APPLICATION OF STEREOLITHGRAPHIE IN MONITORING MUSCLE GROWTH INDUCED BY ELECTRICAL STIMULATION OF DENERVATED DEGENERATED MUSCLES

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Abstract

Spiral CT is used to gather three-dimensional data of upper leg tissue. Data representing muscle tissue type is isolated for measurement purposes. This is done in order to monitor muscle growth induced by electrical stimulation treatment. This treatment of paraplegic patients with denervated degenerated muscles is done in the framework of the EU funded project RISE. Computer models and models made with rapid prototyping methods are made to display and demonstrate the muscle growth. Results show that time and spatial dependencies of muscles growth can be monitored and studied quantitatively and qualitatively with the aid of three-dimensional data set displayed on the computer screen or in form of plastic models.

Introduction

In the frame of the RISE project [1], [2] three paraplegic patients with fully denervated and to a great extent degenerated muscles in the lower extremities are treated with electrical stimulation. These long-term flaccid paraplegic patients have no hope of gaining their muscle function with traditional treatment. On the contrary they suffer from side effects of their lesion. This includes decubitus ulcer, reduced bone density and thus higher risk of breaking the bones, lower metabolism exc. The goal of the electrical stimulation is to restore muscle fibres, mass and function in order to make the patients able to stand up and maintain a standing posture with the aid of electrical stimulation. Body balance is maintained with the aid of bars or other external aids. The muscles force should be enable the legs to bear the patients weight. Building up mass, force and function of a denervated and degenerated muscle has been shown to be possible [1] with long-term electrical stimulation treatment. The muscles are stimulated one or two times a day, six days a week for two years. During that time the muscle is expected to gain considerable in mass and size and thus its ability to perform work. Throughout the treatment the patient's progress is monitored by several means. The monitoring methods are aiming at histology and cell biology, the muscles function and at its mass and shape. For the shape, CT scans are taken, in the case of the m. quadriceps, with a regular 10 cm interval beginning at the trochanter and going down to the knee [1]. In total five scans are taken. A comparison of two scans taken on two different times on the same height shows well the muscle growth in that specific place in the given time. Comparing five scans, taken with 10 cm interval, gives an estimation of the total muscle growth in the same time. However it does not show the growth of the whole muscle. Also the data from only 10 scans is not sufficient data to use as for three-dimensional calculations of current distribution in the leg. They are done to estimate the necessary current intensity to depolarise the muscle cell above threshold and hence produce muscle contraction.

In this work we use a different approach witch will be discussed in the following.

Material and Methods

Spiral CT

With four months interval a spiral CT is taken of each of the three RISE patients in treatment in our institution. This has been done since beginning of treatment and will be done for the two years time of the RISE project. Giving in total a six scans of each patient. The scans are taken beginning at the trochanter and going down below the knee, with a pitch of 0,8 mm giving in total around 750 CT slices depending on patient's size. Each slice has 512 x 512 pixels. Each pixel has a grey value in the Houndsfield scale of 4096 grey scale values meaning that it is represented with a 12-bit value. A total dataset from a single scan is therefore 512 x 512 x 750 x 12 = 2,2 GBit or 300 MB. This dataset gives a complete three-dimensional description of the tissue and hence the muscles in both upper legs.

Tissue differentiating

The dataset is loaded into a computer program used to extract the tissue of interest. This can easily be done to separate bone from muscles or fat from muscles. It is partly done automatically with filters built in the programme and/or partly in an interactive way by the user. The user defines the grey scale values he wants to display, area of interest and some other properties the object has to fulfil that he wants to display. By these means we have however not been able to separate the different muscles or different muscles parts from each other, meaning that we can only show the muscles as one object.

Display

The tissue of interest can then be displayed as a three dimensional object on a computer screen. Thereby different tissue type can be put together on the same image. Figure 1 shows an example of this.

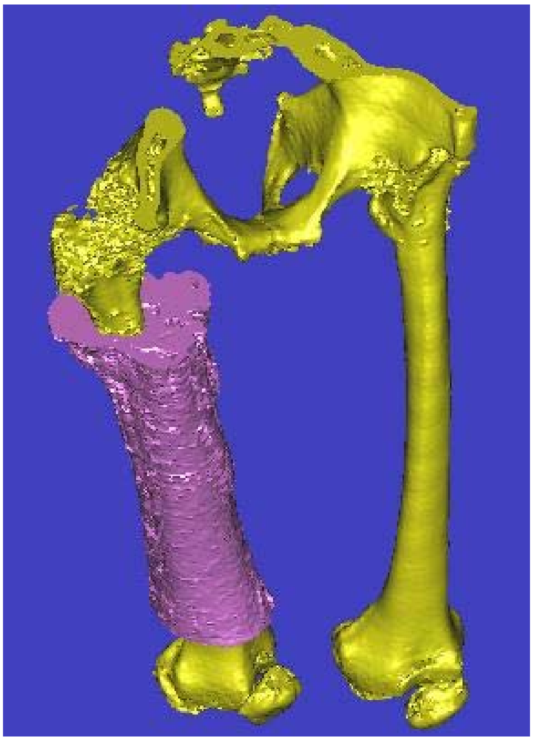

Fig. 1: The two femur bones and the pelvis of a car accident patient. The enervated and degenerated muscles on the right leg are partly shown. Note that the pelvis has suffered from the accident.

Measurements

To monitor the treatment measurements are made with the help of the data representing the isolated muscle tissue and its portion of total tissue in a single slice. Slice area, muscle volume, muscle mass, density are examples on parameters that can be measured or estimated. This will be done in due time to access muscle growth.

Stereolithographie models

Solid models of various materials are done of the muscles of the upper leg with the associated femur bone. These models are done in colour so that bone tissue is clearly distinguished from muscle tissue. These models will be done for every measurement instance. The result is a row of models from every patient showing the patient's progress throughout the treatment. This will be used for demonstration purposes.

Results

Three dimensional computer models of denervated degenerated upper leg muscles of paraplegic patients have been made. These models are the first in a row to monitor the outcome of an electrical stimulation treatment. In due time they will show the muscle growth throughout the treatment period. Since the models are made with data taken periodically every four months they will show the muscle growth rate in every period. They will also show the spatial distribution of the muscle growth, which is believed to be unequal along the length of the muscle.

Discussion

In further work other data sampling modalities than CT will be used. MRI and ultrasound are among the candidates. This gives hope of solving the problem of isolating muscles from one another or separating muscle parts.

References

[1] Kern, H.; Hofer, C.; Mödlin, M.; Forstner, C.; Mayr, W.; Richter, W.: "Functional Electrical Stimulation (FES) of Long-Term Denervated Muscles in Humans: Clinical Observations and Laboratory Findings." Basic Appl Myol, 12, (6): 291-299, 2002.

[2] Mayr, W.; Hofer, C.; Bijak, M.; Rafolt, D.; Unger, E.; Reichel, M.; Sauermann, S.; Lanmueller, H.; Kern, H.: "Functional Electrical Stimulation (FES) of Denervated Muscles: Existing and Prospective Technological Solutions." Basic Appl Myol, 12, (6): 287-290, 2002.

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