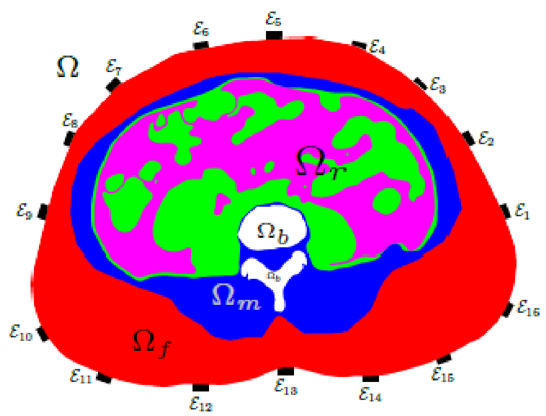
Diagnosing obesity by mathematically estimating abdominal fat

20 June 2017



Simplified abdomen image from CT with 16 electrodes. Red color represents subcutaneous fat region, blue represents muscle region, white represent bone region, pink represents visceral region, and green represents abdominal organs. Credit: SIAM

Abdominal obesity, or fat that accumulates around one's stomach and abdomen, has long been considered to pose a high health risk in individuals. Hence, measurement of "central obesity"—as it's often called—helps predict propensity to disorders caused by excess weight in the abdominal area.

In a paper publishing next week in the *SIAM Journal on Imaging Sciences*, researchers from ETH Zurich and Yonsei University in Seoul propose a new technique to evaluate abdominal obesity by estimating the thickness of subcutaneous fat.

"Recent studies have shown that abdominal obesity is linked with diseases such as congestive heart failure and metabolic syndrome," said author Jin Keun Seo. "Static electrical impedance tomography, or EIT, could be employed as a non-invasive surrogate of disease progression in these conditions."

In addition to being noninvasive, EIT, an imaging technique, provides real-time data without using ionizing radiation, which makes it preferable to computed tomography (CT) since it's less harmful to patients. Another imaging technique commonly used for this purpose, magnetic resonance imaging (MRI) has poorer spatial resolution than EIT.

"Compared to CT, EIT is more advantageous since it is non-ionizing and can hence be used for continuous patient self-monitoring to track body fat status in daily routines," Seo explained. "Unlike CT and MRI, EIT is a low cost, portable, and easy-to-use bedside technique to image electrical conductivity distribution."

Since electrical conductivity of biological tissue depends on its cell structure, it can help image different tissues in the body and distinguish them from each other. The cell structure of fat and muscle are quite different; hence, the electrical conductivity values of fat and muscle differ over different frequencies.

Multi-frequency EIT (MFEIT) reconstructs the image of conductivity inside the human body based on this dependence of tissue conductivity on frequency. And since bone, muscle, and fat conduct electricity differently over various frequencies, MFEIT can use data of the boundary current-voltage relationship at diverse frequencies to estimate the amount of fat. Again, since body fat is less conductive than water and tissues such as muscle, this difference can be used to estimate the thickness of visceral and subcutaneous adipose tissue.

The specific process involves a specially chosen current pattern, which generates a depth-dependent data set that is used to outline the borders between fat and muscle. Current is injected through one pair of electrodes, and the subsequent voltage drop measured at another pair of electrodes. The relation between the injected current and the voltage drop gives the transadmittance—or the ratio of current to voltage, which depends on the positions of the two pairs of electrodes, body geometry, and admittivity distribution, which combines both conductivity and permittivity. Assuming that the size of the electrodes is very small in comparison to the size of the border between the various tissue regions, the authors use a point electrode model, which provides a good approximation of the solution, while also simplifying the model considerably.

One issue with EIT is that the technique is prone to forward-modeling errors; these errors often include boundary geometry and electrode position uncertainties. In this paper, authors propose a new reconstruction method that compensates for this pitfall of EIT, using prior anatomical information at the expense of spatial resolution, and improving reproducibility. Numerical simulations demonstrate that the result of reconstruction is satisfactory in identifying subcutaneous fat.

"Existing approaches for static conductivity imaging are based on minimizing the difference between the voltage measured and that obtained from numerical simulations," Hyeuknam explained. "Therefore, obtaining reliable conductivity distributions requires both accurate modeling of the domain and the electrode configuration. This new method can obtain accurate imaging distribution by canceling out modeling errors."

Further research is needed to take advantage of the frequency dependent behavior of human tissue to estimate the distribution of visceral fat. "Current experimental work has shown promising results in detecting subcutaneous fat thickness as confirmed with ultrasound imaging," said Hyeuknam. "Future work is needed to determine the volume of visceral fat in patients with metabolic and cardiovascular disorders."

Abnormally high deposition of fat tissue in the abdominal area has been associated with disorders such as metabolic syndrome, cardiovascular disease, and malignancies. Quantitative assessment of visceral fat in the abdominal region using techniques such as the one described above can thus aid in evaluating the potential risk of developing such conditions.

More information: Mathematical Framework for Abdominal Electrical Impedance Tomography to Assess Fatness. *SIAM Journal on Imaging Sciences* (2017)

Provided by Society for Industrial and Applied Mathematics