Muscle fiber tracking and segmentation in the human forearm

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Introduction:

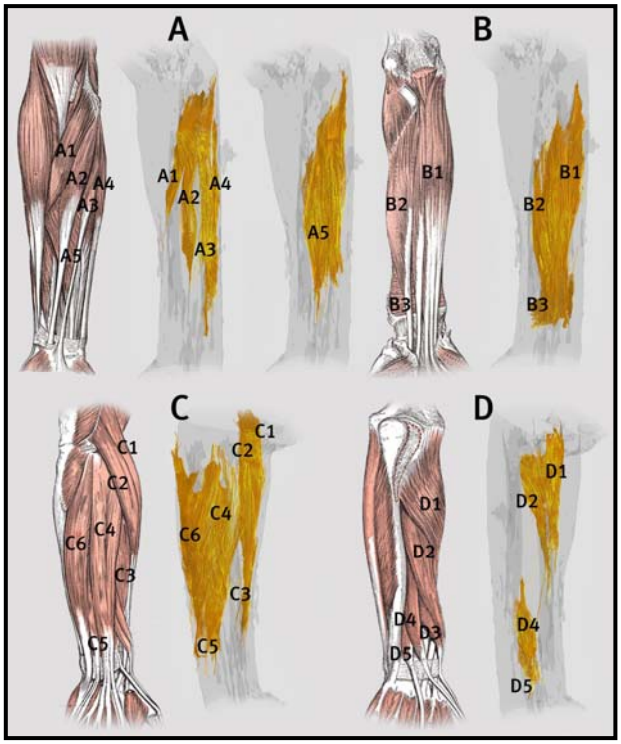
In the last years diffusion tensor imaging (DTI) in combination with fiber tracking algorithms proved a reliable method for obtaining muscle fiber orientation and muscle architectural parameters in vivo, first in rodents [1-3] and more recently also in man [4-6]. The human research so far has mostly focused on the lower and upper leg muscle architecture.
The goal of this research was to determine the potential of DTI to characterize human forearm architecture. We will show that the technique is able to delineate the complex structures of the forearm muscles in great anatomical detail.

Methods:

MRI: The right forearm of a male healthy volunteer was measured using four flexible surface coils on a 3T Philips Intera clinical scanner. T1 weighted imaging (T1w RARE, FOV: 200 x 200 mm^2, matrix size: 400x400, slice thickness: 6 mm, 50 slices, TR: 550 ms, TE: 12 ms) as well as DTI measurements using SE-EPI (FOV: 200 x 200 mm^2, matrix size: 79x79 with 112x112 reconstructed matrix, slice thickness: 6 mm, 50 slices, 16 directions, TR: 8 s, TE: 48 ms, number of averages: 2, b=400 s/mm^2, SPAIR fat suppression) were done. Diffusion weighted images were registered to their corresponding un-weighted image.
Segmentation: For each muscle of the forearm between 4 and 9 seeding ROIs were drawn along the belly of the muscle. Segmentation was an iterative process which started with a roughly drawn ROI in the middle of a muscle. Based on the fiber tracks the ROI was adjusted and more ROIs were added. The T1 weighted images were used as an anatomical reference and to evaluate the end result. Fiber-tracking was performed using the DTI-tool developed in house. Fiber tracks continued bidirectional until stopping criteria (FA < 0.2 or angle change >5 degrees/integration step) were satisfied.

Results and discussion:

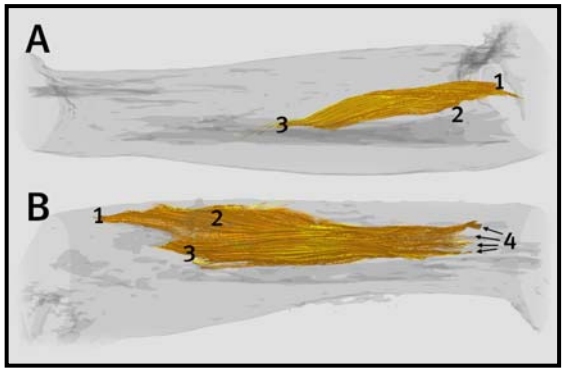
Figure 1 shows the result of fiber tracking and segmentation of individual muscles of the forearm next to anatomical illustrations [7]. For each muscle the fiber structure and origin and insertions could clearly be visualized with high detail (figure 2). We were able to define exact boundaries between neighboring muscles although in some cases this proved to be difficult. The extensor pollicis brevis could not be tracked (figure 1-D3).



^ **Figure 1:** *Fiber tracking of the muscles in the human forearm next to anatomical illustrations [7]:*
***(A)** Volar superficial group: 1) pronator teres; 2) flex. carpi radialis; 3) palmaris longus; 4) flex. carpi ulnaris; 5) flex. digitorum superficialis*
***(B)** Volar deep group: 1) flex. digitorum profundus; 2) flex. pollicis longus; 3) pronator quadratus*
***(C)** Dorsal superficial group: 1) brachioradialis; 2) ext. carpi radialis longus; 3) ext. carpi radialis brevis; 4) ext. digitorum com-munis; 5) ext. digiti quinti proprius; 6) ext. carpi ulnaris*
***(D)** Dorsal deep group: 1) supinator; 2) abductor pollicis longus; 3) ext. pollicis brevis; 4) ext. pollicis longus; 5) ext. indicis proprius.*

Conclusion:

We demonstrated the feasibility of characterization and visualization of human forearm muscle architecture in great detail using DTI and fiber tracking. All but one human forearm muscles could be segmented on the basis of the fiber tracking.



< **Figure 2:** ***(A)** Medial to lateral view of the pronator teres: 1) humeral origin, immediately above the medial epicondyle; 2) ulnar origin, arises from the intermusclular septum; 3) insertion into middle of lateral surface of the radius.*
***(B)** Volar view of the flexor digitorum profundus: 1) origin from a depression on the medial side of the coronoid process; 2) origin from the upper half of the volar and medial surfaces of the ulna; 3) origin from interosseous membrane; 4) ends in four tendons which run to the distal phalanges.*

References:
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