An ultraflexible microminiature multilead electrode

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Winding jig and construction details are given for a microminiature electrode for chronic small animal work. Electrode configuration is that of intermeshed helices. Increasing the number of leads does not affect bulk or flexibility.

Long-term electrodes for chronic implantation are frequently required for either stimulating or recording biopotentials from a preparation. These must display a series of opposing characteristics; they should be extremely flexible but virtually unbreakable, they should be of small physical size yet exhibit good electrical conductance, and both the material of the conductor and its insulation should be impervious to destructive action by body fluids. Available electrode wires are generally unsuitable because they are insufficiently flexible, are poorly insulated, and are made from tinned copper conductors. Noble metal wires are available either as solid conductors or with a plated surface over copper wire, but these suffer much the same mechanical disadvantages as copper.

This note describes a wire material and a method of fabricating a multiconductor, helical coil electrode that combines extreme resistance to breakage with good electrical and chemical characteristics. This device was developed from the single electrode configuration described by Weinstein, Annau, and Senter (in press).

An exploded view of the winding device and an enlargement of the electrode is shown in Fig. 1. The winding jig is made from a Lucite body that holds both bushings to support the winding mandrels and spools for the wire supply. The device is simple to construct and winding may be accomplished by the use of a jeweler's lathe or drill press.

The Lucite body of the jig is $6\frac{1}{4} \times 1$ in. and is made from $\frac{1}{2}$ -in. clear stock. A number of bushings are press fitted through the $\frac{1}{2}$ -in. thickness on the midline. The device shown is bushed to provide electrodes wound on mandrels made from 19-, 20-, and 24-gauge hypodermic-needle stock. The bushings are made from lengths of clock-bearing stock, which is available from jeweler supply houses. The two wire spools on the model shown are commercially available sewing-machine bobbins and are held in place near the ends of the jig by means of 10-24 $\times$ 1 in. thumb screws screwed into tapped holes in the jig. A small brass bushing is required to adapt the 10-24 screw diameter to the inside diameter of the bobbin. A concave beryllium bronze spring pad (Sp) bears on the upper hub of the bobbin and provides a means for varying the amount of restraint imposed on the rotation of the bobbin.

The mandrels are made from 12-in. lengths of hypodermic-needle stock of the required sizes and a short section of the same stock is silver-soldered as a crossbar approximately $\frac{3}{4}$ in. from one end. Twelve-inch mandrels may be handled easily and this length determines the total length of the electrode which may be fabricated.

The wire used in these electrodes is of stainless steel of No. 40 AWG (.0031 in.) diameter, and is available with a quadruple coating of Teflon.² The bobbins must be wound from the supply spool in a fashion that will insure that neither kinking nor reverse set will result. The supply spool is supported on a bearing so that the wire leaves the roll from the top and is wound onto the top of the bobbin hub. When this is done both the

Fig. 1. Exploded view of electrode winding jig. The screw (S) is inserted through the restraining spring (Sp) and the bobbin (B) into the fixture (F). The tension is adjusted until a firm pull is required to unwind the wire from the bobbin. The mandrel (M) is made from hypodermic-needle tubing in the required size and runs in a brass bushing pressed into the fixture. A greatly enlarged view of a section of the bifilar electrode wound on a 20-ga mandrel is shown at (E). The section has been pulled apart to show the bifilar structure of the electrode wires. Dimensions of the fixture and location of the bobbins is not critical.

supply spool and the bobbin will be turning in the same direction of rotation. The bobbins may be wound full and the free end secured with a small piece of Scotch tape.

The loaded bobbins are assembled on the jig with the windings placed so that the wire will be tangent with the mandrel on the same side as it leaves the bobbin. Thus, when viewed from the top of the jig, one spool will be unwinding in a clockwise direction, the other in a counterclockwise direction. Next the mandrel is inserted into the jig and the free end of one wire is brought above and around it, over the crossbar and a turn or two taken on the mandrel above the crossbar. The other wire is brought beneath the mandrel, over the crossbar, and secured in a similar fashion. The protruding end of the mandrel may now be chucked in a jeweler's lathe, drill press, or other device used to rotate it.

The tension on the bobbins must be adjusted carefully to ensure an even winding on the mandrel. This is accomplished by tightening or loosening the thumb screws that press the restraining springs against the flanges of the bobbins. The tension should be set so that a firm, steady pull is required to unwind the wire.

The mandrel is rotated slowly for the first several turns and then stopped while these are inspected with a lens to insure that the turns are winding bifilar, i.e., alternately. If the tension on one bobbin is appreciably greater than that of the other, one helix may be wound outside the other. A little experimentation with the tension may be required initially. When it is determined that the turns are seating properly, the mandrel may be rotated at 200-300 rpm. The winding jig is held lightly in the fingers with a slight back pressure so that the turns are laid down immediately adjacent to the jig and the increasing length of the helix pushes the jig down the mandrel.

