HYPOTHERMIA FOR ADULT CARDIOVASCULAR SURGERY: A TECHNIQUE OF ANAESTHESIA

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AT THE TORONTO GENERAL HOSPITAL various methods of anaesthesia have been used in association with hypothermia for adult cardiovascular surgery. However, as one became increasingly aware of the dangers of metabolic acidosis (1) and noted the clinical picture of acute rewarming acidosis (2), it was necessary to introduce a technique, designed to maintain the acid-base balance within normal limits. The problems of this acid-base relationship are discussed, in detail, elsewhere (2)—the sole purpose of this communication being to outline one technique which has proved most satisfactory in a wide variety of adult cardiovascular cases, with and without circulatory occlusion.

This technique is intended to achieve the following.

1. Maintenance of some degree of ventilatory constancy, in such a way as to hold the blood pH between 7.35 and 7.45 units. The coincident presence of metabolic acidosis and respiratory alkalosis would give such pH values, but the resulting reduction in available base is to be avoided. Consequently, an attempt is made to prevent the production of acid metabolites by
2. Avoiding shivering.
3. Maintaining some degree of peripheral vasodilatation
4. Careful replacement of blood loss.

TECHNIQUE

Premedication

On the evening before operation, promethazine 100 mgm. is given, orally

On the day of operation, chlorpromazine 50 mgm. and promethazine 50 mgm are given intramuscularly, one hour before operation. This is reduced by one-half in diminutive patients.

Induction

The patient is brought to the operating room, drowsy, where a sample of venous blood is taken to establish the preoperative pH level. Measurements are made, in the operating room suite, with a Beckman glass electrode pH meter and results are available within five minutes of sampling.

An intravenous infusion of 250 ml 5 per cent dextrose in water is started. This contains 50 mgm. each of chlorpromazine, promethazine, and meperidine and is

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run in over a twenty- to thirty-minute period. It is stopped earlier if the eyelash reflex is abolished. For nearly every patient, a face piece may be used to give nitrous-oxide : oxygen 4L/2L (for two or three minutes, to confirm complete anaesthesia); but, for the occasional resistant patient, minimal thiopentone sodium will be necessary. Intubation, with a large cuffed endotracheal tube, is carried out under suxamethonium 50 mgm.

Maintenance

The endotracheal tube is attached to a positive-negative phase (Jefferson) ventilator, through a to-and-fro system. Nitrous-oxide : oxygen is given in a flow varying from 3L/3L per min. to 3L/1L per min. Soda lime may or may not be used, as will be discussed later.

On the resumption of spontaneous respiration, d-tubocurarine 18 mgm. is given.

The patient is placed on the pre-cooled bottom Thermorite blanket (3), E.C.G. leads are attached and rectal and oesophageal thermocouple leads inserted.

An intravenous infusion of 5 per cent dextrose in water is started, in one arm, through a no. 15 S.W.G. needle and a no. 17 S.W.G. needle is inserted into the external jugular vein and connected to a small bottle of 5 per cent dextrose in water, through a three-way stopcock. This is of value (a) for inserting drugs intermittently and (b) for sampling blood for pH values.

The practice has been to obtain arterial blood samples from the radial artery, using a Cournand needle inserted blindly. In right-handed people, this is inserted in the left radial artery, provided there is a palpable ulnar pulse. The only trouble encountered has been that of keeping the needle in the artery—especially in the recovery period. Because of this, the current preference is for a modification of the Seldinger technique (11) of sampling from the brachial artery. It is, of course, simpler to perform percutaneous vascular cannulations before cooling starts.

The patient is covered with crushed ice (the wetting effect making this superior to ice bags) and the top Thermorite blanket put in place. A minimal anti-Trendelenburg tilt is used, to allow melting ice to drop into a container at the lower end of the table. The blankets are covered with a white sheet to prevent temperature changes by radiation.

Fluctuations in room temperature influence the cooling rate markedly. For this reason, thermostatically controlled air conditioning is of value.

The top blanket is removed when the patient's temperature is a few degrees above the desired optimum temperature (for example, at 33°C for 29°C.) and the operation is commenced. By the time the heart is exposed, a further temperature drop, or drift, will have occurred. It is noted that the oesophageal temperature tends to change before the rectal reading (5), although this may differ in patients with septal defects. Thus, if the oesophageal temperature is lower,

further drift will probably occur. The difference between the oesophageal and rectal temperatures, speed of cooling, and size of patient are factors which are considered to be indications of the amount of drift to be expected.

If shivering occurs in the first thirty to forty-five minutes on the blanket (easily noted on the E C G oscilloscope), more d-tubocurarine is given. After that, shivering is taken as an indication for further chlorpromazine. Large doses of chlorpromazine are thus avoided, at the unstable time of induction. Difficulty in inflation or attempted respiration is taken as an indication for further d-tubocurarine, although the stimulus to respiration of arrest of the cerebral circulation should be remembered if sudden gasping respiratory efforts occur when a patient is in the higher temperature ranges.

