MR Elastography: Spleen stiffness measurements in healthy volunteers.

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Introduction

Portal venous hypertension (PVH) is important in several clinical situations, particularly in patients with cirrhosis who are at risk of potentially life-threatening variceal haemorrhage. Portal venous pressures can be measure directly but only by invasive techniques that are often not practical for serial monitoring or evaluating treatment response. Over the last four decades alternative indirect non-invasive markers have been investigated including portal venous flow, splenic size, and portal vein diameter but none of these have proven to be reliable indicators of PVH. Currently the most widely used method remains an invasive one – the use of hepatic vein wedge pressure measurements [1]. This technique is safer than direct splenic puncture methods but remains relatively impractical for many patients.

Recently the ability to measure organ stiffness non-invasively using US or MR based elastography [2] has provided an opportunity to investigate whether spleen stiffness is related to portal pressure. An early study has indicated a correlation but in order to investigate this relationship it is necessary to understand the normal range of splenic stiffness and whether or not this is correlated with other parameters such as splenic volume, age or body mass index. There is little or no established literature on physical measurements of splenic stiffness although in clinical medicine many diseases are known to affect spleen size and stiffness based on manual palpation.

The aim of this work was to establish the range of normal splenic stiffness using MRE in healthy adult volunteers and to investigate any correlation with other parameters that might influence the results in future studies of the technique in patients with portal venous hypertension.

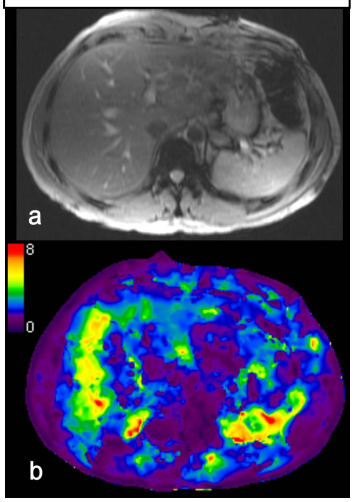

Figure 1. (a) Gradient echo magnitude image, (b) matching LFE colour elastogram.

Methods

16 healthy volunteers (9 male, 7 females, mean age 37 ± 9 years ranging from 28 to 56 years) with no history of gastrointestinal, hepatobiliary or cardiovascular disease and not receiving any regular medication were recruited. Their age, height and weight were recorded and they were fasted prior to an MRI examination using a whole body 1.5T MRI system (Signa HDx, GE Healthcare, Milwaukee, USA) with an 8 channel cardiac receive coil. Following initial localiser images axial FIESTA 10mm sections were obtained through the upper abdomen encompassing the spleen during a single breath-hold. Based on these images a 19cm diameter pneumatic membrane driver was placed over the anterior abdominal wall at the axial level of the midpoint of the cranio-caudal extent of the spleen. Two MRE examinations were performed centred on the spleen during repeat breath-holding with the driver in a right and left anterior abdominal wall position with the following parameters: FOV 36cm, flip angle 30, two sections 10mm thick and 10mm apart, 60Hz excitation, gradient echo based MRE sequence. The MRE images were processed using an LFE inversion algorithm previously developed and described[3]. Volunteers' blood pressure was recorded at the end of the examination while they were still supine.

Splenic stiffness values were obtained using manually placed regions of interest (ROI) outlining the splenic margins on the gradient echo magnitude images (Figure 1a) which were then mapped onto the corresponding MRE inversion images and the weighted (for ROI area) mean of the results for both left and right excitation positions and both sections obtained. The liver and splenic stiffness results were compared for driver location. Splenic volumes were estimated using planimetry of the spleen on the sequential FIESTA images. Splenic volume, body mass index, age and mean arterial blood pressure (MABP) were then compared with the MRE results (liver stiffness using the right driver position and splenic stiffness left driver position) for evidence of any correlation and Student's t-test with a Bonferroni correction applied.

