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Some memories

Contents

1 PREFACE

In a Skype call around 2010, my friend and colleague Joe Jabre whispered to me that a summary of important parts of my life, personal and professional, would be better use of time than another article on EMG. It was a soft tone that immediately resonated with me. Thinking of it, I realized that I could use my time for other projects. It had never before been in my mind to make something like a biography, which would be too much of SFEMG development. But maybe some aspects of it could be of interest. My family has some idea of my professional life, friends have no idea, colleagues know something of the background, but the special struggle and the many sidetracks and dead ends are not documented. Therefore this. I try to relate some of the personal milestones and then a mix of things that have formed my professional life.

Joe Jabre. Thanks for initializing this biography

A physician who nowadays is a well-known author (P.C. Jersild), said that memories probably have their greatest value in the mind of the holder. Memories from way back have

been colored, modified and adjusted to things later in life. They may be partly incorrect and reflect more than pure facts. When printed they become fixed. Like an iceberg, only the small part above the surface can be seen. Therefore, this is my story as I remember it. I have tried to give accurate information to the best of my ability.

2 TIME IN SKELLEFTEÅ, MY HOMETOWN

My city of Skellefteå had 27,000 inhabitants at that time, just south of the polar circle in northern Sweden, 15 km away from a river mouth in the Baltic. My father was a school teacher and later school master. My mother worked at home with 2 children, me and my 6 years younger sister. Not too many "activities" as I see nowadays in my grandchildren. It was piano lessons and then mainly outdoor activities that required an innovative mind to make fun. We, the 2 or 3 neighboring children, constructed a bobsleigh from some planks and lots of water to freeze snow to ice; we made huts in the nearby forest and exceptionally played tricks on neighbors, such as rubbing a piece of resin on a string attached to the neighbor's window. In winter we made large caves in the snow and in summer we could kick a football until 8 pm sharp when I had to go home, although the sun still was high in the sky. I was often skiing with my father.

Homework was important from first grade, middle school to high school. In grades 3-5 I had my father as a teacher and that was no bonus to me, but I understood his decision not to give his son any favors, rather the opposite. He was responsible for the school garden in summertime. For a couple of years at my age of around 10-12 I was his stand in and learned some tricks. During 3 summers somewhat later, around 15 years old, I worked in the garden of the local hospital, my first contact with the medical environment, except for a hernia operation,. at 6.

My first job choice, train driver.

A snow carousel for my sister.

Job at the hospital agricultural garden

2.1 School

In high school I chose the natural sciences track, by chance maybe. No idea yet about my future, now only 3 years away. This was a time of intense reading. Weekends often meant that I invited a friend for some joint efforts on homework, calculus, physics and a nice cup of tea with rich sandwiches made by my mother.

2.1.1 Plankton

My high school teacher in biology gave me the idea of exploring plankton in my home area. My father and I took our bicycles to collect water from a large number (50?) of lakes. Some were 50 km away, others closer. Microscopic analysis of the samples and a full report to my teacher during the following year.

During the 2nd year in high school, I got a summer stipend to visit Swedish mines and steel industries. The aim from the inviter was to recruit young students to civil engineering. During these weeks I decided not to take that track and have never been able to find the reason for that decision. After high school it was time for compulsory military service for 15 months; that seemed long to me. If you chose medical studies, the military service was done during 3 summers plus some extra time as a doctor. Very tempting, so why not. I told my parents and heard no objection. So it was, after finishing high school, directly to the 3 months of service before entering the nearest medical school, then in Uppsala (1955).

3 STUDIES IN UPPSALA

In Uppsala I was helped by friends of my family to find a private room, quite decent. Uppsala is also a small city, at that time perhaps 80,000 inhabitants, of whom 25.000 were students. It was walking distance to the institute of anatomy in the first year, histology and physiology

the next year and so on. During military service I became close friend with a young man (Lars-Olof Dahlbäck) who also was accepted to the Uppsala medical school. We were best friends and studied Hafferl anatomy the first year, day and night, rehearsed before small exams, went for Saturday swims, to cinema and to the telephone station Saturday at 18.30 to call home. None of us had a telephone.

Lars-Olof´s girlfriend from their common home town came at the same time to Uppala for language studies. She stayed with her grandmother. Over the coming few semesters I came to know the family of that girl, her parents and brothers. I had heard that there was only one that I did not know in that family, a sister who was coming a few years later. I waited for herand all of a sudden, I got my Eva. My best friend Lars-Olof became my brother-in-law. Later we made experiments on ischemia together, which were included in his doctoral thesis.

3.1 Assistant in Pharmacology

During the course in Pharmacology, I was intrigued by the experiments (we used string galvanometers, writing on smoked paper), research atmosphere and some special people – Prof. Ernst Bárány and a young assistant, Jan Ekstedt. I was offered to stay and join as the lowest rank assistant (instructor, in Swedish 3:e amanuens), which I happily accepted (1958). This activity meant some teaching and trying to find a project in parallel with continued medical studies.

3.2 Time with Ekstedt

Jan Ekstedt was a couple of years older than me. He was also browsing for research projects that would lead to his PhD thesis. Prof Bárány suggested that we looked into the field of fatigue. His idea was that one can strengthen the heart muscle by means of digitalis. Can we do something to overcome muscular fatigue with drugs? We started to build devices with strange gauges, ink jet recorders, blood pressure cuffs, fixation devices for measuring thumb movements. The model was some relatively new studies by Merton, working with hand muscles (adductor pollicis brevis). I was regularly Ekstedt´s test subject and increasingly more active in constructive discussions about the project. This was the beginning of a long friendship between us as two people with great interest in problem solving, both theoretically and in practical terms. Our families came close for many years in Uppsala. After his dissertation, Ekstedt went to the pharmaceutical industry for some years and then he left Uppsala to become professor in Neurology in Umeå, in northern Sweden. There he focused on cerebrospinal fluid hydrodynamics (initiated by early signs of hydrocephalus in his father,

when he gave a speech at Ekstedt´s dinner after his dissertation). After his retirement we again saw each other when he and his wife moved back to Uppsala.

3.3 Why Clinical Neurophysiology

During my time in Pharmacology, I finished my medical studies in March 1963. I worked for a short period in the Department of Ophthalmology. I spent some longer time in Internal medicine with the well-known prof Eric Ask-Upmark. I was invited by him to work at a spa (Ramlösa) where he was the medical consult in summer time, for many years. Two summers I "enjoyed my right to make military service" (Ask-Upmarks description) as a general practitioner in northern Sweden (Boden, Lycksele). Long distance travel to sick persons in bright nights. It was a great time, but when it came closer to my dissertation, I had to make up my mind. With 8 years working with electrophysiology (Prof Bárány called us "masked neurophysiologists") I decided to continue that track, mainly to implement ideas we had gathered and to get the best use of the knowledge I had at that moment. The final decision was made after a meeting with the new and first head of Clinical Neurophysiology (since 1958) in the hospital, Karl-Erik Hagbarth. He was already well known in his field and a charming, loveable man. He was looking for a new physician to his lab (typically enough in the basement of a hospital building) and promised me a place after my dissertation. Prof Ask-Upmark was unhappy when I left his discipline to become an "instrument doctor". Hagbarth was my only chief during my professional time. He was a great scientist, flexible and fair boss and we got along very well. Among other things I learned from him was that the retired chief should leave all responsibilities to the successor (me, in this case). He did not participate in administrative meetings after his retirement, but was open to give advice when approached.

After some years I was invited for a visit to the Mayo Clinical, Rochester. I was asked to give a speak on Swedish health care during a lunch meeting. Not until later did I understand that this was a test. Shortly after this (1975) I received an invitation for a position as leader of the Mayo EMG laboratory. A family meeting listed pros and cons that led to a decision to politely turn down the very tempting offer, in spite of support letters from Drs A. Engel and PJ Dyck. I preferred to stay in Uppsala thinking of Rochester, rather than to stay in Rochester longing for Uppsala. This method of strictly listing positive and negative arguments has been used by us many times and is also suggested for young people seeking advice.

Was clinical neurophysiology the right choice for me? On one hand it was. I have great interest in the technical part of the specialty and in trying to develop methods for clinical use.

It has given me rich scientific and social rewards. On the other hand, I miss the deeper contact with the patients I examine. Normally we do not follow all aspects of patient´s health other than on rounds with the responsible clinicians and we do not participate in the "care" of the individual patient, in its deepest meaning. As comfort for my feeling of being insufficient as a doctor, I hope that our efforts in the laboratory can help to find correct diagnosis and choice of treatment.

4 DEVELOPMENT OF SFEMG

4.1 How to measure fatigue

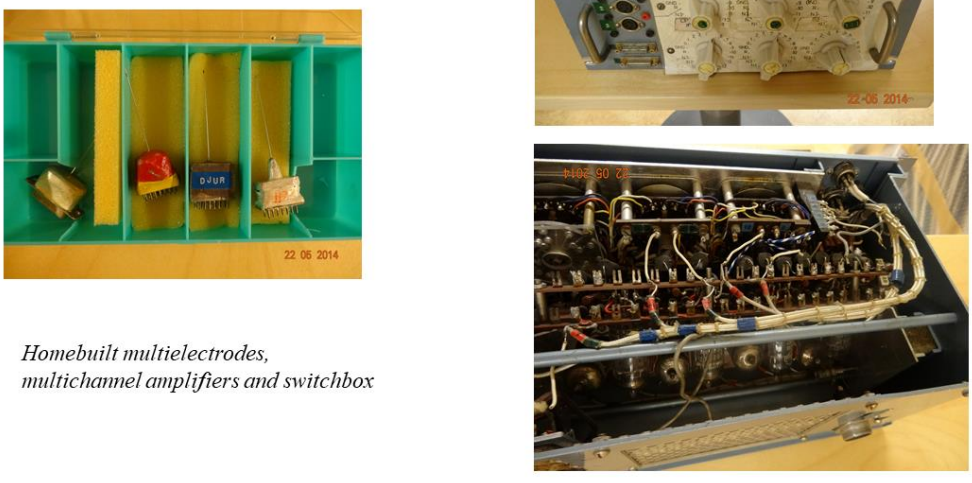
The topic of fatigue has interested muscle physiologists for a long time. In a literature search we quickly became inspired by the recent work of Merton (1954)[13]on "Voluntary strength and fatigue." An experimental set-up similar to his was arranged using homebuilt (by ourselves with professional help from the technical workshop in the institution). Which parameter should be used to reflect fatigue? Force, changes in force of during sustained exercise, twitch tension after single nerve stimulus or tetanic tension after high frequency stimulation? All this was classical physiology and as two relatively lonely enthusiasts, we could not add much new knowledge. In exploring for other parameters, we arrived at the idea of measuring conduction velocity of muscle fibers, to see if "fatigue" could be detected. Surface electrodes did not give us much information at that time. Only many years later would others develop methods and algorithms to see changes in mean velocity among motor units and also see changes in spectral patterns. In their interpretations they referred to our needle electrode work that followed our unsuccessful surface measurements. Intramuscular electrodes were the next steps. First wire electrodes but also here there was no real relationship between what we recorded and fatigue. In order to get somewhat more standardized conditions, we tried with intramuscular needle electrodes. Here the inspiration came from a recent publication by Buchthal et al,[2] and particularly his multielectrode and his measurements of propagation velocity using electrical stimulation. Electrodes were purchased but they were long and had a large diameter and did not really fit for a small hand muscle used for strength

Ekstedt and Häggkvist working with multielectrode construction

measurements. We therefore decided to build our own multielectrode, but much smaller. This was not an easy task and took us months for each trial of one electrode, many of which were defective in some way, e.g. short-circuits between a couple of the 14 platinum wires we used (Ekstedt, Häggqvist and Stålberg).[6] They were insulated from each other by enamel coating, but cracks in this coating gave us problems. The smallness of the recording surfaces offered also the challenge of using better amplifiers with high input impedance. These had to be homebuilt, in these days equipped with pentodes (and later with transistors, but we never reached the digital era during these first years). Finally, our multielectrode contained 1-14 leading off surfaces giving rise to some crosstalk, which had to be prevented electronically. The electrode surfaces were arranged in various patterns; with one row, two parallel rows or rosette shaped. All of our 14 electrodes were spaced over an area corresponding to ONE of the surfaces in Buchthal´s electrode.

4.1.1 **Recording of SF**

Convinced about the possibility of obtaining recordings with the new electrode, Ekstedt and I inserted the electrode (sterilized in Ekstedt´s grandmother´s teapot, in which we had made holes in the side each, covered by a rubber cap) into my left adductor pollicis. Yes, we got some noise, something moving on the oscilloscope screen, increasing with more activity, but not sharp signals that we had seen as typical for conventional EMG. We tried with more activation, with less activation, new electrode positions in the muscle (opponens pollicis). In



Homebuilt multielectrodes, multichannel amplifiers and switchbox

one experiment we recorded continuously for 18 hours and finally recorded a spike shaped

signal! (that nowadays takes 5-10 seconds to get). This reflects a very strong belief in the possibilities with our multielectrode, shielded cables with negative feedback, multi-switches, amplifiers and a persistency and inexhaustible eagerness to reach a goal. We learned to activate minimally, to make very fine electrode adjustments and finally found signals pretty fast. The next step was to interpret these signals. What kind of generator did they represent? They were quite different from those obtained with the much larger electrode of Buchthal and which he had described in detail.

4.1.2 **Relation to Buchthal**

During early studies, we had a suspicion that the recorded signals were not really generated by grouped muscle fibers, called the subunit, a termed coined by Buchthal, as a part of a motor unit. From his multielectrode recordings, studying volume conduction of the electrical field across the electrodes he drew the conclusion that the signals were generated by a group of 10-30 muscle fibers. A direct support to this hypothesis came from studies of muscle biopsies from patients with ALS. In this disease, individual neurons die and the corresponding muscle fibers belonging to a motor unit become denervated. In these biopsies he could see that denervated muscle fibers in ALS were often clustered in groups of 10-30 fibers, the morphological correlate of the subunit. Not until a few years later, 1957, when Wohlfart[23] described collateral sprouting was it clear that the fiber groups did not reflect the organization in a normal muscle, but one that had undergone the compensatory mechanism of collateral reinnervation. We now came in some years later and did not argue on the basis that the morphological support was inadequate, but rather tried to answer the question, that we had posted on the wall in the lab "What are we recording?" In the office, we had a sign "Don´t think, make experiments" and in the lab a sign saying "Don't make experiments, think". In the early 60's we had strong feelings that the signals were actually generated by single muscle fibers. We asked for time for a visit in Buchthal´s laboratory at the Rigshospitalet in Copenhagen. Train and boat (with nice breakfast) brought us there. We stayed at Östergade, which was not a good address according to him, as we later understood. (The reputation has changed over the years). The visit was short, one hour I should guess. We presented our project aiming at recording from single muscle fibers. This did not harmonize with his views about muscle and motor unit organization and it ended relatively abruptly. "Boys, do not squeeze that lemon too hard, you are young and I am old, nobody will believe in you. Go home and ask your professor for another project, something on hormones." Disillusioned, we went, on the return trip way home, to an experimental ophthalmologist in

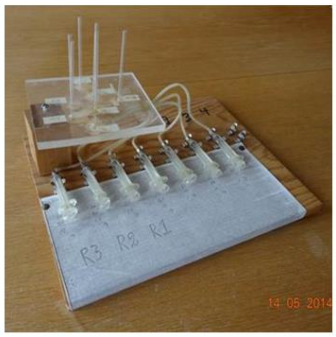
Lund, with good knowledge in recording principles and in electrical fields. He encouraged us to go on. The trip turned out to become a spark to work harder on the subject and really prove that the nice biphasic short signals represented an action potential from a single muscle fiber

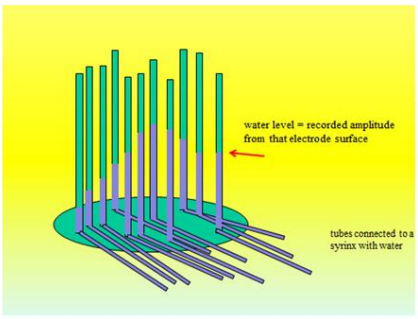
4.1.3 Various evidences for single fiber action potentials

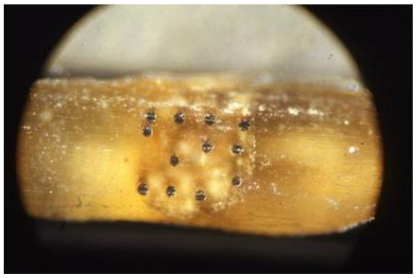
The struggle to understand the signals brought us from Lorenté de No´s complicated books on electrical fields around biological membranes and Hodgkin-Huxley's equations, to the technical effect of cross talk in cables, filter effects, resistance and capacitance problems with the very small recording surfaces. We built amplifiers, switches and oscilloscope–camera constructions. But more on that later. There were a few special tests that helped to verify that the recording came from single muscle fibers.

