

MYOELECTRIC CONTROL OF PROSTHESES

A BRIEF HISTORY

A presentation prepared for MEC'92 by R N Scott, 1992 08 01

PURPOSE

To give the participant with relatively little experience in myoelectric control of prostheses some sense of perspective concerning the evolution of this field

Emphasis is on the clinical significance of developments rather than on the technical details, many of which will be covered by later speakers. One definition is necessary, however, to ensure that we share a common understanding of the topic.

DEFINITION

A myoelectric prosthesis is one which is controlled by the electrical activity of a muscle, i.e. by a myoelectric signal.

Most myoelectric prostheses are powered by electricity from a battery, in which case the myoelectric signal controls the flow of energy from the battery to an electric motor.

THE FIRST MYOELECTRIC PROSTHESIS

Despite the efforts of the media and others to convince us that a myoelectric prosthesis is something new from the space age, I must tell you that **the first myoelectric prosthesis we know of was created in the period 1944-1948 by Reinhold Reiter**, then a physics student at Munich University.

Because the transistor had not been invented, Reiter was forced to use vacuum tubes in the electronic system, and it was not feasible to make the system portable. Instead, this prosthesis was designed for use at a factory bench, powered from the nearest outlet.

Even at this early date Reiter recognized the need to obtain maximum information from the myoelectric signal: his system controlled both opening and closing of an electric hand from a single muscle.

Reiter's system did not gain clinical or commercial acceptance. More regrettably, his work was not published, although it was described briefly in a report on a 1948 Hannover trade fair, printed in an obscure German medical newspaper. It was not discovered by the researchers who succeeded him until 1969, by which time his ideas had been reinvented.

INVENTION OF MYOELECTRIC CONTROL WORLDWIDE

In the years beginning about 1957, researchers in many countries invented myoelectric control. Groups led by Bottomley in England; Herberts in Sweden; Kato in Japan; Kobrinski in Moscow; Reswick, Lyman and Childress in the USA, as well as our own group at UNB were among the pioneers. To a great extent the initial work in each country was independent: we each "invented" Reiter's work

As an aside, it is interesting to speculate as to why scientists and engineers in a number of countries happened upon this same idea at roughly the same time. Possibly the availability of the transistor focused our thoughts on applications for miniature electronic amplifiers

In any event, we all were impaired in this work by two factors. First, what we were attempting to accomplish was well beyond the capability of available technology. Second, we did not understand adequately the needs and desires of the amputees on whose behalf we were working. (It can be argued that these limitations persist today.)

At UNB our initial interest had been in myoelectric control of powered orthotic systems for quadriplegics, but we were induced by the federal government to expand and redirect our efforts to amputees in the wake of the Thalidomide episode. (That tragedy also provided the impetus for establishment of prosthetics research groups in Montréal, Toronto and Winnipeg.)

In 1965 we collaborated with researchers at the Ontario Crippled Children's Center (now the Hugh MacMillan Rehabilitation Center) to fit the first all Canadian myoelectric prosthesis. The control system, designed at UNB, was contained in three boxes worn in a belt around the waist. The prosthesis featured an electric wrist rotator designed at OCCC — although this was replaced quickly by an electric hook also designed at OCCC.

Shortly after this, at the request of Colin McLaurin of OCCC we designed the necessary electronic circuitry to permit operation of his electric hook in a normally closed, voluntary opening mode — what is now referred to as a cookie crusher mode. But in common with most academic and clinical groups, our work did not result in hardware which could be obtained and used readily by the average prosthetist.

Gradually, however, from all of this effort some bits of wisdom did emerge. For me, one of the most significant was Childress' argument on the importance of having the prosthesis self-suspended and self-contained. That is, suspension straps and external batteries should be avoided as a high priority. We engineers finally realized that a hand is not a pair of pliers, nor an arm a device to place the pliers in space: comfort and even cosmesis were accepted as critical requirements.

