Identifying Motor Unit Activity Using a Commercial Ultrasound Scanner - A Proof-of-Concept Pilot Study

Simone Ruiter[1], Robin Rohlén[1,2], and Christer Grönlund[1]
[1]Department of Diagnostics and Intervention, Radiophysics and Biomedical Engineering, Umeå University, Umeå, Sweden
[2]Department of Medical and Translational Biology, Umeå University, Umeå, Sweden
[1] Email: simone.ruiter@umu.se

Summary

Ultrasound (US) research scanners have recently been used to obtain motor unit (MU) activity. To improve clinical applicability, this study investigates whether similar MU activity can be detected using clinical US scanners.

A tibialis anterior muscle was simultaneously scanned using clinical US and surface electromyography (sEMG). Tissue velocity imaging (TVI) data was estimated from B-mode images, and spatial maps and twitch profiles were estimated from the TVI using spike-triggered averaging (STA).

The MU action potentials obtained from sEMG and US-derived spatial maps were estimated to be at approximately the same location. This demonstrates that clinical US may offer an accessible alternative for MU research.

Introduction

MU activity is traditionally studied using EMG, but recent advances in ultrafast US (>1 kHz) have demonstrated its ability to map MU activation over a larger field of view using TVI. This TVI data can be associated with the contributions from individual MUs through STA[1] or direct decomposition algorithms[2].

However, ultrafast US is not widely available in clinical settings. This study investigates whether a conventional US scanner, operating at a lower frame rate (∼64 Hz) without radiofrequency data access, can provide similar spatial information of the short MU twitches.

In this pilot study, our aim is to extract TVI features from a clinical US scanner and assess whether MU activity can be detected. This will be evaluated by comparing MU action potential locations estimated from sEMG and TVI.

Methods

The tibialis anterior of a healthy participant was scanned during low-force isometric ankle dorsiflexion. A clinical US scanner (ACUSON Redwood) with a 14L5 linear probe (64 Hz frame rate) was positioned mid-belly, perpendicular to the muscle fibres. Two surface EMG grids (Sessantaquattro+, 5×13 electrodes, 4 mm inter-electrode distance) were placed proximally and distally of the probe. Three sessions were recorded, each capturing 15 s of US with a 20×35 mm field of view and 90 s of EMG (sampled at 2000 Hz). The EMG signals were decomposed into MU spike trains, from which the lateral locations of each MU were identified.

TVI data was extracted from the US recordings using a recently proposed method [3], which enhances small motions in B-mode images through motion magnification, applies a bandpass filter (5–25 Hz), and performs speckle tracking, resulting in the final TVI data. Axial velocity was positive away from the probe and negative toward it.

STA was performed on the TVI data to extract the spatial distribution and temporal twitch profiles of the contracting MUs. The lateral MU locations derived from STA were compared to those obtained from sEMG. Velocity twitches were analysed by correlating them with the average twitch pattern [4]. Their amplitudes were recorded and the plausibility of the temporal profiles was analysed.

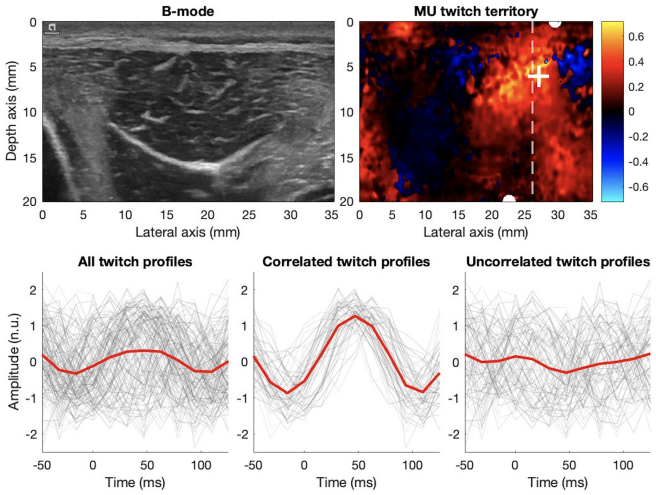

Figure 1: Top: B-mode (left) and detected MU territory (right) of a single MU. Half circles show EMG-determined locations, the dashed line their average, and the plus sign the MU territory estimated from US. Bottom: Twitches (gray) with their average (red) for all (left), correlated (middle), and uncorrelated (right) twitches.

Results and Discussion

EMG decomposition identified 44 MUs in total, with 130 ± 10 firings per MU. Of these, 10 MUs were detected in the US data, with a lateral difference of 5 ± 4 mm. Among detected twitches, 40% correlated with the average twitch pattern. These had an amplitude of 1.2 ± 0.2 n.u. and showed plausible twitch profiles. An example of the detected twitch territory and twitch profiles of one MU can be seen in Fig. 1.

Conclusions

This proof-of-concept pilot study indicates that MU activity can be identified using a clinical US scanner and sEMG. Despite the lower frame rate, the method using clinical US estimated MU twitch territories to be close to the EMG-identified MU locations. This approach offers a promising alternative for studying MU activity in clinical settings. Further validation is needed to confirm its reliability.

Acknowledgments

This project is supported by the Swedish Research Council (Grant Number: 2022-04747).

References

[1] Rohlén et al. (2023). *J Electromyogr Kinesiol*, **73**.
[2] Lubel E et al. (2024). *IEEE Trans Biomed Eng*, **71**: 1466-1477.
[3] Grönlund et al. (2023). *Medicinteknikdagarna*, O17.
[4] Lubel E. et al. (2023). *IEEE Trans Neural Syst Rehabil Eng*, **31**: 3699-3710.