**Wed.18**

**Modelling the detectability of brown fat metabolism using microwave radiometry.**

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Background: Brown adipose tissue (BAT) plays an important role in whole body metabolism and could potentially mediate weight gain and insulin sensitivity. Although some imaging techniques allow BAT detection, there are currently no viable methods for continuous acquisition of BAT energy expenditure. We present the modelling efforts to study the feasibility of using a passive, low-cost and non-invasive technique for long term monitoring of BAT metabolism – microwave radiometry.

Methods: A 3D computational model of the human neck and chest was created in HFSS. A BAT region was segmented in the supraclavicular region with a volume of 2-6 cm³ underlying a superficial layer of 1.5 mm skin and 3-10 mm layer of subcutaneous white adipose tissue (WAT). The model also accounted for relevant bone and muscle structures. The dielectric properties of BAT used in this model were measured in rats over the microwave range 0.5-10 GHz. Measurements were carried out in situ and post mortem in six female rats of approximately 200 g. We used a single-pole Cole-Cole model to fit the experimental data into a frequency dependent parametric model. The anatomical model was coupled to a log-spiral antenna design, which was optimized to maximize radiometric reception of thermal emissions from the BAT target. The power absorption patterns calculated in HFSS were superimposed on simulated thermal distributions computed in COMSOL to predict radiometric signal collected by an ultra-low-noise microwave radiometer. The power received by the antenna was characterized as a function of frequency and different levels of BAT metabolism under cold stimulation (environment temperature at 15°C).

Results: The dielectric properties of BAT are higher than WAT, in accordance with the higher water content. The optimized radiometric receive band was 1.1-1.7 GHz, with average antenna efficiency of 20%. The simulated total received power increased 4-15 mDBm during the cold stimulus, corresponding to 15-fold increase in BAT metabolism. Note that the minimum radiometric signal variation required to be detected by the microwave radiometer is 1 mDBm.

Conclusions: We present a mathematical model that allows studying the feasibility of non-invasive monitoring of brown fat metabolism with microwave radiometry. Results demonstrate our ability to detect thermal radiation from small volumes (2-6 cm³) of BAT located up to 12 mm deep and to monitor small changes (0.5°C) in BAT temperature associated with increased metabolism during cold exposure. The developed miniature radiometric antenna design appears suitable for non-invasive long term monitoring of small changes in BAT metabolism.