INDUCED HYPOTENSION IN ORTHOPAEDIC SURGERY

Hexamethonium Bromide (C₆) in 407 Orthopaedic Operations

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Since Enderby (1950) first described the use of pentamethonium for a temporary reduction of blood pressure in order to prevent excessive bleeding during surgical operations, only one report of the application of methonium compounds in orthopaedic surgery has appeared (Steven and Tovell 1954). A review of figures concerning blood loss and post-anaesthetic progress in 407 operations performed with the aid of hexamethonium bromide may therefore be of interest. The period under review is the first four years of its use at the Orthopaedic Department, Royal Infirmary, Edinburgh.

**TABLE I**

**NATURE OF OPERATION**

<table>
<thead>
<tr>
<th>Region</th>
<th>Operation</th>
<th>Number</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip</td>
<td>Femoral head replacement</td>
<td>177</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cup arthroplasty</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fusion</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Disarticulation</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Girdlestone</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hindquarter amputation</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Acrylic replacement of upper third femur</td>
<td>1</td>
<td>266</td>
</tr>
<tr>
<td>Femur</td>
<td>Plating, bone graft, etc.</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intramedullary nail</td>
<td>13</td>
<td>32</td>
</tr>
<tr>
<td>Shoulder</td>
<td>For recurrent dislocation</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fusion</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Acrylic replacement of upper third humerus</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Disarticulation</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Miscellaneous</td>
<td>7</td>
<td>38</td>
</tr>
<tr>
<td>Humerus</td>
<td>Open reduction upper end</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intramedullary nail</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Spine</td>
<td>Fusion</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Excision of sacrum</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Miscellaneous</td>
<td>2</td>
<td>63</td>
</tr>
<tr>
<td>Total</td>
<td>Number of operations</td>
<td></td>
<td>407</td>
</tr>
</tbody>
</table>

The reason for inducing hypotension was to prevent the considerable loss of blood commonly associated with certain orthopaedic operations which tends to make their execution difficult and may be a risk to the patient. Ischaemia of the surgical wound was achieved by lowering the arterial and pulse pressures by ganglionic blockade and elevating the part to be operated upon so that, as far as possible, it was higher than the rest of the body. Regions such as the lower limbs, which are most capable of storing the blood drained from the field of operation, must be in a dependent position. The lungs can store large quantities of blood but they are not suitable for this purpose because pulmonary engorgement greatly reduces vital capacity.

Types of operation and sex and age distribution of the patients are detailed in Tables I and II.
**Dosage of hexamethonium bromide**—The dose most frequently used in this series was 50 milligrams. This was reduced in the old and frail, in patients who had undergone prolonged immobilisation, and when unfavourable postures were planned. A number of patients required up to 100 milligrams, but this was rarely exceeded and 150 milligrams was the largest dose employed. It should be remembered that less hexamethonium bromide will be required to produce an adequate degree of hypotension in a deeply anaesthetised patient than in one under light anaesthesia.

Once ganglionic blockade was established, it was found that further administrations prolonged rather than intensified hypotension. The duration of depression of systolic pressure below 80 millimetres Hg. varied between 10 and 120 minutes but was most commonly in the order of sixty minutes. The time that elapsed before blood pressures returned to the pre-operative level was usually between six and twenty-four hours, being longer in previously hypertensive patients.

In most cases the systolic pressure fell to between 50 and 65 millimetres Hg., while diastolic pressure was often difficult to assess accurately. It was necessary to lower the systolic pressure to about 65 millimetres Hg. before a good ischaemic result was obtained, except in old patients in whom a pressure of between 70 and 80 millimetres Hg. at times produced satisfactory operating conditions. Vasomotor resistance to hexamethonium bromide was met in a few cases but was not, as has been claimed, confined to the young. On occasions, systolic pressures of between 20 and 40 millimetres Hg. were observed, but while a safe posture and adequate tissue oxygenation obtained, no adverse effects on the patient were noted.

**BLOOD TRANSFUSION**

Table III indicates the total amount of blood transfused in the series under review. It will be noted that one patient was given 15 milligrams of methylamphetamine hydrochloride (methedrine) during operation. This was done by an assistant who had taken over supervision for a time and considered the blood pressure too low, though in all other respects the patient's condition was satisfactory. The injection was followed by haemorrhage requiring transfusion of one litre of blood.

