VENOVENOUS SHUNT FOR RAPID HYPOTHERMIA*

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General body hypothermia produced by physical methods is being used more and more frequently in neurosurgery to achieve protection of the brain from ischemia secondary to operative occlusion of cerebral vessels during intracranial operations.\(^5,6,8,26,33,41\) It has been shown to be useful in brain tumor operations,\(^8,38\) in cerebral trauma,\(^23\) in cerebrovascular occlusive disease,\(^1\) in hyperthermia,\(^24\) and even in shock from burns.\(^12\) In 1940, Fay\(^17-19\) pointed out advantages in the use of this technique in clinical neurosurgery, but hypothermia has gained impetus in neurosurgery only recently. In the interim, cardiac surgeons have used and studied hypothermia extensively as an aid to open heart surgery. Little emphasis has been given to protection of the brain from ischemia during these studies, however. Through these studies it has become clear that fibrillation is the major complication in hypothermia. Even now, the actual cause of this has not been clearly defined. This emphasis on the danger of fibrillation has undoubtedly delayed the use of hypothermia in neurosurgery. Now, however, protection of the brain against ischemia by hypothermia has been clearly delineated,\(^3,22,26,27,31,33\) and the use of hypothermia in neurosurgery is steadily broadening.

External and internal methods of body cooling have been used. External methods include the use of a hypothermia blanket, immersion in ice water in a bathtub, exposure to cooled air, and application of an ice bag to the body.\(^5,6,28,41\) All have the disadvantages of: 1) lack of precise control of the degree of temperature decline; 2) excessive time involved with often cumbersome equipment to achieve the desired level of hypothermia (2 to 3 hours average); and 3) minor danger of trauma of the skin from excessive local cooling.

Internal cooling methods using extracorporeal shunts of circulation have been devised which can produce rapid hypothermia, apparently without increased cardiac complications. An arteriovenous type of shunt has been used mainly, involving a heat exchanger for cooling the blood prior to its return to the body circulation.\(^7,9\) Arterial damage, danger of emboli and expense have prevented wide usage. The advantage of using the arterial pressure to drive blood through the heat exchanger has possibly simplified these systems, but the dangers of producing an arteriovenous shunt of large volume in such people has been stressed.\(^34\)

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Venovenous shunts were first used extensively by Ross\textsuperscript{34,35} and Brock,\textsuperscript{8} using a simple device to cool the venous blood in the shunt in which a hand-operated pump was inserted to provide adequate flow of blood. This method required thoracotomy and cardiotomy, however, since the afferent catheter was introduced through the right atrium into the inferior vena cava, and the efferent through the same site but into the superior vena cava. The report of these experiences was limited, but the simplicity of the apparatus and the rapidity of apparently safe cooling were striking. Others have used this method in experimental animals.15,20

A simple, low-cost, venovenous cooling shunt was therefore devised from commercially available units and tested in the laboratory. This shunt demonstrated convenience, safety, and precise control of temperature in over 50 dogs when utilized to produce hypothermia of moderate degree (26°C–29°C). Spontaneous ventricular fibrillation, the major complication of hypothermia, occurred in 19 of the 30 dogs in this series reported.43 The mean temperature at which this appeared was 22.8°C. (±0.5°C. standard error), a level somewhat higher than the series reported by Hegnauer.21 This critical temperature is therefore much lower than that utilized for clinical purposes.5,6,33 The only modification used to adapt this method for clinical needs was to lengthen the cooling coil by 2 feet. The proposed advantages of such a method of rapid hypothermia for clinical use were substantial. Subsequent to the initial experiences with this shunt, the advantages appear to be sufficient to warrant a description in detail.

