INFLUENCE OF SKIN TISSUE AND AIR CAVITIES ON LOCAL SAR ESTIMATION IN PARALLEL MR EXCITATION

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Introduction: In parallel MR transmission, multiple RF fields with different characteristics pose a new challenge with respect to monitoring the energy deposition in the human body and monitoring local SAR, which is an active area of research. It has been demonstrated that local SAR is highly dependent on water-rich, fat-rich, and lung tissues [2]. This estimation is achieved through electromagnetic simulations of virtual whole-body human models and MR coils. In order to obtain reliable local SAR estimation, it is necessary to have virtual models with tissues relevant to SAR. For this, we investigate the influence of skin tissue and air cavities in the head, pharynx, trachea, bronchi, and the intestines in addition to the fat, muscle, and lung tissues [2], due to their dielectric properties contrasts with their surroundings. In addition, volume and positions of air cavities in the intestines are different among individuals, raising questions about their effect on local SAR.

Method: A dielectric-contrast analysis was carried out, resulting in the previously demonstrated essential tissues (fat, muscle, and lung) in addition to skin tissue and air cavities. Other tissues were also the output of this analysis, which might have considerable effects on local SAR for different body-to-coil relative positions, body types, and fat distributions. Simulations were conducted through the FDTD method (SEMCAD-X, SPEAG Inc., Zürich), over both the Virtual Family “Duke” model [3], and an in-house generated whole-body model. Our model (male, 29 years, BMI: 21.45) was generated through the 2-point Dixon fat-water MR imaging method and an in-house developed processing pipeline. This pipeline includes an automatic segmentation application prototype (Siemens Corporate Technology, Princeton, NJ), a manual correction stage (ITK-Snap) [4], and few customized accuracy detection and correction stages. This male model was formed of fat, muscle, connective tissue, lung, cortical bone tissues and air cavities (fig.2-a) as a result of the automated segmentation stage. Simulations were conducted for a 3T clinical scanner body coil with 8-pTx elements, operating in the bird-cage mode at 123MHz, with 3.655 × 10⁻³ W source power (1V). The coil was positioned at the chest region of the model (fig.2-a). Skin Influence: Our model was wrapped in a 4mm layer through a developed image processing pipeline, using morphological and set operations. To investigate the influence of skin on local SAR, two simulations with this model were conducted. In the first simulation, skin tissue was assigned the dielectric properties of “dry skin” [5] (included), whereas in the second skin model was assigned the dielectric properties of muscle (excluded). Results were compared to those of the “Duke” model. Air Influence: Due to dielectric contrast with their surroundings, air cavities in the head, pharynx, trachea, bronchi, and the intestines were considered, except for the “Duke” model since it did not have air cavities in the intestines. Simulations with settings similar to those for Skin Influence were conducted. To investigate their effect on local SAR, all air cavities were assigned the dielectric properties of muscle in one simulation, except for the bronchi tissue where it was assigned the dielectric properties of lung (included). In the second simulation, all air cavities were assigned the dielectric properties of air (excluded).

Results: Skin Influence: Figure 1, (a) and (b) show hot spots for the in-house generated model in the wrist, shoulder/neck, and the right arm regions for 10g averaged SAR [6]. The relatively large hot spot at the arm is due to strong electromagnetic coupling with a coil element. For the source power 3.655 × 10⁻³ W, SARmax was located at the neck/shoulder region for both cases. Figure 1(c) shows the MI projections of the 10g RMS percent relative differences (MIP) of the model including skin tissue, compared to data from the same model excluding skin tissue. Figure 1(d) shows similar percent relative differences but for local SAR (MIP), including and excluding skin, respectively.

Discussion and Conclusion: Results from “Duke” and the in-house generated model were consistent. The positive relative changes are the ones in concern since they translate into local SAR underestimation in the model without the tissues of interest (skin and air cavities), compared to local SAR in the same model with the tissues of interest. Assigning skin the dielectric properties of muscle caused an absolute maximum local SAR underestimation of 0.01 × 10⁻³ W/kg for a source power of 3.655 × 10⁻³ W, at the worst hot-spot (fig.1-a, near the shoulder/neck region). Air cavities caused an absolute maximum local SAR underestimation of 0.002 × 10⁻³ W/kg for the same source power and the same hot-spot (fig.2-b). Scaling the maximum absolute SAR to the safety limit of 4 W/kg gives a source power of 30W, resulting in skin influence of 92 mW/kg, and air cavities influence of only 17 mW/kg at the shoulder/neck hot-spot for both cases. On the other hand, the biggest relative differences in local SAR, when air cavities and skin tissue are included, occurred at regions where local SAR is below the safety limits (body trunk in fig.1-d, and fig.2-b). Results show that absolute differences in worst-case local SAR are small, suggesting that skin tissue and air cavities are not strongly relevant to local SAR in an 8-channel pTx environment, despite the relative differences they cause on local SAR at inner body regions (body trunk and arms were negligible).


Acknowledgement: INUMAC project supported by the German Federal Ministry of Education and Research, grant #13N9208.