Table IV shows the average amounts of blood transfused in two groups of patients undergoing comparable operations, one with induced hypotension (author's series) and one
without (Kern 1952). The difference is less considerable in the cases of arthrodesis mainly because a number of these procedures were carried out in the supine position, which does not favour the draining of blood from the surgical site. Fairly typical is the record of a man, aged seventy, who suffered from osteoarthritis of both hips. His general condition was good and his blood pressure 150/90 millimetres Hg. When the left femoral head was being replaced by an acrylic prosthesis hypotension was not induced, bleeding was considerable and 1,080 millilitres of blood had to be transfused. Five months later a similar procedure was carried out on the right side and on this occasion hypotension was induced with 50 milligrams hexamethonium bromide. Blood loss was less than 50 millilitres and post-operative progress uneventful.

### TABLE III
**Blood Transfusion in 407 Cases of Induced Hypotension with Hexamethonium Bromide**

<table>
<thead>
<tr>
<th>Indications</th>
<th>Number of cases</th>
<th>Quantity per case (millilitres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low pre-operative haemoglobin</td>
<td>6</td>
<td>540</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1080</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3240</td>
</tr>
<tr>
<td>Blood loss from:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Inadequate reduction of B.P.</td>
<td>5</td>
<td>540</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1080</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1620</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2700</td>
</tr>
<tr>
<td>(b) Insufficient elevation of site</td>
<td>1</td>
<td>540</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1080</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2160</td>
</tr>
<tr>
<td>(c) Methylamphetamine hydrochloride during operation</td>
<td>1</td>
<td>1080</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1620</td>
</tr>
<tr>
<td>Prophylactic in extensive operations</td>
<td>3</td>
<td>540</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1080</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1620</td>
</tr>
<tr>
<td>Reactionary haemorrhage</td>
<td>9</td>
<td>540</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1080</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4860</td>
</tr>
<tr>
<td>None</td>
<td>370</td>
<td>None</td>
</tr>
<tr>
<td>Total</td>
<td>407</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td>28,620</td>
</tr>
</tbody>
</table>

**MORBIDITY**

**Reactionary haemorrhage**—Table III shows that there were twelve cases of reactionary bleeding which required replacement of blood. Some surgeons have gained the impression that the incidence of post-operative haematoma has been higher in this series than after similar procedures performed without ganglionic blockade. However, accurate records of this complication in a control series are not available and a reliable comparison is therefore not possible. Avoidance of reactionary bleeding after operations carried out with the aid of induced hypotension will depend on: 1) meticulous haemostasis at operation; 2) gradual rise of blood pressure (if vasopressor drugs are required, they should be used in small doses); and 3) pressure-bandaging after operation.

**Meteorism**—Meteorism, the commonest post-operative complication in the series, occurred after twenty-six of 266 operations on the hip and after eight of fifty-eight spinal fusions; it was not observed after other procedures. Its incidence was limited to patients who were immobilised in the supine position after operation. In six of the thirty-four cases the condition was severe and took six or more days to respond to treatment by drip and gastric suction;
in the remaining twenty-eight the meteorism was moderate in degree and in four or five days it was corrected by flatus enema and occasionally by sympathomimetic drugs.

Kern (1952) did not report any meteorism in the comparable operations of his series which were performed without induced hypotension and the question therefore arises whether in the cases under review hexamethonium may have been a causal factor. The likelihood of this is supported by the observations of Kay and Smith (1950, 1951) and of Douthwaite and Thorne (1951), who noted in patients given hexamethonium bromide delayed emptying and diminished peristalsis of the stomach and dilatation and immobility of the duodenum and upper jejunum, lasting about six hours. On the other hand, reports of the use of this drug during various surgical interventions other than operations on the spinal column and hip joint contain no record of meteorism or ileus.

The incidence of meteorism is known to be high in patients nursed in a posterior plaster shell or hip spica, and Professor Norman Dott (1955) advises turning of the patient as a cure. The explanation of this predisposition is that in the supine posture the third part of the duodenum is readily obstructed by the overlying root of the mesentery, particularly when the small gut is full. Since the end of the period under review four patients have developed meteorism but improved promptly after being placed in the prone position.

