Detection of the Upper Airway Obstruction using Electrical Impedance Tomography

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Abstract: Obstructive sleep apnea (OSA) is caused by the occlusion of the upper airway. No real-time imaging technique, which can detect such occlusion during natural sleep, exists at the moment. The surface electrodes were attached on the face and neck, and then changes in the conductivity image of the upper airway were successfully detected.

1 Introduction

Apnea means the cessation of respiration lasting longer than 10 seconds during sleep. Obstructive sleep apnea is caused by repetitive occlusion of the upper airway, and it is diagnosed when apnea occurs ≥5 times/h. It has numerous complications such as hypertension, cardiac arrhythmia, ischemic heart disease, strokes and even mortality [1]. Despite several treatment modalities including the surgery, oral appliance, and continuous positive airway pressure device are used, overall control rate of OSA is not satisfactory. One of the main reasons is the absence of a real-time monitoring technique which can detect the upper airway obstruction during natural sleep. In the preliminary study, we ascertained the feasibility of the electrical impedance tomography (EIT) as a real-time monitoring tool for the upper airway obstruction [2].

2 Methods

2.1 Simulation study

In order to assess the potential of detection or feature extraction from the reconstructed impedance images or measurement data set, we generated the patient-specific FEM model based on the MR images. We segmented skin, muscle, spinal code, tongue, upper airway and teeth in the lower head. The conductivity in the literature was assigned into the each part of model. External boundary surface electrodes were placed in a ring.

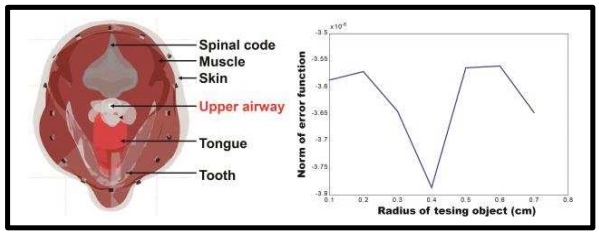

Figure 2. Patient-specific FEM model and size estimation of the upper airway

We assumed that the radius of upper airway was 0.4 cm, and computed the forward solution from the model. Concurrently, we calculated the norm of error function between the patient-specific forward data and pseudo data generated from the simple circular model when changing the radius of testing object. As shown in Figure 1, we can estimate the size of upper airway in the complicated anatomical model.

2.2 Pilot human experiment

We attached small Ag-AgCl electrodes around the upper neck of healthy male subject (28 yr). The upper airway is kept open during normal respiration. Transient airway occlusion was induced by the swallowing maneuver, and then we obtained the reference data. We produced the impedance images when the upper airway was open or closed using the KHU Mark2.5 EIT system [3]. Figure 2 shows the electrode position on the subject and the

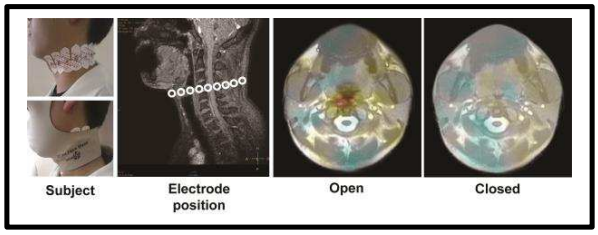

Figure 1. Pilot human experimental results

reconstructed impedance images overlapped on the MR images obtained from the same subject.

3 Conclusions

Based on our simulation and experimental studies, we can detect the status of airway and estimate its size when comparing the simulated model. Although further human studies are needed in natural sleep status, the EIT is presumed to be a useful tool to detect the upper airway occlusion which occurs during natural sleep in patients with OSA.

References

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