DESCRIPTION OF VENOVENOUS SHUNT

Fig. 1 demonstrates the shunt. It consists of a Sigmamotor pump unit (Model T6S)\textsuperscript{*} with an electric motor-power supply (E), and a torque converter (F) for con-
trol of the variable speed of the finger pump (B) which pumps the venous blood from the body through the cooling coil and returns it to the body as cooled blood. The 14 Fr. polyvinyl catheter (A) is inserted through the superficial femoral vein into the femoral vein and then threaded up a distance of approximately 18 inches into the inferior vena cava. This is achieved by a small operative exposure in the groin over the femoral triangle. This catheter is connected with a \( \frac{1}{16} \) inch I.D. segment of polyvinyl tubing which goes directly to the pump (B). The blood is then conducted into a stainless steel cooling coil (C) which is 8 feet long and has an internal diameter likewise of \( \frac{1}{16} \) inch. The blood is cooled as it passes through this coil immersed in ice water, and is returned to the body via the distal catheter (D). This catheter (D) is inserted into the antecubital vein and threaded up only far enough to maintain it in the vein, preferably on the same side of the body as the afferent catheter (A) has been placed. The tubing and catheters* are sterilized by autoclaving.

The internal surface of the shunt is designed so that the adapters make no shoulders or buttresses. The connectors are fashioned so that no change in diameter is greater than 6° and the connectors are all made from Nylon polished internally. Any connection is secured by friction. The large tubing that goes through the pump is latex tubing \( \frac{1}{2} \) inch I.D., \( \frac{3}{8} \) inch O.D. The entire set of tubing is siliconized prior to use and each set is used only on one patient. A water-soluble silicon is utilized to make a nonwetting surface, reducing the possibility of clot formation. To date, extensive use of this type of shunt has shown no serious tendencies to clot formation. It should be emphasized, however, that the shunt is removed as soon as the body temperature reaches the required level.

Prior to catheterization of the veins the entire shunt system is filled with 60 cc. saline solution containing 0.01 per cent heparin. This is achieved by running the pump with both catheter tips immersed in the sterile saline solution to insure removal of all bubbles in the entire circuit. Once this is achieved under sterile conditions, the shunt is ready for inserting the catheters in the appropriate veins. The surgical set-up is very simple as cut-downs are done on both veins and the ligatures around the veins are arranged so that when the catheters are removed the vessel can be easily ligated without extensive re-exposure. The small incisions in the skin are closed with interrupted fine silk sutures with the catheters in place. When the shunt is removed, only the ligature around the vessel need be tied down.

Fig. 2 demonstrates the venovenous shunt set-up functioning in the operating room with the same relationship as shown in Fig. 1. The temperature is monitored by a thermistor monitor† which records three temperatures. Rectal temperature is recorded from a rectal probe inserted approximately 8 inches. Esophageal temperature is recorded from a similar probe placed in the lower third of the esophagus and cerebral temperature is derived from a needle thermistor which is inserted into the brain through a drill hole in the skull. The shunt is established on the side of the patient toward the anesthesiologist in order to maintain an efficient arrangement of the equipment. This

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* Don Baxter, Inc., Glendale, Calif.
† Tele-Thermometer, Yellow Springs Co., Yellow Springs, Ohio.
allows the anesthesiologist to easily discontinue the shunt when the chosen temperature has been reached.

Fig. 3 demonstrates the changes in temperature in brain, esophagus and rectum as usually recorded. The intent in each instance is to carry the cerebral temperature to approximately 27°C, which is the level that will prob-

![venovenous shunt in operation](image)

**Fig. 2.** Venovenous shunt in operation in the operating room. Letter designations as in Fig. 1.

![temperature curves](image)

**Fig. 3.** Decline in temperature curves of brain, esophagus and rectum as induced by venovenous shunt.
ably give optimum protection for cerebrovascular occlusion without serious complications. Esophageal and cerebral temperatures generally remain within 0.5°C of each other, whereas the rectal temperature always lags. Rectal temperature is not allowed to lag more than 2–4° behind the cerebral-esophageal temperature in order to prevent the possibility of a marked temperature gradient between the right and left side of the heart. Rectal temperature eventually does coincide with the cerebral and esophageal temperatures as the body comes into equilibrium. The necessary control of rate of decline in temperature can be achieved in two ways. The rate regulator (F, Fig. 1) can be altered to change the flow of blood through the coil (usually calibrated from 100–900 cc. per min.), or the coil itself (C, Fig. 1) can be partially removed from the ice-water bath so the gradient between the inflowing blood and the cooling coil is not so great. We usually maintain a relatively constant flow at approximately 500 cc. per min. and vary the volume of the cooling coil in contact with the ice-water bath.