4.1.3.1 Volume conduction studies

By means of the multielectrode it was possible to study the distance dependent amplitude decay of the electrical field with high precision. It was found that the amplitude of the signal decayed very quickly and was down to 10% of its maximum after 300 µm recording distance. This should be related to the size of the muscle fiber, which is about 50 µm. This pattern could not correspond to a group of fibers, even lying closely packed.







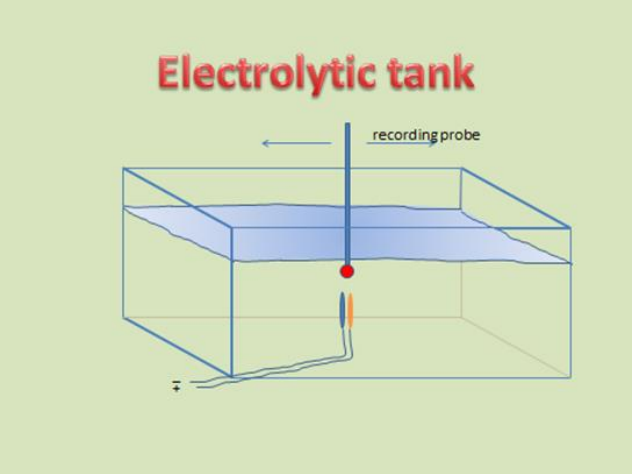
Detail of the electrode surfaces in the multielectrode used to study signals distribution

Another way to study the signal distribution was by an analogue method. We placed vertical glass capillaries in a scaled pattern exactly like the electrode surfaces in the multi electrode.

The glass capillaries were filled with colored water corresponding to the amplitude obtained from the electrodes. In this way an analogue picture was obtained of the electrical field around the electrode.

4.1.3.2 Think Tank

In order to study the electrical field around a dipole, which can be used as a simple model to represent the depolarization in a muscle membrane, we used a water-filled tank with the size of a home aquarium. Two small silver coins (10 Swedish öre, available at that time) were glued together and insulated from each other. A DC voltage was applied between the coins. A probe was moved along the tank (perpendicular to the direction of the coins) and a voltage profile was obtained as a diphasic signal. In the experiments, the distance between the generator and the recording probe was varied. One important finding was the increase in signal amplitude when the recording probe was just under the water surface. This was interpreted as a concentration of currents due to restriction of the volume conductor.



This also happens in the SF recordings. The small surface is surrounded by the isolating Araldite, which relatively speaking is very large. This will increase the amplitude by a factor of 2 compared to a wire recording without a shielding wall. We called this the “Wall effect”.

4.1.3.3 Jitter helps

In recordings where two spikes were time locked a time variability between the two was observed, first in the manual measurements from filmed frames. Since this gave a restless pattern during the recording, we named it “jitter”. This was seen in every pair of signals that we recorded (we did not at that time observe the later described 0 jitter in split muscle fibers) and it was not related to the absolute interval between the spikes. So, also when they were close, or even superimposed, the jitter was present. The spikes jumped along the time axis but did not change shape. Our interpretation was therefore that since the individual spikes are constant in shape at consecutive discharges, observed with a resolution to detect a few µsec, they cannot represent the sum of signals from two or more fibers. The criterion of constant shape has later become a very strong criterion for single fiber recordings. Since the jitter

phenomenon was something new and not established and not understood, the argument that absence of jitter indicated that the spike represented a single fiber did not seem strong enough for us. More evidence was needed.

4.1.3.4 Disturbed neuromuscular transmission helped to explain jitter

Since we suspected that the jitter was related to neuromuscular junction physiology, we looked for conditions with disturbed neuromuscular transmission. One was by injecting curare regionally i.e., in the forearm with a blood pressure cuff around the upper arm. The other was by inducing ischemia in the forearm muscle with a blood pressure cuff around the upper arm. The jitter was increased and also showed intermittent impulse blockings. To our great satisfaction, the blocking signal showed an all or none response, not a fractionation. During this time, we asked for another audience with Buchthal and were given one in Copenhagen, in 1963. We felt quite convinced that our spikes really were from single muscle fibers. When we arrived at the institute at the booked time, the secretary told us that Prof. Buchthal was not there today. Next time we met him was at an international EMG meeting in Copenhagen, in 1963, where we presented "A method of recording extracellular action potentials of single muscle fibers and measuring their propagation velocity in voluntarily

activated human muscle." The next time we met was at an EMG meeting arranged by the late Ian Simpson in Glasgow, in 1967. We gave a lecture on the all-or-none behavior of our signals after small doses of D-tubocurarine

4.1.3.5 A few ways to get single muscle fibers in situ in man

A few additional experimental tricks were performed during the time when we were seeking evidence that our signals were from single muscle fibers.

Fibrillation potentials are usually considered to be generated by individual fibers, so by recordings from such signals we could determine their characteristics – there was a good similarity to our SFEMG signals.

Another trick was to inject intramuscularly a small dose of *sodium citrate*. This will chelate the sodium ions and fibers start to fire independent of each other. A weak pain is felt. Similar spikes as ours were recorded.

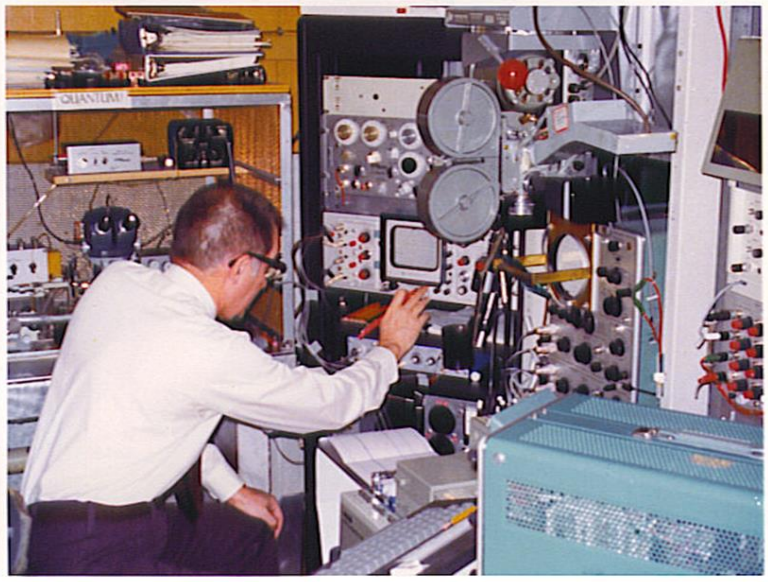
Theoretically, *partial curarization* should be a method. At the initial stage of neuromuscular block of the voluntary activated signal, individual building stones (single muscle fibers) can be seen, when they move away with increasing latency and individual blocking. It is a very

short moment, when this occurs and therefore this technique never became a practical method to prove single fiber characteristics. Often, however, the spiky signal showed an all or none behavior, i.e. was present or absent. This was used as a strong indicator of a recording from a single muscle fiber.

4.1.4 How to explain the jitter phenomenon

The jitter was initially very intriguing. Was it a technical or biological phenomenon? Probably technical, so we replaced the old oscilloscope with a new Tektronix 502, but the problem remained. I remember a telegram (this was before fax or newer media) from Ekstedt, lecturing in Umeå, "it must be in the neuromuscular junction." To test this we got the idea to call a patient. Ekstedt had come across with the relatively uncommon disease called myasthenia gravis (MG), which is known to be caused by neuromuscular dysfunction. He had seen a patient during his short time in Falun with this diagnosis. The patient was now taken the 200 km to Uppsala. And correctly enough, all his recordings showed a large jitter, sometimes with blocking. This was one of the first moments, when I felt a scientific reward. Experiments with local curare and ischemia did not only show the blocking with all-or- none response that we had focused on before, but also increased jitter. The jitter seemed to reflect synaptic events rather than the initial idea that jitter could be generated in the terminal nerve twig or varying velocity in the muscle fiber. These were still open possibilities, but later studies showed that these factors were minor.

Why is there an uncertainty in the neuromuscular transmission delay? The clear proofs could be found in published pictures from Elmqvist et al, in 1964,[7] from intracellular recordings (in Ed Lambert´s lab at the Mayo Clinic) from the end plate zone. They studied the mechanism of myasthenia, at that time not defined as a pre- or post-synaptic disorder. The intracellular recording of the endplate potential reached



Ed Lambert, in his lab at the Mayo Clinic.
Studies from this lab helped to understand the jitter phenomenon

the threshold for an action potential with a slightly variable time. This was noted by the authors without further comments, since they were looking for other parameters. For us it gave the final explanation for the jitter.

We were honored with a few hours visit by the Nobel winner (received 1970, together with Axelrod and von Euler) Professor (Sir from 1969) Bernard Katz. He was an authority in the physiology of Acetylcholine, and was interested in our jitter studies.

4.2 Electrodes

During the initial period we constructed a number of electrodes for various measurements. Examples are: Multielectrodes with 14 recording surfaces in two parallel rows, or scattered with a small area (The rosette electrode). We had one electrode with recording surface of opposite side of the cannula, looking in two directions (the Janus electrode). Another electrode had a small capillary inside the cannula, opening in the side port between two recording surfaces (Marking electrode). In one we instead had a cupper lead, mean to deposited cupper ions with a current in animal muscles. We could not find the copper in biopsies, so the electrode was useless. Some electrodes had an inbuilt thermal element for local temperature measurements. A delicate electrode had a gliding lead inside the cannula being exposed at the tip. Small movements at the tip, such as a twitching muscle fiber, could then be detected from the strain gauge connected at the end of the central lead.

4.2.1 Further – 2 theses on Single fiber definitions, jitter, subunit and propagation velocity

The task was now to summarize our findings over the years in one or two theses. We asked the faculty about the possibility of making one thesis together, but that was unheard of and not possible. Therefore, Ekstedt´s thesis was first in line, “Human single fiber action potentials.”[5] Here we, I say we since this was a close teamwork, gave all our evidence for the fact that the signal represented one single muscle fiber. The jitter was explained in this thesis. As a consequence of our findings on the size and distribution of the generators we also drew the conclusion that the muscles fibers in a motor unit were not arranged in groups, subunits, but were scattered within the motor unit. This gave rise to more discussion with Buchthal, in papers. He redefined the subunit to contain from 1 to 30 fibers. If it was 1 or 2 fibers, then we could agree. He abandoned the idea of subunit in 1971 (see below).

The other thesis was mine, "Propagation velocity in human muscle fibers in human in situ."[15] The topic was initially meant to explore fatigue and we were inspired by the studies Buchthal had made with electrical stimulation at one site in the muscle and recording with two-three electrodes some cm apart. We realized, that it was very unlikely, that his measuring points could study the same muscle fiber and therefore decided to use a multielectrode with parallel rows across, which the fiber passed. The time difference between the arriving of the signal to the row could be measured with great accuracy (fraction of a μsec) and the velocity could be estimated. We could define the mean velocity and the variation of fiber velocities within and between muscle fibers. We also found that the velocity really decreased during activity, more so with strong activation. This is not really fatigue, which is defined as the inability to sustain a given force output, but still it is a parameter related to activity. This has later been used to explain change in the power spectrum of the surface-recorded signal.[12] The other phenomenon that had some focus, was the new finding of a systemic change in velocity after the previous passage of impulses, called the Velocity Recovery Function. This was assumed to be due to accumulation of potassium in T-tubules, a guess that later has been confirmed to be correct by Bostock´s technique of threshold measurements.[24]

I defended the thesis on November 26, 1966. There were 3 opponents, the first (Lars-Erik Larsson) looked at the scientific part, the second (Sigfrid Blom) at the statistics and editorial considerations. At that time the dissertation protocol had a third opponent (Bo Åberg) who should enliven the atmosphere for 5 minutes. He accused me of having killed Lappish people, also called "Same" in Swedish, since "same" occurred quite a number of times in my thesis. After a long discussion including singing the tune that could be seen on some dot diagrams in the thesis (Fig 26 A), all of a sudden 2 policemen entered the room. We had heard sirens outdoors. They asked if there was someone by the name of Erik Stålberg. "Yes." "Follow us, you are suspected of having killed Lappish people to get these results." I was brought out and the very formal ceremony had come to an abrupt end. Now I can confess that I had something to do with this. I had been working with the police for years, knew them all and had in some way helped to organize this. It was breathtaking for my professor and others, some of whom still remember this but nothing from the dissertation itself.

