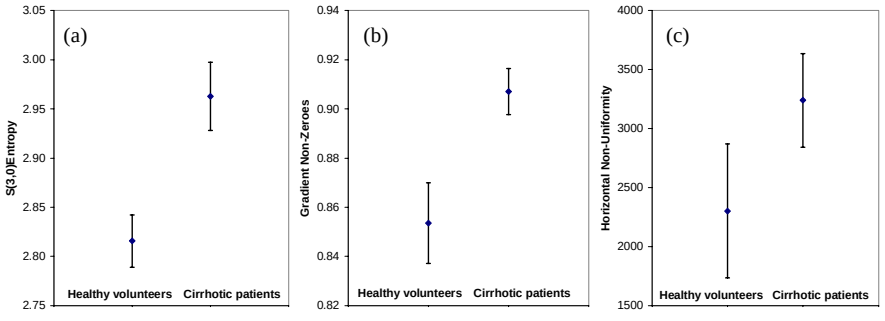

Figure 2 : Group averages for healthy volunteers and cirrhotic patients on the texture measures (a) S(3,0) entropy, (b) gradient non-zeroes and (c) horizontal non-uniformity

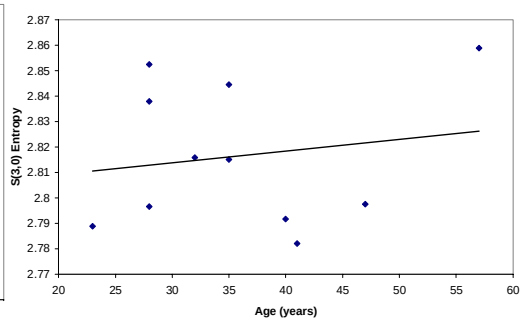

Figure 3 : Variation of the S(3,0) Entropy measure with age of the volunteer