

MUSCULAR BIOMETRY WITH MAGNETIC RESONANCE IMAGING

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Abstract- Electromyographic (EMG) signal obtained from surface electrodes is frequently used to evaluate muscular activity. Analysis of this signal can be facilitated if anatomy of the implicated muscles is known as well as thickness of subcutaneous fat layer and of the skin under the electrodes. Such information can be obtained with a manual segmentation procedure applied on magnetic resonance images (MRI) obtained in three orthogonal planes.

I. INTRODUCTION

The diagnostic of muscular impairment is often achieved from the analysis of surface EMG signal. This evaluation is usually done in absence of any information on the medium separating the skin surface from the muscular zone of activity. Such knowledge can be gathered from MRI, which is a very good tool to study anatomy and to make measurements on various organs [7]. This imaging technique can help to confirm the diagnosis of musculoskeletal diseases [2] and can also be used for the follow up and the evaluation of therapeutic procedures [3]. Measurement on different anatomical structures in an image implies segmentation. This consists in identifying their boundaries and that can be achieved by mathematical algorithms [1,3]. In this context, many research projects are devoted to automatic detection of these boundaries or to the optimization of acquisition parameters such as resolution [4] and contrast [5]. In practice, manual segmentation is the most frequently used method in spite of the fact that experts' supervision is needed [6]. Such studies are mostly made on organs that offer good contrast with adjacent structures. When fuzzy boundaries are found, as between muscles, such analysis gets more difficult. We investigated this situation since analysis of EMG signal can be facilitated through knowledge on anatomical structures involved in surface recording. A method for the segmentation of skeletal muscles from MRI is proposed.

II. METHODOLOGY

MRI acquisitions of the upper limb of 6 healthy subjects were carried out with a 3D gradient spin-echo sequence. Acquisition time was 1 hour to obtain ~70 sagittal slices of the arm or the forearm. To identify the different muscles and measure their length, surface and volume, a specialized software¹ was used on a PC (Celeron 500 MHz, 192 Mb of RAM). According to the field of view (FOV) of the acquisition, the voxel dimension was 1.41x1.41x1.50 mm. For the skin and the fat segmentation, an automatic procedure based on gray-level thresholding was used since their boundaries are well contrasted. For the muscles, a manual segmentation procedure executed along 3 planes was used. This procedure is divided in 4 steps:

1) *Axial segmentation*: work is initially done in this plane because transverse slices of the upper limb can be easily obtained in an anatomical atlas. Segmentation is only carried out on slices where boundaries between the muscles can be easily detected (Fig. 1.B); otherwise the slice is not used.

2) *Sagittal segmentation*: slices in this plane are treated as the axial ones. Segmentation is easier in this step considering the information available from the axial segmentation (Fig.1D and E).

3) *Coronal segmentation*: with the information obtained from the 2 previous steps, a quite satisfactory segmentation can now be obtained. (Fig.1G and H).

4) *Refinement of the segmentation*: by combining the information obtained in each plane from the above steps, and considering that physiological contours are regular, boundaries between the anatomical entities are smoothed. (Fig.2).

III. RESULTS

For a non-expert user, the average segmentation time per muscle was ~5 hrs for the arm and 8 hrs for the forearm (due to the presence of many small muscles), for the first subject. With experience, these periods were reduced by approximately 50% when images of the 6th subject were analyzed. After the segmentation procedure, physical characteristics of each muscle (length, surface, volume) were obtained through interpolation between the slices. 3D rendering of the entire limb or of a single muscle can be done to visualize the structures under study. For instance in Fig.3A, an elastic band with markers was put around the arm to simulate indentation of surface electrodes on the skin. In Fig.3B, the skin is removed, but compression of muscles mass by the band can still be observed. Different lighting or color maps can be used and various points of view obtained.

As the segmentation is only performed on slices where satisfactory contrast is present, information on some part of the structure may not be available. This situation was frequent in the tendon zones. A typical case is illustrated at Fig. 3 D for triceps.

IV. DISCUSSION

In MRI where boundaries between anatomical structures can be problematic, a 3D acquisition protocol can be used. Segmentation in each of the available planes takes time but it minimizes the errors that a non-expert may produce. While the segmentation time is initially long, the operator can improve quite rapidly his knowledge on muscular anatomy and the procedure gets appreciably shorter. Processing time could further be reduced by the development of acquisition sequences or procedures providing greater contrast between

¹ SliceOmatic® 4.2: <http://www.tomovision.com>

Report Documentation Page

Report Date 25 Oct 2001	Report Type N/A	Dates Covered (from... to) -
Title and Subtitle Muscular Biometry With Magnetic Resonance Imaging		Contract Number
		Grant Number
		Program Element Number
Author(s)		Project Number
		Task Number
		Work Unit Number
Performing Organization Name(s) and Address(es) Institut de Genie Biomedical Universite de Montreal Canada		Performing Organization Report Number
Sponsoring/Monitoring Agency Name(s) and Address(es) sponsoring agency and address		Sponsor/Monitor's Acronym(s)
		Sponsor/Monitor's Report Number(s)
Distribution/Availability Statement Approved for public release, distribution unlimited		
Supplementary Notes Papers from 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom., The original document contains color images. , The original document contains color images.		
Abstract		
Subject Terms		
Report Classification unclassified	Classification of this page unclassified	
Classification of Abstract unclassified	Limitation of Abstract UU	
Number of Pages 2		