5 TECHNICAL TOOLS FOR SFEMG

During the development of the SFEMG method, a number of small but often rather useful tools, or "gadgets" as some call them, had been developed and tested. These may have been

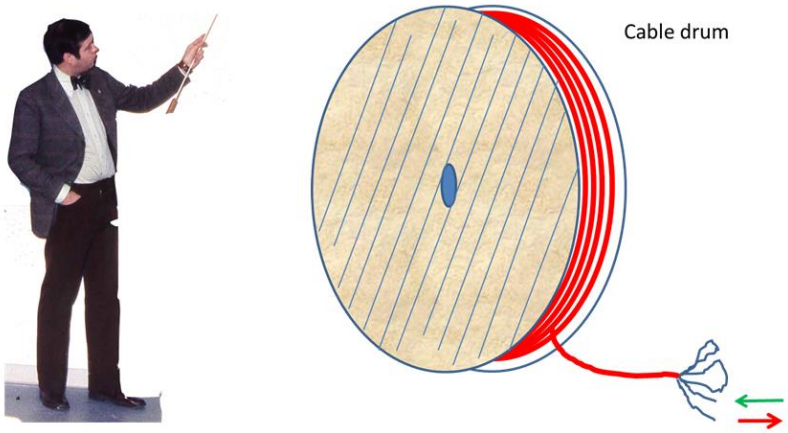
found to be more fun than useful, but in some instances survived, even into commercially available equipment

5.1 Trigger

In order to see signals of short duration, say 1 ms, that occurred with a frequency of 10Hz, i.e. they occupied 1% of the time, it was necessary to use a high sweep speed of the display, often 0.2-0.5 ms/div. Only by technical tricks could this be achieved. In more advanced oscilloscopes, a trigger was built in, i.e., the sweep started when the signal had reached an amplitude that could be optionally varied. This was not used in clinical neurophysiology at this time. We could not trigger on the single fiber action potential with regular EMG equipment, only in our laboratory oscilloscope. The only problem was that only signal segments coming after the time of trigger could be displayed on the sweep. This can be seen in some of our early figures. It should be noted that the trigger function is today found in all EMG equipment. We sophisticated the trigger function. The default is that all signals with an amplitude exceeding the trigger level start the sweep. Then we introduced an amplitude window, so that the sweep started as before when the amplitude was high enough, but shortly thereafter was inhibited if the amplitude exceeded another higher amplitude. The amplitude window could be optionally chosen during the recording. This gave the possibility of triggering on and identifying signals that had a lower amplitude than the highest.[3] This feature has been included in some EMG equipment, but I think that the possibilities offered by it have not yet been recognized to a sufficient degree.

5.2 Delay

The problem with the missing part of the signal before the trigger had to be solved. We tried using a tape recorder with separate recording and reading heads. These are separated by 1-2 cm and by using the correct tape speed, a delayed signal should be obtained. This was not a practical solution. Another type of delay line was necessary.



When triggering a signal on the oscilloscope, segments before the trigger could initially not be seen. We used the speed of electricity (speed of light) along a metal lead to obtain a delay. A drum (about 1.5 m in diameter) with 1 km of a 14 pair cable was purchased and placed in the lab.
The thread ends are connected a so 28 km of cable was obtained.
This gave a delay of 93,4 µs, enough for us.

Our first solution was to use a one kilometer 14 paired cable. We connected the ends of the leads together and got a line of 28 km. This gave a delay of 93,4 µsec, sufficient to see some significant early parts of the signal. This later was replaced by an electronic delay using resistors and condensers and even later by a digital delay, now the standard in all EMG equipment.[3]

5.3 Sweller

In the analysis of complex signals, there was often a need to highlight a selected part of the signal. This could be achieved by combining the oscilloscope triggering signal output and the sweep sawtooth signal with a homebuilt device by which the signal amplitude of separate sections could be decreased or increased from the standard gain.[9] In the current digital environment this can now be achieved much more easily and I am surprised that this feature has been so underused in EMG equipment. We do see separate gains in recording F-waves in commercial equipment, but nothing else.

5.4 Split time base

In a similar way, the time base can be varied along the sweep time in the oscilloscope. In this way certain sections can be compressed, others expanded for optimal visual display. This was achieved in the dual sweep oscilloscope (we used a Tektronix 565) in which we could generate a complex X-sweep signal by means of the second channel. There are rich analogue

possibilities to arrange any type of sweep speed on the other channel. This has later been seen in commercial equipment e.g. for Stimulation SFEMG

5.5 The invaluable oscilloscope gate pulse

One of the outputs of a relatively advanced oscilloscope is a TTL pulse, the gate pulse, with a duration corresponding exactly to the sweep time. We used this gate pulse for a number of applications. The sweep was triggered on the signal segment as described above and this generated the gate pulse. This gate pulse could, for example, trigger the camera in front of the oscilloscope so for each signal seen on the oscilloscope the camera took one picture.

Another application was to use very short sweep speeds in order to trigger the sweep for each potential, single, double or multiple. The short gate pulse (10 µsec or so) was fed to the Z input of the display channel to highlight the point, where the signal was triggered. These highlighted points could also be displayed on a separate sweep without a signal and the first sequential dot diagram was obtained.

We have also used the gate pulse to initiate a step motor to pull the electrode in scanning EMG.

5.6 Wobbler

There was a need for measurements of time intervals with a very high accuracy (it is easier to measure time than distance with accuracy). This was before we had electronic time interval counters and long before built-in digital clocks. The measurements should be made between two signals with a slight slope, in parallel with each other but slightly separated in time of the order of 50 µsec. We tried to display the signals on the X and Y axes of the oscilloscope to obtain a Lissajous figure, but this was difficult to interpret intuitively.

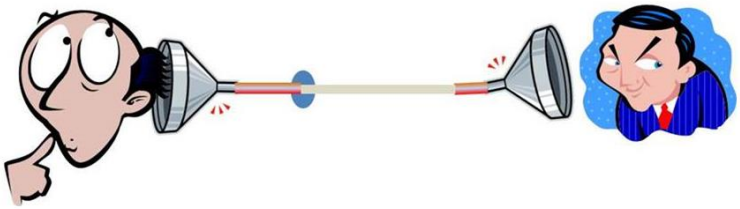
The solution was instead to superimpose in the vertical direction a high frequency (200 Hz) signal on the signal. This signal then looked like a band, the amplitude of which we could optionally change with a potentiometer. By means of well-defined square pulses, we could calibrate the amplitude of the wobbling band to correspond to time intervals. The procedure was to increase the amplitude until the blurred bands exactly met each other. A set of points gave a linear calibration curve. In experiments the SFEMG action potentials were seen with the wobbling band. The potentiometer was manually adjusted until the bands just met (seen nicely by their collision like a light band)and the voltage was read and transformed to µsecs. The accuracy was 1 µsec.

This tool became outdated by modern timers, but the underlying principle can certainly be used in some applications even today.

5.7 Cooler and Intercom

The laboratory space was not equipped for heat-producing instruments, so air conditioning was necessary. We simply installed a truck radiator in the window with cold water from the faucet. The lack of communication between two rooms was solved by a hole in the wall, reminiscent of communications in a ship.

The pharmacology building did not have air condition. We mounted a cooler of a truck (similar to the one in the Figure) in the window, running cold water and a fan in front to remove some of the heat from all instruments.



The lab had two rooms. For communication we used a rubber tube in a hole through the wall, with funnels at both ends. This was also used to send white smoke from Ekstedt's cigar when we accepted the application of a new engineer (c.f. procedure for new Pope).

5.8 Other small tools

We have used a number of features in the signal display to extract some given features. One was to calculate the risetime of the signal, or the derivative. The signal section, that had a derivative that exceeded a given value, was marked with a color and it was easy to see which signals were "sharp" and could be accepted for a given purpose.

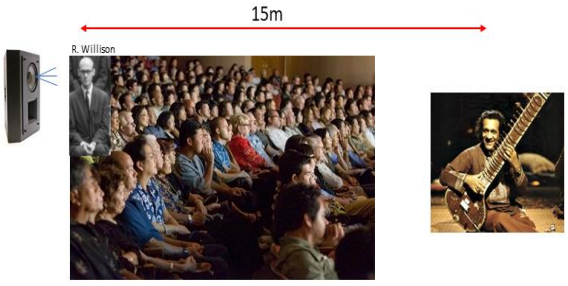
5.9 Sound in neurophysiology

Another presentation mode was to transform the jitter value to an analog voltage that could be displayed. For each recording the jitter "level" could be visualized. The gadget used this amplitude as the input to a voltage-frequency converter. The jitter value could thus be heard

and estimated by its pitch. Alternatively, only abnormal jitter values gave rise to a tone, *a jitter alarm*.

5.9.1 **Position of loudspeaker, remotely or close - GREAT difference**

In 1978 we gave an EMG course in Bombay (Willison, from England, Trojaborg, from Denmark and me, from Sweden). One evening we were kindly invited to Mr Engineer's for dinner. He had also invited Ravi Shankar, relatively early in his career. All of us, around 30 people, were seated on the floor to listen to his music, performed on the sitar and some other instruments played by Mr Shankar's companions. Since the listening group was large and the space quite big, a loudspeaker was placed at the end of the room. Robin Willison was sitting close to this loudspeaker, perhaps 15 m away from the players. A wonderful evening.

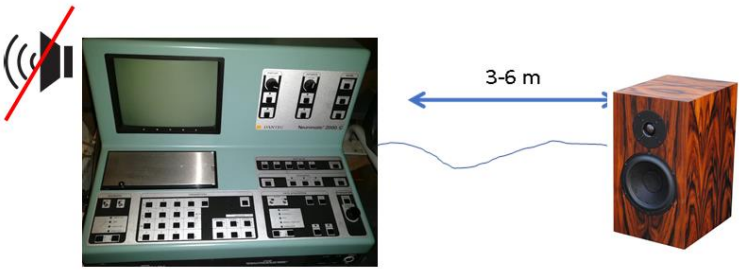


Robin Willison (inserted) calculated the distorsion when the sound from Ravi Shankar came directly in the air or from a close by loudspeaker

Next morning Dr Willison had a comment on the sound quality. He heard the music both directly, with the normal delay for sound in air 44 msec for the 15 mand from the loudspeaker, which produced the sound without delay. His ear was very annoyed by this dual, non-simultaneous sound input.

I well remember, when they described the trick of using different delays for the sound to loudspeakers in Westminster Abbey; those speakers far away from the pulpit had a longer delay than those placed closer to the pulpit.

The opposite situation occurred in our laboratory. During a visit to us by Dr. Jasper Daube, he pointed out, that a problem he had with the EMG they used (at that time a Neuromatic 2000, the same as ours), which gave an annoying time difference between the signal display and the sound, could not be detected in our lab. (Jaspers wife Cindy, also in Uppsala, became interested in combination of bakery and coffee shop "konditori" in Uppsala, and opened a few such shops after returning to Rochester)



This EMG machine had a technical feature to first record a signal segment for the total

Fig showing an EMG equipment (Neuromatic 2000). Internal loudspeaker is muted and a separate loudspeaker 3-6 m away is connected.

display time, say 20 msec. Not until after 20 msec was the trace displayed on the screen, while the sound was “on line,” in real time. With a very slow sweep, you could easily note this phenomenon, but with short sweep times only an expert like Daube could detect this. In our situation, often using a sweep time of 20 msec, we had free-standing loudspeakers placed 3-6 m away (different for different rooms) instead of the inbuilt speaker. Therefore the sound was delayed (time through air) by about 10-20 msec throughout the range of sweep speeds, that we used in routine. We should have had a system by which the loudspeakers moved, depending on the sweep speed! Don Sanders later told me that his EMG laboratory had the same problem (“drove us crazy”), so they sometimes turned off the loudspeaker.

5.10 Transplantation of firing pattern

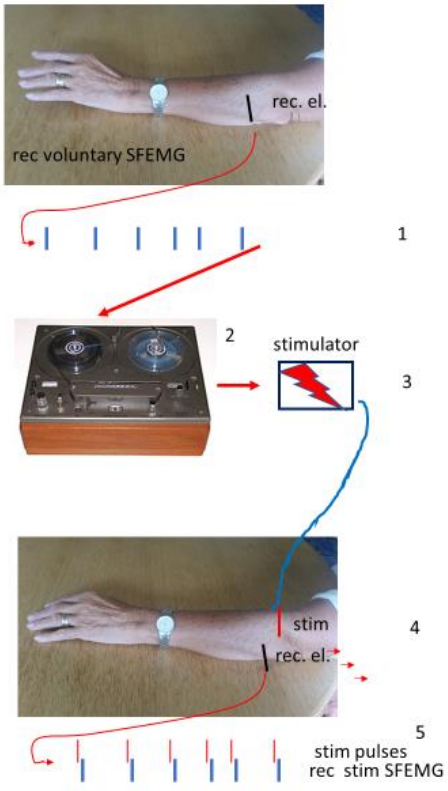
The Velocity Recovery Function (VRF),[15] i.e. dependence of muscle propagation velocity (PV) on the immediately preceding activity of the muscle fiber, can be studied in two ways:

1. By double stimulation with varying inter-pulse intervals.
2. By mathematical calculation of the relationship between the PV and the previous discharge interval. The goodness of fit of this calculation was tested as follows - PV was measured from several hundred discharges. The calculation of the VRF was based on 200 discharges. The obtained algorithm was then applied to the succeeding impulses to give the expected PV based on actual firing intervals. This could be compared to the measured PV values.

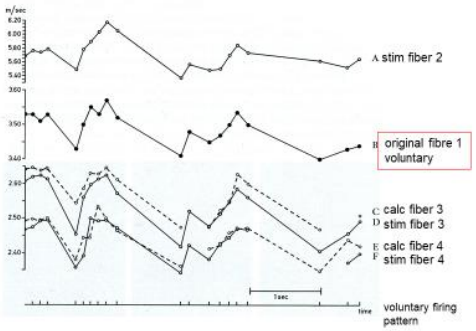
To check the validity of the calculated VRF we fed an obtained firing pattern to the algorithm and calculated the velocity for comparison with results obtained in live recordings.

To do this, voluntary single muscle fiber action potentials obtained during slight voluntary contraction (1) were stored on an analogue tape recorder (2)and the VRF curve was calculated. The recorded firing pattern was then replayed to trigger a stimulator (3) connected to a needle electrode, that activated muscle fibers with the stored pattern (4). SFEMG signals were recorded (5) and velocity was measured

We found a very good agreement between velocity of live recorded signals and those calculated just by applying the firing pattern to the algorithm. The results of this are seen in this Figure.



VRF; voluntary activity, stimulated and calculated



PV variation in relation to firing intervals. Four fibers were tested. They have different mean velocity, but the short term variation (VRF) is "identical".

6 THE BIRTH OF MACRO EMG

Together with Dr. Per Hilton-Brown, I was visiting Columbus, Ohio in the late 70's. We discussed EMG (what else?) while walking on the street. Intrigued by McComas' relatively new publications on MUNE, we asked ourselves if that method could be improved. His method was to use a metal strip as the surface electrode over the muscle, usually small and thin muscles, such as ADM or EDB. Our own studies had shown how motor units deep in a large muscle, such as biceps, did not give a signal to a surface electrode. Was there a way to get a large metal electrode inside the muscle, close to the MU? Well, for EMG with concentric needle electrodes (our standard) we always have a large piece of metal inside the muscle – the cannula of the needle. So, on the street in Columbus we decided to use the cannula for recording. Back home we made such recordings with a SFEMG electrode, triggering on the SFEMG action potential and averaging the time-locked cannula signal. We found that the amplitude depended on the depth of the electrode within the muscle. (By the way, this cannula signal is usually subtracted from the tip-recorded signal in EMG. Since superficial positions of the electrode give larger cannula signals, more will be subtracted in EMG and a superficial MU will be seen with a lower amplitude). We therefore modified the

SFEMG electrode by Teflon insulation except for the distal 15 mm, which gives a large but constant recording surface as long as the electrode is inserted at least 15 mm. The triggering SFEMG electrode was placed 7.5 mm behind the tip, in the center of the bare part of the cannula. This then became the classic Macro EMG setup. Shortly after this, I lectured in Bristol, England. On the railway trip back to London, I had arranged to meet Mr Peter Styles, Medelec in Redding. He was really devoted to neurophysiology. He started by saying that he did not believe that new EMG methods will be born. We sat down, discussed and he left the railway station convinced that this was something interesting.

In our lab we later developed reference values and used the technique, particularly for studies of patients with a history of polio and also for other neuromuscular disorders.

