

# How Single Fibre EMG Moved Into Clinical Routine



## Prof Erik Stålberg

developed SFEMG and a number of other EMG methods such as Macro EMG, Scanning EMG, Multi-MUP analysis. Quantitative EMG analysis in EMG for the understanding of pathophysiology in nerve and muscle disorders is his main research interest.

### Correspondence to:

Erik Stålberg,  
Dept Clin Neurophysiology,  
Uppsala University,  
Sweden.

## History

In the late 1950s, conventional EMG had been proven to be a useful complement in the evaluation of patients with neuromuscular disorders. The method had then been tested in some laboratories for a decade. At this time Dr Jan Ekstedt and myself were introduced to research in the Dept of Pharmacology, Uppsala. Our mentor, Prof Bárány, suggested to us to study fatigue of skeletal muscle. Could this be reduced pharmacologically in the same way as the heart muscle can be strengthened? For that we needed techniques to measure fatigue. Trials with mechanical force measurements with strain gauges in combination with various recordings of electrical muscle activity, electromyography (EMG), were the basic methods to be used. With insufficient information from these routine methods, we concentrated on the improvements of the EMG methods and tried surface EMG, wire electrodes and conventional concentric needle EMG. Inspired by multielectrode studies by Buchthal and collaborators,<sup>1</sup> we started to construct multielectrodes, but smaller and more selective than those previously used. This ended with various multielectrodes with the recording wires sized 25µm in diameter, that is smaller than a normal muscle fibre, exposed in a side-port close to the tip of a small cannula. We recorded brief signals, the nature of which finally, after experiments with ischaemia, curare, simulations, special electrode configurations, were proven to represent activity from single muscle fibers. This resulted in two PhD theses, one on the recording method itself and the description of the jitter phenomenon<sup>2</sup> and one the measurements of propagation velocity and "fatigue" in single muscle fibres.<sup>3</sup> Without substantial work on the original project on fatigue we left the institution and moved to the clinical side, Ekstedt to neurology, and I to clinical neurophysiology. I now had the chance to test this new method in patients, and successively implement it for routine use.

## What do we measure

The method of single fibre EMG is much more selective than conventional EMG. There are two parameters that have a clinical application. One is the assessment of fibre concentration within a motor unit, a parameter called Fibre Density (FD). The background is that muscle fibres, innervated by the same neuron with connected axon, are randomly distributed within an area of 5-15 mm, and separated from each other by about 200µm. In cases of reinnervation the surviving motor unit will innervate denervated neighboring muscle fibres. This so called collateral reinnervation

results in a change in organisation of the muscle fibres that now occur in small or large groups together. On biopsies this is observed as so called fibre type grouping. Also in myopathies, the organisation is different from normal due to splitting, degeneration-regeneration. This parameter is a good complement to the conventional EMG when the picture is difficult to interpret.

The other parameter is the neuromuscular jitter. This is, in the individual motor end-pate, the variability of the trans-synaptic time for a nerve pulse to activate a muscle fibre. This particular parameter is the most important contribution from SFEMG.

## Screening the usefulness of SFEMG in various neurological disorders

The early steps in the development were to test the method in a variety of nerve and muscle disorders. It was clear that the jitter parameter was directly applicable in the diagnosis of myasthenia gravis, MG, and other disorders with disturbed neuromuscular transmission. It also contributed to the understanding of reinnervation dynamics and has found a place in the neurogenic diseases. In myopathies, special new aspects have evolved particularly in the field of channelopathies (myotonic disorders). The results have been published in a large number of publications.<sup>4,5</sup> The interested reader is referred to a monograph on SFEMG<sup>6</sup> with a new edition under preparation (Stålberg, Trontelj, Sanders, 2010).

## Technical improvements

The jitter is based on measuring time variability of the order of four to a few hundred µsec, normally below 50µsec. Initially, the electrodes and amplifiers were home built, and the measuring devices were dependent on separate timers for short time intervals (Figure 1). Since the wide testing of the SFEMG in various pathological conditions successively showed the clinical usefulness, commercial electrodes became available and all high level EMG equipment now have inbuilt software for jitter analysis and other software based on the results from SFEMG studies (Figure 2). The technique to obtain single fibre potentials takes some training and manual skill. It has therefore been of utmost importance that the online signal analysis can be made with user friendly software.