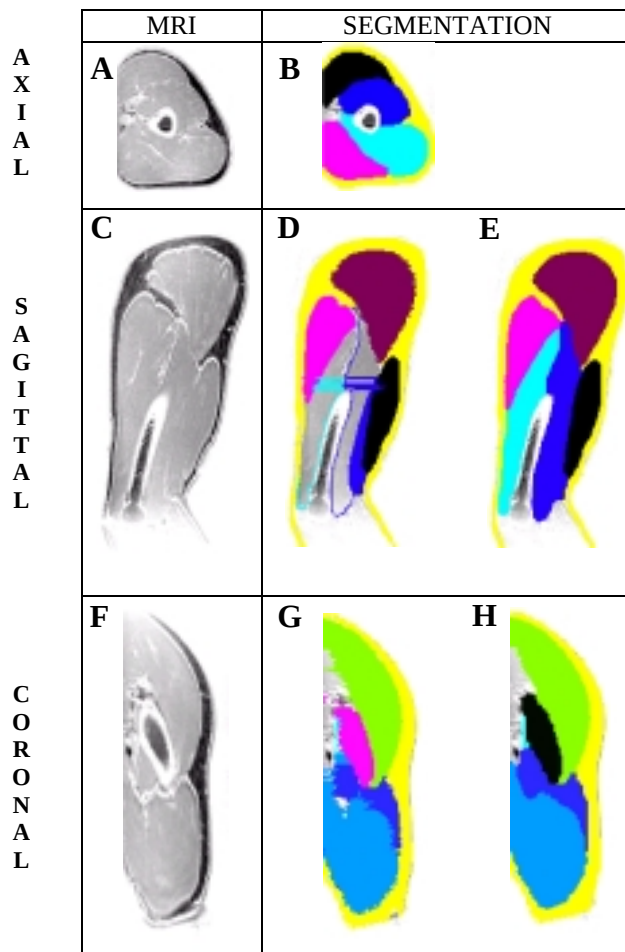


Fig. 1. Original (left) and segmented (right) images. B: Axial segmentation. D&E: Progressive improvement using previous results (axial segmentation). G & H: Coronal segmentation.

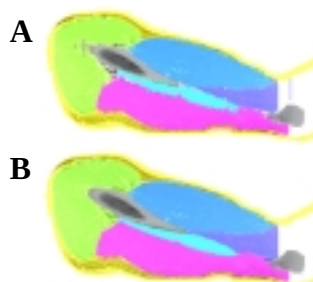


Fig. 2. Refinement of the 3D segmentation process. A: original result. B: Refined contours.

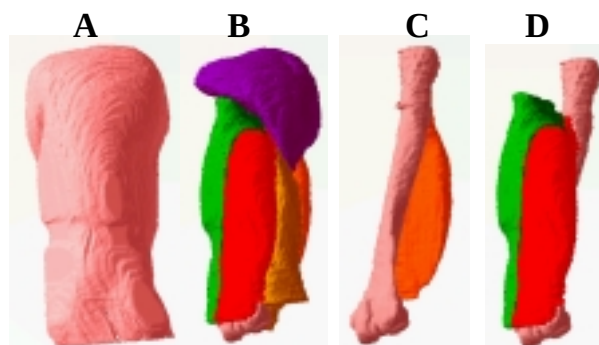


Fig. 3. Rendering of segmented images. Visualization with (A) or without (B) skin. Compression around the arm was induced by an elastic bracelet simulating surface EMG electrodes effect. Illustration of singular muscles: biceps (C) or triceps: med & lat head and long head (D).

anatomical structures. Such improvement may also help to reduce the undefined areas around the tendons. When the entire limb under study is imaged, a full-length view of all its muscles can be obtained but the pixel size is large. For a single muscle, FOV can be reduced and, with a small pixel size, it could eventually be possible to detect muscular mass changes in the course of therapeutic or training exercises.

V. CONCLUSION

On presently available MRI, manual segmentation of the same muscle along 3 different planes can provide reliable results when performed by non-expert persons. The use of contrast agents or new MRI acquisition sequences can help improve image quality. This would make the manual procedure less time consuming and eventually lead to reliable automatic segmentation of muscles.

ACKNOWLEDGMENT

Image acquisition was made possible with the contribution of Dr H. Mallouche of the Centre hospitalier universitaire de Montréal (CHUM). During his stay in Montreal, A. Malanda was supported by a Spanish MEC grant.

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Work supported by NSERC and FCAR