7 THINGS THAT NEVER WERE IMPLEMENTED

Over the years I have had a number of ideas, that never came further than to my mind or perhaps over my lips to reach collaborators. The reason for the crash landings varies. It may be a dead end from the scientific or clinical point of view. It could also be the fact that a very similar idea has already be born elsewhere and been published, when we had come half way. For me the development should either help to solve a scientific question, be useful within the field of clinical neurophysiology, improve daily routines or help propagate the knowledge in the specialty. It may be of value for others to see, what has been left on the table. Some of these things may still have a potential to be developed and used.

7.1 Auto-stim intensity,

It was a simple algorithm to measure the amplitude of the muscle response obtained during electrical nerve stimulation and increase the stimulation strength until no further increase in amplitude occurred. We tried this but were uncertain about the robustness.

7.2 Voice control of some equipment functions

During the EMG investigation there is a need to change various settings such as sweep speed and gainand to initiate actions such as starting the stimulator or saving signals or screen pictures. This sometimes causes a problem since one or both hands may be occupied holding the recording and stimulating electrodes. Foot pedals help a lot and should be used whenever feasible. Another help can be obtained by voice control of certain commands, such as “start stim”, “picture”, “change gain” or “sweep speed.” We introduced this in an early phase with an Apple II and the MS 92 Medelec equipment. In principle it worked, but at that time was

dependent on the user's voice quality (each operator needed to deposit a voice template and a common cold was disturbing). It was not implemented for routine. Nowadays there are usually 2 contacts in the foot pedal and these are programmable to optionally correspond to some of the simple commands.

7.3 Decrement analysis in repetitive nerve stimulation

The conventional way of expressing the amount of amplitude and area decay in signals elicited during repetitive nerve stimulation is to compare parameters in the 1^{st} and 4^{th} or 5^{th} signal. This gives a relatively coarse time resolution. In order to study the decrement curve better we applied various curve fitting algorithms to find the true "lowest point." This was quite possible, but the idea has not been presented scientifically and is therefore not implemented for routine studies.

7.4 CMAP shape comparison

With better understanding of the generation of a CMAP and particularly quantitative aspects of the technical factors involved (filter, reference electrode, stimulus-recording distance) there should be the possibility to quantitate the CMAP shape and assess deviations from normal. We have looked at mean values of the shape (including time alignments and averages). I think, that at present it should be possible to compare groups of recordings. It is still uncertain if such an approach can be used for individual recordings. Here single descriptive parameters (amplitude, area, duration, late components) are still the best.

7.5 F-wave analysis

I find it suboptimal to express the F-wave latency by the shortest value among 10-20 stimuli (we have always used 20, based on the statistical analysis of frequency (5%) of F responses in individual axons). It was initially considered logical to measure the "fastest" F wave since conventional motor conduction velocity is thought to represent the fastest fibers (which is not absolutely true). However, the latency of the shortest F-waves may not represent the axon with the highest velocity. The latency depends also on the travel distance and since each nerve is represented in at least 2 roots, the distance is different for different axons (the rhomboid muscles are said to have single root innervation). Also, the distal nerve velocity differs among axons. Furthermore, each F-response is generated in motor units with various end-plate positions, thus the earliest individual F-response may not represent motor units in the very beginning of the CMAP.

At present we use the value from ONE F-wave out of 20 as the result. A more logical expression would be the median of onset latencies among all F-waves. This was analyzed in great detail in a retrospective study of both normal and abnormal nerves (567 nerves in all) together with a Japanese visitor. We submitted the results, but got critiques due to insufficient individual clinical and laboratory information (MR, CTand other diagnostic details) rather than on the method and the idea itself. In a retrospective study like ours this can be difficult and we judged that this information was not available in all cases and decided not to resubmit. Our presented results showed that Fmean, Fmedian and Fmax were more often abnormal than Fmin in patient groups with diffuse distributions. F-persistence and CMAP amplitude added further information concerning axonopathy. Fmedian and Fmean were more accurate than Fmax.

I think that future F-wave analysis will contain other parameters than F-min. In addition to individual shortest and longest F-latencies, mean value assessment has also been in routine since 1994 in at least in some equipment.

8 MAIN IMPORTANCE OF SFEMG, BEFORE ANTIBODIES, GOOD TIMING

The development and introduction of SFEMG helped the understanding of the organization of motor units and could be transferred to conventional EMG performed with concentric or monopolar needle electrodes (duration, amplitude, shape instability, F-wave dissection). It became known and quickly implemented at many sites for diagnosis of myasthenic disorders. The time was favourable, before antibodies were known and it was therefore on its own for a while together with the less sensitive repetitive nerve stimulation. It was also used in other studies such as

Macro EMG
Scanning EMG
Surface recording of motor unit potentials (MUP) with intramuscular triggering
Studies of individual F-responses
Studies of single axon conduction

The findings in myasthenic disorders, myopathy and neurogenic conditions have been well documented.

9 CONGRESSES AND COURSES

History

Participation in conferences and courses as listener of lecturer

- There are various driving forces for going to congresses, meetings and courses such as: obligatory requirements during education, learning basics and advanced techniques for your own education
- Following trends in the field sometimes delivered as soft data not available from the literature
- Seeing or even meeting leaders in the field
- Specifically browse for methods or functions that can be brought home for implementation
- Lecturing, presenting results

9.1 Me as participant

I have been through most of these stages. With time the meetings have changed in character, becoming larger and broader in scope or smaller and more specific. Depending on the stage of my own situation I have acted in different ways. From the beginning the priority was the educational part. In the 60's to 80's most meetings contained lectures, sessions, symposia. I attended mainly Swedish, Scandinavian or Nordic meetings as being less expensive and also providing the most useful introductions to the field and to nearest colleagues. I learned from them, but most of all I got inspiration and got ideas for my work. There were moments when I longed to be home to test this idea or expand on some of the presented topics. One example was, when I wandered along a street in Columbus, Ohio on a break, together with my PhD student Per Hilton-Brown. It just came to my mind to record not from the tip of the electrode, but see what the cannula signal could mean. The day we came home, we knew something more and Macro EMG was born.

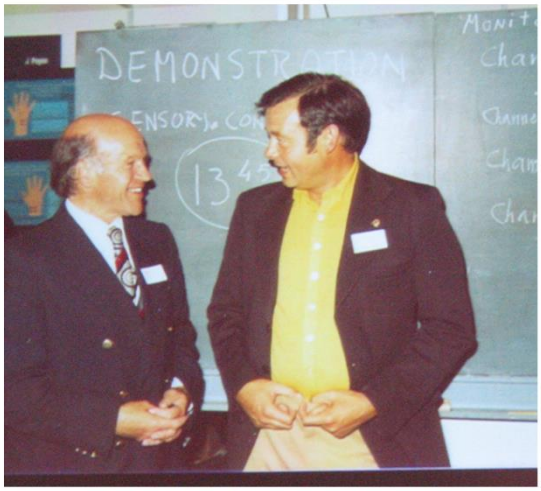
These meetings opened different doors. Buchthal showed the way neurophysiology could be precise and scientific. Ingmar Petersén in Gothenburg, Sweden early on pointed to the need for collaboration with the engineering side. Eric Kugelberg, the silent, modest and highly respected neurologist, established neurophysiology in the field of clinical neurology, and complemented the detailed clinical analysis with electrophysiology, that he performed himself. He was the first to detail the myopathic EMG pattern and stressed the discrepancy

between muscle force and fullness of the interference EMG pattern. Lambert developed the connections between basic neurophysiology and the clinical side.

Ekstedt, Stålberg and Buchthal at the IVth International Congress of Electromyography Brussels, 1971, Sept 13.

Later I got the chance to go to international meetings, perhaps preferentially those in Europe because of costs involved. Scientifically I will not forget a meeting in Brussels, in 1971, organized by Desmedt, where Ekstedt and I had presentation on motor unit organization, based on SFEMG recordings. Desmedt actually helped to coin the term "microphysiology" from our technique, something I later used many times. Our concept of random fiber arrangements was not accepted by Buchthal. At the same meeting Kugelberg and Edström had presented their important mapping of motor units in rat by means of glycogen depletion. These studies well supported the random distribution concept. At the banquet, Buchthal declared that the idea of subunits was dead, referring to Kugelberg and Edström, without mentioning the SFEMG evidence, but still, it was rewarding for our struggle.

In the very same meeting, after the "exit session", Jože Trontelj took the same elevator as the Buchthal group. As JT was still hardly known, Buchthal openly commented, with rather sad tone that the subunit concept was over (from JT to Jose Fernandes)



I had the privilege of meeting Prof Ian Simpson a few times. His suggestion that MG is an autoimmune disease, was the beginning of understanding MG and triggered new ideas on autoimmunity.

Another distinct impression remains of a meeting in Glasgow, arranged by Ian Simpson. I am sure he talked on MG, which he correctly and on clinical grounds had suspected to be an autoimmune disease, a clinician's clear-sighted interpretation. The memory however comes from the congress dinner, that Ian and his wife gave us in their own garden at home. Ian was personally slicing the excellent salmon, something many participants remember.

Later meetings have taken me to other countries. The AAEM, later the AANEM, has provided a way to see another approach to clinical neurophysiology, called electrodiagnostic medicine in the US. The growth in quality and quantity of their organization has been extraordinary. I was honored to be on the board for a year and got insight into the seriousness with which they work. The office was mainly run by one person, Ella van Laningham. They had e.g. no fax, which I wanted to use in my contacts with them (I was called the faxing member). Ella had to use the fax of a neighboring office but in the same building in Rochester. Now the staff is 40 persons, fax, email but not Skype for membership use.

The AANEM has its focus on education and I have with varying success tried to get younger colleagues in my lab and elsewhere in Europe to attend at least one AANEM meeting as an educational experience.

As pointed out above, these meetings have also given me the opportunity to see or even meet some of the most important scientists, that have provided the basis for our field in neuroscience. I just mention a few, knowing that the list should be much longer; Adrian (the father of the concentric electrode together with Bronk, 1929 and Nobel prize winner together with Sherington 1932), Gilliatt, Walton, Granit, Eccles, Refsum, Huxley, Cobb, Willison, Engel, Dyck, Lambert, Simpson, Buchthal, Hugon, Desmedt, Kimura, E Johnson, M Shahani, Ertekin, Dimitrijevic, Lance, Struppler, ……all those outstanding profiles in the field.

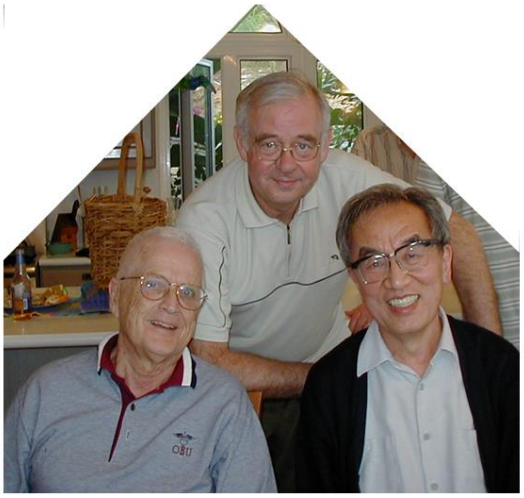
One may ask if it is worth the time, cost and effort to attend meetings in the days, when electronic communication bring us together with email, Skype and videoconferences and also provide an impressive coverage of literature. Still the answer is yes. There are many aspects of physical meetings, such as information and impression that cannot easily be obtained in the lonely office or in a video studio. You may use IT media among people you know or for pure lectures or business meetings. For the creative scientific atmosphere and for the personal interaction in the educational situation you still need to meet in real life. With increasing concern on decreasing global resources, we may have to modify today's behavior. As a note of today, January, 2021 in the time of the Covid pandemic, lecturing via webinars has been in use for the last year with great success. The technical problems have been gradually overcome, but my comment above about the need for personal meetings remain. Internet-based education and presentation of results will probably remain, even after the pandemic. The presentations with practical hands-on demonstrations will need physical meetings.

The organizers should acknowledge, that meetings should give priority to functions and aspects, that we do not get via the computer: free discussion among many participants, live demonstrations or hands-on sessions, meet-the-expert sessions, overview symposia and social programs. As participants, we have to be selective in choosing meetings that fulfill defined needs. I have a feeling that the relatively passive behavior of attending meetings, being fed with information, is still dominating among colleagues. Some institutions require that permission to go to a meeting is only given, if the applicant presents some scientific material.

9.2 Me as lecturer

Going to meetings, conference and courses as a lecturer provides a different aspect of scientific travelling. Here the task is to give not only to take. You have to be well prepared, change your presentation from the previous one since some have heard you, include your news and try to understand, what the listeners expect and need and to give them value for money. Often your group in the session have paid extra for your demonstration or course. For me teaching in courses and small groups has been a challenge. It needs more preparation than just a scientific presentation of latest results and it is also extremely rewarding. The very much-requested lecturer Dr. Shin Oh gave me one of his books with the dedication "You learn when you teach." So true. The preparation in literature studies, the layout of the figures and videos you show, the presentation itself and not least the following discussion. This may be a strong eye-opener. The questions reveal your own shortcomings in presenting the material. You have taken some underlying facts for granted, you have been misunderstood or you may even have given facts, opinions or advice that someone correctly opposes. The experience from one course may hopefully help to improve your next presentation.

From Uppsala we initiated training courses under the ECCN in Southern and Eastern Europe. Our team consisted of 2 physicians (Björn Falck and me) and 2 technicians (Lena Eriksson and Maggan Grindlund). A special activity was the technicians´ training course with Spanish technicians. From us it was 2 technicians (Lena and Maggan) and me. Other courses were the SFEMG courses around the world, initially held semiannually,



Ernest Johnson, Erik Stålberg and Jun Kimura in a Super-EMG course

later often back-to-back with international congresses.

For a period we organized comprehensive 3 days courses, some of which being the most memorable on a cruise ship along the fjords of northern Norway.

One type of training course is the so called SuperEMG, later Ultra EMG. These were courses initially organized by Ohio State University under Ernest Johnson. These were one-week courses in Hawaii, in the Caribbean or later in the US. The faculty became good friends and often brought spouses. A lifelong friendship was established.

One special form for lecturing is certainly during courses in Uppsala. We have had numerous training courses over the years, usually together with Björn Falck. This is great inspiration. It is made possible with the help of lecturing colleagues and a fantastic staff from the lab taking care of all administration.

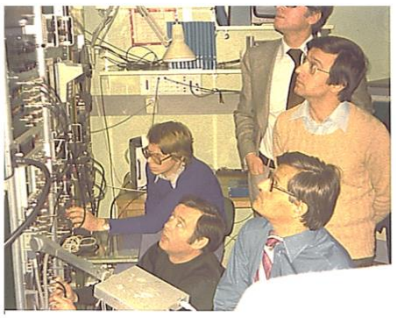
Helper Sussie and secretaries Karin and Gun were important parts of the ground team, for running the late Uppsala courses

Hands on is appreciated. Here with technician Lena and me as instructors

One part includes a dinner in our home. Eva has been wonderful in organizing, cooking and being hostess. We have enjoyed this very much and reportedly also the participants. Five years later they have forgotten the scientific part, but the dinner remains as a memory.