## Applications and Present indications

The jitter parameter is the most sensitive physiological test of neuromuscular transmission.<sup>4</sup> It is possible to detect even subclinical disturbance, i.e. before the patient has symptoms in that mus-



Figure 1: The author and his engineer (1977) in front of their assembled EMG recording system. Large, multi-knobbed and very flexible equipment connected to a separate computer.

cle. The method has therefore become a routine method in many laboratories all over the world, and is recommended to be used when the repetitive nerve stimulation (RNS) test is negative. It should be stated that increased jitter is not equal to MG, but indicates disturbed neuromuscular transmission. One such situation is during ongoing reinnervation. The sensitivity in MG has been tested by many authors. The largest study is published by Sanders and collaborators.<sup>7</sup> They find a correlation to severity of the MG. In 503 MG patients, the sensitivity of SFEMG was 97% in ocular MG if two muscles are studied and 99% in generalised. They have also shown that the degree of jitter follows the clinical situation and that the method can be used in monitoring over time.

Usually SFEMG recording is performed under slight voluntary activation of the muscle. Some investigators prefer to use stimulation SFEMG. Here a monopolar electrode is inserted in the muscle as stimulating cathode and the individual endplates are studied.<sup>8</sup> The advantage is that no patient cooperation is necessary (small children, unconscious patients, patients with movement disorders). In addition, the neuromuscular junction can be studied during different stimulation frequencies, one way to differentiate presynaptic from postsynaptic defects. Stimulation SFEMG has been used in the study of congenital myasthenic syndromes.<sup>9</sup> Stimulation is performed with a small needle electrode near the facial nerve, and recording is performed in the frontalis or orbicularis oculi muscle.

The fibre density, FD, parameter is used to evaluate the organisation of the motor unit, as a sensitive indicator of abnormality, neurogenic or myogenic. No special measuring software is necessary. FD measurements can be performed in all EMG equipment where the sweep can be triggered. This is often a parameter that is included in the complete SFEMG study. The SFEMG indications can be briefly summarised as follows:

#### **Jitter**

Neuromuscular transmission disorders  
diagnosis,  
distribution between muscles,  
monitoring.

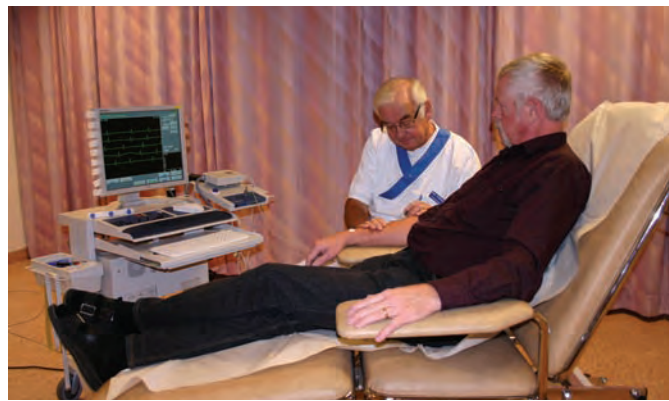


Figure 2: The author and an engineer (2009) from the Dept of Clinical Neurophysiology using modern EMG equipment, developed in the Department (by S Stålberg and the staff, and by Dantek A/S, Copenhagen, Denmark). Note the size reduction of this compact, multi purpose EMG equipment for routine use with inbuilt computer connected to a laboratory network.

Reinnervation dynamics (larger jitter in the phase of ongoing reinnervation, larger jitter in active than in chronic myositis).

#### **FD**

Reinnervation

Degree of involvement.

Complement to EMG when results are uncertain.

Myopathy

When conventional EMG is uncertain.

