Experimental Improvements in the Use of Silastic Cuff for Peripheral Nerve Repair

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For nearly 90 years experimental and clinical evidence has favored structural support about a nerve repair7,17 with a material that permitted direct and reproducible maximal axonal spanning without axonal disorganization or connective tissue build-up. Only during the past year has such a material become available.4 This material, Silastic, formed into thin, elastic tubes was tested in chimpanzees against thicker tubes of the same material, wraps of millipore, collagen, or silicone, and against standard epineural suturing without wrapping. The results have been promising.5 However, ill-fitting tubes, regardless of the material, can strangle a nerve anastomosis if too tight or fail to support it if too loose.18 Therefore, establishing the best cuff dimensions, including such specifications as the proper ratio between the cross-section area of the nerve and the tube, became an important prerequisite to clinical trials. This report describes refinements in the technical details of nerve repair utilizing a Silastic cuff.

Materials and Methods

Dogs were used for the initial basic experiments, but the final studies were on the chimpanzee, since tissue reactions analogous to those of man occur only in higher primates.11,12 The principles of laboratory care promulgated by the National Society for Medical Research were observed.

Thirty-six mongrel dogs, weighing 12 to 28 kg, and six chimpanzees, weighing 15 to 20 kg, were used in the following eight sets of experiments:

1. Tube thickness 4 dogs
2. Tube internal cross sectional area 8 dogs
3. Tube length 4 dogs
4. Tube position 6 dogs
5. Delayed repair 6 dogs
6. Suture material 3 dogs
7. Tube tolerance 4 dogs and 2 chimpanzees
8. Tube dimensions in higher primates 4 chimpanzees.

Intramuscular phencyclidine (2 mg/kg) delivered by Cap-Chur injection pistol* facilitated preoperative handling of the chimpanzees. All animals were anesthetized with (15-20 mg/kg) pentobarbital intravenously. Endotracheal tubes were passed to assure patent airways. Under standard sterile operating room conditions both radial nerves were exposed and transected at the mid-lower third of the humerus proximal to their branches to the brachioradialis; both peroneal nerves were exposed and transected in the superior aspect of the popliteal fossa. The ulnar nerves of the chimpanzees in Experiment 8 also were exposed and transected in the upper aspects of the forearms. The suture material was 6-0 Mersilene for neurorrhaphies, No. 36 wire for epineural markers, and 4-0 silk for closure of the incision. A dissecting surgical microscope was used routinely. Repaired nerves were placed within a tube of Silastic† as previously described.4,5,13 The dimensions of the tube varied with the experiment. The cross-section area of the nerve rather than its diameter was chosen as a dimension variable since the same nerve passing within tissue planes can be either a circle or an ellipse. No splints were used postoperatively, and the follow-up period consisted of 4 to 5 months for the dogs and 7 months for the chimpanzees. In Study 7, two chimpanzees were followed for 3 years. When both functional and electromyographic evidence indicated regeneration of the repaired nerve, the animals were killed by giving them large doses of pentobarbital. The repaired nerves were removed, pinned on paraffin blocks, and

* Palmer Chemical and Equipment Company, Inc., Douglasville, Georgia.
† The Silastic was kindly supplied by Dow Corning Center for Aid to Medical Research, Midland, Michigan.
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fixed in 10% buffered formalin. Thereafter, the tissue was embedded in paraffin, sectioned longitudinally, and stained with hematoxylin and eosin, Masson's trichrome stain, and by the Bodian technique. The pathologic evaluation by comparative grading included evaluation of neuroma build-up, direct axonal spanning, neuronal carry-through, axonal disorganization, and mesenchymal tissue organization.11,12

Details of each segment of the experiment follow.

1. Tube thickness was studied using Silastic tubes 0.4 inches (10.16 mm) in length and twice the cross-section area of the nerve. Thickness of the walls of the Silastic tubes ranged from 0.065 to 0.005 inches.

2. The relationship of internal cross-section area of the tube and the cross-section area of the nerve was evaluated by using Silastic cuffs 0.4 inches in length and with a wall thickness of 0.005 inches. The internal cross-section area of the tube was calculated from the manufacturer's specifications which were in English units of measure and not the metric system. The circumference of the nerve 1-inch proximal to severance was measured by passing a fine silk suture completely around the nerve, and its cross-section area was calculated from this dimension. The ratio of the internal cross-section area of the tube to that of the proximal nerve cross-section area varied from 1:1 to 1:43.

3. Tube length was studied by applying different lengths of the thinner tubes (0.127 mm) with a wall thickness of 0.005 inches that varied from 0.2 to 1.8 inches.

4. The effect of tube position about a joint was evaluated on the peroneal nerves of the dog. Neurorrhaphies were performed at different levels above and below the bifurcation of the peroneal nerve; these were encased in Silastic cuffs 0.4 inches long with a wall thickness of 0.005 inches, and an internal cross-section area twice that of the nerve.

5. The influence of delayed repair was studied in six dogs that had had the peroneal nerves sectioned 1 month prior to definitive neurorrhaphy. The surgical wounds were closed primarily in half the animals. The wounds of the remaining half were left open and uncovered so that they would become infected and heal secondarily. The definitive neurorrhaphies were performed with four epineural stitches using tubes with the same dimensions as those used in Study 4.

6. The size and material of the suture employed in neurorrhaphies covered by a Silastic cuff were evaluated. In addition to the standard 6-0 Mersiline for the epineural stitches, we used 5-0, 6-0, and 7-0 Mersiline, Tevdek, and silk.

7. Tolerance of the nerve to a loose-fitting Silastic cuff was studied in dogs followed for 1 year and in chimpanzees followed for 3 years.

8. Because of the species variation in tissue reaction to nerve repair, only chimpanzees were used to determine the optimal tube dimensions. Thin tubes, with wall thicknesses of 0.005 inches, were applied in primary repairs in which the cuff's length was varied from 0.4 to 0.8 inches; the ratio of the cross-section area of the cuff to that of the nerve ranged from 1:1 to 1:43.

Results

1. Tube Thickness. The most consistent pattern of direct spanning of regenerating neurons across an anastomosis was achieved by use of tubes with thin walls. Although all cuffs promoted improved axonal carry-through and limited the size of the neuroma in continuity at the anastomosis, use of the thicker-walled tubes often resulted in secondary neuroma buildup proximal and distal to the tube. This complication was not associated with use of the thinner, more pliable, elastic cuffs.

2. Tube Internal Cross-Section Area. In the dog, the maximum direct axonal spanning without connective tissue or neuroma buildup was achieved with tubes whose internal cross-section area was twice that of the nerve. Tubes smaller than that constricted the nerve anastomosis, resulting in a diminished axonal count distal to the anastomosis. Also, the smaller tubes occasionally caused formation of a neuroma proximal and distal to the cuff itself. On the other hand, larger tubes, with internal cross-section areas greater than three times those of the nerves, failed to provide uniform encasement at the anastomosis and allowed connective tissue buildup at the repair site. The resulting neuroma in continuity interfered with direct spanning, and led to axonal disorganization.

3. Tube Length. Often tubes as short as 0.2 inch accomplished the task of protection and encasement of the repair site. However, any slippage, even as little as 0.1 inch, resulted in no cuff over the anastomosis. Tubes 0.4