Fig. 4 demonstrates the cooling efficiency curve of this cooling coil when immersed in an ice-water bath at 1°C. The heat exchange of whole blood at 36°C and 32°C is demonstrated. This is expressed in kilo-calories per min. related to the flow of blood in cc. per min. A straight-line relationship is demonstrated which has a decreased slope at the lower temperature. Fig. 4 also gives the calculated Reynold’s number at each of these points indicating that the flow of blood is laminar in the range utilized. In spite of the laminar flow the heat exchange is adequate.

A comparison of the time involved in achieving adequate cooling of the body by both the shunt and the blanket technique is shown in Fig. 5. The time of the venovenous shunt is shown in (A) and that of the refrigeration blanket in (B). The actual cooling by the shunt took less than 55 minutes,
whereas, in a person of very similar build, cooling with the blanket required 5 hours and still did not achieve a similarly low temperature. The stress on the patient and the surgical team from a prolonged period of cooling is obviously greater than when the shunt is used.

The use of this shunt is demonstrated by a time chart in Fig. 6. This

Fig. 6. Time relationships from anesthesia record of a case in which venovenous-shunt cooling was used.
shows that the anesthesia was begun at 7:45 a.m., the catheterization of the two veins to establish the shunt was begun at 8:00 a.m., and the shunt was established by 8:20 a.m. The craniotomy was begun at 8:30 a.m. Cooling was under way at the time the craniotomy was begun and, by the time the bone flap was elevated, the body temperature was down to the desired level of 27°C. The efficiency of this technique in the operating room is demonstrated, since the craniotomy can be started while the body is still being cooled with assurance that an adequate level of hypothermia will be reached by the time it is needed to protect the brain. Once the cerebral temperature has reached 27°C, it remains stable at this level for 3 to 4 hours. This temperature can be maintained for long periods of time by simple application of ice-bag packs to the body or by use of the usual refrigeration blanket* which can be put into position before the operation. Before the conclusion of the operation, the patient can be slowly rewarmed by the blanket until ventilatory efforts are adequate without assistance, then spontaneous rewarming occurs without any difficulty. It has been our policy to allow the patient to recover gradually with only minimal assistance with rewarming. It has been helpful to have ice packs or a refrigeration blanket available in order to prevent any overshoot of temperature in the recovery phase. The refrigeration blanket with a rectal thermometer has been exceedingly useful in this regard and is used routinely. Body temperature is back to normal 6 to 7 hours after termination of the operation. The patient is under close surveillance during this entire time to achieve early recognition of any complications.

Anesthesia for these procedures was obtained by utilizing light preoperative medication consisting of a barbiturate, a sedative antihistamine, and scopolamine. Opiates are used in small doses if pain is present and increased intracranial pressure is not a problem. Anesthesia was induced with nitrous oxide and intravenous adjuncts were used for maintenance with intubation and controlled ventilation throughout the entire procedure. Ventilation is maintained at a volume comparable to that present before induction of anesthesia. The electrocardiogram is monitored on the oscilloscope and blood pressure can usually be monitored by the usual auscultatory means. If blood pressure could not be determined by this means during the procedure, an intra-arterial catheter was placed in the radial artery and blood pressure was recorded directly from this. Additional hypotension with the use of a substituted camphor sulphonate (Arfonad) has rarely been used. However, if it is used, strict attention to dose is imperative as the action is prolonged by hypothermia. Shivering has not been vigorous in spite of very light anesthesia, and can be easily prevented by additional doses of muscle relaxants.4

**COMPLICATIONS**

*Cardiac Irregularities.* Table 1 summarizes the electrocardiographic findings in the clinical series. There is no evidence of rapid cooling causing sig-

