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SOLEUS AND *TIBIALIS ANTERIOR* ACTIVITY DETECTION USING ELECTRICAL IMPEDANCE TOMOGRAPHY

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SUMMARY

To access muscle activity during exercise is a difficult task with traditional image techniques. Electrical Impedance Tomography (EIT) is a promising non-invasive medical image technique due to its portability and high temporal resolution. In this study, EIT images were produced from data collected in a healthy subject with EIT tomographer during ankle flexions performed in a isokinetic dynamometer. The difference of two EIT images, one with full plantar flexion and the other with full dorsi-flexion, revealed an increased resistivity close to the anatomical position of *soleus* and *tibialis anterior*. This result indicate that EIT can be used access muscle activity.

INTRODUCTION

Several methods exist to access muscle activity. Surface EMG is one of the most common for superficial muscles. For deep muscles, needle EMG, ultrasound and, in some cases, MRI can be used. The physics behind each method determines its choice depending on the objectives of the analysis. For instance, EMG is a measure of the electrical potential generated by muscle cells and is associated with its neurological activity. Ultrasound senses density differences and is used to identify pathologies and structural muscle changes. MRI provides a better resolution than ultrasound for soft tissues but usually requires that the patient remain perfectly still while the images are being recorded. This restriction makes it difficult to apply MRI in dynamic muscle images.

Electrical Impedance Tomography (EIT) is a novel medical image technique that estimates an electrical resistivity distribution map within a subject's limb. For that, an array of electrodes should be attached over the skin. They are used to inject a small current into the body and to measure the resulting electrical potential. Then, this data is used as input to solve a non-linear ill-conditioned inverse problem that estimates resistivity distribution inside a domain that best explains measured potentials at the boundary [1].

EIT has been successfully applied to monitor lung function in Intensive Care Units [2], as well as other medical applications [3]. However only a few works has been published applying EIT to image musculo-skeletal system [4]. Kim et al, for instance, used a mixed method of EIT and magnetic ressonance to produce an in vivo conductivity image of the calf [5]. The aim of this study is to show that EIT images can be used to identify active muscle groups during exercise.

METHODS

A healthy individual was selected to perform an ankle flexion with the knee bended in an isokinetic dynamometer (Biodex). Thirty two electrodes where distributed in four layers, with eight electrodes per layer, around the calf. The distance between layers was approximately 60 mm and the electrodes were equally spaced around the layer.

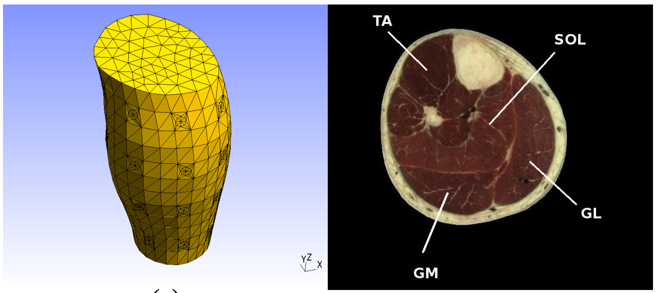
The subject was seated with the back reclined and was asked to perform 30 successive ankle plantar/dorsal flexions. Angular velocity was held constant at 150 deg/s by an isokinetic dynamometer.

The electrical potentials at the calf were measured by an EIT tomographer constructed at Laboratório de Engenharia Ambiental e Biomédica, University of São Paulo. It consists of a 125kHz voltage controlled current source, a multiplexer and an ICS-645 digitizer card using a sample rate of 2.5 MHz. With this equipment, it was possible to obtain 30 frames per second of demodulated data. From this data set, two frames were chosen to be used as input to solve an inverse problem with the Newton-Raphson method [6]. It was assumed that the resistivity of the medium was isotropic in the mathematical model.

RESULTS AND DISCUSSION

The resistivity distribution was reconstructed within a 3D mesh, shown at Fig. 1(a), representing a segment of the right calf. It was created based on the male dataset of the Human Visible Server from EPFL [7]. A section of the human calf, approximately 60 mm below the head of the fibula, is shown at Fig 1(b), indicating the anatomical position of the *soleus* (SOL), *tibialis anterior* (TA), *gastrocnemius lateralis* (GL) and *gastrocnemius medialis* (GM).