TABLE IV

<table>
<thead>
<tr>
<th>Operation</th>
<th>336 cases without induced hypotension (Kern)</th>
<th>262 cases with induced hypotension (Holmes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral head replacement</td>
<td>743 millilitres (179 cases)</td>
<td>27 millilitres (177 cases)</td>
</tr>
<tr>
<td>Cup arthroplasty</td>
<td>945 millilitres (106 cases)</td>
<td>48 millilitres (45 cases)</td>
</tr>
<tr>
<td>Arthrodesis</td>
<td>770 millilitres (49 cases)</td>
<td>102 millilitres (37 cases)</td>
</tr>
<tr>
<td>Disarticulation</td>
<td>2650 millilitres (2 cases)</td>
<td>180 millilitres (3 cases)</td>
</tr>
</tbody>
</table>

Thrombophlebitis and pulmonary infarction—Eleven cases of thrombophlebitis, six of which led to pulmonary infarction, occurred in this series. One additional case of infarction exhibited no previous signs of venous thrombosis. Six of these seven patients had only moderate symptoms; the remaining one suffered a massive fatal embolus.

A period of very low blood pressure may be thought to predispose to venous thrombosis, but a comparison of the incidence in the present series and that of Kern (1952) does not suggest this (Table V). It may be of interest to mention the case of one patient, a man aged forty-three, who suffered from osteoarthritis of both hips. Acrylic replacement of the right femoral head was carried out without induced hypotension at another hospital. Severe thrombophlebitis of the contra-lateral leg developed with pain and swelling, the latter lasting many weeks. After a similar operation on the left side nine months later with the aid of C₆ no thrombosis or other complication supervened though there was still some residual swelling of the left leg dating from the thrombophlebitis which followed the first operation. Table V includes only eight cases of thrombophlebitis and six of infarction, the other three cases being excluded because they occurred after spinal fusion, an operation that does not figure in Kern's series.

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Thrombophlebitis frequently follows operations on the hip joint and femur. However, the difference in incidence between the comparable series, shown in Table V, recalls the possibility that intravenous transfusion may be responsible for initiating venous thrombosis. Post-operative mental confusion—This complication was observed in nine patients, all over seventy years of age. Each had a pre-operative history of periodic confusion occurring particularly at night. Six recovered completely and in one the condition was more marked after operation. The remaining two patients died of congestive cardiac failure. In one, confusion began thirteen days after operation, which makes it unlikely that the period of induced hypotension was responsible in this case. It is believed that a pre-operative history of confusion and disorientation or cerebral thrombosis should be regarded as a contra-indication to the use of hexamethonium bromide.

Retention of urine—Difficulty of micturition to a varying degree was experienced by twenty-five patients. In twelve it followed the operation of spinal fusion. Furthermore, only the patients who were nursed in a posterior shell were affected and females more often than males. It appears that retention was due to posture rather than the use of any particular drug. After operations other than spinal fusion the incidence was about 3 per cent.

<table>
<thead>
<tr>
<th></th>
<th>After 395 operations on hip and femur without induced hypotension (Kern)</th>
<th>After 298 operations on hip and femur with induced hypotension (Holmes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thrombophlebitis</td>
<td>48 (12%)</td>
<td>8 (under 3%)</td>
</tr>
<tr>
<td>Pulmonary infarction</td>
<td>14 (3 died)</td>
<td>6 (1 died)</td>
</tr>
</tbody>
</table>

Mortality

Total mortality for this series was ten (2.5 per cent). Six patients, three men and three women, died of congestive cardiac failure. Their ages ranged from sixty-five to eighty-two years, all had had operations on the hip joint and all suffered before operation from some degree of myocardial degeneration and pulmonary congestion. Death occurred at four to thirty days after operation. It has been suggested that hexamethonium bromide may be responsible for precipitating congestive cardiac failure in this type of patient. However, the work of Kelley et al. (1953) and of Burch (1955) indicates that $C_b$ has a beneficial effect by reducing venous pressure markedly and effecting an “impressive improvement” in the clinical picture in cases of established congestive failure. A recent study by Bromage (1956) shows that hypotension induced by ganglion-blocking drugs or sympathetic blockade increases vital capacity considerably in patients suffering from pulmonary congestion.

