Anatomical Models of Pregnant Women in 3T pTx Body Coils: Evaluation of SAR and B1+ Optimization in Various Imaging Positions

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TARGET AUDIENCE: For researchers in RF MRI safety.

PURPOSE: Magnetic resonance imaging (MRI), which has become routine in clinical diagnostics, is also used more and more frequently to scan pregnant women, especially in cases where ultrasound yields insufficient information. While the absorbed radiofrequency (RF) energy must be carefully managed already in standard systems with non-pregnant patients, the use of multitransmit (pTx) systems may pose additional risks to mother and fetus. The highly conductive amniotic fluid is not perfusion-cooled, and sharply focused fields may lead to local hotspots of unacceptably high temperature. Within this study, exposure scenarios with pTx body-coils of various dimensions are investigated with anatomical models of pregnant women and their fetuses in three different gestation stages, with five imaging positions around the fetus. Implications regarding the specific absorption rate (SAR), as well as the potential benefit in terms of more uniform B1+ distribution in identified regions of interest (ROI), are investigated.

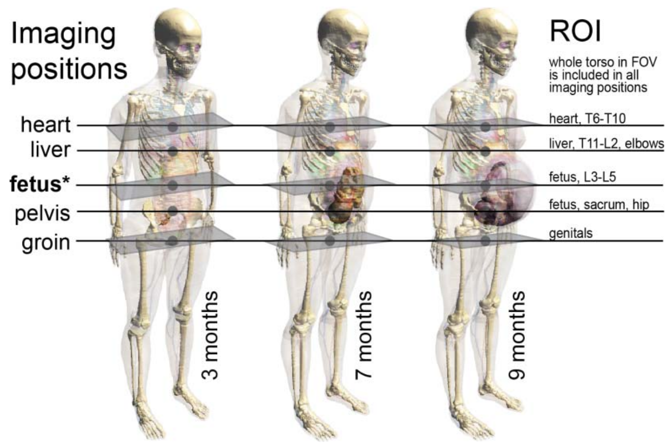

Fig. 1: Pregnant anatomical models in 3, 7, and 9 months of gestation, with 5 investigated imaging positions around the fetus and their specific ROI. Developed under the framework of the Virtual Population [1], details described elsewhere [2]

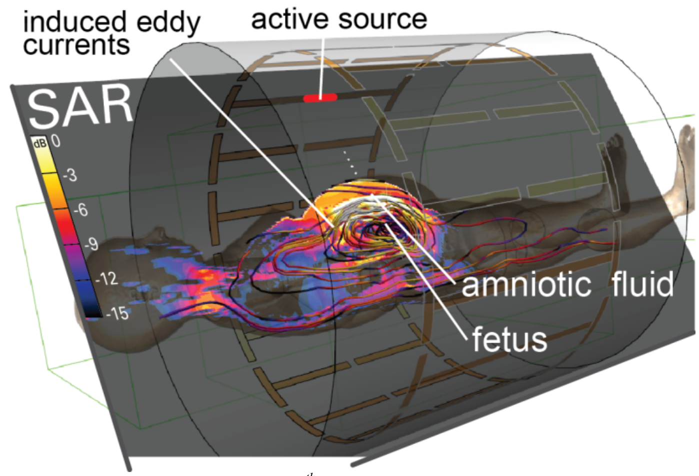

Fig. 2: Pregnant anatomical model, 7th month of gestation within the generic pTx body-coil. Here, only one channel is active. SAR distribution in tilted slice field view, and induced eddy currents visualized in streamline view.

METHODS: The anatomical pregnant human model Ella [1] (3, 7, 9 months gestation, Figure 1), is evaluated in five landmark (z-axis) positions (heart to groin) within generic 16-rung 3T pTx body coils of various dimensions at 128 MHz. The simulation scenario is depicted in Figure 2. The body coil has a length of 500 mm and a diameter of 750 mm, with 20 mm distance to the RF shield. Each rung is fed with a current source corresponding to a rung-current-controlled system. Variations include lengths of 400 and 600 mm, and a diameter of 650 mm.

The dielectric tissue properties of mother and fetus have been assigned on the basis of comprehensive literature reviews [3,4]. The 16 individual simulations, one per rung, were performed and then combined in post processing to evaluate the potential effects of pTx exposure. The exposure level was normalized to the current standard for resonating body coils, which corresponds to a whole-body SAR (wbSAR) of 2 W/kg. Apart from circular polarization (CP), different excitation vectors were computed by means of various optimization strategies. To obtain the best B1+ uniformity and the highest |B1+| in the ROI, unconstrained and constrained, respectively, magnitude least squares problems were solved through a local phase exchange method. The worst-case local SAR was computed as the maximum generalized eigenvalue that maximizes the local SAR to wbSAR ratio. The covariance of B1+ (CV(B1+), defined as the standard deviation (SD) divided by the mean within the ROI and the local SAR enhancements are evaluated, as well as the maximally reachable average B1+ in the ROI subject to a wbSAR of 2 W/kg.

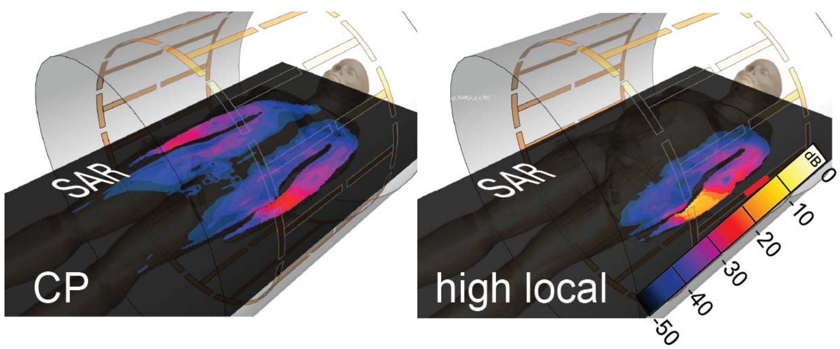

Fig. 3: psSAR10g distribution for CP and high local SAR excitation, where essentially only one source is active.

RESULTS: The pTx excitation evaluations for the 7th month of gestation in fetus-centered imaging position show that the CV(B1+) within the fetal ROI can be substantially decreased from 25% in CP mode down to 12% for best-case. At the same time, local SAR in the mother is reduced from 31 to 23 W/kg, all with wbSAR = 2 W/kg. Scenarios with the worst-case 10g averaged SAR excitation vector for the 16 pTx feeding points reach levels up to > 1000 W/kg, a factor > 30 compared to CP, which is unacceptably high. These values are comparable to earlier evaluations of multitransmit systems on non-pregnant anatomical models, where enhancement factors of 14 – 48 have been estimated [5].

CONCLUSION: Use of pTx body-coils may increase the B1+ uniformity within the fetus by a factor of 2, and by a factor of up to > 4 for other, smaller ROIs. With optimal tuning, the local SAR can be significantly reduced. However, unconstrained excitation vectors may lead to unacceptably high SAR hotspots in worst-case configurations, which indicates the need for very robust management of exposure safety. The effect of various body-coil dimensions and imaging positions is under investigation.

 REFERENCES: 1. Christ et al. 2010 PMB(55); 2. Christ et al. 2012 BEMS(33); 3. Hasgall et al. 2012, www.itis.ethz.ch/database; 4. Peyman et al. 2012 PMB(57); 5. Neufeld et al. 2011 PMB(56)