Figure 2 shows EIT images, i.e. resistivity distribution maps in Ohm.m, of a calf cross section located approximately 60 mm below the head of the fibula in the mesh. At the left, the image was computed when the ankle was in complete plantar flexion and at the middle, the image was computed when it was in complete dorsi-flexion. The differences between the two images are very subtle, and difficult to analyze. Thus, a difference image was computed and presented at the right of Fig. 2. The color scale was adjusted in a such way to minimize artifact effects.



(a) (b)

Figure 1: (a) Calf mesh, (b) Anatomy of the calf, right leg, view from bottom to top (adapted from [7]).

Subtracting the dorsi-flexion image from the plantar flexion image, a region became more resistive (positive variation in red) and a region became less resistive (negative variation in blue). The locations with positive and negative resistivity variations are close to the anatomical positions of the SOL and TA muscles, respectivelly. It means that SOL muscle was more resistive and TA muscle was less resistive during plantar flexion. The opposite happens in dorsi-flexion. These results indicate that, for the particular isotropic mathematical model, the arrangement of electrodes and the current pattern adopted, muscle contraction increases resistivity in EIT images.

CONCLUSIONS

In this work an experimental protocol was proposed to observe the activity of SOL and TA muscles with EIT images during ankle flexion exercise. The EIT images computed with this formulation presented very subtle resistivity variations and were prone to artifacts. However, a difference image between the plantar and dorsi-flexion, were still able to reveal the aproximate location and size of these muscles in a cross section image of the calf.

This result indicate that EIT can be used to access muscle activity and, due to its particular characteristics, is a promissing technique to study deep muscles. However, the spatial resolution and image artifacts are limitations that still need to be addressed.

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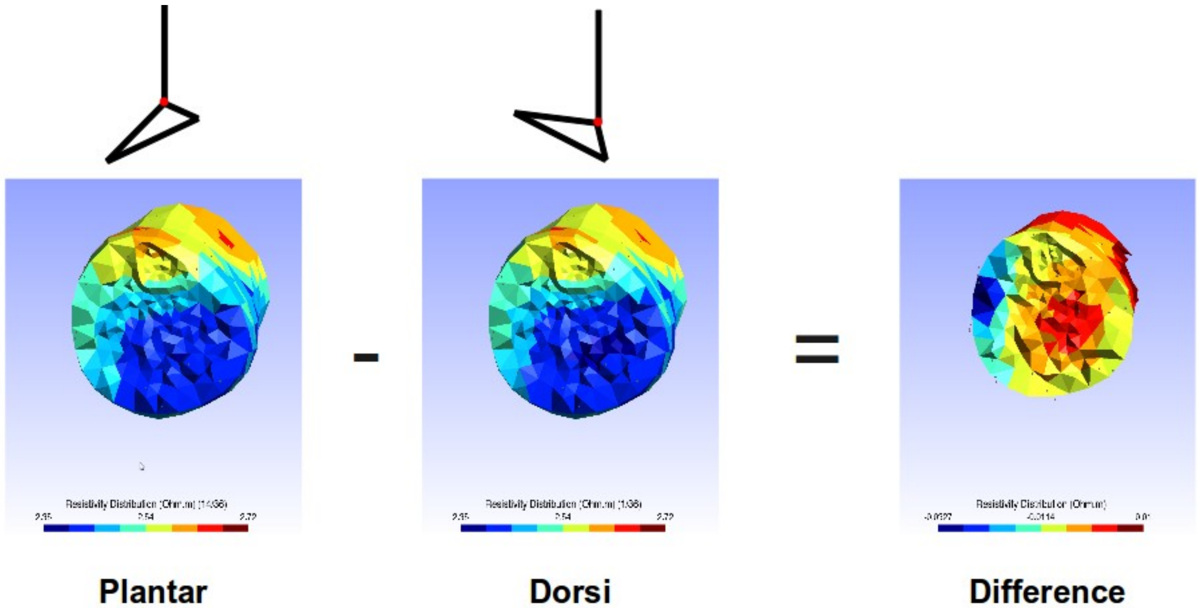

Figure 2: EIT images of the calf. Left: with dorsi-flexion. Center: with plantar flexion. Right: difference image between dorsi and plantar flexion.