Study of Functional Recovery Produced by Delayed Localized Cooling After Spinal Cord Injury in Primates*

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IN SPITE of the sophisticated advances in modern surgical therapy, the present day management of spinal cord trauma generally remains unsatisfactory. Current methods used in the treatment of spinal cord trauma consist of immobilization with skeletal traction, surgical decompression with or without incision of dural coverings, and immediate or delayed bony fusion to provide stabilization. Controversy even exists as to the merits of "conservative" treatment versus surgical decompression. Even among those favoring early laminectomy in patients displaying sensory-motor paralysis associated with a spinal fluid block, there is no unanimity of opinion whether the dura should be opened or left intact.

In reviewing other approaches to the problem of spinal cord injury, we were impressed with some of the work relating to the protective effect of cold on brain. It has been shown that hypothermia will decrease the cerebral metabolic demand, reduce brain volume, bring about a reduction in the inflammatory response to brain injury, and allow the brain to tolerate extended periods of circulatory arrest. It has also been demonstrated that total body cooling to 30°C will protect the spinal cord of the dog during occlusion of the thoracic aorta. Because of the accessibility of the injured segment of the spinal cord during surgical laminectomy, an attempt has been made to assess the practical advantages of direct cooling to the traumatized area of the cord, in the belief that the advantages operant with cerebral cooling might also apply to spinal cord tissue.

To evaluate the effectiveness of hypothermia in experimental trauma to the spinal cord it was thought necessary to fulfill the following criteria:

1. The development of a predictable, quantitative method for producing irreversible spinal cord trauma in the control animal
2. The provision of a simple technique of rapidly and efficiently cooling the area of traumatized cord
3. The demonstration of significant functional differences in recovery from injury in the experimental group that was cooled when compared to the control group of animals.

We have shown in previous reports from this laboratory that it was possible to selectively reduce spinal cord temperature in the dog, that such temperature reduction was not in itself injurious, and that significant recovery occurred in the dog when focalized spinal cord cooling was carried out immediately after induced trauma.

This paper evaluates the effect of delayed localized cooling about the area of spinal cord injury in the subhuman primate, Macacus Mulatta.

Method

In this study, acclimatized Rhesus monkeys (Macacus Mulatta) ranging in weight from 7 to 11 lbs were used. All animals were anesthetized with 25 mg of intravenous sodium pentobarbital per kilogram of body weight, with supplements of 15 mg per kilogram when needed. To eliminate uninten-

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Fig. 1. Device for producing impact injury: teflon dropping tube is 30 cm long with perforations every cm starting at the 10.0 cm level. This is attached to metal impounder saddle that rests on lateral sides of vertebral body to give stability to dropping tube. Metallic impounder fits convexity of posterior surface of spinal cord and is placed in saddle. Teflon tube is loaded with weight and held in place by weight-restraining pin which is placed through desired centimeter perforation hole. In this manner, weight can be dropped any preset distance on impounder, delivering a force calculated in gram centimeters. A small rounded spirit level

tional bias on the part of an investigator, the procedures listed below were performed and evaluated by at least three investigators participating in this study.

**Technique of Injury.** Spinal cord trauma was produced by dropping a weight a known distance (through a virtually frictionless Teflon tube) on a contoured metal impounder resting on the spinal cord surgically exposed at the tenth thoracic vertebral level (T-10) with all investing membranes intact (Fig. 1). This method for producing impact injury provides a predictable quantitative model for studying spinal cord trauma with the resultant forces of injury calculated in gram centimeters of force (gcf).

**Normothermic Control Studies and Paraplegia Thresholds.** To determine the threshold for irreversible paraplegia, 15 monkeys were subjected to laminectomy at T-10. They were then divided into three groups of five monkeys each and subjected to the following forces of injury:

- **Group 1.** 200 gcf (20 gm weight dropping 10 cm) followed by a 4-hour delay after injury
- **Group 2.** 300 gcf (20 gm weight dropping 15 cm) followed by a 4-hour delay after injury
- **Group 3.** 400 gcf (20 gm weight dropping 20 cm) followed by a 4-hour delay after injury.

After the 4-hour delay, the dura was incised and left open, the wounds closed aseptically, and the animals observed for at least 3 months. When the lowest threshold for irreversible paraplegia was determined, an additional eight monkeys were traumatized at this gcf and followed neurologically for at least 3 months.

**Localized Spinal Cord Cooling.** Twelve monkeys were subjected to localized spinal cord cooling after they had undergone laminectomy at T-10, exposure of the spinal cord, and incision of the dura. With the surgical area as a reservoir, cold isotonic saline entering between 2°C to 5°C from a Mayo pediatric heat exchanger was continuously recirculated at a flow rate of 100 ml per min-

(not shown here) is used to align the dropping tube perpendicularly to spinal cord. This spirit level easily fits on top of the dropping (tube).