So much has already been said and written about hypothermia in the past decade that one hesitates to add yet another paper. The excuse for doing so is that our experimental and clinical work over the last 5 or 6 years has led to some practical results and conclusions which have greatly reduced the mortality and increased the usefulness of this technique.

There are so many occasions on which benefit can be seen from the lowered metabolism resulting from the reduction of the body temperature and so many cases where the ill effects of anoxia may be lessened by hypothermia, that we believe many cases must benefit from its application, provided the method of cooling is safe and readily controlled.

GENERAL CONSIDERATIONS

The principal advantages from cooling are:

1. Reduction in metabolic rate and a lowering of oxygen consumption to something in the order of 50% of normal at 30°C.
2. Reduction in cardiac output.
3. Reduction in clotting time, which may prove useful in cases of cardiac disease with polycythemia.

Our clinical experience has been predominantly in the surgical field, but hypothermia does also have important applications in other than surgical cases and its employment should be extended. In particular, we firmly believe that children are often most suitable subjects for this technique. Not infrequently one hears a physician doubting if an infant or small child should be subjected to the “stress” of hypothermia; the truth would appear to be just the opposite—that hypothermia, properly managed, actually protects against shock.

The principal cardiovascular operations performed under hypothermia in this center are: 1) Closure of interatrial septal defects of the secundum type; 2) pulmonary valvotomy; 3) aortic valvotomy. An analysis of the last 100 operations in this group shows an interesting relationship between age and survival. Of these cases, 52 were under the age of 16 years and showed a mortality rate of 9.6%; in contrast, 48 cases over the age of 16 years showed a
mortality rate of 25%. This difference in mortality is basically due to the difference in the state of the myocardium. The one great contraindication to the use of hypothermia is the existence of fibrosis of the myocardium, such as is seen in the acquired disease of the adult. This is not seen in the child—hence the added safety factor.

In addition, as in many other centers, hypothermia has more recently been combined with extracorporeal circulation with distinct advantage. The use of this technique has enabled us to employ much lower temperatures, which result in spontaneous cardiac arrest without the use of acetylcholine or potassium salts. It has also allowed us to study the condition of the cardiac muscle more fully under these conditions. Laboratory studies have been made with both human and rat atrial muscle. The muscle was suspended in Kreb's solution and the contractility studied under conditions of full oxygenation and of anoxia at temperatures of 37°C, 31°C and 25°C. Figure 1 shows the great difference in the performance of the muscle at various temperatures. Under conditions of full oxygenation there was a 30% decrease in the amplitude of contraction at the end of 3 hours at 37°C, whereas at 25°C there was actually a slight increase in amplitude. After periods of 2 and 4 hours of anoxia there was no change in contraction at 25°C, compared with very great changes at 37°C.

PRACTICAL CONSIDERATIONS

From a purely practical point of view we have revised our technique considerably in the last 2 or 3 years. There is no particular novelty about the methods; rather, we have found that results have been greatly improved by the simplification of something which was formerly regarded as a complicated procedure.

Here, very briefly, are some of the more important points in this regimen:

1. Surface cooling still has many advantages in speed and simplicity over other methods. Rapid cooling is in no
way detrimental to the patient and in some cases the body temperature has been reduced as much as 5°C in 10 minutes without any sign of disturbance.

2. The avoidance of shivering is of paramount importance, not only because it slows the process of cooling so much, but because it produces a very significant rise in metabolism. Shivering can be entirely avoided by the use of muscle relaxant drugs and chlorpromazine.

3. Digitalis. We have repeated the experimental work of Lombardo et al., confirmed it clinically, showing that the digitalized heart is much less irritable under hypothermia than the undigitalized. Full digitalization is, therefore, regarded as an essential part of the preoperative preparation.

4. The use of a mechanical respirator seems to be of considerable value. Not only does this insure good oxygenation but it also helps to preserve a reasonably constant pH of the blood. Conflicting views have been advanced concerning the dangers of respiratory acidosis or alkalosis in connection with the occurrence of cardiac arrhythmias during hypothermia, but we are impressed by the fact that the most important requirement is the avoidance of sudden changes in pH of the blood, rather than the pH level itself.

5. Wherever possible, the patient should be monitored with an electrocardiogram, for certain arrhythmias (such as nodal rhythm and QRS changes) occur frequently and are of little concern, whereas ventricular fibrillation and its precursors are most hazardous.

