Extravascular Local Cooling of the Brain in Man*

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When we cool the homeothermic brain of man, we disturb its functions. In exchange for an improved ability to withstand ischemia, we hazard the little known factors of abnormal survival at subnormal temperatures. These hazards increase in direct proportion to the depth, duration and extent of cooling. The metabolic and cardiovascular dangers of surface cooling of the whole body below 30°C. and the technical complexities of perfusion techniques are well known.1,9,10,18,22 Bearing in mind that even the most specialized individual tissues are able to survive near freezing temperatures, it would appear that it is not the actual process of cooling the tissues that is hazardous, but rather it is the sequence of physiological changes in various parts of the body in response to cold.2,6,11,22 The recognition of these facts has led to the development of local cooling as an attempt to by-pass the general effects of hypothermia, particularly when deep hypothermia is required; i.e., in the terminology of Bigelow,2 temperatures below 28°C. Fig. 1 is a suggested classification of hypothermia which will serve to guide our use of terms in this report.

Local cooling of the nervous system has been achieved in animals by a number of workers9,24,25,30,34,42 using pervascular methods. In man, a few reports using such methods also have appeared.20,21 However, extravascular local cooling has not, to our knowledge, received sufficient attention. In another study we have reviewed the earlier work in this field and reported our results with local extravascular cooling in animals.29 It was emphasized there that the pioneer observations of Trendelenburg29-41 in 1910 and Leyton and Sherrington22 in 1917 were directed more by an interest in the functional effects of cold on the brain rather than its uses. On the other hand, the original observations of Temple Fay13,35 on hypothermia in man were directed primarily to the uses of cold in the management of cancer, pain and infection. These observations, which initiated all the current interest in cooling, also contained the first experiences with local extravascular brain cooling. This was a study of the therapeutic value of cold metal capsules within glomas and of the irrigation of abscess cavities with cold sterile solutions. In addition, while designing the first blankets for body cooling, Fay12 also developed and used separate cooling caps to produce local cooling of the head in cases of severe head injury. Surprisingly few observations in man have appeared since.

Recently, Negrin26,37 has reported his results in 2 cases. On the basis of a series of experiments in dogs he was able to achieve cooling of the spinal cord in a spastic quadriparetic patient. In a second case, he carried out a hemispherectomy in a severely epileptic, hemiplegic, mentally deficient child, using local extravascular cooling. The effects of ventricular irrigation with Ringer’s solution at 5° to 10°C. on the severity of epilepsy and behavior in 3 psychopathic children have been reported by Tokuoka et al.38 However, no measurements of brain temperatures were reported for these cases.

Our interest in this subject was awakened by our first case, described later in this paper, and prompted the following questions:

1. How efficiently is the brain cooled by extravascular local techniques?
2. Are such techniques of practical use?
3. Is direct local cooling of the brain a safe procedure?
4. What effect does local brain-surface
cooling have on localized brain functions, such as speech?

5. What effect does cooling have on epilepsy?

This initiated a series of experiments in cats, monkeys and rabbits, which have been reported separately.29 Therein we were able to prove to our satisfaction that local extravascular cooling is safe and rapidly effective, producing a moderate hypothermia at adequate depths from the surface cooled. Our next step was to proceed cautiously in the application of such techniques in man.

Techniques

The principle of extravascular local cooling of the brain is to achieve a close and uniform apposition between brain surfaces and the nontraumatic cooling agent. Mock cerebrospinal-fluid solutions at temperatures approximately between 3°C to 10°C are the ideal media. However, if a more precise area is to be cooled selectively, the use of special malleable "capsules" becomes necessary. In previous investigations on animals,29 a variety of such devices has been described. These require only brief review here as our observations in man have been made primarily by direct methods of fluid irrigation. For ease of description, the techniques fall into two groups; i.e., "open" and "closed" methods.

Open Method. In its simplest form, this consists of the constant irrigation of a standard craniotomy exposure with cold Elliot’s solution B. The field is arranged so that a thin layer of the irrigating fluid is flowing over the area exposed; the excess fluid is removed by constant suction. The irrigation may be extradural or subdural after elevating the dural flap. The source of cold irrigating medium is arranged as shown in Fig. 2.

Closed Methods. (a) Closed irrigation technique: Fine rubber catheters are placed for entry and exit of the cooling fluid below the dura mater and into the ventricular cavities as required. If perfusion rates do not exceed 30 to 50 ml./min., there is little danger of producing dangerously excessive intracranial-fluid pressures. The fluid entry is by gravity and the emerging fluid may be recirculated with a pump or allowed to drain off as required. This technique can be achieved as a completely closed system; by a permutation of the position and amounts of internal- and external-surface irrigation, approximately selective cooling of regional areas of the brain may be produced. Ventricular irrigation may be combined with the open-irrigation method when a more uniform cooling of part or all of one cerebral hemisphere is required at craniotomy.

(b) Cooling of restricted cortical areas: This may be achieved by any one of the following methods:

1. Cold fluid is circulated through small Teflon capsules placed in burr holes so that their open ends lie against the cortex or closely set extradurally.

2. The cooling medium is circulated through flat coils of polyethylene tubing laid on the cor-

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**Fig. 1.** Classification of hypothermia.

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**Fig. 2.** Two methods of obtaining a constant source of cold irrigation fluid. The metal coil is immersed in a mixture of salt and crushed ice.