Prior to circulatory occlusion, 100 per cent oxygen is given for a few minutes. During occlusion, gross pupillary dilatation occurs and no further nitrous-oxide is given until this is reversed and the patient shows some reflex movement—a sign of viability of the C N S. This stage is usually reached within one to fifteen minutes of restoring normal circulation, the pupils constricting first. Commonly, the next change noted is the return of spontaneous respiratory movements, which may be abolished with 50 per cent nitrous-oxide, in many instances!

Virtue describes pupillary dilatation throughout hypothermia (6), but this has not been observed in using this technique, the lowest temperatures (rectal) reached being above 28°C.

After the period of occlusion, the fluid in the bottom blanket is rewarmed by turning on the pump, the fluid in the Thermorite unit having been rewarming during the first part of the operation.

Ventilation

The tendency to produce respiratory alkalosis with controlled respiration (7) is avoided by adjusting (i) the presence or absence of soda lime in the circuit and (ii) the total flow of gases. It is found that, in a young adult with healthy lungs, no soda lime will be necessary at all and the flow may have to be reduced to 4L per min. In the more elderly patient, soda lime may be necessary to maintain a normal blood pH level. While clinical assessment is of considerable value in judging the ventilatory circumstances which will be required at the outset, adjustment is made, during the operation, according to the blood pH values obtained. The respiratory rate is kept constant.

With regard to the Jefferson ventilator, it is felt that it is preferable to use this apparatus with a to-and-fro system, thus reducing the elasticity to about one-third of that in a circle-type circuit. As a result, hypoventilation is less likely to occur.

At the end of operation, spontaneous respiration is permitted as soon as the chest is closed, the patient then being better equipped to control his own acid-base balance. An anti-cholinesterase is given routinely, since sub-clinical residual curarisation may prevent the necessary hyperventilatory response to the produc-

tion of acid metabolites (2). In this connection, it is noted¹ that the increased "vagotonia" of hypothermia potentiates the parasympathomimetic effects of the anti-cholinesterases. Consequently, greater doses of atropine than usual should be given. Severe bradycardia has been seen even after giving edrephonium.

Heart Action

Fibrillation Auricular fibrillation has been observed in some cases. Should this produce an immediate rise in heart rate, the resulting cardiac inefficiency may cause a fall in blood pressure. The sequence, normal blood pressure—auricular fibrillation with tachycardia—hypotension—ventricular fibrillation, has been observed and it is recommended that, if auricular fibrillation occurs with an associated tachycardia and hypotension, this be considered an emergency situation. Ouabaine 0.25–0.5 mgm is given intravenously. On occasions when this has been done, ventricular fibrillation has not followed the auricular arrhythmia—which may even revert to sinus rhythm. The advantages of this drug's quick, short-acting effect offset the possible disadvantage of the action of digitalis glycosides on the excitability of the myocardium. This opinion is based on the belief that myocardial ischaemia is the chief cause of ventricular fibrillation and that other factors are of secondary importance. Acetyl strophanthidine has not been used in these circumstances but may prove even more applicable.

In this centre, blood pH during cooling and operation has usually been maintained at normal levels, or above, and ventricular fibrillation has only occurred at such levels. Thus, having no clinical experience of ventricular fibrillation in association with acidosis (except as a terminal event in the acute acidotic syndrome of rewarming), no opinion can be given about the need for hyperventilation as an anti-fibrillatory measure. The current view is merely that *adequate* ventilation is all that is required.

Bradycardia Lowering the body temperature results, classically, in a fall in heart rate. This is seen in clinical hypothermia and is disregarded unless there is an associated hypotension. Should the two occur together, atropine 0.2 mgm is given intravenously and is very frequently effective.

It is not accepted that hypotension is a necessary accompaniment of clinical hypothermia. On the contrary, it is felt that it is to be avoided, as one of the main causes of complications arising during the procedure.

REWARMING PERIOD

The patient is dried and placed in bed with hot-water bottles (maximum temperature 100°F). The endotracheal tube is left *in situ* until the patient begins stirring or coughing on it. Oxygen is given, either through this or, after its removal, by nasal catheter. Shivering is an immediate and urgent indication for

chlorpromazine (25 mgm. I.V.), which will probably have to be repeated. Occasionally, a patient will be awake and shivering and complaining of pain. Shivering and complaint of pain is an indication for meperidine (25 mgm. I.V.), *not* further chlorpromazine, which will only result in prolonged depression, as the complaint of pain will continue and the meperidine will be required in addition. These patients all having had chlorpromazine before, it seems that meperidine alone is sometimes effective in abolishing shivering coincidentally to its use as an analgesic

The pH is determined at intervals and an initial fall in pH is the constant pattern. This does not usually go below 7.25 and, once it has started to rise again and the patient is awake and breathing well, he may be handed over to a special postoperative nurse with instructions to give chlorpromazine (25 mgm.) intravenously, and to call someone immediately should shivering occur. It is not desirable to return patients to the ward under 34°–35°C. and no special nurse has yet had to give chlorpromazine

Should the acute acidotic syndrome develop, the immediate treatment is (1) a large dose of muscle relaxant—it is possible that succinylcholine is inadvisable in the presence of the vagotonia of hypothermia and decamethonium (5 mgm.) is preferred, (11) vigorous hyperventilation. Intravenous bicarbonate may be necessary (2)

DISCUSSION

Dundee has demonstrated the value of chlorpromazine in aiding cooling (8) and Gray has described its use in nine cardiovascular cases (9). Code Smith finds the "lytic cocktail" safe in paediatric cardiovascular surgery (10).

