VEČELEKTRODNI SISTEM ZA ZUNAJŽIVČNO SELEKTIVNO AKTIVACIJO ŽIVČNIH VLAKEN

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KLJUČNE BESEDE: funkcionalna električna stimulacija, večelektrodni sistem, platinske elektrode, mielinizirana živčna vlakna, periferno živčevje, električno polje, biokibernetika

POVZETEK: Razvit je bil večelektrodni sistem za zunajživčno stimulacijo živčnih vlaken. Sestavljen je iz štirinajstih stimulacijskih elektrod iz platine ovite z izolacijskim listom iz biokompatibilne snovi v obliki spirale v prečnem preseku. Razvoj je temeljil na rezultatih ob histoloških preiskavah perifernih živcev, ki naj bi jih stimulirali in modelih aktivizacije mieliniziranih živčnih vlaken. Število stimulacijskih elektrod, ki so aktivirane,je odvisno od premera živca, ki ga stimuliramo. Debelejši živci avtomatsko aktivirajo več elektrod, kot tanjši.

MULTIELECTRODE CUFF FOR EXTRANEURAL SELECTIVE STIMULATION OF NERVE FIBERS

KEYWORDS: functional electrical stimulation, multielectrode cuff, peripheral nerves, platinum myelionated nerve fibers, electric field, biocybernetics

ABSTRACT: A multielectrode nerve cuff for extraneural selective stimulation of nerve fibers has been developed.It consists of fourteen platinum stimulation electrodes embedded within a self-curling sheet of biocompatible isolation exhibiting a spiral transverse cross section. Development was based on results obtained by hystological examination of peripheral nerves planned to be stimulated and on models of excitation of myelinated nerve fibers. The number of stimulating electrodes which are activated depends on the diameter of the stimulated nerve. Nerves with greater diameter automatically activate more electrodes than thin ones.

INTRODUCTION

Functional Neuromuscular Stimulation (FNS) is based on electrical excitation of the myelinated fiber starts by imposing a sufficiently large voltage gradient over the Ranvier nodes in a fiber in the axial direction. In literature, models of nerve stimulation can be found (1,3,8,10). They describe excitation of myelinated nerve fiber during nerve stimulation when all parameters are known. Introduction of the models of the effects of electric field on myelinated nerve can be useful for the design of electrodes and electrical parameters in FNS. Models calculate and evaluate potential fields around electrodes, excitatory mechanisms and choice of electrode sites (6,9). For many aplications using implanted electrodes it is important to know how many fibers could be activated by a given current signal. A simple rule is that distant fibers need stronger currents in order to be stimulated and the number of firing fibers increases with the strength of stimulation signal (2,4,7).The ideal stimulating electrodes should be able to activate individual or small groups of neural fibers within a fascicular bundle, for example, in a motor nerve. One of the possible approaches is selecting of the extraneural electrodes while the other is used for the intraneural electrodes.In both the realization of clinical systems to effect electrical activation of paralyzed muscles depends strongly on the development of electrodes that have realible,selective and reproducible muscle force recruitment characteristics. The nonhomogenity, anizotropy, and poorly defined geometry of biological media set very serious limitations on design of such stimulation multielectrode arrays. Selective stimulation of fibers or small groups in peripheral nerves needs the development of multielectrode arrays. A possibility created by the use of multielectrode configurations for selective nerve stimulation is the independent control of groups of motor neuron fibers belonging to muscles or muscle groups with different functions. In this situation the motoneuron groups recruited by different electrodes should also belong to different muscles or muscle groups (6,9). Selective stimulation of fascicle in the middle of the multifascicle nerve is best with intrafascicular electrode and worse with extraneural electrode (9). However, with extraneural electrode, selective stimulation of superficial fascicles near the electrode seems to be possible. It was shown that with an extraneural electrode parts of fascicle closest to the electrode are recruited, as shown experimentally by McNeal and Bowman (6).Consequently,multielectrode configurations can be used for stimulating different muscles from the same nerve. In spite of the fact of inverse recruitment found for extraneural electrodes by Petrofsky, Fang and Mortimer, and Veltink (2,7,9) and the fact that it is hardly possible to achieve stable, selective stimulation of fibers from outside the nerve, we decided to develop a multielectrode system for extraneural stimulation. Such a decision was based upon the request for minimization of neural damage which can occur by using intraneural or intrafascicular electrodes.