One patient, a woman of seventy-four, died of cerebral thrombosis forty-three days after femoral head replacement, and another, a man of sixty-five, died of a massive pulmonary embolus on the eleventh day after cup arthroplasty.

The remaining two deaths exhibit some unusual features:

Case 1—A woman aged thirty-three suffered from paraplegia from a pathological fracture of the body of the twelfth thoracic vertebra. The patient’s general condition was good and before developing paraplegia she had had no complaints. The blood pressure, observed on a number of occasions, was 140/90 millimetres Hg. Laminectomy was proposed and anaesthesia was induced with 750 milligrams thiopentone and 10 milligrams d-tubocurarine chloride. A cuffed orotracheal tube was inserted and nitrous oxide, oxygen and cyclopropane administered. After the patient was placed in the prone position her blood pressure was 150/100 millimetres Hg. This was considered unusual
as in most subjects thiopentone produces a fall in blood pressure, but, in the absence of any alarming
signs, 40 milligrams hexamethonium bromide were injected. After about two minutes, while skin
preparation was proceeding, the patient's face became deeply congested as if due to spasm of the
larynx or bronchi. While the airway was being checked congestion gave way to an ashen grey colour
and neither pulse nor heart sounds could be elicited.

Post-mortem examination revealed a malignant phaeochromocytoma extending into the body of
the twelfth thoracic vertebra, which had collapsed. Though the circulatory phenomena associated
with benign phaeochromocytoma are not always present in the malignant variety, the pathologist
stated that the findings in this case were consistent with the patient's having died in hypertensive
crisis. Ganglionic blockade cannot prevent the hypertension which is related to the release of secretion
from a phaeochromocytoma.

Case 2—This patient, a small, thin woman, sixty-three years of age, had pleural friction at the base
of the left lung but no respiratory disability. Radiological examination revealed pleural thickening.
She had been bedridden for over six months, but her general condition was fair and her blood pressure
135/90 millimetres Hg. With the patient in the lateral horizontal position femoral head replacement
by an acrylic prosthesis was performed under general anaesthesia and hypotension induced with
40 milligrams hexamethonium bromide. The systolic pressure fell to 30 millimetres Hg, but had
returned to 100/70 millimetres Hg an hour after the end of the operation without resort to vasopressor
drugs. Loss of blood was negligible and post-operative progress was satisfactory apart from a slight
rise in temperature, coupled with an increase of the pleural friction at the base of the left lung for a
few days.

One month later disarticulation at the right hip was carried out. Anaesthesia, as for
the previous operation, was induced with 400 milligrams thiopentone and continued with nitrous oxide
and oxygen with the addition of small quantities of cyclopropane. The patient was placed in a supine
"jack-knife" position with a sandbag under the right hip and loin. The break in the table was
approximately 15 degrees from the horizontal in its upper and 45 degrees in its lower half. The blood
pressure was now 100/70 millimetres Hg. and 30 milligrams hexamethonium bromide were injected.
Systolic pressure fell to about 40 millimetres Hg. and loss of blood was less than 20 millilitres. The
right leg was elevated before ligation of the great vessels in order to return as much blood as possible
to the general circulation. The operation was completed in seventy minutes.

The patient was moved from the operating table to her bed in the recovery room, placed in a
5 degrees Trendelenburg position and given oxygen. The systolic pressure was then 60 millimetres Hg.
but twenty minutes later it had risen to 75 millimetres Hg. and the pulse rate was 88 per minute.
She was awake and her colour and capillary circulation were good. Thirty minutes after the end of
operation the systolic pressure fell to 65 millimetres Hg. A post-operative fall of blood pressure is
always regarded as a grave sign and 5 milligrams methamphetamine hydrochloride were injected. This
produced no result and was repeated, again without effect. Blood transfusion was now started twenty
minutes after the drop in blood pressure was first observed, 540 millilitres being given in fifteen minutes.
In spite of these measures systolic pressure could not be raised. Since the loss of blood during operation
had been negligible and no improvement was obtained by rapid transfusion, further intravenous
therapy was thought to be contra-indicated. During the next twelve hours the pulse varied in rate
between 68 and 80 per minute, was regular in time and force and easily palpable, and systolic pressure
fluctuated between 40 and 60 millimetres Hg. The skin was dry and warm, the colour good and
cerebration normal. Thereafter the pulse rate increased steadily and systolic pressure declined further
in spite of repeated injections of methamphetamine hydrochloride and continued administration of
oxygen. At this stage a rapid intravenous infusion of Dextran was given but after about 150
millilitres it was found that the systolic pressure had fallen further and the infusion was therefore
discontinued. Just before death, seventeen hours after operation, the pulse rate was 120 per minute
and systolic pressure 20 millimetres Hg., the latter being taken by palpation without difficulty. The
patient was conscious, her colour good and respiration normal until the end.