It took a long chat with a teenaged amputee in Toronto and a challenge by Dr. John Hall, then clinic chief at the OCCC, to convince me that function was not the only purpose of a myoelectric prosthesis, and maybe not the primary purpose. The late Dr. Bob Tucker, of Winnipeg, introduced the important concept of dynamic cosmesis with respect to upper limb prostheses. Finally we began to get our priorities straight.

Understanding of the process by which the myoelectric signal is generated improved significantly in this period, providing important new insight into how to use this signal for control. And technology advanced, devices becoming obsolete as soon as they were incorporated into our designs, but in the process making possible much more sophisticated systems in ever smaller packages. Some of the problems which consumed most of our attention in the early years disappeared altogether with improvements in technology.

But in the early days our results were pretty crude.

KOBRINSKI

At the 1960 International Federation on Automatic Control Congress in Moscow, Kobrinski presented a myoelectric below elbow prosthesis developed in the USSR Academy of Science in the period 1957-60. This was **the first myoelectric prosthesis to see clinical use**, and was fitted not only in the USSR but also to amputees in Canada and the UK in the early 1960's.

The Kobrinski prosthesis used the myoelectric signal from one muscle group to cause the electric hand to close, and the signal from another muscle group to cause the hand to open, a control mode which remains very popular today because it mimics the body's natural use of muscles. Unfortunately the early versions of that system were unable to respond effectively to co-contraction of the two muscle groups, and indeed electronic components were often damaged by co-contraction. This necessitated extensive and frustrating training sessions for amputees.

The prosthesis was fully portable, the batteries and electronics being worn separately and connected to the prosthesis by cables. The electric hand was heavy, its movement slow, and pinch force inadequate by modern standards. Only one size — adult male — was available.

COMMERCIAL DEVELOPMENT

At international symposia on myoelectric control in the early 60's, it was common to deplore the fact that none of the systems demonstrated was available for clinical use. (The USSR prosthesis was available in other countries only by protracted and costly commercial arrangements, and to my knowledge was not used outside the USSR except in Canada and England.) Amputees had to seek out a research facility if they were to be considered for a myoelectric prosthesis.

This unfortunate circumstance was corrected eventually, although to this day the field of myoelectric prosthetics remains very risky for manufacturers due to the limited, highly specialized market and the rapid evolution of the product.

By the mid 70's Otto Bock of Duderstadt was established firmly as the predominant supplier of myoelectric controls and electrically powered components for prostheses, but there were also manufacturers in Austria (Viennatone); Canada (Leaf Electronics, UNB and Variety Village); the USA (Fidelity Electronics, Liberty Mutual Research, and Motion Control) selling to the North American market. Many of these manufacturers were producing the product on procurement contracts for a government agency, or were otherwise subsidized.

Of those listed above, Otto Bock, Variety Village (now Variety Ability Systems), Liberty and Motion Control still manufacture a product line of components for myoelectric prostheses, as do Hugh Steeper of England and Hosmer-Dorrance of the USA. Significant improvements are being made constantly by these manufacturers as they respond to the availability of new technology and to clinical demand.

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LIMITATIONS**

Size and weight reduction have been foremost among clinical demands from the outset. In contrast to the situation initially, it is possible now to fit a below elbow amputee younger than 12 months of age with a self contained self suspended myoelectric prosthesis in which neither size nor weight is inappropriate, using off the shelf components.

I must leave the saga of more recent developments to others, but cannot close without noting that some 45 years of research involving many of the developed countries of the world has not resulted in an acceptable solution to the needs of the amputee. Among striking deficiencies which remain, one can cite poor durability of the outer "glove" covering existing terminal devices, lack of supplementary tactile or proprioceptive feedback, inability to execute coordinated control of two or more functions, lack of powered shoulder function and of wrist flexion, and high cost, — and others can expand the list. Nonetheless, it is appropriate from time to time to reflect upon how much worse the situation was at the beginning, and hope....