EMG course in our home, Spring 2019

Coffe and cake (no more left) after the dinner. Here Eva, Maggan (technician) and one of the participants. Spring 2017



Look at the high jitter

Demonstration of RNS (Stefan Stålberg subject late EMG software eng.) during an EMG course (Bob Lovelace is seen to the left)

Chief Technician Maggan, here teaching during a course.
The technicians are indispensable in our routines

9.3 Courses in general

Basic and advanced education is necessary in Clinical Neurophysiology to improve understanding, methodology and quality, and to provide instructions for the practical moments of an examination. This is primarily focused on making our specialty an important partner in diagnosis and monitoring nerve-muscle disorders. Another aim is to provide educational training for colleagues in their efforts to be certified in the field. At present we have too few courses in many countries.

Some years ago, the IFCN tried to collect opinions from their members on the best educational means, such as handbooks, congresses, videos, courses, etc. Small courses with hands-on seem to have been the most requested.

At present the quality of a course regarding accuracy, objectivity and usefulness is not measured other than by the individual course evaluations. It is generally agreed that many courses should be made available in different parts of the world to widen the spectrum of

topics, to meet the demand and to give course organizers ideas on how they should make their course updated and attractive.

I do not see a course as a primarily commercial product that is competing with others in recruiting participants. As seniors we collaborate to provide the best possible training opportunities to those entering the field. It is important for patient care and also for the survival and development of Clinical neurophysiology.

9.4 A few memories from courses

Interpretation to Mandarin gave bleeding ulcer. In 1982 I was invited by Dr Xiao- Fu Tang and DISA company to Beijing. In addition to visiting the Great wall and the Forbidden city I also gave a few lectures for 100-200 colleagues. I spoke in English and a colleague should make the interpretation. After a while, I noticed that his sentences were much longer than mine. Was it inherent in the Mandarin language? I had to ask him. He told me, that the participants may not understand exactly what I said, so he added his own information (unknow to me what he said). He was not just a translator of the text he saw on powerpoint slides, but also interpreter of the content in the spoken presentation. For him the entire afternoon was stressful and he ended up in hospital with bleeding ulcer. Next day I had a non-physician as translator.

Auf Deutsch, bitte! These courses and teaching activities have usually been very rewarding. But, embarrassing moments occur. One such example when in the 1970´s I was asked by DISA (later Dantec) to give a seminar in East Berlin. After passing Checkpoint Charlie we came to the lecture room when all of a sudden I was informed that my lectures were supposed to be in German. I had not spoken the language since high school. I am not sure that the participants learned anything about Einzel-Faser EMG, but they probably remember the event for other reasons.

Slight myasthenia. In an EMG meeting (probably a neurology meeting in Holland, 1977?)) in the session on MG, Desmedt and I (with Tronteljs support) should demonstrate 2 different ways of diagnosing MG in a patient with very slight symptoms. He used repetitive stimulation with his called double step method with ischemia as a provocation to make the transmission defect more pronounced. I should perform SFEMG. Desmedt´s examination, preceding mine, failed to show any abnormality and he doubted the diagnosis. SFEMG was clearly abnormal (the first pairs were abnormal), but I suspect there was not much blocking,

since then RNS should have revealed something. My conclusion was different from Desmedt´s, but we did not have the final diagnosis - there were not antibody tests at that time. Some of the participants have reminded me of this demo session on later occasions.

Concentric jitter by mistake. In another situation I went to Brazil to give lectures and particularly demonstrations in SFEMG. Customs complications prevented the supporting company from getting the SFEMG electrode in time, but we had concentric electrodes. Somewhat unfaithfully, I never told the group about this, I managed to get the message through by setting appropriate filters in the amplifier. By the way this method, CNE jitter, is now becoming the accepted surrogate for SFEMG.

Botulism. Once in Taiwan I was asked to give an SFEMG demonstration. They brought in a patient with proximal weakness since yesterday. I inserted the SFEMG electrode into a muscle and heard immediately increased jitter and blocking, even before I had started the sweep. I suggested botulism as a spot diagnosis. “Yes, and the chef, at the restaurant where he is working, died yesterday” they told me. The study was continued and verified the typical pattern.

Myasthenia in a dog. At an SFEMG course in Chapel Hill, North Carolina (1987) I was asked to examine a dog with weakness. At the vet school they had arranged an operation room and anesthesiology support waiting in case we needed to have the dog sleeping. The dog was lying on one side and I inserted the SFEMG electrode into the deltoid muscle. When I lifted the dog´s paw slightly, I got very good slight muscle activation and could easily see and hear increased jitter and blocking in many recordings; myasthenia!

Grounding problems. There are certainly a number of things that may happen before or during a practical demonstration in a foreign country where you have had limited possibilities to test equipment ahead of time. Just to mention a couple that had to do with grounding, the ever-present problem with electronic recording equipment. Once in Spain in Salamanca (a Refresher Course), the equipment testing one hour before the main part of the course showed quite a lot of 50 Hz interference. Everything was tried in the hotel and the engineers, qualified, helpful and ambitious were pouring off sweat. We found that the only solution was a long cable to some properly grounded point. A 50 meter cable was purchased in town and the cable was run like a long snake from the equipment to the kitchen, I think to the sink. And the problem was solved and now remains as a nice memory.

Temporary Grounding

We have also had cables through the window to the ground between bushes outside the lecture room in Rumania.

At another occasion in Cartagena, Colombia, Kimura tested equipment the night before, skipped the faculty dinner just to be sure that everything worked fine and he reported good success. Next morning when we connected the equipment, severe 50 Hz made recording impossible. We tried with cables to various radiators and even through the window to some metal outside without success. For some reason we had to unplug the system and use an electric outlet just 2 meters away and everything was fine. Obviously, the first outlet was not grounded properly. All fine.

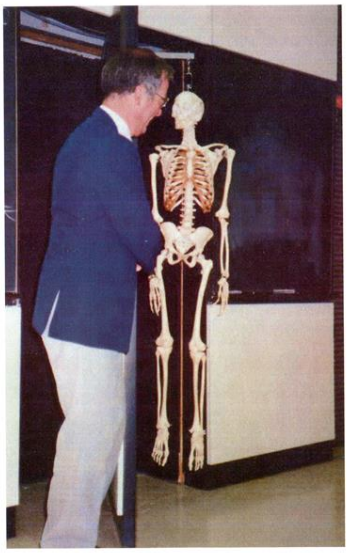
At an SFEMG meeting in Venice (2009) we were in the magnificent Scuola Grande of San Giovanni Evangelista and my long preparative efforts to get rid of 50 Hz were in vain. I thought, how can we ground something, being completely surrounded by water, a very nonscientific thought. My colleges reported the same thing, but and that was the sad part of the story, some had no problem whatsoever in another room. Obviously some outlets were grounded, others not. My demo was barely acceptable.

The lesson learned from all this is to test in advance with the correct electrode, don't use a needle electrode, when you should use a surface electrode and vice versa. If there are problems, try conventional tricks, such as finding a radiator or a faucet. Do not use many outlets for your equipment and finally, if nothing helps, try another outlet.

We love making demos. After a full course day in Istanbul Jože Trontelj, Hacer Erdem and me sat in a restaurant by the Bosporus. "What a day we have had! When in heaven, I said, there may not be an interest in our lectures, but maybe we can at least be allowed to do some Demos". Jože then referred to this conversation in his speech at the farewell dinner at Uppsala Castle at my retirement.

Appreciations and thanks. The reward of giving courses and demos has not been of an economic nature in my case. Doctors do not seem to charge, when they train their younger colleagues. No, it has been happy faces, later comments on the value of the course long ago, new friendship. One of the special thanks was given to Robin Willison, Nick Murray and me after a 2 week course in Bombay. Dr. Gourie-Devi on behalf of the participants expressed in a poetic way, that a gift that you get from someone can later be reciprocated, but knowledge that you get from your guru can not and therefore you are in debt forever. These words come to my mind, when I learn something special from someone, in a lecture or in a private dialogue.

End of course. Another memory was from the last day of an SFEMG course in Chapel Hill NC, US in 1987, held in an anatomy auditorium. At the end of my good-bye speech I tripped backwards and banged into the wall behind. This was assembled from swinging segments about 2 m wide. Each segment could rotate around its vertical central axis. I pushed one segment which rotated 180 degrees and came into a small pitch-black room. At the same time I heard laughter and applause. I had really not said anything funny, but perhaps my exit was funny enough. When I after a short moment returned in front of the wall, I saw a skeleton, hanging on the back of the segment, now widely exposed. The course really had a happy end.



End of course, a skeleton appeared

1987
SFEMG course in Chapel Hill, NC
Chip Howard, S Nandedkar, J Massey
D.B. Sanders

1987, Chapel Hill, NC
Erik and Stefan Stålberg

P Fawcett,C Howard,
D.B. Sanders, J Jabre,
E Stålberg, D Wiechers,
J Trontelj

Social program of the meetings. Among the many extra things during all the courses I will mention three. In one of the fjord-courses in Norway, there was a "ladies program" with Scantaste (Scandinativan specialities arranged by Brith Torbergsen and my wife), midnight

skiing or fishing, dog sleigh riding and new music composed by H Lang (piano Lang, violin Kamp Nielsen) ”fibers in harmony”. In one meeting in Santiago de Compostela, Spain (Spanish annual meeting on CNP, 2005) our congress visited the Cathedral of Santiago de Compostela. We (Eva and me and others) were impressed by the botafumeiro (smoke-expelling) . There was a short prayer (read by the convenor of the meeting Jose Fernandes) for the success of the meeting, touching for me.

In a congress in Lyon (when I was chairman of the European Chapter for CN) we had the gala dinner at the fancy restaurant of Paul Bocuse (very famous chef) and met him personally.

9.5 Working abroad

I have travelled quite a lot to various countries, mainly to conferences and courses. To a lesser degree have I spent time abroad for work. Some of the short periods are summarized here.

In late 1970´s in Charlottesville, to visit Don Sanders (Neurology Department, headed by T.R. Johns) for a couple of weeks. They had just started to implement the SFEMG method for their famous work on myasthenia gravis . Chip Howard came for a short visit from Chapel Hill. I showed Macro EMG and included a practical session with Chip as subject. Fifty years later, he tells me about this - he did not like to be needled.

Columbia University, New York with Lewis (Bud) Rowland and Bob Lovelace. I spend a week or so there, gave some seminars, participated in grand rounds and saw some patients.

Auckland 1987 for three weeks. It was a program with half day lecturing, half day with patients.

Bethesda 1990´s. King Engel and Tulio Bertorini. They brought in a large number of patients with various neuromuscular disorders. King Engel was generally not impressed by EMG (he had his outstanding research and routine with histochemistry) but liked what SFEMG contributed here. In patients with central core disease and rod disease, fiber density was not increased despite massive type I fiber predominance. The normal distribution of type I fiber subtypes in those patients indicated that their fiber predominance was not due to sprouting and reinnervation, but probably to paucity of the type II fibers. In patients with type I fiber hypotrophy with central nuclei, fiber density was increased, perhaps attributable to the small diameter and consequent denser packing of the type I fibers. So, discrepancies between fiber density and fiber type grouping added new aspects to the interpretation.

Tromsö. I was invited by my friend Torberg Tobergsen (head of the EMG lab) to participate in routine work and accepted immediately. I had visited Tromsö so many times before during the sunny period (midnight sun) but had not experienced the dark period. So from November 2003 to March 2004 I worked there, special experience and nice. The sun came back on January 21, which was celebrated with "sun buns" (bakers made 34,000 buns) for the entire city.

Riyadh November 2012. Here the program was half day lecturing and half day seeing patients during one week.

10 TELEMEDICINE

10.1 Background

Clinical neurophysiology is an independent specialty in Sweden. The main focus is on diagnosis of neurological dysfunction by means of neurophysiological recordings. It also includes intraoperative monitoring, preoperative and intraoperative evaluation of epilepsy and new developments parallel to imaging techniques, such as ultrasound and MRI.

Some recordings are performed by technicians (there is a university 2.5 years training course for this group), others are performed by physicians, usually needle EMG or invasive techniques.

Our laboratory in Uppsala is responsible for all neurophysiological studies in the hospital and provides service to satellite hospitals in the region of middle Sweden (Karlstad, Gävle, Västerås, Falun, Örebro, Eskilstuna, Hudiksvall, Säter, Mora and on the Finnish island, Åland). Technicians stationed at these laboratories perform daily EEG and in many of them also neurography, which are analyzed in Uppsala by an allocated physician. These physicians are travelling weekly to their satellites to perform EMG and have rounds with the clinicians.

During the 1980's these EEG paper recordings (many kilograms a day) were sent by surface mail to the Uppsala laboratory. Later (middle of 1990´s), digital recording systems have allowed a more efficient transfer of data.

For us, telemedicine for the transmission of biological signals and videoconferences is the basis for the service we give to the satellite laboratories and to their hospitals. The number of recordings is on the order of 15,000 per year (2010). In addition, we use telemedicine in different forms of international contacts, such as consultations and scientific collaborations.

10.1.1 **Digital technology for long distance measurements of short time intervals**

My own interest in using computers began in the early 1960's when I worked on my doctoral thesis and collaborated with Jan Ekstedt. We needed to measure very short time intervals of the order of 100 µs with an accuracy of < 1 µsec and with a repetition frequency of 5-30 Hz, sometimes lasting for hours. A Hewlett-Packard time interval counter made the time measurements, which were shown on the instrument in a display window. Manual analysis of this large amount of data was not an option.

At this time Uppsala University had its first computer (IBM 1620) at the institute of physics. Ekstedt and I took some courses in Fortran programming and Ekstedt made our first programs. But how to get data into digital form? We placed a camera in front of the counter display and had a technician punch all data onto cards. We used this system for a while and were probably the first at the Medical faculty to use computers.

Later we purchased an 8-bit incremental tape recorder and the analysis could be expanded. The next step was, when we bought our own computer, an LSI-11 with software for time measurements and we were self-contained.

The recording and analysis methods that Ekstedt and I had developed, moved together with me in 1967 to the Academic Hospital, Department of Clinical Neurophysiology, while Ekstedt moved to other activities. Initially I kept my experimental laboratory across the street, where I could perform all signal analyses, supported by one research engineer. In order to be able to make recordings in the hospital department and do analysis in another building, the Swedish Telecompany made an extraordinary effort. They buried a 300 meter long 14 double-paired cable under the road to connect the two labs. With this cable we could transmit analogue signals, control signals from the oscilloscope, bilateral sound channels (I had a throat microphone, as used by pilots) and video signals. This was the first telemedicine connection over a long distance in Sweden. This connection was used for some year,s until we were ready to install new equipment in the hospital lab.

The next step was taken, when in the 1990's our special jitter methods were implemented into commercial EMG equipment, now opening the possibilities for worldwide connections (see below).

10.1.2 **Telephone transmission of biological signals**

One of the types of signals recorded in a neurophysiological laboratory is the low frequency rhythms from the brain, EEG with a frequency spectrum of 0.1 – 30Hz. There was a need to transmit such signals from a small hospital, where technicians had made the recordings, to our central laboratory for analysis by physicians. These signals cannot be transmitted directly over the telephone net because of the frequency content. By means of frequency modulation around a higher central frequency (e.g., 1,300 Hz), this is possible. On the receiving side there is demodulation and the signal can be printed on paper, the routine at that time. The first transmission was made from my summer house on the Swedish west coast, with EEG equipment on the lawn, properly grounded to the well and recording from my wife's skull. Signals were sent to Uppsala and recorded on paper. My online paper recordings superimposed exactly with those obtained at a distance. No distortion, no artifacts were added by the telephone switches. Single channel transmission of EEG and of ECG was tested to another hospital but was never adopted for routine use. A multichannel system of similar kind was however implemented and used between some hospitals in Gothenburg for some years.

