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*Instruments and Techniques*

# A Simple Electrode for Intact Nerve Stimulation and/or Recording in Semi-Chronic Rats

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**Abstract.** A cuff electrode for extracellular nerve stimulation and/or recording is described. It can be made from common laboratory material without the need of special equipment, and consists of a tubular silicone rubber holder enclosing the nerve and keeping it in position against two platinum wires. The assembly is sufficiently insulated to be kept amidst the surrounding tissue, hereby preventing the nerve to dry during recording periods. It can be attached to an adjoining structure, thus allowing further manipulation of the animal.

**Key words:** Electrode – Extracellular – Nerve – Stimulation – Recording – Semi-chronic

## Introduction

Extracellular recording of nerve electrical signals is a widespread technique in the study of the peripheral nervous system in situ. Several types of electrodes have been devised, of which the best known is the bipolar hook-type, held in place by a rod adequately rigged to the experimental set up. Such a system, however, makes any further gross manipulation of the animal problematic, since any movement will cause severe artifacts during recording. In the cat, the technique has been improved by the devices of De Luca (1976), Hoffer (1981), Janssens (1979) and Stein (1977). In the rat, two attempts have been made (Shiraishi 1980; Sakaguchi 1979) though with poor matching of the electrode to the nerve diameter. We describe hereafter the fabrication and use of a simple cuff-type bipolar electrode that largely follows the animal's movements and stays in the tissue without being short-circuited by the surrounding abdominal fluid or letting the nerve dry out.

## Materials and Methods

### *Fabrication of the Electrode*

Most manufacturing steps are carried out under the binocular lens. The cuff is made of a segment of a silicone rubber tubing (o.d. 2 mm) used in peristaltic pumps; it is commercially available in several inner diameters (0.25 to > 1.3 mm) which allows the fabrication of electrodes fitting various nerve sizes; platinum wire (0.1–0.2 mm diameter) is 99.9 % pure; the copper lead is of the plastic-insulated, multistranded type (1 mm overall diameter or smaller). First, two bits (8–10 cm) of it are stripped of their insulation at both ends on 5 mm. A 5 mm segment of platinum wire is soldered in the core of the strand bundle, on one end of each copper lead, so that a 2.5 mm portion of platinum wire remains visible. Holding the other end of the copper bundle, the insulation is slipped over the soldering by repeatedly squeezing the insulation and pulling it towards the soldered end.

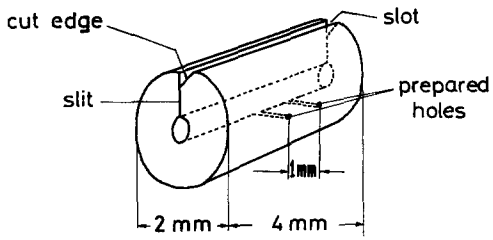


**Fig. 1.** Perspective of a tube segment showing the slit, the cut edge, the slot and the location of the wire holes

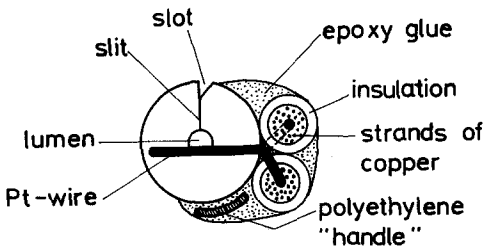


**Fig. 2.** Section of the cuff at the electrode level, showing location of the Pt-wire with respect to the lumen, the copper leads, the epoxy embedding and the "handle"

With a razor blade, a 4 mm segment of peristaltic tubing (of the desired i.d.) is slit open radially on its full length, and one edge removed by a slant cut, hereby forming a wedge-shaped slot (Fig. 1). A pin (0.2–0.4 mm diameter) is then driven through the cuff wall, perpendicularly to the cuff axis and to the slit plane, and tangentially to the inner lumen. Two such holes are prepared, at 1.5 mm of each end of the cuff (Fig. 1).

Each platinum wire stump has to be introduced into such a hole, by pushing it and guiding it so that it does not deviate from the prepared path. In its final position, it should be apparent in the lumen but its end should not make contact with the outside (Fig. 2).

