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ROUND TABLE DISCUSSION I: NEURO MUSCULAR CONTROL MECHANISMS

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Background material was presented by T.Mortimer with the intent of facilitating discussion during this session. The effect of an applied electrical field on the nerve membrane was described to develop an understanding of the classical "strength-duration" curve. From the strength-duration curve the charge injection dependence on pulse width could be shown. This latter relationship indicated that the charge injection required for threshold excitation decreased with decreasing pulse width. Charge injection was then related to charge density at the electrode surface, which has been found to be a determining factor in the degradation of stimulating electrodes and in causing tissue damage during stimulation. Relating charge injection for threshold excitation to damage of electrode and tissue considerations indicates that one is generally advised to use a short pulse width over a long pulse width whenever possible. Three implantable stimulating electrodes were discussed for use in motor prostheses: intramuscular, epimysial, and nerve cuff electrodes. Factors that should be considered when selecting an electrode are: 1) relative difficulty required to implant or to replace; 2) likelihood to induce tissue damage; 3) nonlinear recruitment characteristics; and 4) expected life-time. Each electrode configuration has specific advantages and disadvantages and no one design was sufficiently free of problems that it could be recommended over the others for all applications. Closed-loop control techniques may remedy many of the problems associated with electrodes. Also, it is anticipated that each electrode configuration will find applications in motor prostheses. Although there are many problems associated with the assistive devices available, technological solutions are available to solve them.

The discussion that followed centered on five areas and each was started with initial comments from a worker active in the field.

1. Electrode reliability. H. Peckham stressed the problems of physiological failures (recruitment properties, insufficient selectivity) as well as physical failures such as material related and stimulation related corrosion, fatigue and incapsulation problems. During the discussion it was reported, that the failure rate of wire electrodes is 6 % in the first months and 2 % per month for the following months. The clinical and biological difficulties with inextensible leads were debated and tissue reaction was shown as a major problem area.

2. Tissue dagame. W. Agnew started with a report on the method of using evoked potentials to test the efficiency of stimulation. Tissue damage is assessed through loss of conduction. Bipolar nerve electrodes were used and several mechanical problems of such implanted electrodes were enumerated. The charge density acceptable for the nerve and types of damage were elaborated. A plead was made for bipolar currents which should start with the negative phase otherwise tissue damage might be much higher.

3. Recruitment characteristics. H. Peckham reported on the regulation of the number of active muscle fibers and presented functional dependencies of the force from amplitude, pulse width, frequency and wave-shape. The importance of linearity of I/O characteristics, the dynamic range of stimulation as well as length dependence were mentioned. Other topics within this area were: selectivity and repeatability of response in various electrodes, fatigue reduction by closed loop control.

4. Automatic control and transducers. D. McNeal and U. Stanič offered their experiences in closed loop control of neuromuscular systems. A clinically applicable system was predicted for the next 5 - 6 years. Until then only preprogrammed cycles will be triggered in the clinical setting. In paraplegia closed loop will be first used for safety in standing but not yet for balance. It was concluded that feedback systems should be used to change the recruitment characteristics and to control function of joints, not individual muscles. It seemed that the critical problem is not closing the loop but determining the parameters to be controlled.

5. Limitation of FES. L. Vodovnik suggested that major limitations might not be technological but physiological (e.g. spasticity, denervated muscles) and psychological (learning problems for generation of control signals). From the discussion it became evident that spasticity or other abnormal reflex activities do not seem to be a great drawback as long as proper patient selection is practiced. High energy requirements for denervated muscles however, are an important limiting factor. Limitations may have also geographic

origin: In Italy for example, FES is not well accepted while Japan is starting large programs.

In summary it may be stated that, while all speakers frankly discussed their present difficulties in controlling the neuromuscular system, the prevailing atmosphere regarding the future of FES was optimistic.