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* Therm-O-Rite blanket, Thermo-O-Rite Products Corp., Buffalo, N. Y.
significant increase in the cardiac complications. In most reported series of hypothermia, the cardiac complications occurred in the early cases while the team was becoming familiarized with the problems involved. The one instance of ventricular fibrillation in our series occurred after the patient had been at 27°C for 15 minutes. It was complicated by the fact that an excessively large dose of Pentothal Sodium had been administered shortly preceding. This fibrillation was easily reversed by cardiac massage and electrical defibrillation. A small amount of intravenous epinephrine was given after defibrillation with the hope of maintaining an adequate pressure for perfusion and of speeding up the cardiac rate to a slight degree. The initiation of the fibrillation was observed on the oscilloscope and was identical in all respects to fibrillation as observed in the laboratory on dogs using this same shunt, and reported by West et al. This work indicates that fibrillation may be the result of a disassociation of the active and passive ionic movement across the cardiac-cell membrane. The evidence for this is based on recordings of action potentials and these single-cell action potentials have been correlated with electrocardiographic changes. Thus the degree of decrease of active transport is probably related directly to the rate of change of the S-T segment during the production of hypothermia. The occurrence of this characteristic elevation of the S-T segment (Osborn wave) has been utilized somewhat as a prognostic sign. This does not imply that its presence means hypothermia is too great but early onset of this wave probably indicates early disassociation between active and passive transport. For this reason, the continuous monitoring of electrocardiographic changes is of maximum importance. Serious cardiac arrhythmias seem to occur much more commonly during rewarming than during cooling. This is believed to be true because of the fact that the higher pace-maker areas would be warmed much more quickly than would the greater mass of the ventricular muscle. For this reason, stimuli would be more apt to occur during the susceptible period of ventricular repolarization.

The centrogenic factors contributing to cardiac irregularities in hypothermia have not involved the production of ventricular fibrillation. It has been our experience, however, that atrial arrhythmias are not dangerous and that the occasional auricular extrasystoles have not been found harmful. The cardiac rate itself appears not to be significant within the limits utilized by Torres et al. who subjected dogs to auricular and ventricular driving throughout the period of cooling. This study suggests that fibrillation is not dependent on conducting mechanisms in the heart, but

| TABLE 1 |
| Summary of electrocardiographic abnormalities in clinical cases |
|-----------------------------|---------|
| Normal sinus rhythm throughout | 16 |
| Auricular extrasystoles, occasional | 2 |
| Ventricular fibrillation (easily reversed without warming) | 1 |
| Total | 18 |
that the primary change is probably more nearly at the cellular level. There is disagreement as to the exact factors involved in hypothermic ventricular fibrillation.\textsuperscript{2,10,11,37} It is very likely that multiple factors, including defects of centrogenic conduction, changes in refractory periods, and changes in metabolic components within the cell, are responsible for ventricular fibrillation in hypothermia. Certainly with adequate anesthesia and close observation of changes in the patient, the risk of ventricular fibrillation in hypothermia for neurosurgical operations does not seem as great as the risks of doing the same operation under normothermic conditions.

\textit{Emboli.} In none of the animals in which the shunt has been used nor in any of the 18 clinical cases to date has there been any evidence of serious clot formation in the shunt itself. We have found no evidence of pulmonary emboli. Since this is a vein-to-vein shunt, the danger of emboli is further minimized by the filtering effect of the lung. A small pulmonary infarct might occur but significant clinical symptoms may not result from this. Routine roentgenograms of the chest and examinations of the chest following surgery in all clinical cases have failed to show any evidence suggestive of such infarcts.