10.1.3 **Radio transmission of EEG signals**

Another EEG application was made by the first mobile EEG John Seabury and by Kaiser in Denmark with the same technology as he had used for the NASA program (starboard and Kaiser, the atrocity). It is put on the head or in a holder on the belly connected to EEG electrodes and one marker channel. The operational radius was up to 100 meters and it was used in routine for some years, mainly over short distances within the hospital room from where a cable connection ran to the laboratory.

10.1.4 **Internet for communication**

From 1991 through 1993 we participated in the development of a new type of ENeG/EMG equipment under the leadership of Stefan Stålberg in our department. It was introduced into routine use in 1993, both in our own department and with a PC and recording equipment at our satellites.

This later became a commercial product, Keypoint Classic, built by a Danish company (Dantec). The software allowed communication between all neurophysiological equipment in the system. Initially we used telephone modems, but later the Internet. When a special

national healthcare net was developed, Sjunet, we achieved a fast communication between our department's satellites in the middle part of Sweden, that is still used in the daily routine[20] . Initially this was only meant for signals from nerves, but later EEG equipment became compatible. When this system, had proved to be very successful and important in the routine, we moved from a push system where activity was sent between the two different equipment, to a pull system, in which data are retrieved from the local server at each satellite. It was then possible to securely read and review the data at a convenient time during the day. Internet transmission of EMG signals can also be used globally for consultations and scientific collaborations.

10.1.5 **BITNET**

The Swedish government put money aside for development of some medical disciplines, one of which was clinical neurophysiology within the Baltic countries. Our department became a partner and with a responsibility to develop and support clinical neurophysiology. We installed seven EMG equipment and seven media equipment (video stations for conferences) in four neurophysiology laboratories in the three Baltic countries. Introductory courses were given initially and signal transmission was used for three years in this project. In this way, the specialty clinical neurophysiology, which was previously relatively unknown in the Baltic countries, was introduced. Clinical neurophysiology is now in routine use.

10.1.6 **Artificial intelligence**

Since a large portion of the information in clinical physiology is numeric in character and the interpretation of results is relatively standardized, many attempts have been made to use artificial intelligence in this field. None of these projects, some of them rather large, have been implemented on a large scale. For my own part, we formulated a smaller rule-based module that gave set suggestions for the classification of EMG results[18] Japanese colleagues were interested in filtering their data through our laboratory system, but at the time it was not feasible. Later on other laboratories in the world have opened up such remote services.

10.1.7 **Simulations**

Many new neurophysiological projects have used simulation models to understand the relationship between the generators of the signals (muscle and nerve) and the recorded signals. This includes everything from simulations of muscle fiber action potentials to more complex projects, including analyzing various types of electrodes. Two such projects have

resulted in educational models, one for EMG and the other for nerve studies. These are used both in education and as scientific models applied to the study of different types of neuromuscular disease conditions.[19,17,16]

10.1.8 **Remote investigations**

Investigations have also been made at a distance, where I have been sitting at my desk in my office and guided untrained personnel at other locations and helped them to do certain complicated procedures (e.g., quantitative EMG - QEMG) in an EMG investigation. We had bilateral signals and speech connections at both ends. We compared QEMG analysis performed in this way by five staff members with very different backgrounds, such as senior positions, an engineer and a technician. For the same muscles we obtained results, that did not differ significantly from each other. Thus, theoretically it shall be possible someday to make investigations at distance, particularly in situations where an emergency investigation was requested. We can call this bed telemedicine and guided operations.

10.1.9 **Telemedicine in summary**

Clinical neurophysiology lends itself to a number of IT applications. These have been used to establish the “Integrated Neurophysiological laboratory”. The different parts of these are:

Information:

Administrative	Referrals	
		Booking
		Economy
		Statistics
Examination	Signals	
		Results
		Conclusion
Knowledge bases	Strategies	
		Anatomy
		Methods
		Reference values
		Education
		Conference

Technology:

Recording Equipment
Signal analysis
Local area net
Intranet
Internet
Video – ISDN, rounds, committee meetings, education
Modem

Our laboratory of clinical neurophysiology has often introduced technology even when it has been relatively new. We were probably the first to use a fax in the hospital. The hallmark is that we have with great emphasis tried to implement the idea of new methods into the clinic routine in order for them to be of real usefulness. The results have often been presented to health care administrators and to our research reviewers.

The development of telemedicine has been driven by well-defined medical needs. This has been an important factor in successfully implementing IT efficiently. Naturally the technical development has been followed with great care. This has given us ideas and identified possibilities to reach the defined goals.

11 SPECIAL MOMENTS OF SCIENTIFIC HIGHLIGHTS

Nearly every examination in patients gives rise to questions, speculations, new ideas. Here I find that discrepancies between findings of different parameters in a given patient should not automatically be taken as an error in one of them. No, instead discrepancies may lead up new alleys (e.g. fiber type grouping in some congenial myopathies with normal fibre density; many situations with disagreement between EDX and clinical findings). Over the years I have experienced some extraordinary and breath-taking moments, two of which I will present.

11.1 Decrement in paralyzed rabbits, EAMG!!

Myasthenia depends on antibodies against the cholinergic receptor.

One of the big moments was the day in late 1973, when we verified disturbed neuromuscular transmission in immunized rabbits. Prof. Heilbronn at the Swedish Research Institute for Defense (FOA) had been working with neurotoxicity, including neuromuscular blocking agents. They had purified cholinergic receptor protein from *Torpedo Marmora* (from France).

About 2-3 weeks after injection the rabbits developed muscular weakness. Heilbronn called me (we did not know each other) and asked, if I had some idea of how to test neuromuscular transmission. “Yes, I have, bring a couple of rabbits here”. In a few days we had them in the lab. Repetitive nerve stimulation on the fibular nerve and recording (I think with the cannula of a needle) of tibialis anterior showed a decrementing response. Wow. Dr Payan from UK was in the lab and my technician and the technician from FOA. What a feeling! This really indicated strongly that antibodies against the acetylcholine receptor had developed and produced the same symptoms and signs as human MG. We had a positive effect of Tensilon and Neostigmin. Similar studies, we understood, were ongoing in the US, but not yet published. (We had a first presentation in the Proceedings of the 3rd International Congress on Muscle Diseases, Newcastle 1974). Our independent report came out just after the report by Lennon VA, Lindstrom JM, Seybold ME. Experimental autoimmune myasthenia: A model of myasthenia gravis in rats and guinea pigs. J Exp Med 1975; 141:1365-1375. This was a great thrill, certainly indicating the future of understanding and diagnosing myasthenia.

The studies continued with needle recordings and jitter analysis with stimulation SFEMG. Also other experiments in rats and rabbits. A fruitful collaboration that lasted for at least 6 years, until Heilbronn passed away. (My technician and Prof. Heilbronn´s married.)

11.2 Konzo

A memorable moment in my scientific life was, when in October, 1991 we were asked to examine two patients brought to Uppsala from Congo. They had acute spastic paraparesis and the pathophysiology was unknown. For these patients, accompanied by family doctors and some locals, this event must have been very demanding. Flying in an airplane, coming to a hospital, instruments giving electric shocks and the noise in MRI. The hospital staff did its best to understand their situation and help them adapt.

Blood chemistry - normal. Imaging techniques - normal. A full EDX revealed no abnormalities in peripheral motor or sensory nerves. EEG was normal in one and of low amplitude in the other patient. But when it came to transcortical magnetic stimulation, we got the clue. No responses from arm or legs. The conclusion was cortical inexcitability in this disease, which was called Konzo. Insufficiently dried cassava that produced cyanide poisoning with irreversible symptoms was found to be the cause. The studies continued and led to Dr Tshalas’ doctoral thesis. Later Dr. Karin Eeg-Olofsson and engineer P.O. Fällmar from Uppsala went to Zaire for field studies. Local education on the cause was implemented.

12 THE IMPORTANCE OF TECHNICAL COLLABORATION

12.1 General technical collaboration

Over the years the input from manufacturers has been changing dynamically and the input has varied in importance. A few examples and thoughts will be given in this section.

The collaboration between Buchthal, being the physiologist, Paul Rosenfalck, the mathematician, Anne-Lise Rosenfalck, the engineer and Christian Guld, the electronic engineer on one hand and the EMG manufacturing company in Copenhagen DISA (later DANTEC and so on) is well known. We have all gained from the fantastic input from that team, which produced results that still are referenced. Similarly the collaboration between Edmund Kaiser and Buchthal and later also Swedish neurophysiologists became successful. Kaiser was an engineer with solid physiology knowledge who started a successful company making routine EEG equipment and also telemetry equipment for EEG.

Some laboratories in the world were lucky to have good engineering support and also collaboration with technical university institutions. We built our own amplifiers and made a large set up with amplifiers, oscilloscopes, tape recorders and film cameras.

With time the EMG manufacturers, who followed the development, started to extract the commercially attractive parts of EMG development from different laboratories. We were also a part of that collaboration, when DISA had seen, e.g. our home-built trigger and seen our attempts with delay lines and finally with various types of jitter analysis. In the DISA 1500 system all these functions were implemented (with Mr. Jörn Ladegaard leading the company´s development), including the first commercial jitter meter. Similarly Medelec (Old Woking in England with Mr. Peter Styles as the leader) became interested in various technical developments. For their MS 6 they made modules for signal averaging, dual sweep facilities, an integrated printer using heat sensitive paper and superimpositions of an optional number of sweeps based on printer-controlled features. Various display options facilitated the early use of manual jitter analysis. Our collaboration with these two companies and some others were very stimulating, since some of our ideas could be implemented in a professional way and distributed to other users for broader testing. In those days the collaboration between academics and industry was not always recommended. I therefore kept out of economic contracts and had no financial revenue. The only practical output has been, that the lab initially received samples of SFEMG and Macro electrodes for testing and an equipment or two for “long term” loan for functional assessment and feedback.

12.2 Insufficient training of physicians

Even those colleagues, who have equipment with all necessary software, may not have been given correct and sufficient instructions of how to perform a procedure (e.g., slight or strong activation, superficial or deep in the muscle in EMG, which signal epoch is analyzed during recording and editing). This is up to all actors involved, the individual user, the mentor, the departmental head, the manufacturers (manuals, courses) and standards committees.

12.3 Lack of reference material

My opinion is that quantitation is in principle a good thing for standardization, for increased accuracy and thereby, hopefully for higher sensitivity in detecting abnormalities. By having quantitative EMG data, one can compare findings in one patient from time to time, exchange results between physicians and promote research in the field. Lack of reference data is the factor that has hampered the introduction of quantitative EMG on a large scale.

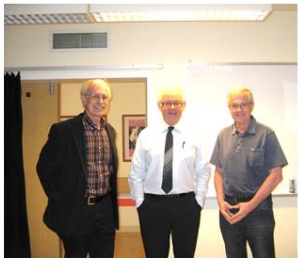
It is not clear, which mechanism one should use to get the reference data we need for all of our quantitative studies. It is not scientifically challenging, it has not been economically rewarding and it takes much time for physicians, subjects, statisticians. Reference values may actually be the most important resource in a laboratory, that performs quantitative analysis in neurophysiology. Without this there is really no need for the physician to train in the methods.

Our own efforts to collect reference material was as follows. For EMG we first gave introductory training to the participants. Then the participating colleagues had to deliver 10 studies from the biceps muscle of healthy subjects, both signals and data from new investigations performed in their own environment. These results should be consistent with the results from this muscle, that we already had collected at home in a larger sample. This was the “entrance ticket” to participate and collect reference values from a few more muscles. Each lab usually provided studies from 1-3 muscles in about 30 subjects. Data were centralized in Uppsala, where we performed statistical analysis and returned the pooled results to the participants. They were also made available to the KeyPoint manufacturer. The principles of data collection were published,[1] but not the individual EMG data since these values are generally speaking only relevant for this particular equipment.

The reference material is unfortunately not transferable from one EMG equipment to the other, since each uses slightly different algorithms to extract MUPs, to average and to set duration cursors. This is a great disadvantage and beyond the control of the physicians. It

seems that the EMG manufacturers are unaware of the need for reference limits and of the large effort required for the collection of these values. There have never been attempts for consensus in this area, regrettably. What does that mean? Some equipment manufacturers have implemented a given software, e.g. its own multi-MUP program and announced this in sales brochures but without appropriate reference values.

Another way to study normal effect of age is to repeat studies with long intervals. We have done that both in health and disease. One extreme example is the 30 year follow up of FD and Macro in a few muscles



30 year follow up

In a project on aging in hand muscles and masseter, temporalis we made studies in 1986,2011 and 2018 with FD and Macro EMG measurements.
These pictures are from 1986 and 2018.
(Erik has not changed tie)
MUs become smaller in masseter and temp, but larger in IOD.
Prof PO Eriksson, T Winkler and me

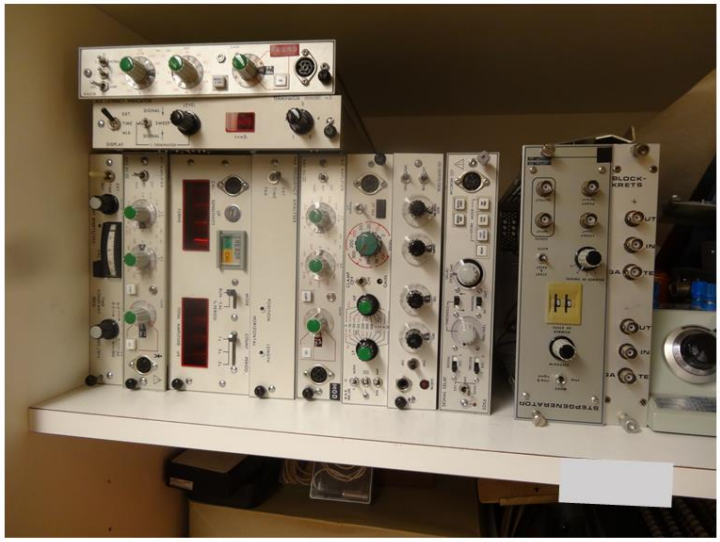
NCS are based more standardized methods. The reference data are more transferable than those for QEMG.[8] . For the individual lab there are two options for reference material for NCS. One way is to collect its own data, which is time-consuming and therefore expensive. The other way is to use other investigators' normative data, provided one is prepared to modify their methods to become an exact copy of methods used for the imported reference material. Uppsala has its own reference material. We tested the influence of demographic data and other factors such as physical activity, alcohol intake, medication (pain killers). Age and height were most important if temperature, electrode type, filters and stimulation-recording distance were kept constant. Others can freely use these data in any equipment as long as methods and filters are the same.

New statistical principles have been published[11,14] that allow reference values to be extracted from a mixed database of normal and abnormal values, typical of the database in an EMG

laboratory. With these techniques it is possible to use values from a local database and create reference values for that specific laboratory. This may be very useful future approach, giving better results and keeping quantitative methods alive.

