Quantitative index of EIT based on 3D abdominal bleeding simulation model

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Abstract: According CT images, a 3D abdominal bleeding simulation model with real shape was set up using COMOSOL Multi-physics. By parameter sweeping, the surface measurement data for EIT were obtained while bleeding from 0~800ml. Total relative changes (TRC) of the data were calculated, shown a linear correlation (R>0.99) with bleeding volume (BV), which implies TRC be a good quantitative index to indicate BV.

1 Introduction

Electrical impedance tomography (EIT) is noninvasive and sensitive to abdominal bleeding. Bleeding model in pig shown that 30ml of blood could be detected by EIT [1], also EIT is sensitive to detect 20ml of conductive fluid in the peritoneum of patient [2].So abdominal bleeding can be dynamically and sensitively detected by EIT in vivo [1-3]. How to quantitatively monitor bleeding volume is the key problem which should be solved by abdominal EIT. Several quantitative indexes (QI), such as resistivity index (RI) [2,4,5], total relative changes (TRC) [6] and singular value decomposition (SVD) [7] have been reported to quantitatively estimate the volumes of lung air or liquid in dogs, abdominal liquids in phantom or patients, and balder volume in simulation, respectively. In order to systematically testify the relation of QI and BV, a 3D real shape abdominal bleeding simulation model was built.

2 Methods

The simulation model has been built from abdominal CT images. According the grey values of CT image, 3D shapes of liver, spleen, stomach, kidney and backbone, etc., were segmented and saved as CAD files. Then the data of different organs were input into COMSOL to form a 3D real shape model of abdomen. To solve the forward problem of EIT, 16 copper electrodes placed on the the model for polar driving and adjacent measuring.

2.1 To simulate different bleeding volumes

A sphere with different volumes to simulate different BV was put into the abdominal model at the electrodes plane, as shown in Fig.1. The volumes of sphere was set to 0, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700, 750, 800ml, in total 26 volumes. 0ml was treated as reference without bleeding. Using parameter sweeping function of COMSOL the radius of sphere was swept from 0 to 5.78cm, and 26 EIT data for the above BV were obtained.

2.2 To set parameters of the 3D model

In the 3D model, there are 243120 volume elements. For different organs and tissues, such as liver, spleen, stomach, kidney, backbone and blood, their conductivity and permittivity were set accordingly.

The bleeding simulation was done in COMSOL using the AC/DC module. Automatic changing of the current injection electrodes (polar driving) was accomplished by COMSOL LiveLink for Matlab interface [7]. For each BV a frame data with 16X16 was obtained by rotating 16 times of driving electrodes.

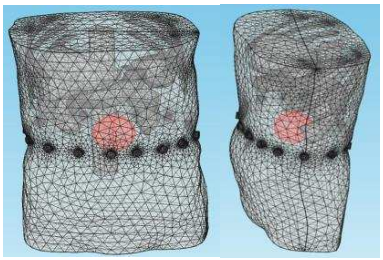

Figure 1: 3 D abdominal bleeding model with 16 electrodes

2.3 To calculate quantitative index

TRC was used as QI. The frame data without bleeding was set as reference data, and the other 25 frame data with different BV were used to calculate TRC [6], then the 25 TRC data and 25 BV data were analysed by linear fitting.

3 Conclusions

The TRC has a significant linearity with the BV (R=-0.999). Equation (1) gives the linear relationship between TRC and BV.

$$TRC = -0.0067*BV-0.0484 \quad (1)$$

The results shows that in 3D abdominal simulation model, TRC is a good QI to estimate BV in the range of 0-800ml, the results is also same as in phantom experiments [6], in which TRC has a good linear relation with the volumes of saline solution (150ml in total) perfused into physical phantom.

In practice, abdominal motion arising in breath and organ movements would cause impedance changes [2]. How to filter such kind of interfere and how to evaluate different QI, more trials in vivo should be studied further.

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