MR Elastography Sequence Comparison: Standard PC MRE vs. Balanced Alternating Steady-State Elastography

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Introduction

MR elastography (MRE) has been shown to be capable of non-invasively measuring tissue elasticity even in deep-lying regions. The feasibility of performing these measurements in skeletal muscle has already been established (1). The present study makes a phantom and an *in vivo* comparison between a standard MRE phase-contrast (PC) sequence and a balanced SSFP based sequence called Balanced Alternating Steady-State Elastography (BASEL) (2). A cylindrical agarose phantom (1%; 18cm height and 12 cm diameter) with a stiffer cylindrical inclusion (2%, diameter 2cm) and the biceps brachii in a group of 8 healthy volunteers in the age range of 27-38 years were examined.

Methods

All measurements were performed on a 1.5 Tesla scanner (Sonata, Siemens Medical Solutions, Erlangen, Germany) equipped with a gradient system capable of 40 mT/m maximum amplitude and a slew rate of 200 mT/m/ms. The mechanical waves were induced into the region of interest with a piezoelectric oscillator (3). To visualize the mechanical waves in the phantom and the biceps tissue, a gradient echo PC MRE sequence and a BASEL sequence synchronized to the oscillation were used. The shear modulus was determined from the wavelength inside the tissue using eight equidistant phase offsets and motion encoding in the spatial direction parallel to the mechanical excitation.

The oscillator was coupled to the region of interest via a Plexiglas rod. Properties of the mechanical wave were: a frequency of 200 or 147 Hz and an amplitude of 200 µm or 600 µm in the left to right direction for phantom and *in vivo* measurements, respectively. Transverse slices through the phantom and coronal slices along the muscle were acquired for both sequence types. Parameters: TR= 60 / 7.5 ms (84 / 10.48 ms), TE = 18.6 / 3.75 ms (24.9 / 5.24 ms), FOV 200 mm^2 (100 mm^2), BW 260 / 888 Hz/pixel, 1 slice, matrix 256 x 256, slice thickness 5 mm resulting in a TA of 123 / 31 s (172 / 43 s) for all eight phase offsets for PC / BASEL in the phantom (*in vivo*). Special parameters of the PC sequence: 3 trapezoidal motion sensitizing gradients with 10 mT/m (20 mT/m) amplitude; the motion sensitivity of BASEL is derived from the inherent readout gradient.

For comparison, the phase images were compared regarding equivalency (wave peak and trough appearance). Additionally, the LFE technique (4) was used to determine shear wave speed and to estimate the shear modulus of the phantom/muscle. The shear modulus for each sequence was taken as the average reconstructed elasticity in identical ROI's placed in 1) the background of the phantom, 2) the inclusion of the phantom, and 3) the muscle belly.

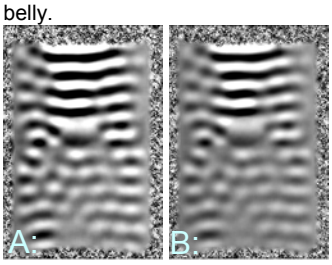

Fig. 1: A: PC and B: BASEL phase image. Note: except for small amplitude differences the images looks quite similar.

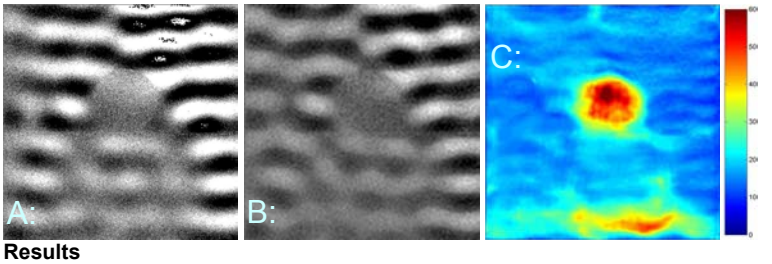

Fig. 2: A: PC and B: BASEL phase image with FOV set to image the inclusion. C: LFE elastogram from eight phase offsets for the BASEL sequence. Note: the stiffer inclusion is clearly visible; minor artifacts at the bottom edge are due to reflection and refraction.

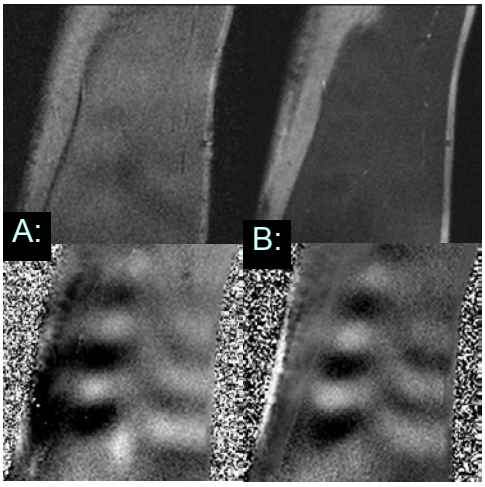

Fig. 3: Magnitude and phase image from A: PC and B: BASEL of the biceps brachii. Better magnitude contrast in B: with the same wave propagation in one fourth the time.

Results

The manual comparison of the wave peak and trough appearance in the phantom showed good agreement (Figures 1 & 2) for both sequences. The LFE reconstruction led to an average shear modulus of 13.4 (+/-0.4) kPa / 13.2 (+/-0.5) kPa and 50.4 (+/-0.7) kPa / 51.0 (+/-0.8) kPa for the standard PC / BASEL sequence in the phantom background and inclusion, respectively.

In vivo imaging revealed similar results. Manual comparison showed no significant variances in the phases. Typical 2D wave images of a transverse acoustic strain wave given by steady-state phase modulation are shown in Figure 3. These examinations yielded mean shear moduli for the biceps of 18.3 (+/-2.7) and 17.9 (+/- 2.3) kPa as determined with PC and BASEL, respectively. In addition, all volunteers tolerated the examination of the biceps with both sequence types.

Discussion

The transverse acoustic strain waves at 200Hz and 147 Hz generated by the piezoelectric oscillator were visualized by both sequence types. For the examined agar concentrations, the results of the present study are consistent with the published elasticity values. The advantages of the BASEL approach were its short repetition time, which thereby improves scan-time efficiency, the higher SNR, and the inherent sensitivity increase when small FOV´s are measured (the area of the phase accumulating readout gradient increases and therefore the sensitivity is enhanced). Furthermore, the magnitude images demonstrated better contrast and thus more potential to be used for diagnostic purposes. Unfavorable is that BASEL is more sensitive to tissue properties (the accumulated phase is especially dependent on the relation between TR and T2). Furthermore, BASEL is only sensitive along the readout axis; therefore, measurement of the complete elasticity dataset which consists of wave information in all three spatial directions is not currently possible. However, this information is only needed when more complex reconstruction approaches are used. The benefits of BASEL (small FOV, higher SNR, shorter acquisition time) would be especially favorable in MRE applications like the skin (5), where other potential methods to accelerate the image acquisition such as multi-echo readout have not worked well.

References

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