A CRYOGENIC METHOD FOR PHYSIOLOGIC INHIBITION AND PRODUCTION OF LESIONS IN THE BRAIN*

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I t is the purpose of this report to bring to attention an extension of our cryogenic system for neurosurgery.2,5,6 The physical modality of extreme cold is capable of fulfilling all of the desirable criteria for an ideal method of production of lesions in the central nervous system. These criteria are: reversibility, consistent reproducibility; sharp delimitation; avascularity; variability, when desired; safety; simplicity; and rapidity of application.

The earliest systematic investigation of freezing temperatures applied to the brain for purposes of physiologic investigation was that reported by Opendowski11 in 1883. Subsequent to this report, there have been intermittent investigations which suggested that the physical modality of cold has the potential of serving as an ideal method of both physiologic inhibition and production of lesions in the brain.

Hass and Taylor5 investigated freezing lesions in the brain of various animals and reported that this method is capable of producing discrete, circumscribed lesions, which carried no danger of suppurating complications, could be absolutely controlled, was reproducible, produced its effect within a matter of seconds, and was essentially hemostatic.

Balthasar4 produced localized lesions by freezing in the cerebral cortex of cats and concluded that the use of extreme cold was the most physiologic method available with which to produce inhibition or discrete lesions of the central nervous system.

Rowbotham et al.12 produced localized cooling, to −20°C., in 3 cases of human glioma. The cannula that they employed was not insulated, resulting in cooling along the entire length of the instrument. However, this experience demonstrated the safety of extreme cold within tumors of the human brain, and indicated the value of an attempt to develop instrumentation that could produce temperatures at a much lower depth in a controlled fashion. Efforts in this direction have been reported recently by Ries and Tytus,12 Dondey et al.,9 Tanche and his co-workers,14 and others.

The physical factors affecting the rate of transfer of heat at the tip of a cannula to be used for cooling within the brain are: the area of the surface of the freezing tip; the temperature and the rate of flow of the agent passing through this freezing tip; and the thickness and capacity for heat of the metal wall of the uninsulated portion of the cannula. The biologic factors of importance are the coefficient of heat and thermal diffusibility of the tissue and the radius of the lesion to be produced. A more searching inquiry into the physical and cryobiologic aspects of this subject is reported elsewhere.3

We have developed a cryogenic surgical system which fulfills all of the requirements for safe, consistent, controllable, reversible or permanent production of lesions. The source of refrigeration is liquid nitrogen, maintained at −196°C. This refrigerant is delivered to a brain cannula by a double-layered, insulated withdrawal tube. Both the withdrawal line from the supply of nitrogen and the surgical cannula are constructed as an integral unit, and are insulated by vacuum. This unit,*


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which engulfs the line delivering the liquid, also contains a vent for escape of nitrogen gas as it removes heat from contiguous brain, and thermocouple leads from the tip of the cannula (Fig. 1).

Selected temperatures at the tip are obtained instantaneously and are maintained by an automatic flow-control system. The actual temperature realized at the tip of the cannula is monitored by thermocouples and displayed on a recorder. The surgeon may control this unit completely by manual adjustment of a dial for selection of temperatures. Although various types of insulation have been used in the development of our system, including a heating coil along the body of the cannula, silk insulation, and other methods, our final system employs vacuum insulation, since this is the most efficient type of insulation employed in cryogenic engineering. This insulation insures the fact that only the tip of the cannula removes heat from the contiguous brain. The remainder of the cannula is not cooled—an obvious requirement for its use within the brain. The over-all diameter of the brain cannula is 2 mm.

Physiologic inhibition within the brain is obtained in a temperature range from +10°C to 0°C. Between 0°C and −196°C, the lethal effect of freezing is caused by: removal of water from solution into ice, with toxic concentration of electrolytes; crystallization and rupture of cellular membranes; denaturation of lipid-protein molecules; thermal shock; and vascular stasis.10

The lesions produced by this cryogenic method within the brain are spherical, sharply delimited from normal brain, avascular, and consistently reproducible depending on the temperature of the tip of the cannula. Within the brain, with a freezing time of 3 min., a temperature of −40°C at the tip produces a lesion with a maximum of 6 mm.; −50°C produces a lesion with a maximum diameter of 8 mm.; and −100°C produces a maximum diameter of 12 mm. In gelatin, consistent spherical lesions are produced, which are sized somewhat differently than those in the brain, for the obvious reason that there is not a constantly circulating blood stream within the gelatin, which transfers heat to the vicinity of the lesion by convection. However, the consistent nature of formation of lesions by this system may be demonstrated in gelatin solution, as shown in Fig. 2.

Between April 1, 1961 and April 1, 1962, I have used this cryogenic surgical system in 150 cases, including surgery of basal ganglia, hypophysectomy, and for necrosis of deep and superficial brain tumors, as well as for cryogenic congelation and necrosis of malignancies elsewhere in the body.4

In the first 100 consecutive cases of cryothalamectomy for parkinsonism, tremor and rigidity were abolished in 90 per cent of the cases.5 There was only one complication, a hemiparesis unrelated to the freezing procedure, and there was no postoperative mortality. Moreover, the postoperative course of each patient was unusually smooth, there being virtually no postoperative mor-