The resulting electrode is in the form of a bifilar-wound pair of helices of the same diameter on a common axis. A pair of helices

requires only half the length of a single one and additional conductors wound on a common axis reduce the total length of wire in each proportionately. Three or four electrodes may be wound in this fashion with a modification of the jig to an "X" shape to hold four bobbins.

When the desired length of electrode is wound, the wires are clipped and the mandrel may be withdrawn; if a protective coating is required the electrode is left on. It may be coated with a silastic rubber paste (Dow Corning Medical Adhesive, Type A) put on with an artist's brush to the rotating mandrel. Greater protection is afforded by inserting the electrode in a tightly fitting silicone rubber tube. This may be done by selecting a section of silicone tubing that is .005 to .010 in. smaller in bore than the outside diameter of the electrode. The tube is then soaked in xylene or ether, which causes it to expand. The electrode on the mandrel is then inserted into the tubing and when the solvent evaporates, the latter will shrink to its original size.

The electrodes thus produced are extremely flexible, resist breakage through flexion almost indefinitely because the bending stress is distributed over an appreciable length of wire. A bifilar pair electrode, close-wound as described, contains 46 in. of wire per inch of electrode length and presents a dc resistance of only 125 ohms. Both the Teflon coating of the wire and the silicone rubber coating is nearly impervious to most biological agents as is the stainless steel of the conductors.

A number of variations on this electrode are possible. A flexible cannula may be inserted in the hollow core of the electrode for the application of chemical agents to the site being electrically monitored. If a pair of electrodes is allowed to remain on the mandrel after winding and the process repeated, the result is a coaxial electrode in which all four conductors may be active or the outer pair may be grounded and thus form a shield for the inner conductors. If a thin-wall silicone tubing is used it is possible to build up two or three layers of alternate electrodes, insulator, electrodes, etc. Each variation retains the advantages of flexibility and resistance to breakage and to chemical deterioration from body fluids.

REFERENCE

WEINSTEIN, S. A., ANNAU, Z., & SENTER, G. Chronic recording of ECG and diaphragmatic EMG in rats. *Journal of Applied Physiology*, in press.

NOTES

1. Clinton C. Brown, Associate Professor of Medical Psychiatry, Department of Psychiatry and Behavioral Science, J.H.H. Zoltan Annau, Assistant Professor of Environmental Medicine, School of Hygiene, J.H.H. Supported in part by NIH Grant HE0-6945.

2. The wire may be purchased from Havg, Inc., Super Temp Wire Division, West Canal Street, Winooski, Vermont.

ECS disruption of avoidance produced by an air blast and tone

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Rats were taught to bar press for food in a Skinner box. The amount of time needed to make 10 bar presses increased significantly after a bar press was accompanied by an air blast and loud tone. This increase did not occur if the air blast and tone were followed 8 sec later by an ECS. The technique is simple and effective, and preserves the previously established effects of ECS on recent memory. Hopefully it will prove useful in situations where the investigator wishes to establish a one-trial passive avoidance without the use of painful shock.

Electroconvulsive shock (ECS) has been widely used in experiments attempting to disrupt retention. Most ECS studies have used a one-trial learning paradigm, which allows precise control of the training-ECS interval, and also minimizes adverse reactions that might build up to the ECS itself after repeated administrations (Hayes, 1948).

Although it is possible to devise a one-trial appetitive learning task (Tenen, 1965), most investigators have used the passive-avoidance paradigm. In these studies the S always has been trained to avoid a particular behavior by pairing that behavior with a painful electric shock. The effects of an ECS immediately after training typically have been to negate the effects of the painful shock so that the behavior continues at the prepunishment level.

The use of painful shock for establishing a one-trial passive avoidance is widely accepted, and generally appears entirely

adequate for this purpose. There are several reasons, however, that an alternative means for producing a one-trial passive avoidance would be of value. First, it would be useful to know the effects of ECS upon retention of an avoidance response established without using painful shock. In addition, some ECS investigations might require that the same S be trained on two completely different tasks, or that he be trained to make an avoidance without receiving painful shock. In the present study, a method is described for producing a one-trial passive avoidance using an air blast coupled with a loud tone. The effects of ECS upon this training also are described.

METHOD

Subjects

The Ss were 28 male albino rats (Holtzman), individually housed and maintained at 80% body weight throughout the experiment.

Apparatus

The test chamber was a Skinner box equipped with a lever and a pellet feeder, and enclosed in a sound-insulated cubicle. The ECS was delivered through modified alligator clips fastened to the rat's ears. Leads from the clips to a shocker (Lafayette No. A-615B) emerged through a small hole in the top of the cubicle, and allowed free movement without entangling the animal.

A length of latex rubber tubing (Aloe R780; o.d. 1/4 in., i.d. 1/16 in.) was mounted on the grid floor so that an air blast could be directed at the underside of a rat that was bar pressing. Compressed air was forced into the rubber tube until an air