6. Vasoconstriction. We believe that little attention has been paid in the past to the problem of the intense peripheral vasoconstriction which occurs at lowered body temperatures especially in children. This vasoconstriction is so great that it may frequently be impossible to obtain the pulse or the blood pressure in the limbs, although it is obvious from the electrocardiographic monitoring that the heart is functioning well. This increase in peripheral resistance must inevitably add to the work of the heart and also delays the rewarming process. The treatment, which we have used with success on a number of occasions, is to reverse the process with a ganglion-blocking agent such as trimetaphen (Arfonad®) and to stimulate the myocardium with isoproterenol (Isuprel®) which in itself is also a vasodilator. Clinical trial is now being made of mephentermine (Wyamine®) which may well perform the dual function of peripheral vasodilatation and myocardial stimulation.

7. Ventricular fibrillation. Inevitably it is necessary to discuss ventricular fibrillation, since this was one of the greatest drawbacks to hypothermia in its early use. Our first aim is to avoid body temperatures below 30°C in the ordinary cases of hypothermia.

Of the many drugs suggested and tried, all have been abandoned except neostigmine (Prostigmine®). It is difficult to understand, on a purely pharmacologic basis, why neostigmine should be of any value. However, in practice it does seem to help and it seems probable that it is simply because it slows the heart and reduces the cardiac work. Therefore we use neostigmine to slow a fast heart, but do not use it if bradycardia already exists.

If ventricular fibrillation occurs, the treatment should be:

1. Massage to improve the myocardial blood flow.

2. Electrical defibrillation.

No drugs should be used at this point, though if defibrillation should produce actual cardiac standstill or only a weak organized beat, calcium chloride or isoproterenol may be of value. It is
interesting that, with this revised scheme for the management of hypothermia, ventricular fibrillation is now rarely seen.

8. Finally, it must be stressed that the effects of anesthetic agents and muscle relaxants are considerably prolonged at lowered body temperatures. The changes in the feeding patterns of infants whose temperatures have been reduced during surgery, as noted by Hackett et al., and other similar effects, are due to this prolonged action of the drugs employed and should be borne in mind in all cases where hypothermia is used.

USES OF HYPOTHERMIA IN CONDITIONS OTHER THAN SURGICAL

All the clinical and experimental work that has been done on this subject, mainly for surgical procedures, has resulted in a much safer technique which may now easily be applied to nonsurgical problems. It is obvious that a febrile child may frequently benefit from cooling; it is not so well recognized, however, that the application of cold itself is going to be of little value unless precautions are taken to avoid shivering. This can be done by the use of chlorpromazine, promethazine or the muscle relaxants. In particular we believe that the use of moderate hypothermia in the immediate postoperative period can be of considerable benefit.

One important effect of cooling, without shivering, is to lower the cerebrospinal fluid pressure and reduce brain volume. This can be of considerable value in cases of neurosurgical disorders, in which circumstances we are using it more and more. It has certainly contributed on several occasions to the salvaging of children after cardiac arrest; it is noticeable that after cardiac arrest the body temperature is usually several degrees below normal, and that if circulation is successfully re-established there is frequently a reactionary hyperthermia. However, if surface cooling is immediately instituted, the patient's temperature may be kept at a low level very easily, with excellent results. A recent report confirms this observation.

The severely cyanotic child, e.g., in the tetrad of Fallot, has been shown to benefit from hypothermia. Here it may be impossible to improve the oxygenation, no matter how high the concentration of oxygen administered. It seems logical, therefore, to combat the problem by producing a state in which the oxygen demands of the tissues are less—and this situation can be produced by hypothermia. On the basis of this experience it has seemed for some time that many newborn infants in a state of asphyxia should benefit from intentional cooling, rather than warming. Some particularly interesting work along these lines has been done by the Drs. Faith and James Miller at Emory University, who have shown that young animals, in which the body temperature has been drastically reduced, can survive periods of anoxia 6 to 7 times longer than the ordinary lethal period. They have also recently revived several infants with neonatal asphyxia pallida, who had failed to respond to all other forms of treatment.

The whole problem of the optimum body temperature in the treatment of shock would seem to merit more investigation, though it is almost certain that strict attention must be paid to the problem of peripheral vasoconstriction, which appears to be a very detrimental factor in both the hypothermic state and severe shock.

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