THE CLINICAL USE OF SURFACE EMG WITH HEMIPLEGIC PATIENTS

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INTRODUCTION

In this paper some work is presented we are doing in our institute of Rehabilitation "het Roessingh" in Holland.
In 1979 it was decided to develop a new unit in our institute that should investigate the use of surface EMG in order to examine the state of muscles for various purposes:

1. to investigate neuromuscular diseases such as hemiplegia, dystrophic diseases, plexus lesions and peripheral nerve lesions.
2. to evaluate individual plans for treatment. For example the question whether muscles can be trained or not.
3. to evaluate specific treatments e.g. phenolisition.

The reason to have such a unit is simply that the state of a muscle is one of the main parameters in an institute of rehabilitation. We are only working with surface EMG because it gives a reliable global indication of the working of a muscle. Furthermore we soon found out that all kinds of disorders are clearly reflected in this signal. An additional advantage of the use of surface electrodes is its non-invasive character which causes no discomfort for the patient. This is especially of importance with follow up investigations and investigations with children.
In the present paper we will discuss the clinical use of a standardised way of measuring and analysing EMG signals, especially applied to hemiplegia.
It is generally known that with hemiplegia a decrease of the amount of activity occurs which causes a decrease in the maximum force (e.g. Prevo, 1981). It is also known that a dysbalance between agonistic and antagonistic muscles may occur, which results in a poor control. On the other hand only little is known about the changes of the shape of the EMG signal that may occur with hemiplegia. In this paper we will discuss the changes we find concerning these three points.

METHODS

In the present investigation we used a device with which we could registrate the exerted force of the flexor and extensor muscles of the elbow. The force is measured by straingauges and is amplified by a carrier frequency bridge (Philips PR9307).
The subject is seated in a chair and his arm is placed in the device as shown in figure 1.

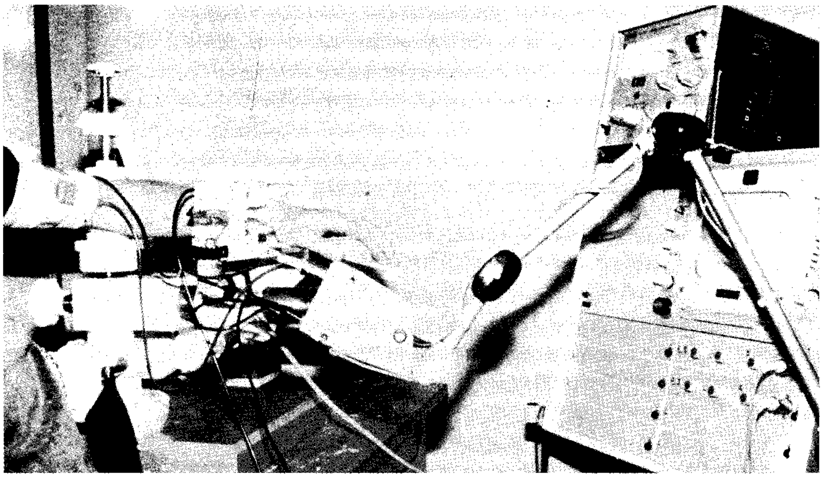

Figure 1.

Electrodes are placed on the biceps and triceps, always in a standardised way. A grounding electrode is attached around the wrist. The exerted force is displayed on a device that is placed in front of the subject so he can maintain the exerted force on a constant level.
The subject is asked to exert four different forces in the range between 20 and 50% of the maximum force. Such a serie is repeated twice at every investigation.
During periods of two seconds the EMG signal of agonist and antagonist are sampled (f=1024 Hz) by a mini-computer (DEC LSI/1103) and the samples are stored on floppy disc.
After each investigation a computer program is started that analyses the EMG records in a standardised way. It determines the amplitude histogram and the power density spectrum. From these functions a number of parameters are calculated. These parameters are described extensively in a previous paper (Hermens et al., 1984). In this investigation we used the following parameters:

SD: the standard deviation of the EMG signal.

EFG: the EMG Force Gradient; this parameter is defined as the increase of the EMG activity (expressed in SD) which is needed to increase the exerted force, divided by this increase of force. The EFG is always determined in the range of 20-50% of the maximum force. In this range the relation between SD and force is linear and the occurence of fatigue is avoided.

RIC: the Coefficient of Reciprocal Innervation; this parameter is defined as the quotient of the activities in the antagonist and the agonist. As the activity dependends on the exerted force, this parameter also dependends on this force. With normal subjects the value of this parameter decreases with an increase of force.

Fmed: the centre of the spectrum; the total power below and above this frequency are equal.

Fmax:the frequency of the maximum power density
F-10:the frequency at which the power density is 1/10 of the maximum power density.

Subject characteristics
In order to obtain normal values 10 healthy subjects were examined. With two subjects another investigation was made on fifteen consecutive days in order to estimate the reproducability of the parameters. The results of these investigations have been described extensively in another paper by Hermens et al. (1984).
Fifteen subjects with a hemiparesis due to occlusion of the rignt middle cerebral artery were examined. The time between the accident and the examination was between two weeks and fourteen months. They were investigated at least five times during the proces of rehabilitation.