The post-mortem examination gave no evidence as to why this patient had failed to regain
vasomotor control after an operation carried out under hypotension induced with hexamethonium
bromide, though the use of a similar technique on her a month earlier had been uneventful. No
deterioration in her circulation was observed during the period between the two operations and there
was no evidence that her blood volume had been unduly disturbed during the last operation. Yet,
this patient died in irreversible shock.

The one factor that differed materially in the two procedures was posture. There can be
little doubt that the position adopted on the latter occasion must have impaired circulation,
particularly as the patient's legs had been allowed to hang too steeply. The first thought
which comes to mind is that the interference with venous return had produced a serious

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reduction of cardiac output, but if this had been so one might have expected a circulatory emergency during operation. In fact, systolic pressure had fallen to a lower level during the first procedure.

There remain two further considerations: 1) The pronounced "jack-knife" position with elevation of the right loin, coupled with hypotension of a marked degree, is likely to have caused a reduction of blood flow through the liver. Though the theory first advanced by Shorr et al. (1945) that liver ischaemia leads to the release of vasodepressor material (VDM) and the production of irreversible shock has recently been discounted (Frank et al. 1952, Zweifach and Metz 1955), one feels that an inadequate hepatic circulation over a period of seventy minutes could cause serious metabolic abnormalities. 2) Tilt-table experiments by Deitrick et al. (1948) on normal healthy volunteers showed that continued immobilisation produces a marked deterioration of vasomotor efficiency and these changes were noted to begin within a week of enforced rest. The patient under discussion had been in bed for over seven months and it is thought that if prolonged immobilisation had been solely responsible for circulatory failure, the latter would have occurred as a result of the first operation.

It is suggested that the unfavourable posture adopted during the second procedure, combined with ganglionic blockade in a patient with an already impaired vasomotor efficiency, initiated irreversible shock.

DISCUSSION

The figures in Tables III and IV show that induced hypotension can effect a considerable saving of blood. Surgeons generally agree that operating conditions are improved and the duration of operation shortened. But it will be asked: "Are these advantages not obtained at an unjustifiable risk to the patient?" Experience in some 600 cases, including the group presented here, has shown that this technique can be safe provided certain safeguards are observed scrupulously. A reduction of arterial pressure will lower cardiac output, but as long as an adequate flow of fully oxygenated blood is maintained through the vital organs, this departure from the physiological norm has been shown to be within the limits of safety.

The following points must be carefully considered:

Posture—The patient must be positioned in a way which, while allowing drainage of blood from the site of operation, will not interfere with a constant and effective blood flow through such structures as brain, liver and kidneys despite the absence or depression of vasomotor control. Furthermore, unfavourable posture can by gravity or obstruction interfere with venous return and prevent adequate filling of the heart, thus leading to a further reduction of cardiac output. In this way, hypotension may be carried to a dangerous level. Thus, the acute "jack-knife" and reverse Trendelenburg positions are undesirable. The prone position can be dangerous, as shown by the observation that systolic pressures are, on the average, lower than in the supine. The face-down position tends to impede venous return. It has been said that hypotension can be intensified by employing a head-up tilt but this practice is not without the risks of reducing flow through the inferior vena cava and cardiac output and incurring the danger of cerebral ischaemia. Excessive slowing of pulse rate (below fifty per minute) indicates dangerous retarding of cardiac filling from a reduced venous return; it can be corrected by modifying posture.

