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CT-based reconstruction and modelling of muscle and nerve tissue

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ABSTRACT

Introduction

Biomechanical models have been successfully applied to screen potential risk factors for injuries and to plan and evaluate the effects of orthopedic surgical procedures.[1] These models have made apparent the feasibility and necessity for the generation of subject specific models that are aimed at custom clinical applications including computer- assisted preoperative planning and navigated surgery, robotic guided surgery and applications in the designs and analysis of customized orthopedic implants. In order to develop a model, capable of both accurate biomechanical analysis and predicting of position and characteristics of soft tissues and more specifically nervous and vascular structures, a methods needs to be developed that allows accurate geometrical visualization and reconstruction of these structures. [2] In this study we present our approach to develop a methodology to obtain both bony as soft tissue features necessary for upper limb modeling from computer tomography alone.

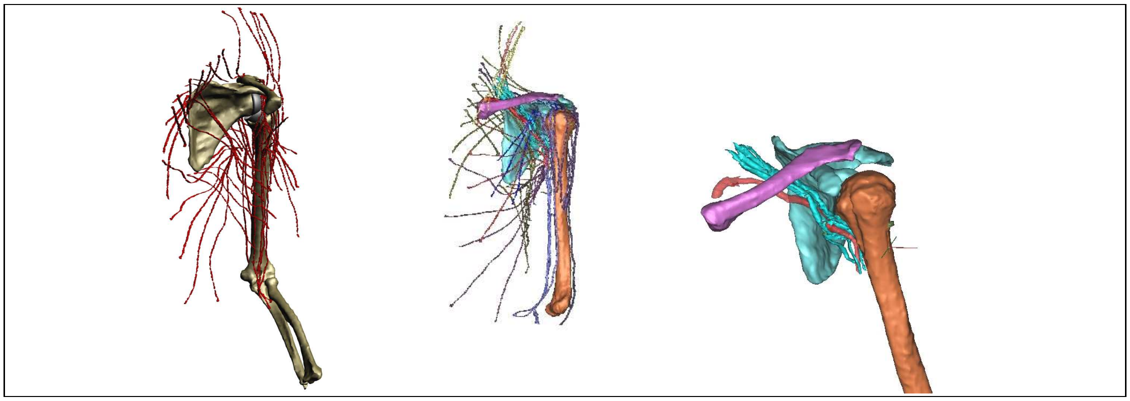
Methods

In order to visualize and reconstruct the different muscle segments of the shoulder girdle, flexible 0.7mm copper wires were sutured from origin to insertion according to the fiber directions on ten different cadaver specimens. The nerveous structures were dissected using an anterior approach and injected with a mixture containing iodiumcontrast (visipaque), glycerine and toluïdineblue to highlight the tissue on Ct imaging. At the same time sixteen 1.2mm diameter leaded markers were implanted in the plexus and peripheral nerves at topographically crucial via points for later enhanced recognition on CT reconstructions.

The specimens were studied by a helical CT scan with a 0,5mm slice increment (Siemens/ volume zoom). The software package Mimics ® (Materialise NV, Heverlee, Belgium) was used for visualization and segmentation of CT images and 3D rendering of bones, muscle segments, brachial plexus and peripheral nerves. Major vascular structures could be segmented based on the presence of air in their luminae. The same method was applied on a formalin embalmed female cadaver specimen containing a surgically placed plastic replica of the Delta extend reversed shoulder prosthesis (Depuy ® J&J).

Results

Bones, muscle, nerve and blood vessel features were visualized and segmented as separated masks. [Figure 1]. Analysis of the representations showed that the morphologic parameters were within the normal anatomical ranges. After applying a cluster method algorithm interruptions of the masks, scattering rustle and small irregularities due to the copper wires were filtered. After reconstruction, the vascular and nerve segment paths were accurately approximated using the draw spline function in the Mimics® software package. Each segment was exported in STL format and the respective positions and lengths were calculated. Muscle fibre positions and lengths were approximated using the global optimization wrapping algorithm. [3]



Discussion and Conclusion

The necessity for the generation of subject specific biomechanical models that are aimed at clinical applications, in particular in the design and analysis of orthopaedic implants, preoperative planning and accurate interpretation of post operative outcomes, is becoming increasingly apparent. Currently, musculoskeletal imaging techniques like magnetic resonance imaging and computed tomography scans can potentially provide a source for complete individualized models, however, the constraints of clinical reality e.g. cost, exposure to unacceptable levels of radiation and time, preclude at the moment the creation of full complex models of a region of interest. This gap can be bridged by creating an idealized generic musculoskeletal model that can be morphed into a specific patient model using limited computed tomography and morphometric data obtained pre-operatively and a database being created from a cadaver study where bone geometry and muscle fascicule paths are measured in detail.

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