12.4 The importance of support from manufacturers and sales persons

The help and understanding from manufacturers have been of utmost importance for me in implementing various ideas. They have listened to arguments for new modules and often come up with a technical solution, sometimes just for my lab, sometimes for routine use. Sometimes I have been invited to give a demo with equipment with which I am not fully acquainted and it turns out that understandably the sales person is not knowledgeable about all the complex questions we as customers formulate. “Can you perform Multi-MUP analysis?” “Yes.” Unfortunately, that turned out not to be true. “Do you have reference values for MUP analysis?” The less surprising lack of knowledge is when I ask for a special feature, just to make a demonstration of a given phenomenon, e.g., can we display the same signal with two different filter settings on two simultaneous traces? Do you have peak detection for jitter analysis? How do we remove all the disturbances in the jitter analysis due to occasional spurious disturbing signals? Often the solution is available in the equipment. The company support is essential and has usually been very good. There is an increasing demand for support from the companies.



A large number of plug-in modules were produced by Medelec, many of them for SFEMG

12.5 Unclear definitions of terms

One quantitative method is to assess the recruitment pattern numerically, such as the frequency of MU1 when MU2 is recruited and similar parameters. This should be very easy to measure automatically if we had criteria for accepted MUs. In a recording obtained during slightly increasing muscular force, there are sometimes very clear individual MUPs of good

amplitude, but at the same time, more remote MUs have started to fire. This weakness in the method has prevented it from getting wide use, but I see new solutions for this.

13 DEVELOPMENT OF OUR LABORATORY IN UPPSALA

As mentioned, the first laboratory (1958-1966) was located in the basement of a building for dermatology. A table tennis table was removed and space was just enough for an EEG machine and homebuilt EMG equipment (engineer Persson from Karolinska institute). At the time for my start in January 1967 the lab was moved to a newly build barrack.

Here we had at least four offices for physicians, two EMG room and 2 EEG rooms, 1 room for echo encephalography, 3 secretaries, 1 engineer with workshop, library/meeting room, kitchen and waiting room. There were 2 nurses, but very soon we hired 2 certified technicians. We were happy there, full of enthusiasm for the expanding specialty. More physicians and technicians were hired, more pieces of equipment was purchased and with time, the space became too small.

13.1 Lay out of the laboratory

In early 1970ies a very small steering group (Karl-Erik Hagbarth and myself, an architect and one representative from the administration) were set to define and suggest a new lab in the hospital. We were invited to frequent discussions. Given a relatively free hands in defining the funjction of the laboratory and its general lay out we suggested:

- separate patient flow from personnel traffic (2 parallel corridors in the lab)
- Examination rooms large enough for a bed
- Separate screen of the rooms (to prevent that a short circuit in one room should not interfere with the rest of the system
- Secretariats within the lab space
- Our own lecture room for rounds and internal education
- Our own workshop (hardware and electronics)
- Coble connections (nowadays digital hospital network) to neurology, neurosurgery, intensive units
- Coffee room (that had to be called class room at that time). This has become an important room over the years where socials contacts have been strengthened and scientific and clinical problems have been shared.
- Own library for meetings courses (later this was merged with the so called lecture room

A few details were not accepted such as a sink in each officed for hand washing after each patient. We planned for a histochemistry lab room, that was never in operation. With new technology, photo lab became obsolete after a short time.
We have been were very pleased with the functionality of the initial planning. It remained in original lay out for about 35 years but was then reduced to half because of hospital need for space for patient care and the trend to have just 1 or 2 patients in each room. Ophthalmology moved in to part of our old space. Now 45 years from the original lab, we are very satisfied with the principles of the laboratory lay out.

We got more rooms than necessary at that moment, but OK "as long as you do not fill them up with personnel". In January 1974 we moved in to the new large lab. After some years we had around 10 physicians, around 10 technicians (for EEG and all neurographies with surface electrodes), 2 hospital engineers and 3 research engineers (these research engineers disappeared with my retirement). We were early well equipped with EMG machines from DISA and from Medelec and EEG from Elema and later also with other machines. .
Four mornings every week did the physicians gather for 30 minutes to discuss every case from yesterday. Here we learned and taught. I think we all found this inspiring, meaningful and leading to a good quality in our service. In addition we had weekly rounds with neurologists and paediatric neurologists and more seldom with hand surgeons. In Sweden (and in many other countries) technicians perform independently high quality neurophysiology (nerve conduction studies, repetitive stimulation, autonomic tests, EEG and nowadays intraoperative monitoring).
We had more or less continuous work to improve service quality: projects on signal quality, writing method books, developing reference values, developing administrative programs for daily routines and naturally internal education.
The lab had for many years distinctly separated research areas: microneurography with motor control (Karl-Erik Hagbarth) and autonomic function (Gunnar Wallin) and pain (Erik Torebjörk), epileptology (Sigfrid Blom, Roland Flink) and Single Fibre EMG (me). The lab became known because of papers, international presentations and course giving. Many colleagues from other disciplines made their thesis with us.

13.2 Flooding

On Sunday August 18, 1997 there was an exceptional rain in Uppsala. Our hospital building has a helicopter pod on the roof, with its drain passing a wall in our department, located on

the third floor. The pipe makes a “knee” in the wall and in late evening the pipe broke, disaster! One physicians visited the lab in the evening and saw the water on the floor. He called me and I and my wife came there promptly. The water was pouring from the wall. Soon many in the staff came in. Many of our computers were safely fixated to the floor (not to be stolen) and a recent safety inspection in the lab verified electrical safety and good condition of pipes passing in the ceiling of the rooms. With the water level was 5-10 cm on the floor, we could fell 50Hz if we worked bare feet, so boots were a must. We managed to free the computers, and with hairdryers we were lucky to rescue all of them. We shovel water out to the balcony or to the stairways hoping that it should not reach the MRI lab on the ground floor. The head of the Neurocenter (Dr Per Olof Osterman) came to help, and at 2 am I the night a member of the administration came with sandwiches. When leaving in the morning, with pretty dry floors, we hoped to have rescued the lab. Unfortunately, the water had soaked the lower 50 cm of the wall boards, so the entire lab had to be renovated. We moved to an empty internal medicine department for many months. One memory from this move is how engineers and physicians help to institute a cable network for our machines and got it working within 3 days!

The night with flooding was extra difficult for me, with rather severe headache since some weeks. A month earlier I got the sailing boom on the top of my head. A week after the event in the lab I was diagnosed with bilateral subdural hematoma (missed on CT, but seen with MRI). I recovered slowly over months, without surgery.

2 Physicians and
2 technicians

Night duty after FLOODING

Moving from water damaged
department to other hospital space

13.3 Early introduction of digital techniques

13.3.1 General

The implementation of digital techniques in the laboratory has passed through the following stages [22]:

During the 60's computers were used for research purposes only. Punch cards were manually and personally fed to a new university IBM 1620 and later to a new "datacenter" for processing. The results were ready to be picked up the following day.

About ten years later, 1974, when the department moved into its current space, we bought the first Digital Equipment PDP (11/40) computer, which was used for signal analysis and some word processing, boosting research and routines. Later the larger PDP 11/34 was installed and word processing now started, particularly when terminals were installed in a few rooms. A Micro Vax replaced the PDP 11/34. Word processing, database storage and off line signal analysis were the main tasks for this machine. We changed computer philosophy in 1989 and sold this computer and installed a network of PCs.

Relatively early in the late 1980´s, when individual instruments had individual software programs, we discussed an internal network of PCs (LAN) or a hospital network. Because of timing for the alternatives, we chose the local LAN (named LANtastic) and used that from around 1990 for many years, before a central solution was implemented.

Two engineers worked full-time programming. It became possible to digitize recorded analog signals and to apply digital signal analysis. Almost no commercial software was

available at that time, except for a word processor, which was only slightly better than a typewriter.

Usage of Internet. The Internet was introduced into the department in the early 90's. Over the years we have used it for: E-mail, Web-search, Videoconference for clinical rounds and scientific meetings, Home page, Intranet and Remote neurophysiology (telemedicine)

13.3.2 **Implementation of digital techniques into routine EMG**

In the end of the 70's, our engineers developed software for routine usage.[4] The first Decrement, SFEMG, Scanning EMG, Turns/Amplitude and Template matched EMG programs were written (PDP 11/40).

The Apple II computer was introduced in the late 70's. A range of routine software packages was developed (SES software "Stefan Erik Stålberg"). The signals were recorded on smaller digital EMG equipment (Medelec MS92 and Dantec Neuromatic/Cantata) and transferred digitally to the Apple II for analysis, display and reporting. A voice recognition system for the Apple II was implemented and used routinely during the investigations to operate the analysis programs hands-free. In the early 80's, the IBM PC was introduced. All routine software was transformed to fit the new range of IBM PC models and still worked in conjunction with the smaller EMG equipment. This setup was used routinely until 1991, when it was replaced by the Keypoint (Medtronic), developed by Stefan Stålberg.

Administration was the next area to be computerized. In the mid 80's a patient administration system was developed in the department (ProMan), a program that was used routinely until 2018!

By the end of the 80's our department had about 20 IBM PCs. The initial local area network was installed by a group of enthusiastic engineers and physicians.

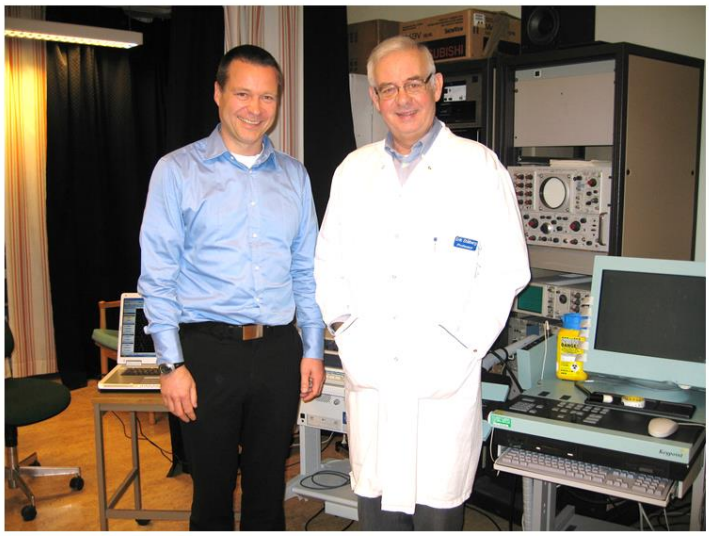
Connecting computers, recording equipment, printers, etc. by means of a local area network increases the performance and possibilities dramatically.[20] The main advantage is the accessibility to information from all computers within the department, regardless of where it was obtained. Data are stored on servers with daily backup routines.

The NCS software was rather simple, user-friendly and intuitive and was in many places welcomed to speed up the NCS and decrement analysis. The EMG programs for MUPs were still analyzing one MUP at a time, a method that really was too slow for routine use. It took 20 minutes for a complete study of one muscle.

Software capacity was integrated into the development of EMG equipment and many more functions could be controlled from the PC keyboard. A variety of algorithms for signal analysis were tested and often implemented into commercial systems. During this period all EMG manufacturers saw this as the future and explored the scientific arena for ideas. Some of these we implemented. If successful other companies copied the ideas, but with somewhat different layout and user-interface.

We are now in a phase when all pieces of EMG equipment are digital but have become designed by the companies according to the advice or sometimes lack of advice from users. They have therefore become very different in operation and offer very special features, although most of them have the basic capacity to serve for NCS, EMG and perhaps SFEMG and evoked potentials.

Some equipment, including the one in which I and the rest of the staff was involved (with my son as software engineer), the Keypoint (DANTEC), had advanced EMG analysis and rather extensive NCS software.



Stefan in front of the Keypoint which he developed

After initial testing, a multicenter study was undertaken to collect reference material both for EMG and NCS for this equipment. It is clear to everyone that a quantitative result, usually as a number, is rather useless if the limits for normality are unknown.

Other software was developed, including administrative programs (ProMan) for booking and administration (the program was in use for an amazing 31 years). Later another type of software (Cross Neuro Database) provided the possibility of extracting data from our large database (85.000 patients) for routine retrieval on an office PC or for research.

14 BLESSED WITH MANY COLLABORATORS AND VISITORS

Collaborators and supporters. My work has never been an isolated effort, but a work with small or large teams. My wife and family have been the bases. Then the staff at the

department, all of them; helpers, cleaners, secretaries, engineers, technicians and physicians, a great happy crowd. The staff has not only struggled with the routine work, but also enjoyed free time during Lucia, travels to Norway, England, Denmark, Finland and my summerhouse. Sometimes I (and often my wife) and a few physicians and technicians have travelled to congresses. To all of them I express my thanks; their support has carried me everywhere and every time.

Writing reports and scientific pares is important, otherwise your results are not spread and not easily accepted, "Is this published?" Usually I have done this with a co-author or been a co-author. Many times the authors have been to my lab as visitors. The later activity of writing has been a way to continue friendships and scientific discussions. One example is the 3rd edition of the SFEMG book,[21] written with my friends Jože Trontelj and Don Sanders.

Visitors. Over the years a large number of colleagues have visited my lab. We tried the principle of "one day or one year," or more realistically, a couple of weeks or half a year. The longer period was for those, who wanted to participate or develop a project in the lab. Three months only work for those, who already have the expertise and experience. Some of these have been quite successful. 6-12 months have been for those, who needed an introduction and a helping hand for a project. Nearly all of them have come from other countries. I have been inclined to think that these, often young people, really represent a positive bias. They have a deep interest to come and learn, they have been ready to spend time away from home, spend money (unless they have received a grant from their home country - we unfortunately usually have not had economic support to offer.) Usually, they have been in competition with others and have prepared their visit by contacting me for a letter of invitation, plan for the period in Swedenand so on. The typical situation has been that they came with some knowledge in neurologyand maybe neurophysiology. An initial

DB Sanders, E. Stålberg, J Trontelj at XXth International SFEMG & QEMG Course and XIIth QEMG Conference Istanbul June 2-6, 2012 in the Military Museum and Culture Center

time for introduction that usually included becoming acquainted with the clinical routines was followed by participation in ongoing research projects, or even more commonly starting a new project. We tried to finish experiments, data collection, analysis and part of writing a manuscript about one month prior to the end of the visit. This was the ideal situation, but certainly did not become true in all cases. The last month should be used to finish details, to discuss new things, plan for the future and so on. The reason for my intention to organize the visit in this way was based on experience from early years. We workedand became absorbed by interesting results, that created new questions and more experiments. By the time when the visiting colleague should go home, we were left with integrating and reporting the findings. If this should be made by mail (surface mail in those days)and the visitor was suddenly thrown into a busy routine, then the project tended to be protracted. Some manuscripts were delayed by months or moreand exceptionally were never finished. For us in the lab, all these visitors have meant a lot of positive influences. First, the contact with other cultures, other routines, other ways of thinking has been enlightening for us. In general the visitors have brought positive vibrations to all of us and they have always been welcomed and we have made lifelong friends all over the world. The other thing for me has been the possibility of running projects in parallel to my routine work and later to my administrative work. This collaboration has often continued for years, when the colleague now is in their own lab and we can continue the collaboration. Not uncommonly data collection has been performed in their own lab and we have corresponded regarding analysis and writing. It has been a great reward for me to see how many of my "students" have become respected clinical neurophysiologists, some of them professors, department chairs or otherwise have successfully fulfilled their wishes for their own future.