Oxygenation—Obstruction of the airway must be scrupulously avoided and the respired mixture must contain a high percentage of oxygen. Hypovolaemia and anaemia must be corrected before operation, and if haemorrhage occurs once ganglionic blockade has been established, blood must be replaced promptly.

Degree of Hypotension—The frequent question: "What is the lowest reading of systolic blood pressure which can be regarded as safe?" cannot be answered by an arbitrary figure. The lowest safe level will vary in different individuals and according to posture. It would be a mistake to rely too rigidly on sphygmomanometer readings in assessing the patient's condition. An unchanged respiratory rate and rhythm and adequate capillary circulation and oxygenation...
are the most reliable signs. The degree of ischaemia of the wound tissues is an important
guide in as much as too marked a result must be regarded as a danger sign. This consideration
becomes more serious the nearer the site of operation is to vital organs. In most cases
modification of posture is sufficient to improve capillary flow, but if this is not effective the
blood pressure must be raised to a safe level by a small dose of methylamphetamine
hydrochloride.

**Controlled respiration**—Apart from the fact that normal spontaneous respiration is, in the
presence of low systolic and pulse pressures, a valuable guide to the adequacy of the medullary
blood flow, passive inflation of the lungs, particularly if forceful, reduces venous return. In this
way, controlled respiration tends to lower cardiac output and further decrease arterial pressure.

**Post-operative care**—Vigilant supervision of the patient must continue after operation. Moving
from operation table to bed should be carried out with the utmost care and there should
never be more than one move. Intermediary transfer to a trolley has no place in the management
of the hypotensive patient. The patient must remain under close supervision by the anaesthetist,
in the recovery room attached to the theatre, until the blood pressure has reached at least
80 millimetres Hg. During this period a 5–10 degrees Trendelenburg position should be
adopted, oxygen administered and respiratory obstruction guarded against. It has been the
practice to allow the patient to return to the ward only after his systolic pressure had remained
at a minimum of 80 millimetres Hg. for at least half an hour. If the pressure remains low in
spite of blood loss during operation having been negligible or replaced, methylamphetamine
hydrochloride will have to be administered. An initial dose of 3–5 milligrams is recommended
because too rapid a rise of blood pressure is apt to provoke haemorrhage. Failure to produce
or maintain a rise of pressure after a total dose of 10 milligrams should be taken as indicating
a deficiency of blood volume and must be treated by transfusion. A fall of arterial pressure
was observed in a number of patients as they were regaining consciousness, but it was found
possible to correct this by an intravenous injection of morphine.

The following observations may be of interest:

**Renal function**—Post-operative oliguria or anuria were not encountered. This may appear
contrary to the accepted view that 70 millimetres Hg. is the critical renal filtration pressure,
which is based on observations in haemorrhagic hypotension with consequent vasoconstriction
and ischaemia of the kidney. When systolic pressures below 70 millimetres Hg. are induced
by means of ganglionic or sympathetic blockade, an adequate renal blood flow is possible.

**Contra-indications**—The conditions which were from the outset regarded as absolute contra-
indications to inducing hypotension were coronary thrombosis and serious respiratory
disability. Only one patient with a history of coronary thrombosis was given hexamethonium
bromide—a woman of sixty-five years of age. She had a severe attack on the nineteenth day
after operation but made a satisfactory recovery. Observation in this series has shown that
periodic mental confusion is likely to be aggravated after induced hypotension, and patients
with that history should be excluded. A considerable proportion of the patients under review
suffered from arteriosclerosis of varying degree, and there was no indication that this condition
should be regarded as a bar to the use of ganglionic blockade. Hypovolaemia and anaemia
are definite contra-indications, unless they can be corrected before operation.

**SUMMARY**

1. Figures relating to blood loss and post-anaesthetic progress during and after 407 orthopaedic
   operations performed with the aid of hexamethonium bromide are presented.
2. Two deaths from circulatory failure are examined in detail.
3. The criteria that must be observed to ensure safety are discussed.
4. Measures designed to avoid reactionary haemorrhage are enumerated.
5. Observations regarding contra-indications are presented.
I wish to thank Professor Sir Walter Mercer for his co-operation and encouragement in this investigation and Dr John Gillies for his interest and advice in the preparation of the paper.

REFERENCES

Dott, N. M. (1955): Personal communication.