TECHNICAL NOTE

A MINIATURE, SKULL-MOUNTED, MULTIPLE CONNECTOR FOR SMALL ANIMALS¹

In working with chronically implanted brain electrodes, the selection of a suitable miniature connector often presents a problem. Some laboratories have designed special connectors, but these are usually not widely available. Commercially available products, such as the Amphenol, Cannon, or Winchester miniature connectors, usually have the metal contacts permanently secured in a plastic base, and the experimenter must solder close to the rat's head during surgery in order to join the electrodes to the connector. Soldering raises the possibility of acid-flux contamination and overheating of the electrode wires in the brain. Some commercially available connectors also require a great deal of force to disconnect, increasing the danger of dislodging the electrode assembly. The few commercially available electrodes specifically designed for brain stimulation work are usually restricted to one pair of wires, twisted together for bipolar stimulation. This paper describes a small six-contact connector that can be readily made in a small machine shop. It has the following characteristics: (1) It is easy to connect and disconnect from the animal. (2) The experimenter can determine the desired number of connections, from two to six. (3) There is no need to solder close the animal. (4) The connectors are re-usable after removal. (5) The animal cannot disconnect itself accidentally.

MATERIALS AND METHODS

The connector is made from $\frac{5}{16}$ -in. round-stock acetal "Delrin" plastic, which is very resistant to organic solvents; the dental or cranioplastic cement used to secure it to the skull will not permanently adhere to it. Also, the material can be machined without difficulty. The contacts used in the connector are Winchester sub-miniature, male and female contacts (Winchester Electronics, Oakville, Connecticut; Catalogue #27023-27024). Additional materials needed are: $\frac{5}{16}$ -in. #48 (or any fine-thread) tap and die, acrylic dental cement (we use Dura Lay Inlay pattern resin, made by the Reliance Dental Mfg. Co., Chicago, Ill.), and tightly wound $\frac{5}{32}$ -in. diameter, stainless steel springs (12 in. long, made from 20-gauge wire). These springs can be obtained locally from commercial spring winders.

A drill jig is made from a 1-in. diameter, 1-in. long

steel cylinder. Using a "J" size drill, a hole is drilled through one end of the cylinder to a depth of $\frac{3}{4}$ in. and is then tapped with the #48 tap. On the other end, a $\frac{3}{32}$ -in. circle is drawn around the center mark, and a hexagon is laid out on it. With a #56 drill, five holes are drilled through the corners of the hexagon, leaving one corner undrilled for keying purposes. A sixth hole is drilled through the center of the circle. The holes are drilled through to the $\frac{3}{4}$ -in. deep hole previously drilled from the other side. The drill jig is illustrated in Fig. 1.

The Delrin stock is threaded with the #48 die and cut into $\frac{9}{16}$ -in. pieces. These pieces are screwed all the way into the drill jig, and the six holes are drilled through the plastic from the other end, using a #56 drill. The female connectors are made by cutting the $\frac{9}{16}$ -in. threaded and drilled-out pieces in half, obtaining two $\frac{1}{4}$ -in. long connectors. The male connectors also are made from the $\frac{9}{16}$ -in. drilled-out pieces by machining them down on a lathe to 0.248-in. diameter, except for the last $\frac{1}{16}$ -in. on the end, where the diameter is $\frac{9}{32}$ in. The male and female connectors are il-

Threaded Plastic Stock Female Contact Male Contact

Fig. 1. Left to right: cross-section of the drill jig with the threaded $\frac{9}{16}$ -in. long plastic stock below; the drilled, $\frac{1}{4}$ -in. long female connector and contact below; and the machined male connector with appropriate contact below it.

¹Acknowledgments: N.A.S.A. Grant NGR-21-001-035. U.S.A.R.D.C. Contract DA-49-193-MD-2726. N.I.H. Grant HE-10342-01. Wallace Laboratories. Warner Lambert. Reprints may be obtained from Zoltan Annau, Johns Hopkins School of Hygiene and Public Health, Room 702, 615 North Wolfe Street, Baltimore, Maryland 21205.

illustrated in Fig. 1. A metal sleeve is used to join the male and female connectors. This is made from $\frac{3}{8}$ -in. aluminum round stock, cut into $\frac{5}{16}$ -in. pieces. These are drilled out with a $\frac{1}{4}$ -in. drill, and this hole is then enlarged with the "J" drill to a depth of $\frac{1}{4}$ -in., leaving a $\frac{1}{16}$ -in. portion of the hole $\frac{1}{4}$ -in. in diameter. This is illustrated in Fig. 2. The enlarged hole is then tapped with the #48 tap. The sleeve will slip over the narrow end and will hook onto the protruding portion of the male connector. This can also be seen in Fig. 2.

