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Placental elastography: a new approach based on Shear Wave Speed dispersion in normal pregnancies and placental insufficiencies

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Objective

In clinical practice, the mechanical properties of the placenta are not explored. However in case of placental insufficiency (PI), changes in its tissue architecture could cause variations in elasticity. Among the ultrasound (US) elastography methods, transient elastography (TE) seemed suitable for such an application. This technique consists in calculating the shear wave speed (SWS) generated by an external vibration propagating in the medium under consideration. Elasticity values obtained from current US methods are calculated at a single frequency. Theoretical and physical considerations indicate that microscopic obstacles in a tissue may influence not only the absolute value of viscoelastic tissue parameters, but also their relation to frequency. We evaluated the interest of a multifrequency approach to distinguish the elasticity of healthy placentas and that of placentas with PI signs in the third trimester of pregnancy.

Methods

We developed a 2D TE system, dedicated to the placenta and adapted for in vivo measurements, based on the coupling of a shear wave generated by 2 vibrating rods and US images acquired at an ultrafast rate. Two electrodynamical exciters, decoupled from the US linear probe (128 elements centered at 2. 8 MHz), generated the vibration of the rods. For the purpose of measuring SWS, beamformed demodulated IQ data were acquired with an ultrafast US scanner (Aixplorer, SuperSonic Imagine, France): acquisition at 2. 8 MHz during 128 ms with a PRF of 4 kHz. The particle velocity was computed using extended autocorrelation method. Calculating the spatial FFTs of Vz(z, ω), the shear wave speed dispersion curve Cs(ω) was obtained between 20 Hz and 80 Hz. The experimental data obtained from TE were fitted with a fractional rheological model in which the frequency behavior was modeled as a power law (G*(iω)=Ge+K. [iω]n). The exponent parameter n represents the frequency behavior inherent to a given material. The method has been applied ex vivo on 35 delivered placentas (<12h after delivery): 22 uncomplicated pregnancies, 7 isolated IUGR, 2 isolated PE, 2 cases of IUGR and PE, and 2 placental abruptions. Measurements (3 times with repositioning, 2 operators) have been performed on 2 regions, central and peripheral. Histopathological analyses have been carried out. Then, the experiment has been conducted in vivo on 2 pregnant women with a normal pregnancy and an anterior placenta. The protocol has been approved by the local ethics committee.

Results

The mean SWS was significantly lower in case of IUGR (1. 05 m/s +/-SD 0. 05) than in control group (1. 77 m/s +/-0. 48, P<0. 001) or in PE cases (1. 20 m/s +/-0. 22). In addition, the mean exponent n value was lower in case of IUGR (1. 01+/-0. 24) compared to control group (1. 27+/-0. 11, P=0. 006) or PE cases (1. 18+/-0. 36). We found no difference between central and peripheral regions. The optimal cutoff values of SWS and n for distinguishing normal and pathological situations were 1. 37 m/s and 1. 13 respectively, with AUC of 0, 98 (IC 95% 0, 94-1) and 0, 75 (IC 95% 0, 51-0, 99) respectively. SWS and n values were not related to gestational age or mode of delivery. Intra and interobserver reproducibility was good for both Cs and n values. The in vivo experiments identified the shear wave, and demonstrated feasibility of this method during pregnancy.

Conclusion

The frequency analysis could improve the ability of TE to distinguish IUGR cases and uncomplicated pregnancies or PE cases. This frequency approach provides a new quantitative parameter, the ‘exponent n’ of the fractional rheological model for assessing placental elasticity, in addition to the standard parameters such as Young’s modulus or SWS at a particular frequency. This parameter n is sensitive to a shape factor of the considered tissue and provides additional information about the placental microarchitecture.