Dynamic imaging of muscle activity by optical tomography

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Abstract: We have explored the real–time response of the forearm vasculature to rhythmic contraction of antagonistic striated muscle groups. Dual–wavelength measurements were collected at 2 Hz, and the resulting image series (30 images per wavelength) was analyzed using appropriate time–series analysis methods. This revealed absorption coefficient fluctuations that were spatially coincident with the relevant muscle groups, occurring at the expected frequency and with the expected phase relation between the involved flexors and extensors.

OCIS codes: (170.6960) Tomography; (170.5280) Photon migration

1. Introduction: Adequate muscle performance is essential for everyday physical activity. Insufficiencies can result from neuropathy, destruction of the myofibril structure (myopathy), or from an inadequate vascular supply. In many cases, it is only in the latter instance that successful clinical intervention is feasible. The vascular response to exercise can be monitored in real time using optical methods. Of particular interest would be to perform similar measures, but in a cross–sectional imaging modality. For this report we demonstrated the feasibility of this sort of imaging measure, by performing dynamic tomographic measurements on the human forearm during a finger flexion study involving the fourth digit. We chose this as a simple test to monitor the coordinated movements of muscle groups. Finger movement is accomplished by contraction of flexor and extensor muscles located on opposite sides of the forearm. Repeated movement of the digit should produce an out–of–phase, time–correlated response that is spatially coincident with the involved muscles. Evidence of this response is given.

2. Methods: Data collection was accomplished by performing dual wavelength (780, 810 nm) parallel optical tomographic measurements at rate of 2 Hz using an iris imaging head [1] on the right forearm. For each of six source positions the fourth digit was flexed at a rate of approximately 0.28 Hz for several cycles. Variations in intensity readings about the temporal mean value were used as input for image recovery [2]. For each wavelength, images for 30 consecutive time points (15 sec real–time) were computed by simultaneously solving for perturbations in the absorption and diffusion coefficient. The resulting image data were analyzed using appropriate time–series analysis methods [3].

3. Results: Figure 1 shows an MR image of the right forearm, with some of the major anatomical structures, including the flexor and extensor muscles responsible for movement of the fourth digit, identified. Figure 2 shows a map of the amplitude of the Fourier transform, at the finger–flex frequency, of perturbations in the absorption coefficient at 780 nm. Figure 3 shows an overlay of Figures 1 and 2. Indicated by the arrows are two regions that

Figure 1

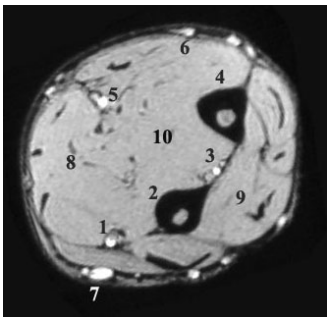


Figure 2

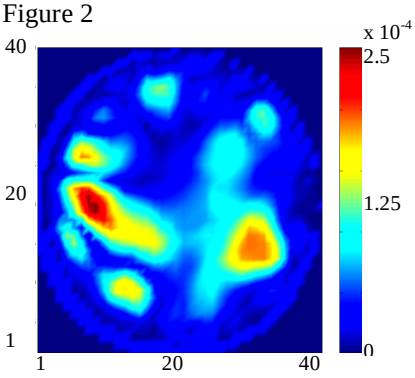


Figure 3

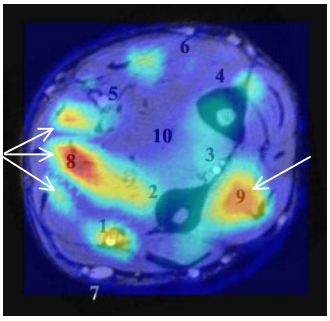


Figure 1: MR image of right forearm. Legend: 1), radial artery, 2) radius, 3) interosseous artery, 4) ulna, 5) ulnar artery, 6) basilic vein, 7) cephalic vein, 8) flexor digitorum superficialis, 9) extensor digitorum, 10) flexor digitorum profundus. Figure 2: Amplitude of Fourier transform at finger flex frequency for absorption coefficient at 780 nm. Figure 3: overlay image.

experienced relatively large amplitude variations upon finger–flexing and that overlay closely with the expected involved muscle groups. Another area that showed relatively large amplitude variations coincides closely with the radial artery. We interpret this as evidence that this vessel experienced compression against the fixed–diameter iris during the cycles of muscle contraction. Figures 4 and 5 show time trends in the extensor and flexor regions. Comparison reveals the expected out–of–phase response associated with opposing muscle movement. A map of temporal correlation throughout the cross section is shown in Figure 6. Here we observe significant positive correlations among pixels *within* each affected muscle group, and significant negative correlations *between* the two groups. Interestingly, the area that is strongly negatively correlated with region 9 of Figure 1 includes region 10. This corresponds anatomically to the flexor digitorum profundus muscle, which also contributes to flexion of the digits.

Figure 4

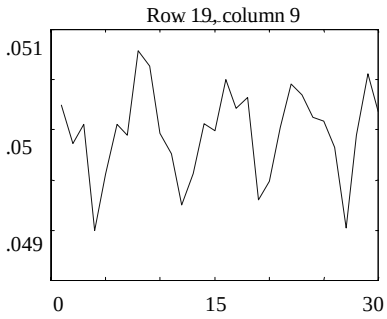


Figure 5

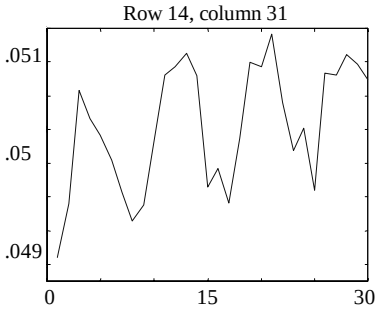
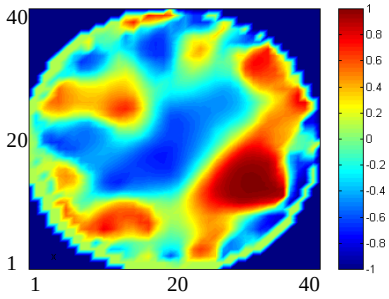


Figure 6



Figures 4 and 5. Time trend at indicated pixel positions. Figure 6. Cross-correlation image. Coordinates of index pixel; (15, 30).

4. Summary and conclusions: The feasibility of monitoring the real-time movement of antagonistic muscle groups by dynamic optical tomography has been demonstrated. Results revealed an expected out–of–phase, time–correlated response that is spatially coincident with the involved muscle groups.

5. References:

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[2] Y. Pei *et al.*, "Model–based imaging of scattering media based on a modified perturbation formulation using relative detector values," Optics Express, submitted.

[3] R. L. Barbour *et al.*, "Optical Tomographic Imaging of Dynamic Features of Dense Scattering Media," 1999 JOSA–A, submitted.

6. Acknowledgements:

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