MOTOR PROSTHESES: AS I EXPERIENCED THE DEVELOPMENT OF THE FIELD

(KEY NOTE ADDRESS for the 1st International FES Symposium in Sendai)

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The focus of a great deal of the First FES Symposium held in Sendai, in July of 1992, is on the important task of restoring motorfunction to the extremities of the paralyzed person. I was just beginning my career in this area of neural prostheses at the time the motor prostheses field was getting underway at what was then Case Institute of Technology, which is now Case Western Reserve University. The story I want to tell is the story of motor prostheses as I experience the growth of the field. The story is one of an epidemic spread of ideas among people that has led to the present state of device development, which includes the commercialization of devices at a time when research support is becoming more and more limited due to the high demands placed on limited budgets. New opportunities to create new and more effective motor prostheses are surely ahead of us and I will suggest a couple of directions that might be investigated. I trace the beginnings of this present era of motor prostheses development to the early 1960's and the work of Wladimir Liberson and Adrain Kantrowitz. In 1960, Liberson published his work on a walking aid for the stroke patient and Kantrowitz published his work in 1961 on causing a paraplegic patient to stand. Charles Long, (1963) published a couple of years later his work on restoring hand function to the spinal cord injured patient. Lojze Vodovnik, the individual I feel is most responsible for the infectious spread of this field, came from Ljubljana to Cleveland in 1964

to work in Jim Reswick's research group at Case Institute of Technology. He was clearly influenced by the work of Liberson, Kantrowitz and Long. Vodovnik and I came to Case within days of each other, he as a post doctoral fellow and I as a graduate student. We were both working in Jim Reswick's research group where the main emphasis was on the development of a pneumatically powered arm assist device. It was becoming apparent to some in the group that the externally powered exoskeletal device was not going to provide the rehabilitation solution to the patient with the paralyzed arm. The intellectual environment that existed at Case in the midsixties was particularly well suited to nurture alternative approaches to restoring limb function. Vodovnik was the right man at the right place at the right time and I was the susceptible individual at the right place and the right time to get a full-fledged inoculation of the infectious disease that Vodovnik had contracted and was beginning to spread. The arrival of Vodovnik in Cleveland marks the beginning of the path that traces the development of motor prostheses at Case.

One of the early problems encountered by Vodovnik and others at Case was rapid fatigue of the electrically activated muscle. That problem and the report by Doerr and Long (1969), condemning the concept of a motor prostheses because their study showed that the muscles of most interest would likely be denervated, nearly stalled the effort that Vodovnik had started. Two important events occurred in the late sixties that were important factors in sustaining the continued evolution of the motor prostheses at Case; the development of the intramuscular electrode (reported by Caldwell and Reswick, 1975) and the finding that electrically induced exercise could convert rapidly fa-

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tiguing types of muscle fibers to fatigue resistant fiber types (Salmons and Vrbova, 1969 and Peckham et al., 1973). The way was paved to these latter studies by the report of Edström and Kugelberg, (1968) on the properties of the different motor units. I consider the intramuscular electrode and fiber conversion as important events that mark two milestones on the path that traces the development of motor prostheses at Case. With intramuscular electrodes, electrically induced muscle conditioning and tendon transfers (Keith and Peckham, 1991), paralyzed arms have performed functional tasks and paralyzed legs have been made to move individuals over previously insurmountable obstacles. With these demonstrations the cry for more function to be restored through these techniques has dramatically increased. The solution to restoring more function almost always calls for control of more muscles. Control of more muscles, with the technology we have today, calls for more implanted electrodes and more leads, both sources for increased likelihood of device failure.

Future milestones along the path tracing motor prostheses development will, in all likelihood, involve electrodes placed in peripheral nerves (e.g. Nannini and Horch, 1991) or around peripheral nerves (Veraart et al., 1993) and capable of effecting selective activation of specific muscles served by these nerves. Such electrodes should be readily implantable in locations that are surgically easy to access and not subject to motion that could displace the electrode or cause injury to the nerve. Such electrodes are under development and with luck they will prove satisfactory for the needs of motor prostheses developers and users.

Also in the future are the problems associated with making these devices available to clinicians and patients. This implies that the devices will be built by some commercial concern and that the commercial concern will derive a profit from the investment. Profit is the key word, without it the devices will not become available in today's economy. For a profit to

be made the market for a particular device must have a perceived minimal size, which for many countries, even big ones, is not large enough to encourage investment.

This suggests that market studies should focus on many countries rather than on a select few. Also, with profits comes the possibility that some money can be returned to support more research and/or personal gain for the investigators. The potential for these rewards could be great and it is this potential that could enhance the development of our research community or divide our community and seriously cripple our future rate of development. It is up to us to chart the course for the future.

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References

- 1) Caldwell, C.D. and J.B. Reswick, "A Percutaneous Wire Electrode for Chronic Use", IEEE Trans. on BME, Vol. 22, 429- 432 (1975)
- 2) Doerr, G.M. and C. Long, "Electrical Response and Electromyograms of Upper Extremity Muscles in Quadriplegics", Orthotics and Prosthetics, Vol. 23, 20- 26 (1969)
- 3) Edström, L. and E. Kugelberg, "Histochemical Composition", Distribution of Fibers and Fatiguability of Single Motor Units, J. Neurol., Neurosurg., and Psychiat., Vol.31, 424-433 (1968)
- 4) Kantrowitz, A., "Electronic Physiologic Aids", Proc. 3rd IBM Med Symposium, 549 (1961)
- 5) Keith, M.W. and P.H. Peckham, "Tendon Transfers using FES Control in the Tetraplegic Hand", Proc. 4th Int. Conf. on Surg of the Tetraplegic Hand, Palo Alt, Cali fornia, Mar., (1991)
- 6) Liberson, W.T., H.J. Holmquest, D. Scat, and M. Dow, "Functional Electrotherapy : Stimulation of the Peroneal Nerve Synchronized with the

- Swing Phase of the Gait of Hemiplegic Patients” ,
3rd Int. Conf. of Phys. Med., 705-710 (1960)
- 7) Long, C. and V.D. Masciarelli, “An Electro-
physiologic Splint for the Hand” , Archives of
Phys. Med. and Rehap., Vol. 44, 499-503 (1963)
- 8) Nannini, N. and K. Horch, “Muscle Recruitment
with Intrafascicular Electrodes” , IEEE Trans. on
BME, Vol. 38, 769-776 (1991)
- 9) Peckham, P.H., J.T. Mortimer and J.P. Van Der
Meulen, Physiologic and Metabolic Changes in
White Muscle of Cat Following Induced Exercise,
Brain Research, Vol. 50, 424 -429 (1973)
- 10) Salmons, S. and G. Vrbova, “The Influence of
Activity on Some Contractile Characteristics of
Mammalian Fast and Slow Muscles” , J. Physio.,
Vol. 201, 535-549 (1969)
- 11) Veraart C., W.M. Grill, and J.T. Mortimer,
“Selective Control of Muscle Activation with a
Multipolar Nerve Cuff Electrode” , accepted,
IEEE Trans. Biomed. Engineering, (1993)