\textit{Intravascular Hemolysis.} Increased fragility of red blood cells is caused by the use of blood pumps because of the physical trauma of the pump on the red blood cells. In all clinical cases, icteric indices on the first and subsequent postoperative days have remained normal with no suggestion of hemolysis. In addition, the level of plasma hemoglobin in 5 cases never was significantly above that of the controls. However, in 1 case, this method of hypothermia was used with intravenous administration of concentrated urea for reduction of brain volume. A rather significant intravascular hemolysis of red cells occurred on the 4th postoperative day. This was attributed to the combined hemolytic effects of the urea and the pumping action of the pump. Treatment was successful with transfusions and supportive therapy.

\textit{"Freeze Burns."} Burns of the skin secondary to localized external application of cold have been nonexistent since this type of internal cooling has been used. When the blanket is used for the maintenance of low temperature, the body temperature is already at the required hypothermic level. Therefore, excessive degrees of cold need not be applied directly to the skin and the consequent danger of burns is indeed minimal.

\textit{Prolonged Bleeding.} Prolonged clotting time in the presence of hypothermia is somewhat difficult to demonstrate because of the lack of precision in method.\textsuperscript{13,14} Studies by Willson \textit{et al.}\textsuperscript{44} demonstrated that prolonged bleeding in hypothermia is a phenomenon dependent on temperature. In uncontrolled bleeding, the mechanism of coagulation could be restored easily by heating the area locally with warm packs. This has not been necessary in this series. Moderate prolongation of bleeding time does appear to be present but has caused no complications. The use of a small amount of heparin in the shunt initially has no significant effect on clotting, but may actually improve capillary circulation in hypothermia.\textsuperscript{16,25,42}
TABLE 2

Summary of clinical cases in which venovenous shunt was used

<table>
<thead>
<tr>
<th>Case</th>
<th>Description</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Intracranial aneurysms</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>Intracranial angiomas</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Brain tumor</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Carotid-cavernous fistula</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Total (no death)</td>
<td>18</td>
</tr>
</tbody>
</table>

brain substance locally. Hypothermia was not used for "brain swelling" in any case.

The aneurysms included 5 anterior cerebral or communicating aneurysms, 4 middle cerebral aneurysms, and 1 internal carotid aneurysm. In all instances, temporary vascular occlusion of the feeding vessels was extremely helpful in achieving a good result. A parietotemporal and a bifrontal angiomatic malformation were completely removed by means of temporary vascular occlusion under hypothermia without causing increased disability.

Two of the 5 brain tumors were extremely vascular meningiomas of the convexity, and the other 3 were neoplasms in the pituitary-optic chiasm region in which extensive retraction of the frontal lobes was necessary. It seemed that retraction of the frontal lobes during hypothermia could be done with greater safety and with less ischemic softening than is usual under normothermic conditions. Such extensive prolonged retraction was considered safer with hypothermia than by using intravenous concentrated urea. The intracranial ligation of a carotid fistula was accomplished under hypothermia for the same reasons.

Whereas in all clinical cases it was felt that the hypothermia did make the operative procedure much safer, the degree of cerebral protection of hypothermia in our cases is not as great as Rosomoff's results might indicate. By arteriography, an unusual aneurysm of the left middle cerebral artery was demonstrated in a 38-year-old man. It extended upward from the second portion of the middle cerebral artery toward the insula and internal capsule. Under hypothermia, the base of this aneurysm was ligated with a
large clip. Complete dissection around the vessel at this level was not necessary at all and in fact the middle cerebral artery was at no time occluded. In spite of this, upon recovery from hypothermia at 27°C. for 5 hours from the time of this occlusion, the patient showed a marked right hemiplegia with aphasia. These defects cleared over the subsequent 4 days and the patient is now entirely normal neurologically 14 months after operation. It does illustrate, however, that vascular occlusion under moderate hypothermia is not always as safe and without danger as one might assume from some of the experimental work recorded.

Nevertheless, the advantages of hypothermia in protecting the brain against ischemia far outweigh the disadvantages. The use of hypothermia for this purpose should be encouraged. The venovenous-shunt method for rapid induction of hypothermia enlarges possible clinical applications because of the factor of promptness with which the protection can be obtained. Our program is to plan for early and rapid hypothermia in all clinical emergencies in which cerebral ischemia is a factor, including cerebral embolus, cerebral thrombosis, certain cases of head injury, and occlusion of major cerebral vessels.