The wires are then bent against the cuff, parallel with the cuff axis. Epoxy glue (with a slight default of hardener to keep it somewhat flexible) is applied as shown in Fig. 2 to insure

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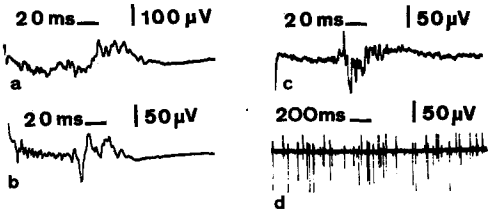


**Fig. 3, a, b.** Cervical vagus stimulation with cuff electrode, recording on intact subdiaphragmatic vagal trunk. **a** Recording with cuff electrode. **b** Recording with hook electrode. **c** Subdiaphragmatic vagal trunk stimulation with cuff electrode, recording on cervical vagus with cuff electrode, nerve intact. **a–c** Stimulation: 0.5 mA, 1 ms, 2 Hz. Recording: 64 averaged sweeps. The signal occuring during the first 60 ms in **a** and **b** is of electromyographic origin and is absent in **c**, where the recording is antidromic. **d** Spontaneous activity recorded on cervical vagus with cuff electrode, 10 superimposed sweeps

good insulation and attachment. To fasten the cuff to the tissue, a suitable "handle" can be embedded, in our case a 6 mm × 1 mm × 0.3 mm bit, cut out of a polyethylene tubing, protruding at each end of the cuff.

*Implantation of the Electrode*

On a intact nerve, the electrode is put in place by laying the nerve, desheathed or not, in the wedge-shaped slot. Moving the cuff back and forth along the nerve while exerting a gentle traction on it will make the nerve slip into the cuff by squeezing its walls apart. On a cut nerve, the traction will be exerted on a thread tied to the end of the nerve. The cuff can be attached by its "handle" (e.g. by sewing) to an adjoining muscle or tissue so that it is not torn away during further manipulation. The free ends of the copper leads are left sticking out (for day-long experiments) while closing the wound, or suitably driven to an implanted connecting socket (for chronic experiments).

## Results

A typical recording (differential amplifier, experimental setting in a Faraday cage) made with this type of electrode (cuff i.d.: 0.25 mm, Pt-wire diameter: 0.125 mm) of rat abdominal vagal responses is shown in Fig. 3, and compared to such a one obtained from a hook-type electrode. Stimulation is achieved by another electrode of the same cuff-type. Both abdominal and cervical openings were closed, because the animal had to be put subsequently in a prone position.

For chronic testing, rats were implanted with an abdominal vagal electrode fastened to the oesophagus by sewing its polyethylene "handle" to the oesophagal superficial muscle with a thin catgut thread. The lead ends of the electrode were put together in a blind segment of plastic tubing to prevent any injury to the organs, and left floating in the abdominal cavity when this was sutured. Safe recovery was assessed by body weight gain monitoring during 2–4 weeks. The animal was then anesthetized; a stimulating cuff electrode was fitted to the cervical vagus and recordings were made from its chronically implanted electrode. In 5 cases out of 6, they were still functional and displayed similar recordings to Fig. 3a after a period of 2–4 weeks.

## Discussion

Platinum has been chosen because of its extreme chemical inertness. Silver is less suitable for this use; it is less resistant to repeated bendings, and is readily oxidized. It should be chloridized when the electrode is used for monophasic stimuli.

Optimally, the lumen diameter ought to match the nerve diameter. Too large a diameter will result in a short-circuit with the outside medium; a too small lumen will squeeze the nerve and damage it in the long run. There will be, however, important stimulus artifacts if the stimulating and recording electrodes are too close to each other (e.g. less than 10 mm if they are bathing in the abdominal fluid).

Two to four weeks after having been implanted, the electrodes were overgrown by connective tissue. This probably helped to keep the cuff assembly attached to the oesophagus. It also might have made up for a possible separation of the cuff from the epoxy embedding; adhesion of epoxy glue to silicone rubber is not optimal. Upon removing the electrodes from the connective tissue, they showed no sign of getting apart and could be used again readily.

A multistranded copper lead extension is necessary for chronic implantation. Leads made entirely of (Teflon-coated) platinum wire were broken by the movements of the animal during the chronic implantation period.

In the present design, and with a suitable method of leading the wires to the outside of the animal, the described electrodes can be considered for semi-chronic to chronic use in recording the electrical activity of intact peripheral nerves.

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