Results

Figure 1 demonstrates typical MRE images in a volunteer. Figure 2 displays the plots of the MRE values against the other parameters with their correlation coefficients. With the driver placed on the right the mean splenic stiffness for the group was 3.6 ± 0.59 kPa (range 2.4 to 4.4 kPa); with the driver on the left the mean splenic stiffness was significantly different ($p < 0.004$) at 4.3 ± 0.63 kPa (range 3.2 to 5.6 kPa). There was no significant difference ($p > 0.08$) in the mean liver stiffness for the group between the two driver positions: Right position mean liver stiffness 3.0 ± 0.28 kPa (range 2.6 to 3.6 kPa); left position mean liver stiffness 2.8 ± 0.33 kPa (range 2.4 to 3.4 kPa). Spleen volumes ranged from 122 to 427 mls (mean 231 ± 82 mls), BMI from 22.2 to 32.4 kg/m^2 (mean 26.3 ± 3.2 kg/m^2), mean arterial blood pressure ranged from 68 to 102 mmHg (mean 83 ± 9 mmHg).

No significant correlation was observed between liver and spleen stiffness ($r = 0.32$, $p = 0.223$). A moderate negative correlation was observed between splenic stiffness and volunteer age but this was not significant after Bonferroni correction ($r = -0.499$, $p' = 0.25$). No significant correlation was observed between spleen stiffness and the volunteers' BMI, AMBP, and spleen volume (all p and $p' > 0.05$) or between liver stiffness and volunteer age, spleen volume, and MABP (all p and $p' > 0.05$). A significant correlation was observed between the volunteer BMI (body mass index) and liver stiffness ($r = 0.652$, $p' = 0.03$).

Conclusion

These preliminary results in a small number of healthy volunteers demonstrate that spleen stiffness is not significantly correlated with BMI, AMBP, spleen volume, and liver stiffness. A significant difference was observed using different driver positions and the reason for this is unclear but may relate to the direction of excitation wave and its relationship to the image plane, the influence of the stomach may increase non-orthogonality when using the left anterior driver position. Our results using the right anterior driver position are very similar to those observed in the only other similar published study[4]. These findings suggest that with a consistent technique splenic stiffness measurements could be useful in studying portal hypertension. Splenic volume, body mass index and blood pressure do not appear to influence the results in healthy volunteers. In this study a non-significant trend was observed with age and the importance of this may become clearer with a larger population.

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References

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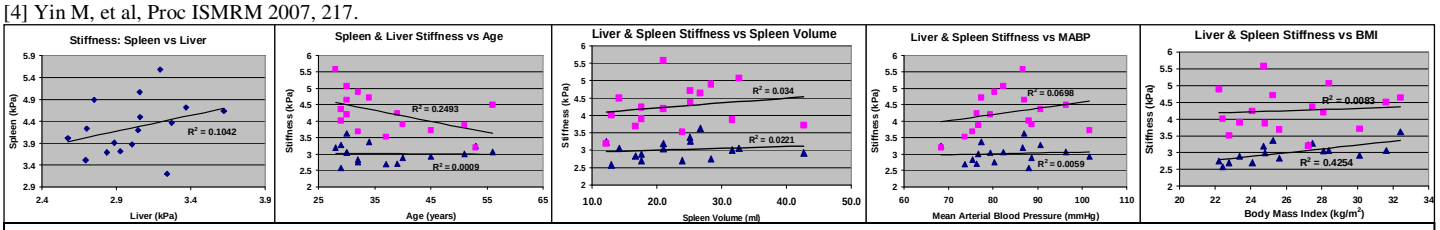

Figure 2. Volunteer Results. The left scatter plot displays liver vs spleen stiffness. The right hand four plots display spleen (■) & liver(▲) stiffness results against Age, Spleen Volume, Mean Arterial Blood Pressure (MABP), and Body Mass Index (BMI). In all plots the related linear correlation coefficients (R^2) are displayed. The only significant correlation after Bonferroni correction is between the liver stiffness and body mass index (corrected p value = 0.030).