The technique used by Vandewater for neurosurgery (11) provides pH levels within normal limits throughout cooling, operation, and rewarming period, using spontaneous respiration (12) with a chlorpromazine mixture

The method outlined above has been used for several patients in whom a fall in peripheral resistance might be considered serious. No gross hypotension or tachycardia has been encountered. A stable heart rate and blood pressure throughout the procedure has been the rule. The only exception has been the period of occlusion, after which a quick return of blood pressure has been observed.

The main objection to the technique has been the added difficulty of the inefficacy of adrenaline as a cardiac resuscitating agent. However, calcium chloride has been used as a means of restoring myocardial tone and, with the present confusion as to the relative merits of these two drugs, the seriousness of this disadvantage cannot be assessed

Using d-tubocurarine and chlorpromazine during the operation, the level of central depression is not so great as to make it impossible to assess the reflex response, etc., should a cardiac emergency arise during the operation. The avoidance of thiopentone, when possible, and the low dosage of meperidine may account for this somewhat unexpected asset

In the attempt to avoid respiratory alkalosis, it is of importance to note that hyperventilation with, say, 5 per cent carbon dioxide would prevent a fall in alveolar CO_2 much below the normal 5.6 per cent and maintain the arterial CO_2 tension at a constant level. However, if a patient's ventilating mechanism is pathological (for example, emphysematous), this could result in respiratory acidosis. Thus, the *routine* use of 5 per cent CO_2 with hyperventilation, as a means of avoiding respiratory alkalosis, is, possibly, ill advised in adults. Hence the use of the technique of ventilation described. Tidal volumes based on the Radford nomogram (13), which is dependent upon body weight and respiratory rate, cannot be utilized since this does not take into account the possibility of pathological pulmonary variations. Experience with this method of controlling ventilation has shown that great variations may be necessary from patient to patient.

It will be appreciated that, during hypothermia, a constantly varying situation exists with regard to acid-base balance. Of necessity, one is destroying the patient's means of moment-to-moment adjustment by controlling the respiration. Herein lies the essential difference between the circumstances attending anaesthesia for neurosurgery and those attending anaesthesia for cardiovascular surgery. Whereas the neurosurgical patient may control his own balance, the patient with controlled respiration requires frequent assessment as to how this balance is proceeding. Intermittent blood pH readings are the best single indication but do not distinguish metabolic from respiratory factors. This may be done by measuring alveolar CO_2 levels in addition, or, in view of the frequent presence of some degree of error (for example, difficult sampling or right to left shunt), the more time-consuming and, therefore, less available total blood CO_2 or bicarbonate levels.

Abdominal aortic surgery For patients requiring abdominal aortic occlusion, proximal to the renal vessels a similar technique is used. However, greater doses of chlorpromazine, promethazine, and meperidine are necessary. On removing the abdominal aortic clamps, a further temperature drop is to be expected, presumably owing to the return of cold blood from the relatively static circulation in the legs.

In conclusion, it is pointed out that, although clinical hypothermia has been in use for some years, the continued collection of experimental data renders the clinical techniques subject to frequent readjustment.

SUMMARY

A detailed description and discussion is given of the anaesthetic and hypothermia technique currently in use at the Toronto General Hospital for cardiovascular surgery. It is aimed at avoiding acid-base imbalance and the resulting acute acidotic syndrome of rewarming. The monitoring of the acid-base balance is briefly discussed.

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RÉSUMÉ

Cet article donne une description détaillée de la technique d'anesthésie avec hypothermie, employée couramment au cours de la chirurgie cardiovasculaire à l'hôpital Toronto General

Dans la littérature, pour faciliter le refroidissement, on a conseillé des mélanges contenant de la chlorpromazine et on a fait une mise en garde contre les dangers de l'acidose métabolique

Avec la technique que nous préconisons actuellement, nous employons de la chlorpromazine, de la prométhazine et de la mépéridine dans le but de maintenir dans le sang une concentration normale et uniforme en ions Hydrogène et d'éviter aussi, au moment du réchauffement, le syndrome de l'acidose aiguë

Le maintien de l'anesthésie se fait par le protoxide d'azote et l'oxygène et, à l'aide d'un ventilateur automatique et de l'usage intermittent de D-tubocurarine, nous contrôlons les échanges respiratoires. Nous ajustons ces échanges de façon à éviter l'alcalose respiratoire durant le refroidissement aussi bien que durant l'opération

Nous donnons, en détail, les avantages et les désavantages de cette technique. Le principal inconvénient réside dans l'action anti-adréalinique de la chlorpromazine. Cela diminue la valeur de l'adrénaline dans l'occurrence d'insuffisance cardiaque

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