RESULTS

As mentioned in the introduction we may find three kinds of changes compared to the "normal" EMG: changes in the amount of activity at a certain force, changes in the balance between agonist and antagonist and changes in the shape of the signal.
These will bee discussed in the next three paragraphs. In a fourth paragraph a summary will be given of some important parameters.

I. Changes in the amplitudes of the EMG
With hemiplegia a decrease of the amplitude of the EMG at maximum effort is often found. In the examined group we found a wide range from 5% to 75% of the normal values.
Due to this reduction maximum force also decreases. But if we compare the decrease of maximum force with the decrease of SDmax (hence EMG activity) we often find that the maximum force has decreased relatively more. This can be stated by the increased value of the parameter EFG.

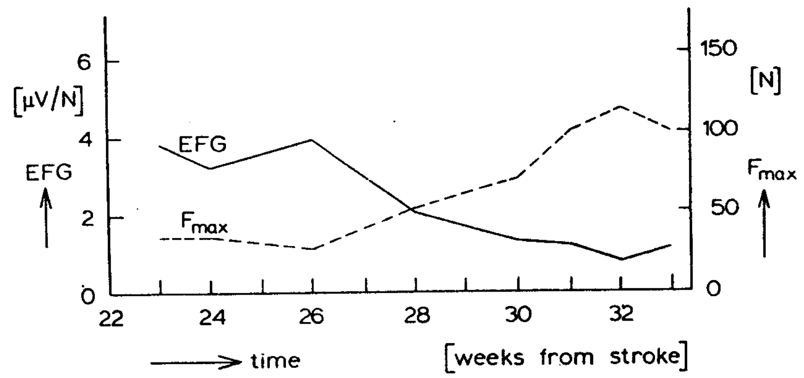

Fig.2. The course of the parameter EFG and the maximum force with a hemiplegic subject.

During the follow up of the subjects we often find that the EFG decreases whereas the maximum force increases.
A characteristic example of the course of this parameter is shown in figure 2. During the follow up of this subject the maximal EMG activity hardly changed. There was also a normal balance between agonist and antagonist as could be seen from the parameter RIC. So the increase of force is mainly due to a change of the parameter EFG.

II Changes in the balance between agonist and antagonist.
With a few hemiplegic subjects (2 out of 15) we found a disbalance between agonist and antagonist at isometric contraction. This occurred with both subjects during the first ten weeks after the stroke.
An example of the course of the parameter RIC which indicates this balance is shown in figure 3.

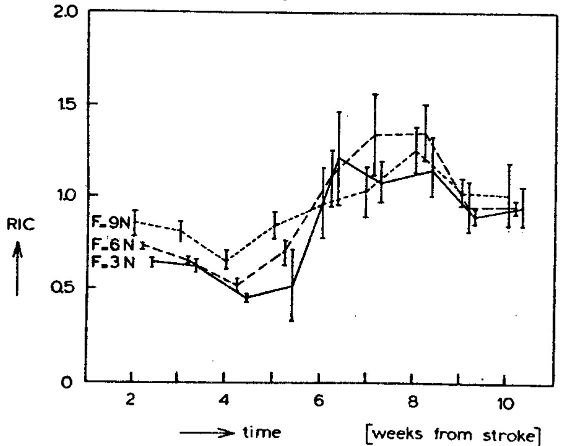

Fig.3. The course of the parameter RIC with a hemiplegic subject.

The course of the parameter shows, after an initial decrease, a strong increase of the co-contraction of the antagonist, which means a dibalance between these two muscles.

III. Changes in the shape of the EMG
With hemiplegia a change of the shape of the EMG signal as it can be estimated from the power spectrum is often found, especially relatively short after the stroke.
An example of the power spectrum of a hemiplegic subject,relatively short after the stroke, is shown in figure 4. If we compare it to the normal spectrum it is obvious that the spectrum shows a significant shift to higher frequencies, resulting in increased values of the parameters Fmed and F-10.

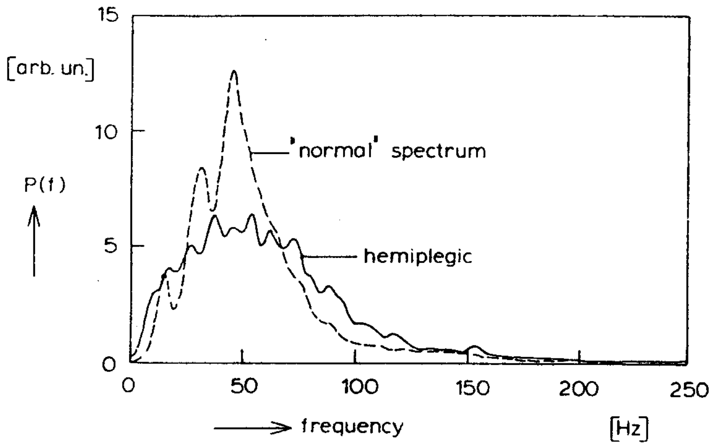

Fig.4. Averaged spectra of a healthy subject and a hemiplegic subject eight weeks after the stroke.