The short-term visitors for 1-2 weeks is another category. They have also been of great importance for me and my lab in the way they comment and question our routines, our research results and point to things, that we may not have been thinking of – eye-openers, informal peer reviewersand hopefully future ambassadors for the best of our ideas that they take home. These visitors usually are automatically more demanding for us. We want to make their time worthwhile and therefore spend extra time and effort with them. It also takes time to arrange accommodations and all the small details. Every time it has been worthwhile for us and we have always enjoyed them.

For me, all these contacts have not only meant professional challenges and some achievements in individual research projects, but also the social contact. In many cases its has

resulted in lifelong friendship. Many have been back one or many times or we have met at various meetings and congresses. As we read it from their own comments, this is a reciprocal feeling. Often they have thanked us, not only for the professional part of the visit, but also for the insight they have gotten into the Swedish lifestyle, working habits, "fika," and social systems.

Many aspects of a visit have only occurred to me after many years. I have become aware of the dynamics that occurred and have some long-term follow up of the effects of the visit for us and for the visitor. I am sure, that we made many mistakes during the early years and certainly continue to make errors. Some of these we recognize, others only history can judge. The reason for my talking about visiting colleagues, fellows and post-docs is my feeling that this aspect of work has been a continuous learning process to meet them and in some way to understand their situations. For many of them this may be their longest time studying abroad and they often refer back to this as an important time. It is a great responsibility on both sides; for the host to give proper and balanced attention, different for short- and long-term guests and for the guest to make the best of their time and to communicate to the hosting department their feelings, needs, problems and satisfactions.

Other visitors. Our laboratory has also been honored with visits by people outside the medical field. Both the Swedish King and the Swedish Prime Minister have seen our laboratory.

The King and I, prof Hagbarth, staff and visitors watching EMG

From the right. Swedish Prime minister Carlsson, Prof Blom, local Governor Ahlsén and representatives from the hospital administration watching our epilepsy section

15 FUTURE

At this moment, I am concerned that QEMG has been so slowly accepted compared to the development of other procedures. The development QEMG has slowed down. Either we need to develop completely new parameters, not sensitive to details in the algorithm definitions,

such as MUP duration, or we have to work harder on the above-mentioned factors that stand in the way today.

16 MEDICAL MIRACLE GAVE BONUS TO LIFE

I had been blessed with good health. We have no outstanding family history of cardiovascular diseases other than a fatal aortic aneurysm in my father. Migraine-like headaches, like my mother, is the only thing that is worth mentioning.

One evening April 6, 1993, I suddenly had a very severe pain between the scapulae and during 30 seconds it moved down to the lumbar region. Infarction, dissection? I said, let us not wait for ambulance, take me to the hospital. When we came out on the door steps around 23.10, a neighbor, who had looked after our car was out for a walk and stood beside the car! An angel?

He, a good driver, drove at high speed to the emergency unit with me lying in the back seat. I was initially thought to have an infarction, with hypertension (200mm Hg)and spent the night with Eva and one of my sons by my side. I had the chance to say good bye, thinking the prognosis was more pessimistic than my family did. In the morning, blood tests did not really indicate infarction, neither did an ECG. A CT or MRI and ultrasound, I do not remember and have not looked in my own files, showed a long dissection from the arch down to just above the division of the iliac arteries. Esophageal ultrasound verified the diagnosis. A cardiologist and thoracic surgeon (who was been spending Easter free time at his summerhouse) came to decide the acute strategy and I was taken to the intensive care unit and given antihypertensive therapy. I do not really remember much of this time, which lasted for weeks. Eva cancelled all my obligations. It is fantastic how easy it is to clear the calendar, when more important things get in the way of programs that previoulsy were considered absolutely necessary. After many weeks in intensive care, I came to the ward, lying still in bed, with the order to keep the blood pressure below 120/70. No visits in the beginning that could excite me. After more than a month, I was mobilized, first by sitting up. Some days later by standing up by the bedside. Then trying to walk to the foot of the bed and after a week to the door. After about 2 months I could take short walks in the hospital walkways and was released shortly thereafter. The order was to keep the blood pressure low, no physical exercise, no carrying of bags, no car driving.

After some weeks into the situation I understood that the cardiologists had consulted both Boston and Hannover (I think)and I was offered to go there, if I considered it a good move.

The final word was not to operate, wait and see. I had full kidney function and spinal function.

A few things to mention. From a previous visitor, a Japanese colleague and his family, I received a big parcel during my stay in the ICU. It was 1,000 handmade origami cranes, hanging on many strings like a waterfall. During their stay in Uppsala they had given my diseased father some for his hospital room, saying that we incorporate a wish for good luck and good health in each crane, that we make. Here, among the ECG, monitoring equipment and lots of infusion cables, was a mobile with 1,000 cranes from Japan wishing me good luck. It helped!

One of the difficult things was the exhausting moment every day of sitting on the toilet chair, obstipated, with low blood pressure and extremely weak. My muscle mass, not much to start with, decreased dramatically during the weeks in bed. I was not allowed to have someone come to follow changes in my EMG during recovery, which could have increased my blood pressure.

Extremely close monitoring of my status was provided by my internist, to whom I already owed lots of thanks.

A semiannual control of my status showed after 3 years the development of a thoracical aneurysm. A meeting with my internist, thoracic surgeon, abdominal vessel surgeon and my wife gave us only one option – operation with thoracic and possible abdominal graft. After a few weeks during which I made a lecture trip in the UK, somewhat distracted by the upcoming event, the operation took place on November 26, 1996, on the day 30 years after my dissertation. After a full day operation, I woke up the next day, saw my feet sticking out below the blanket and I could move my toes! Another victory. My family barely recognized me, since I had accumulated 15 liters of edema with a swollen face. Rehabilitation was uneventful and I was released after 14 days. The good-bye message was, “Erik now you can carry your suitcase again.”

Three years later the semiannual CT control showed further widening of the abdominal aorta, which had not been operated but left as a double pipe. New technology gave me the possibility to get stented, two telescoped into each other to achieve sufficient length.

I could watch the procedure all along on the monitors during the procedure.

All these serious medical events certainly have been in my mind, nearly every day. I thank God for every new day. In my own mind I have changed. I think I focus more on what I find

important, do not care so much about details and know that life is unpredictable. I have been operated a couple of times more.

During the bonus part of my life, lots has happened; my children have met their partners, married and had children; I have been involved in the development of a new EMG equipment that is spread internationally; and I have finished my professional duties and can enjoy a situation without responsibility for economics, personnel and university commitments.

17 OTHER ACTIVITIES

Muscle group. With the development of new methods for the diagnosis of muscle diseases such as histochemistry, biochemistry and electrophysiology, I created a group of neuroscientists to meet annually on a Saturday and Sunday morning at each other's working places. This group consisted of persons in the frontline of neuromuscular research. It consisted of:

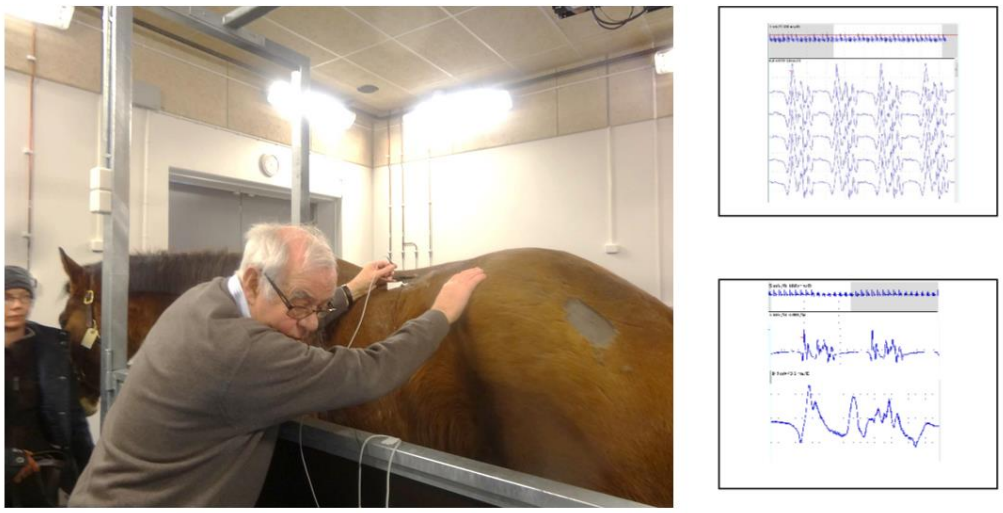
Prof. E. Cedergren, Dr. L.O. Dahlbäck, Dr. J. Ekstedt, Dr. D. Elmqvist, Prof. I. Gamstorp, Dr. L. Grimby, Dr. K.G. Henriksson, Prof. E. Kugelberg, Dr. L.E Larson, Dr. P.O. Lundberg, Dr. E. Stålbergand Prof. L. Welander. We met from 1972-1995 and found value in sharing experiences between different neuroscience disciplines.

Drugs. During several years in the 60's I worked as on-call doctor in Uppsala some nights a week as a complement to my small salary from pharmacology ($100/month). This included testing and blood drawing of suspected drunken drivers, many nights a week. After having defended my thesis in 1966 I had promised my wife to stop the police work. The same month however, the police asked me to make a survey of drug "problems" in Uppsala together with a policeman and social worker. We got our own office in the city center. My teammates knew the social problems in the city quite well and our survey progressed. We communicated our experiences with the police- and social departments in the city. We were invited all over the country to talk about drugs and about the Uppsala group. I was once at WHO in Geneva and formulated some of the early developments of drug abuse. I felt that I was playing in the psychiatry backyard and stopped this non- neurophysiological track after a total of about 9 years.

Church. For 23 years I was an usher in our local church. This was usually a Sunday morning event and did not interfere with my regular work.

Lions Club. In 1967 I was asked to charter a new Lions club in Uppsala. I easily got the 27 first members and we have continued since, in larger or smaller groups.

Veterinary school. We have the Swedish veterinary school in Uppsala. I have been invited a few times, in spite of my lack of training in veterinary neurology. I have seen a number of myasthenic dogs, some horses with back stiffness that had an EMG full of CRDs (that even



By pushing the horse slightly sidewise, I got nice motor unit potentials.
(Ordinary concentric needle electrode inserted through a small skin cut.)
We also saw abundant CRDs in this "stiff" horse

persisted for many minutes inside a large beef like biopsy we took), myotonic dogs (Chow-Chow)and intoxicated cows with neurogenic findings after drinking water containing acrylamide - they had denervation, a neurogenic EMG and reinnervation and clinical improvement after some months.

Leisure. Since childhood I have enjoyed skiing and skating. Later, boating came into my life when my wife brought me to the paradise of the family and where we spend every summer. We started with motor boats, but our children opened our interest for sailing, which has been wonderful. Later in life we do not stress balance, muscle and joint systems to maximum and have returned to motor boating.

18 RETIREMENT 2001

The age for compulsory retirement at the time when this should occur for me was 65 years. Only shortly thereafter it was changed to 67 years, which I would happily have accepted. We arranged a conference for SFEMG and QEMG in conjunction with this breakpoint in my life.

I thought it appropriate to end my active professional life with a congress, something that we had done many times before. Fantastic input from the entire lab made preparations including a number of new details - internet applications, not common at that time; well-developed media displays; internet corners; all things that are standard nowadays. For each day we added a few pots of white flowers from left to right on the podium as a progress time bar.

The first 3 days were courses and the congress in facilities downtown; the last afternoon was spent in the auditorium of the hospital, where invited speakers gave short summaries to some extent related to my work. Altogether we had 193 participants from many countries in the world. We ended with a wedding for one of the Japanese delegates.

The event was summarized in a Supplement to Muscle and Nerve (Festschrift for Erik V. Stålberg). This was a very nice gesture from M&N. (I should mention that the first article in that journal was on polymyositis by Henriksson and me in 1978.[10] I suppose they did not have other articles that early on to choose from, so we were accepted right away.)

Officials from the hospital expressed their thanks and handed over gifts and flowers. During the entire week we had lots of musical events, which I think was appreciated. The banquet dinner was held in the castle banquet hall, with good food, funny and serious speeches and a special musical performance (led by Dr Jan Fagius, neurologist in Uppsala), the Moor's last sigh. Coming out from the Castle that bright summer night was breathtaking and stays in my heart.

Now, what do to? I was kindly offered to have an office in the lab, to have access to my research lab and keep my files intact. This was very generous of the new chairman and the entire staff. In addition, I was asked to perform routine EMG 2 sessions a week and participated in teaching activities, all of which I accepted with great pleasure and relief. This continued for another 17 years. I have seen friends from other professions being worried about the day, when their office should be cleared, the calendar gets no new additions and nobody is asking for advice, help or other professional input. And more, loss of the social aspect of a job with daily informal contacts is for many the dark clouds rising on the horizon.

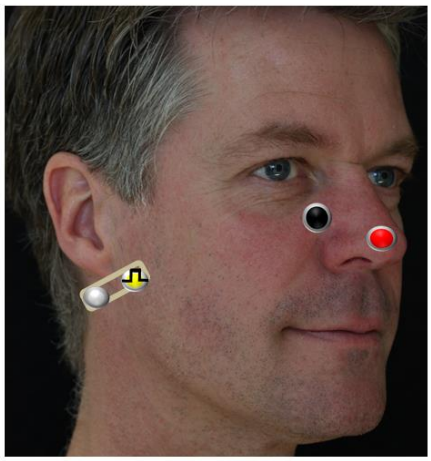
During the free time that has been given to me, I have spent writing articles and giving courses around the world. One special activity was to write the 3rd Edition of the SFEMG book[21] together with my friends the late Jože Trontelj and Don Sanders. We did the final writing in my summer house on the Swedish west coast, Edshagen, which then became the "Edshagen Publishing House".

Edshagen, our summerplace on the Swedish westcoast (Fiskebäckskil) where we have had many of the visitors to the lab in Uppsala

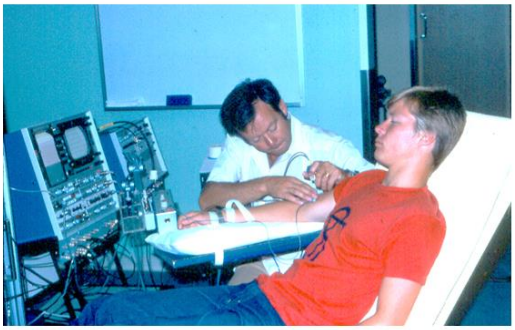
We also met in Don´s house and produced a number of videos on SFEMG (with the Nandedkars) to be placed on a new homepage for SFEMG (www.sfemg.info)

The collaboration with my son Stefan started in 1963 (development of the KeyPoint) and continues to the present time, when we nearly daily Skype each other to discuss developments in new EMG equipment.

I have had a lovely time from my early years in a good home, to a supportive wonderful family, to interesting studies leading to a doctoral thesis and an academic path, to a wonderful time in my department with the best of collaborators, to surviving aortic dissections and finally to a rich retirement time. Thank you all!



Family members have served for my demo slides



"Grouped" family picture from 2019

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