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Editorial Open Access

Evolution of Quantitative Approaches for Muscle Spasticity Measurement

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Editorial

About 20 years ago, I first joined the spasticity measurement research group at biosignal laboratory (leaded by Dr. Jia-Jin Jason Chen) of Institute of Biomedical Engineering, National Cheng Kung University. At that time, the limitation of clinical approach for spasticity evaluation was initially noted by the researchers [1]. We developed our first quantitative measurement system based on driven motor and torque sensor to precisely measure the reactive resistance of elbow flexors during constant-velocity stretches [2]. We also proposed a parameter (ASRT, averaged speed-dependent reflex torque) to overcome the gravity and inertia problems in vertical stretch circumstance and to quantify the elbow spasticity of stroke patients under the constant-velocity stretch. During the development of spasticity, the changes of ASRT and velocity sensitivity of ASRT (i.e. velocity-dependent properties) of the involved and the intact elbow joints are presented and discussed in the same article [2].

Furthermore, we used the measurement system to evaluate the different features between muscle spasticity and rigidity [3]. Spasticity and rigidity are two major hypertonias found in patients with lesions of the upper motor neurons. Without quantitative approach, we commonly differentiate these two hypertonias with clinical experience. In our study, elbow flexors were vertically stretched under four different velocities (40, 80, 120, and 160°/s) through a 75° range of motion in 12 hemiparetic and 16 parkinsonism patients. With velocity dependence analysis, we found very interesting results indicating that rigidity and spasticity have approximately equal velocity dependent properties. In contrast, position dependent properties might be one of the main features to differentiate between these two hypertonias.

The motor-based system is excellent in its precise stretch with selected constant-velocity to eliminate the effect of inertia, but the bulky system is obviously not suitable to be online used in clinics. With the knowledge and experience of our motor-based system, a hand-held device was developed [4]. Light-weight air-bag cuffs with a differential pressure sensor and a goniometer were used to measure the resistance and displacement of elbow joint during to-and-fro stretches. Before it was used in stroke patients, three simulation modules representing inertia, damper, and spring modules were evaluated and validated for measurement of reactive resistance and displacement during manual evaluation. We applied the concept used in dynamic shear rheometer test for mechanical analysis of material [5] to decompose viscous component of spastic muscle. From viscous components at four different stretch frequencies (1/3, 1/2, 1 and 3/2 Hz), averaged viscosity denoting the velocity-dependence of joint properties was used to differentiate normal muscle tone and hypertonia. These findings suggest that measurements of viscous component and averaged viscosity during manual sinusoidal stretching using the portable device could be clinically useful in evaluating spasticity.

Furthermore, we applied our approach to evaluate the effects of botulinum toxin type A (BTX-A) on spastic elbow flexors [6,7]. BTX-A has been used for spasticity reduction because of its localized effect and convenience. However, evidence supporting the clinical efficacy of BTX-A still is not convincing, because the dosage for each person still cannot be accurately decided due to a lack of a suitable assessment tool. Our portable design allows for the convenient use of the device for quantifying spasticity in clinic environments. In short-term effects, our quantitative measurements suggest that BTX-A decreases spasticity within 2 weeks of injection. In our time-course observation [7], the results show that early relapse of spasticity (within 9 weeks of the injection) can be detected from our biomechanic assessments in a clinical setup.

For conveniently using the portable device in clinics, a compromise between precision and convenience is necessary. Compared to motor-based system, measurements using hand-held system might be compromised by the inappropriate operation in stretch range and stretch velocity. We minimized the effect by using the joint limiter to constrain the range and the metronome with sound cues to guide the stretch rhythm, but the patient compliance might be therefore compromised. To solve the issue, I decide to invent a novel quantitative device based on a clinical approach, i.e., modified Tardieu scale (MTS). With the help of fast development in MEMS sensors, our quantitative modified Tardieu approach (QMTA) [8] measures the angular displacement and resistance of stretched joint with a lightweight device that can be operated similar to conventional approaches for MTS. Our device for QMTA can objectively measure the changes in spasticity of the gastrocnemius muscle in children with cerebral palsy after BTX injection.

Our quantitative studies provide valuable information for clinicians when making decisions to perform additional rehabilitation interventions or another BTX-A injection in the early stages of treatment. In recent years, several researches [9-11] also have successfully developed instrumented manual devices for spasticity quantification. I hope more approaches can be developed in future and one of the approaches could be widely accepted to benefit the clinics.

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