Fig. 2. Cross-section view of the metal collar used to connect the male to the female connector shown below. A monopolar rat brain electrode is shown in the middle, and, on the right, a cross section of the completed male assembly as used in the connecting cords.

To connect the animal to recording or stimulating instruments, six #30 gauge, insulated and stranded wires are threaded through the narrow end of the male connector until they merge at the wide end. The wires are soldered to six male Winchester contacts. The diameter of the contacts is enlarged by a layer of solder to make a better pressure-fit inside the male connector. The contacts are pushed back into the male connector until only the connecting ends protrude. The metal sleeve is slipped over the connector next, wide-end first. The wires emerging from the male connector can be protected by threading them through a $\frac{5}{32}$ -in. stainless steel spring. A small rubber hose is slipped over the end of the male connector and the end of the spring. This junction is covered with dental cement as illustrated in Fig. 2. The rubber hose prevents the dental cement from gripping, and perhaps eventually shearing, the wires emerging from the male connector. A connecting cord can be made by putting male connectors at both ends of the wire leads, and the protective spring runs the entire length of the cord.

For electrode implantation in the brain, the wires are soldered to the female Winchester contacts. For rats, we usually make the wires about 1.25-in. long and bend them twice at right angles to form a step near the end to be implanted. Such an electrode is illustrated in Fig. 2. The bend in the wire facilitates anchoring in dental cement. When the electrodes are implanted in the brain, an anchor screw is placed in the skull next to each electrode. The screw and bend in the electrode are covered with dental cement. Five monopolar electrodes and a ground wire can be implanted in this manner. Alternatively, three pairs of bipolar electrodes can be used. After the cement has set at all anchor points, the female Winchester contacts

at the ends of the electrodes are inserted into the base of the female connector. More dental cement is applied around the base of this connector to secure it to the skull. This last layer of cement will also grip the contacts, which protrude slightly from the base of the connector, securing them firmly.

DISCUSSION

These connectors are ideally suited for brain-stimulation work with rats. Although not yet used with larger animals, the same connector probably would be suitable for cats, dogs, and pigeons. The experimenter can implant monopolar, bipolar electrodes, or a combination of these simultaneously; each electrode is implanted independently so that widely separated anatomical regions can be reached, and the electrodes can be implanted at any angle to the skull. The connector has also been used for recording heart and respiration rates in rats; in this case, the female contacts are soldered to subcutaneous leads. These leads are made by winding 0.007-in. stainless steel wire into a spring around a 0.0025-in. hypodermic needle tubing. The springs can be wound by hand on a small lathe. The springs are then insulated with silicone rubber tubing (Dow Corning "Silastic" Medical Grade Tubing, cat. #602-155, available from Storz Instrument Co., 629 Park Avenue, New York). Undersize silicone tubing can be greatly expanded by soaking it in xylene, and then slipping the spring through it. When the xylene has evaporated, the silicone shrinks, and the springs are enclosed in an inert autoclavable jacket. The leads are virtually unbreakable during the life of an experimental animal.

The fine thread of the connector, and its small size, decrease the probability of the animal dislodging it from its head by hooking it into the grid floor of the home cage. If the cages are the usual self-cleaning type, no dust caps are required to keep the contacts in the connector clean. After completing an experiment, the dental cement can be dissolved with ethylene dichloride and the connectors used again.

The steel spring protecting the wires of the connecting cord prevents the rats from damaging the leads. This spring also provides a semi-rigid frame, which is not too heavy, for connecting the animal to some kind of swivel device, thus allowing relatively unrestrained movement in the experimental situation. To provide a practical connection between the animal and the swivel device, the connecting cord can be made with male connectors at both ends. A female connector is permanently attached to the swivels. During an experimental session, one end of the cord is attached to the animal, the other to the swivel on top of the chamber. With the metal sleeve of the male connector firmly screwed on the animal's head, it is virtually impossible for the rat to disconnect itself.

We have been using these connectors for over a year for brain stimulation, heart rate recording, and recording of electromyograms in rats. Apart from normal wear and tear, no difficulties have been encountered with the system. The design of this connector is flexible enough to enable most small animal experimenters to use it without modification.

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