IV. Summary.

Figure 5 shows a summary of our findings with some important parameters. In this figure each dot represents the mean value of a parameter at the first investigation of one subject. In figure 5a and in figure 5b two values have been omitted, because these two subjects could hardly exert a constant force.

Figures 5a and 5b show the maximum force that could be exerted with the flexors of the elbow and the EFG of the M.Biceps brachii. It can be seen that none of the subjects achieved a normal maximum force after the stroke. There seems to be a tendency to higher values of the EFG and lower values of the maximum force relatively short after the stroke. After this first period maximum forces tend to be larger whereas the values of the EFG tend to be more normal. There is no clear relation between these two parameters although high values of the EFG often result in low forces.

Figure 5c and 5d show the changes in two parameters that are often used to describe changes in the shape of the EMG signal. From this figure it can be seen that a shift to higher frequencies may occur during the first fifteen weeks after the stroke. After this initial period a shift to lower frequencies may also be found.

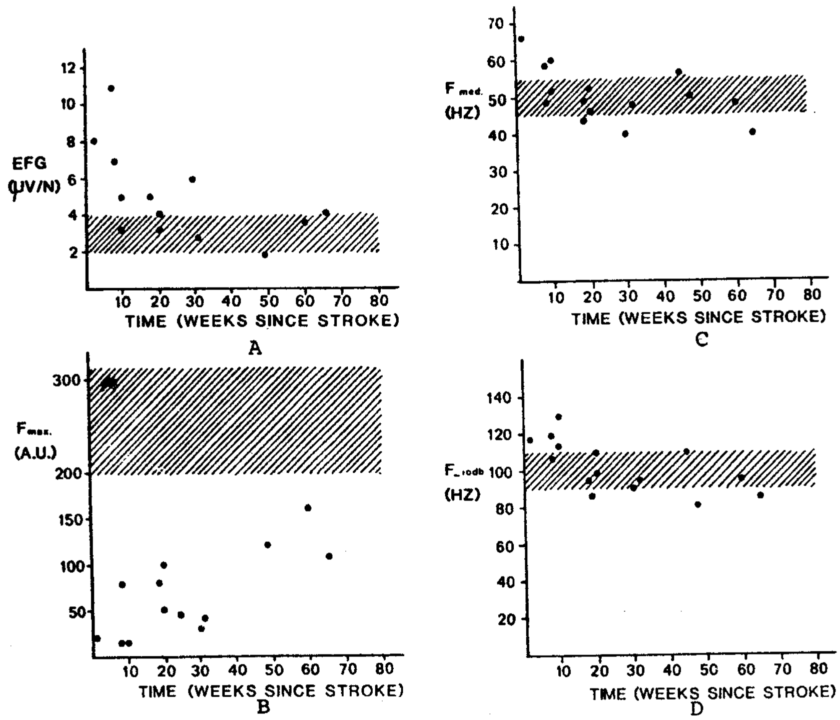

Fig.4. Mean values of maximal force, EFG, Fmed and F-10 of each hemiplegic subject at the first examination.

DISCUSSION

With aproximately half of the subjects we find an increase of the slope between amount of activiy and exerted force. This is according to the findings of Tang and Rymer (1981). We also find no obvious relation between the EFG and the maximum force although there is a tendency to combinate a high value of the EFG with a low value of force. These findings reflect the fact that there are two ways to explain a reduction of force: (i) a decrease of EMG activity and (ii) a less efficient way of generating the force. The first argument can be caused by a loss of control of motor units due to loss of descending excitation. The second argument may be caused by one of the following reasons:

- a decrease of the motor unit discharge rate
- a decrease of the mean fibre diameter which causes a relatively larger decrease of the force compared to the decrease of the amplitude of the action potential
- antagonistic co-activity

Only with two subjects we found an increase of antagonistic activity, so this is not the most occurring argument.
It is generally known that the fibre diameter of muscle

fibers is directly related to the conduction velocity. A decrease of the fibre diameter will cause a decrease of the conduction velocity and therefore the power spectrum will shift to lower frequencies (Lindstrom, 1977). A spectrum that has shifted to lower frequencies, as it can be seen from the value of Fmed, was observed with three patients. With two of them the EFG had a value higher than the normal range.
The cause of the increase of the high frequencies in the power spectrum especially relatively short after the stroke is difficult to explain. According to model studies (eg. Griep et al., 1982) the power spectrum is mainly determined by the shape of the motor unit action potential. This means that presumably the shape of the mean motor unit action potential has been changed. Edstrom (1970) using histochemical techniques on muscle biopsies of hemiplegic subjects, found an atrophy of white fibres and unchanged or even hypertrophic red fibres. These changes will undoubtedly also result in changes of the motor unit action potentials. But whether these changes are the main reason for the significant shift to higher frequencies remains a question to be solved.

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