**SUMMARY**

A venovenous-shunt method for rapid hypothermia in clinical cases is described in detail. Experiences in 18 neurosurgical cases have proved it to be a simple, inexpensive, safe, reliable, and precisely controlled method of producing hypothermia rapidly. The advantages appear to be:

1. **Rapid (20–50 minutes) production of hypothermia with consequent decrease in stress on the patient as well as on the operating team.**

2. **Precise control of the rate of production of hypothermia by preventing excessive divergence in declines of the cerebral, esophageal and rectal temperatures by altering the pumping rate or by changing the volume of the coil immersed in the ice-water bath.**

3. **Accurate level of hypothermia since no "overshoot" occurs when blood-cooling methods are used.**

4. **Minimal danger from embolus since the lungs can act as the filter for small emboli.**

5. **No need for use of anticoagulant because of the use of siliconed surfaces and the short duration of the shunting procedure.**

6. **Little effect on the volume of the patient's circulating blood since the shunt utilizes only 60 cc. of blood.**

7. **Relatively minor surgical set-up to establish the shunt.**

8. **Possibility of establishing the cooling shunt during craniotomy should the need for hypothermia become obvious at such a time.**

9. **No increase in fragility of red blood cells, since the pumping action is so short.**

10. **No apparent increase in cardiac complications as yet in spite of rapid cooling.**
REFERENCES


DISCUSSION*

Dr. Eben Alexander, Jr.: I want to raise a question since there will be subsequent papers that might touch on this point. There are patients with intracranial aneurysms who come in such poor condition that they are not suitable for surgery at the time, though they may be improved as time goes on and get to the point where we might consider them suitable surgical risks. This can be done in certain cases by cooling the patient. I would like to ask Dr. Bering under those circumstances this would be likely to increase their likelihood to bleed or is this bleeding he speaks of only that that would occur with surgical intervention, the bleeding you get at the time of opening the wound?

The movies that Dr. Thomas showed are certainly beautiful and this marked change in the pulsation of the veins, and particularly the arteries with assisted respiration, makes me wonder whether the paranoia many of us feel about what the anesthetist is doing to us might not really have some basis of fact. They do a lot of things under the table and they tell you that these drugs are good for the patient, and they probably are, but they may not know everything that is going on over the head of the table. In spite of the fact that in this case

* In addition to the foregoing papers by Drs. Gurdjian, Thomas and Webster, and by Drs. Foltz and Frederickson, another paper on hypothermia was presented at this meeting: "Studies on the physiology of hypothermia: effects of cooling on blood clotting," by Dr. Edgar A. Bering, Jr.
the cranium is closed, and there really isn’t any pulsation of the brain itself, nevertheless these major vascular changes are very impressive.

The discussion by Dr. Foltz is fascinating. I hope that this particular mechanism will be so simplified that all of us will be able to utilize it.

I noticed that you still had that old cooling blanket under the patient in spite of the fact that you had the apparatus. You must not have been absolutely sure of it at the time.

Still this appears to be a simple and effective method. There are many people still not using hypothermia because it is so complex or their cardiac surgeons have not taken it up.

I am sure that the real usefulness of this method in terms of all neurosurgery depends on the method becoming simple enough that it can be utilized without having to make such a major procedure out of it. This, of course, would be particularly applicable to those patients who had to be cooled quickly, even on the wards, where one might get their temperature down and maintain it by simpler methods at a later time.

I want to congratulate all of these men on their excellent papers; they have been of great interest to me personally.

Dr. William B. Scoville: I cannot resist adding a few words in the light of Dr. Alexander’s discussion. These are superb papers showing the complexities and joint problems in hypothermia between the anesthetist and the neurosurgeon. We must have neuroanesthetists, men specializing in the anesthesia of neurosurgical patients. Anesthesia, as roentgenology, has become too large a field to permit adequate progress in anesthesia in each surgical specialty when under the supervision of general anesthetists or “general” roentgenologists. The Cushing Society is now sufficiently large to sponsor the development of such new specialists and might well form a committee and registry for this purpose.