#### **Special indications**

For spike triggering (motor unit counting, Macro EMG, Scanning EMG), Firing rate of individual motor units.

#### **New developments**

Over the last 10 years, the use of re-sterilised products has been discouraged or abandoned due to potential risk of prion infections. The SFEMG electrodes can be used for hundreds of investigations if properly maintained, but are too expensive for single use. Therefore there has been a great interest in alternatives with disposable electrodes. One such alternative is the conventional concentric electrode used with special filter settings on the amplifiers. A small facial needle electrode seems to be a reasonable replacement.<sup>10</sup> Reference values have been established in a few individual laboratories (for summary see reference 11) indicating that the jitter values for concentric recordings are about 3-5µsec lower than those published from a multicenter study with regular SFEMG.<sup>12</sup> This new possibility is therefore accessible for all electromyographers, since the electrode has the same low price as other disposable electrodes. Great care should be taken during recording and interpretation, and some more work is necessary to define some details of the technique.

#### **Summary**

- The principles of SFEMG should be known by all electromyographers, since the single fibre action potentials are the basic components of the motor unit potentials. The jitter seen in SFEMG can also be observed in the motor unit potentials as variability in its shape at consecutive discharges. Thus, this should be interpreted as an indicator of disturbed neuromuscular transmission, a useful observation from conventional EMG.

- SFEMG should be applied in patients with suspicion of neuromuscular disturbance, particularly when RNS has been negative.
- SFEMG can be used to assess the dynamics of neurogenic and myogenic disease. An increased jitter indicates active reinnervation after denervation that has taken place during the last 3-6 months.
- The electromyographer may also use SFEMG in situations when conventional EMG has given uncertain results. The additional information may then help understand the condition better.
- SFEMG can be performed in all muscles where conventional EMG can be performed.
- Small children, unconscious patients can be studied by using stimulation SFEMG.

#### **REFERENCES**

1. Buchthal F, Guld C, Rosenfalck P. *Multielectrode study of the territory of a motor unit.* Acta Physiol Scand 1957;39:83-103.
2. Ekstedt J. *Human single muscle fiber action potentials.* Acta Physiol Scand 1964;61:1-96.
3. Stålberg E. *Propagation velocity in single human muscle fibres.* Acta Physiol Scand 1966;suppl 287:1-112.
4. Trontelj JV, Stålberg E. *Single Fiber and Macro-Electromyography.* In: Bertorini TE, ed. *Clinical Evaluation and Diagnostic Tests for Neuromuscular Disorders.* Woburn, MA, USA, Butterworth-Heinemann / Elsevier Science; 2002. pp 417-47.
5. Sanders DB, Stålberg E. *Single-fiber electromyography.* Muscle Nerve 1996;19:1069-83.
6. Stålberg E, Trontelj JV. *Single Fiber Electromyography in Healthy and Diseased Muscle.* New York: Raven Press; 1994. 1-291 p.
7. Sanders DB. *Clinical impact of single-fiber electromyography.* Muscle Nerve 2002;Suppl 11:15-20.
8. Trontelj JV, Stålberg E. *Jitter measurement by axonal stimulation. Guidelines and technical notes.* Electroencephalogr Clin Neurophysiol 1992;85:30-7.
9. Tidswell T, Pitt MC. *A new analytical method to diagnose congenital myasthenia with stimulated single-fiber electromyography.* Muscle Nerve 2007;35:107-10.
10. Stålberg EV, Sanders DB. *Jitter recordings with concentric needle electrodes.* Muscle Nerve 2009;40:331-9.
11. Kouyoumdjian JA, Stålberg E. *Reference jitter values for concentric needle electrode in voluntarily activated Extensor digitorum Communis and Orbicularis Oculi muscles.* Muscle Nerve 2008;37:694-9.
12. Gilchrist J, Barkhaus PE, Brill V, Daube JR, DeMeersman J, Howard J, Jablecki C, Sanders DB, Stålberg E, Trontelj JV, Pezzulo J. *Single fiber EMG reference values: a collaborative effort.* Muscle Nerve 1991;15:151-61.