Transverse Anisotropy of Breast Lesions measured by MR-Elastography -Initial Clinical Results-

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Synopsis

3D steady-state MR-Elastography is utilized to assess the transverse isotropic properties of benign and malignant breast lesions. Both shear moduli as well as the local fibre-orientation are reconstructed. Attenuation effects are treated as isotropic and only the shear viscosity is reconstructed. The results indicate that malignant breast lesions tend to be stiffer as well as more anisotropic as benign lesions.

Introduction

One of the current aims of MR-Elastography (MRE) is the provision of addition diagnostic parameters for the improved characterization of breast tumours [1]. Given the heterogeneous architecture of tumors it is most unlikely that breast lesions exhibit isotropic viscoelastic properties on the millimetre scale. Thus, it is desirable to extend the reconstruction of viscoelastic parameters to also consider potential anisotropic properties. The so-called transverse isotropic elasticity model is rather appealing because it describes the elastic properties of a bundle of fibres (like in the case of muscle), i.e. there are two shear moduli involved (Fig. 1a): one parallel to the fibre direction (μ_{para}) and one orthogonal to the fibre direction (μ_{ortho}). The assessment of both shear moduli carries the potential to better differentiate between benign from malignant breast lesions.

Methods

Dynamic steady-state MR-Elastography at 85Hz mechanical excitation frequency is performed within a clinical environment with the patient in prone position. The MRE-setup is utilized for both, the standard MR-Mammography for the identification of the suspicious lesion, and the subsequent MRE measurement (12min data acquisition time). MRE sequence parameters are: FOV=128mm, res. 64^2 pixels, 2mm slice-thickness, TE/TR=47/495 ms and $\alpha=90^o$. The steady-state oscillation is measured at 8 time-points equally spaced over one oscillatory cycle for all three spatial directions. Reconstruction is based upon the technique presented in [2] with the extension, that contributions from the compressional wave are removed via the application of the curl-operator. This makes the results independent from the particular choice of the second Lamé coefficient λ and of Poissons ratio σ, which is in soft tissue very close to 0.5. Viscosity is assumed to be isotropic, because current values of SNR (about 10%) prevent a correct treatment of viscous anisotropy. The reconstruction of elastic anisotropy necessitates consideration of local rotations of the fibre axis. Thus, there are altogether 5 unknown coefficients (μ_{para}, μ_{ortho}, shear viscosity and 2 Euler angles).

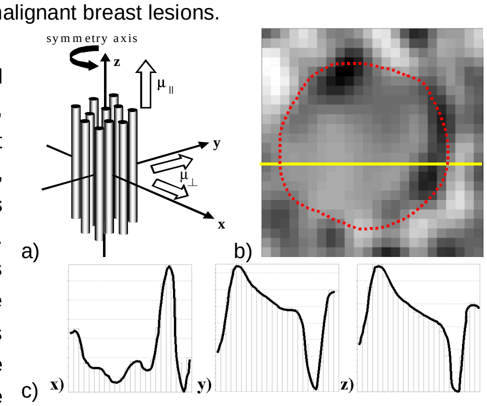

Fig.1: a) Bundle of fibres. b) x-component of the curl. The tumor is inside the red-dotted area. c) Distribution along the yellow line in b) for the three components of $\nabla\times\mathbf{u}$.

Results

Fig.1b shows the x-component of $\mathbf{q}=\nabla\times\mathbf{u}$ ($\mathbf{u}$ being the displacement vector) at the location of an ductal invasive breast cancer. It is obvious from Fig. 1c that the spatial wave-lengths of the shear wave varies significantly within the three spatial components of $\mathbf{q}$. While q_x provides a short wave-length (i.e. indicating softness) the other components (q_y and q_z) indicate long wave-lengths (i.e. hardness). Fig.2a-c show the reconstructed maps of μ_{para}, μ_{ortho} and shear viscosity for this patient. The lesion is clearly differentiated from the surrounding background tissue. The expected difference in magnitude between both shear moduli is well visible. Fig. 2d shows the compiled results for a collection of benign (blue and green marker) and malignant (red marker) breast lesions. Note, that μ_{para} is always larger than μ_{ortho}, which is characteristic for soft tissue.

Discussion

The measurement of transverse anisotropic properties of breast lesion indicates that malignant tumors tend to be more anisotropic than benign tumors. Moreover, they appear harder as well as more viscous (not shown). All these information in combination with contrast medium uptake values might help to improve characterization of breast lesions.

References

[1] Muthupillai et al., 1995 Science 26 1854-7 [2] Sinkus et. al, MRM 2004 (in press)

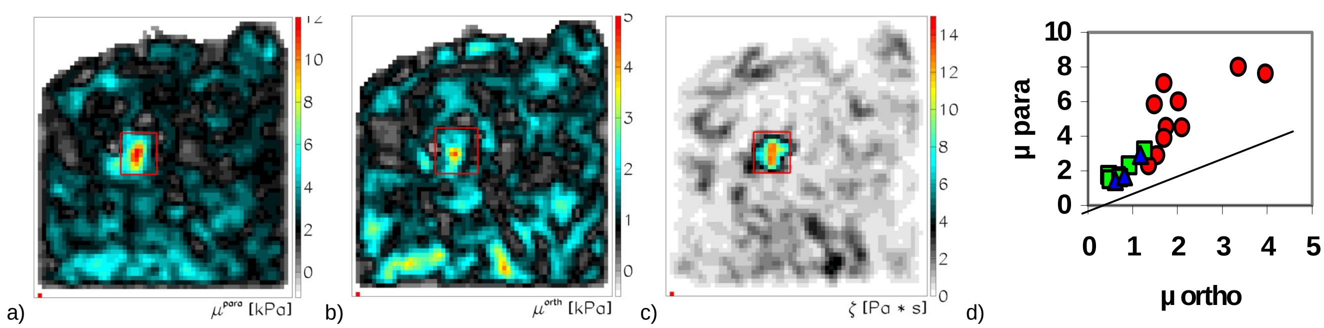

Fig.2 : Reconstructed maps of a) the parallel shear modulus, b) the orthogonal shear modulus, and c) the shear viscosity in case of breast cancer. d) Compilation of benign (blue and green) and malignant (red) breast lesions. The average value within the individual lesions of the parallel shear modulus is plotted versus the orthogonal shear modulus. A lesion is isotropic if the point lies on the 45^o-line.