METHODS

A multielectrode cuff with a spiral transverse crosssection for extraneural selective stimulation of nerve fibers was designed to be expandable so that it could be sized to fit around a nerve (5). It was designed to be simple to install on the nerve trunk without the use of sutures. The cuff is manufactured by bonding two flexible silicone sheets together. One sheet is streched and fixed in that position; an adhesive layer is spread over the streched sheet while a second unstreched sheet is placed on top of the adhesive and the composite is compressed to a constant thickness. The cuff having been released, curls into a spiral tube as the streched sheet contracts to its natural rest lenght. The diameter of the cuff is related to the amount of the stretch,the smaller the diameter. Fourteen electrodes with geometric surface of 2 mm^2 made of thin platinum ribbon (99.99 % purity) together with lead wires are then mounted on the third reinforced silicone sheet and bonded on the inner side of the mechanically opened spiral cuff. The completed multielectrode cuff is then cut from the bonded sheets and trimmed to appropriate lenght as shown in Figure 1.

RESULTS

Small electrodes of the multielectrode cuff are needed to effect selective activation of small groups of the nerve fibers. However it is necessary to depolarize axons at some distances from the electrode, and consequently it is desirable to be able to inject enough charge without tissue damage and electrode corrosion. The electromechanical technique of cyclic voltammetry was used to delineate an operational potential window between hydrogen and oxygen evolution in a protein containing solution. In Figure 2 is a cyclic voltammogram of one electrode showing the potentials at which reversible surface reaction occur. Hydrogen evolution began at about -0.8 V, oxidation of the absorbed hydrogen appeared when the potential was changed in positive direction at about -0.7 V. Oxidation of the electrode surface and decomposition of water started at about 1.0 V.

DISCUSSION

The cuff was designed to enable monopolar, bipolar and multipolar extraneural stimulation of the peripheral nerve. In the monopolar type, the neutral common anode can be situated elsewhere in the vicinity of the multielectrode cuff, while each of the stimulating electrodes can be connected to one of the stimulating channels alone or in any combination with the other electrodes. In bipolar and multipolar type, each of the stimulating electrodes can be used as stimulating or neutral electrodes or in all possible combinations with other electrodes of the multielectrode system. Consequently, there is a great possibility of creating different electrical fields around the nerve for the aim of activating desired fibers or small groups. For the multielectrode cuff important factors relating to safety, such as chemical composition, mechanical flexibility, geometric configuration, and size, were considered during manufacturing. Accepted biomaterials such as medical grade Silastic and Teflon, type 316 stainless steel, and platinum were used in cuff manufacture. Animal experiments with the goal of getting information on selectivity, sensitivity and stability of stimulation using such system are in preparation.

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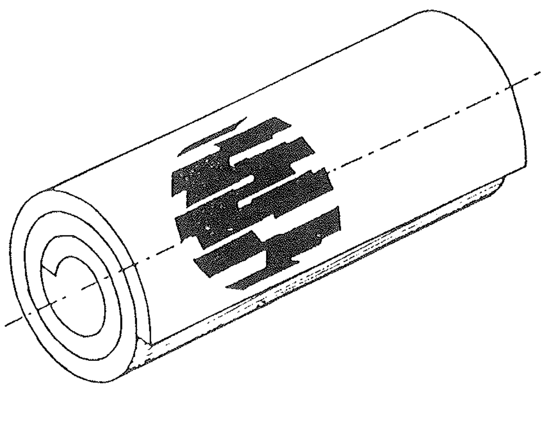

Fig. 1: A multielectrode cuff of extraneural selective stimulation of nerve fibers.

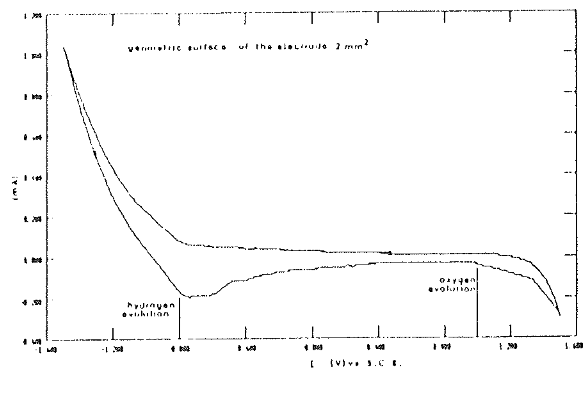

Fig. 2: Cyclic voltammogram of one Pt electrode Sweep rate: 0.5 V/sec. Electrolyte: Eliott' s buffered solution, pH 7.3.

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