Dr. Edgar A. Bering, Jr.: Dr. Alexander, we have used hypothermia in patients with intracranial bleeding in order to help the surgeon, just as you describe. It has been in some of these patients that we have encountered trouble. The bleeding in these patients usually has been hematuria occurring about the 2nd or 3rd day of hypothermia. It may have been caused by trauma from the catheter, but we are not sure as we do not know whether the bleeding has been coming from the kidney or from the bladder. We have been unable to control it until the patients have been warmed up, when the bleeding has stopped spontaneously. It is probably fair to say that if the patient had the average concentration of constituents of the clotting mechanism in the blood and if the clotting time was measured at the patient’s temperature, it would be increased. This is important because if you take blood from a hypothermic patient and send it to the laboratory and they do their studies in a water bath at 37°C, they may easily get normal values. In order to measure what the state of affairs in the patient is, the tests must be done at the patient’s temperature.

I would like to ask Dr. Foltz one question which I may have missed in his discussion. What are the rates of flow through the pump?

Dr. W. James Gardner: I think that Dr. Foltz has described a very ingenious method of lowering temperature, but it appears to me that no method is more simple than immersing the patient in ice water. May I point out that any operating table, or any bed for that matter, can be converted into a tub very simply by a fence of plywood one foot high, the size and shape of the top of the operating table. Place a plastic sheet over the table, place the patient on the plastic sheet, lower the fence over the patient, drape the plastic sheet up and over the sides of the plywood fence, and you have a tub ready to be filled with ice and water. The only piece of apparatus needed is a suction pump or a siphon to remove the water when it is no longer needed. The plywood fence is then removed and the patient is readied for operation.

After operation, if active rewarming is desired, the tub may be reconstituted by replacing the plywood fence, bringing the plastic sheet over it and filling it with warm water.

Dr. Eldon L. Foltz: I would like first to emphasize the part Dr. Frederickson contributed to the development of this shunt. He is one of those rare anesthesiologists who has been work-
ing with the neurosurgeon and talks the same language. There are going to be neuroanesthesiologists and Dr. Frederickson represents the type we certainly should have. It has been a very revealing experience to me to work with him.

With regard to the use of the blanket, that “old blanket” which happened to creep into the picture was filched from the cardiac service. We put it into position at the start simply to avoid using ice packs or ice bags to prolong the hypothermia.

Hypothermia will last from 3 to 5 hours by this technique alone. There are some cases in which prolongation of the hypothermia is necessary. Having the blanket already in place makes this easy by using the blanket as an external cooling method. It also is useful for re-warming should re-warming be necessary.

We have another use for this blanket. It is kept in place occasionally for 3 days. Once a patient reaches his normal body temperature, there is a tendency in some to overshoot and go into hyperthermia. This is to be avoided. It can be very easily avoided by using the blanket at that time or by the use of ice bags.

I did not mention the cost; I may say that it is only $400 for the entire set-up. It is, we feel, a very simple device and can be instituted very rapidly, and our plans are to use it on the ward in those emergency cases in which the patient comes in with sudden hemiplegia caused by thrombosis or embolus.

In answer to Dr. Bering’s question, the one slide showed that the rate of pumping can be carried from 100 cc. a minute to 900 cc. a minute. Our usual rate is 500 cc. a minute since it is quieter at that rate and we can control the actual rate of decline in temperature by the amount of the coil immersed in the ice water. This is an empirical approach, as I mentioned.

In regard to Dr. Gardner’s remarks, I think his method is a simple one, but it still has the disadvantage of external cooling in that precise control of the level of hypothermia produced is lacking. The temperature will drift on down after cooling has stopped and no one is really sure where it is going to stop. Such an overshoot does not exist in blood-cooling methods. The temperature is dropped to the desired level and the shunt then is discontinued. The temperature does not drift up and down but stays at that level.