Induced Hypotension

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For many years surgeons have recognized the value of a low blood pressure in reducing or controlling bleeding. In 1945 Gardner employed arteriotomy during neurosurgical procedures. The problem of purposefully lowering blood pressure has been re-explored and the field of deliberate hypotension has come to the fore in the last few years. Enthusiasm exhibited by some investigators would propose it as a panacea for surgical bleeding. Our medical colleagues have long insisted that the patient undergoing anesthesia and surgery have not only a plentiful supply of oxygen but that the blood pressure not be allowed to fall. There has been perplexity on the part of the anesthetist who in one room worries because a patient's blood pressure has fallen to 90mm. Hg. systolic, while in another operating room, where induced hypotension is to be employed, the anesthetist is unhappy because the patient's pressure refuses to go below 90. This paper will indicate a basis for the rational approach to the problem of deliberate hypotension.

### Purpose of Induced Hypotension

Surgery today is often more extensive than 20 years ago. Radical operations for the cure of malignant diseases and for the correction of congenital and acquired anomalies have been made possible to some extent by new techniques in anesthesia, in better pre- and post-operative care and by the use of antibiotics. Controlled, induced or deliberate hypotension has been advocated during some of these procedures to conserve blood loss, reduce the number of whole blood transfusions, facilitate surgical dissection and hence achieve a reduction in the operative time as well as to obviate some of the difficulties encountered in large tissue dissections. Dripps has stated, "The incidence of post-transfusion viral hepatitis continues to be a hazard. Sensitization of a recipient to subsequent transfusions has always posed a problem. With the discovery of numerous Rh groups an important source of sensitization was uncovered. Other similar, but as yet incompletely studied factors, remained to be evaluated. The cost of transfusions to the patient, the availability of whole blood, and the proper temperature for storing blood are problems requiring solution. The occurrence of generalized unmanageable bleeding from traumatized surfaces during operation appears related to multiple transfusions in certain instances. Blood stored for more than a few days suffers almost a total loss of platelets, a reduction in the amount of accelerator globulin, one of the substances which acts as a catalyst in the formation of thrombin from prothrombin, and an increase in potassium. Furthermore, with passage of time increasing fragility of stored cells occurs so that approximately 30% of the infused red cells may be destroyed within 24 hours if a transfusion consists of blood more than 14 days old. For these various reasons one would like to decrease the number of transfusions".

Does induced hypotension really significantly reduce the blood loss and decrease the operative time? Various authors have stated that blood loss is only 30 to 50% of that seen with normotensive techniques. Other studies have indicated that operations are completed in far less time and that the patient seemed far less prostrate post-

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operatively following deliberate hypotensive techniques compared with normotensive
techniques. Ditzler and Eckenhoff7 have reported a study of 90 patients undergoing
surgical procedures in whom the blood pressure had been deliberately lowered and
compared the results with 84 patients having similar operations without induced
hypotension. Patients were matched as to the type of operation and skills of the
surgeons. A reduction of blood loss in terms of percentage was found to be of little
value unless compared with the actual amount of blood saved and the amount of
blood still necessary to be transfused. In a series of radical dissections of neck and
pelvis the reduction in blood loss was approximately 35%. This represented one unit
of blood saved in dissections of the neck but 2 units saved in resections in the pelvis.
It still remained necessary to use 2 units of blood in the instance of the radical neck
dissection and 4 units of blood in the case of radical dissections of the pelvis. These
authors indicate deliberate hypotension does not guarantee a reduction in blood loss.
There were instances when the blood loss was considerably in excess of the average seen
during deliberate hypotension. Some surgeons commented that occasionally patients
demonstrated more oozing at lower blood pressures than at higher pressures. It is of
interest that the operative time in this study was not usually reduced by the use of
hypotension and in some instances was considerably longer during periods of hypo­
tension. One might argue that the drier field permitted a more extensive and complete
dissection, and allowed for better teaching of residents. It also reduced the pressure
on the surgeon for speed. The study also indicated that surgeons by experience alone
could considerably lessen blood loss and operative time.

Circulatory Physiology—General Considerations

Tissue oxygenation involves multiple factors of which the important circulatory
factors are 1) an effective blood volume containing an adequate amount of hemo­
globin, 2) the peripheral resistance as a whole as well as in selected areas of the
body and, 3) the cardiac output. In general, flow is equal to pressure divided by re­
sistance (F=P/R). If for example, mean blood pressure is 100 mm. Hg. and re­
sistance is arbitrarily measured in units of ten then the flow would be: 100/10 or 10.
If the blood pressure is allowed to fall to a mean of 80 mm. by virtue of peripheral
vasodilitation, total peripheral resistance is less (arbitrarily 8 units) and accordingly
the flow would be 80/8 or again 10. If, however, the pressure is reduced from 100 to
80 mm. Hg. by means of hemorrhage, and compensatory vasoconstriction occurs increas­
ing peripheral resistance (arbitrarily to 12 units) then the flow is 80/12 or 8.3. Hence
the flow of oxygenated blood to the tissues during hemorrhage is reduced.

In 1918 Sir Henry Dale shed light on the problem of circulatory physiology when
he demonstrated the differences between hypotension induced by intravenous histamine
and that seen following intravenous acetylcholine. In both instances the blood pressure
was decreased to approximately the same level. With histamine there was arteriolar
constriction and increased capillary permeability, loss of plasma from the capillary
bed, and the return to a normal blood pressure did not often occur. This is the picture
that is commonly seen with reactions of the body to hemorrhage or traumatic shock.
On the other hand the picture with acetylcholine was one of arteriolar dilatation, no
loss of plasma from the capillaries and a rapid return of the blood pressure to normal
levels and this is what is achieved with hypotensive techniques employed today.

Blood volume in order to be an effective volume must be as near normal as
possible when the peripheral resistance is altered. The cardiac output must not be in
doubt by reason of myocardial disease and the blood which is circulating must carry
a maximal amount of oxygen. Ignorance of these considerations early led to increased
morbidity and mortality with induced hypotension.

Circulatory Physiology of the Patient Undergoing Induced Hypotension

Dripps stated that the factors which determine whether the body can tolerate
hypotension appeared to hinge upon the following, “a) the duration of hypotension
b) the degree of the hypotension c) the previous condition of the blood vessels . . .
if these vessels are sclerotic or otherwise abnormal, changes in their caliber in response
to hypotension may not occur as readily as with normal vessels and an insufficiency of
blood flow may result d) the metabolic needs of the tissues during hypotension, again
with particular emphasis on the heart and brain; the lower the metabolic requirements
the greater is the reduction in the supply of blood which can be tolerated . . . Likewise,
the heart may be better protected than one might imagine because it is being called
upon to do less work, if there be lessened peripheral arterial resistance. The coronary
arterial blood supply may be curtailed but so may the demand for this blood. e) the
liberation of specific depressor substances from ischemic tissues.”

A study of the physiological alterations associated with hexamethonium in­
duced hypotension was made by Van Bergen in 1954. Studies were carried out on
14 patients either before or during surgical intervention. The patients were anesthetized
by a standard technique and hypotension was obtained with hexamethonium drugs.
Intra-arterial blood pressure recordings were done and catheters were inserted into
the external jugular vein and the right atrium for venous pressure studies. Circulation
time was determined by injecting methylene blue. By the Van Slyke method arterio­
venous oxygen difference of the brain was determined. A “Coleman anoxia photometer”
was used to study relative arterial oxygen saturations. Electrocardiographs were also
taken. Their conclusions are as follows:

Circulation times, oximeter studies and EKG as well as the electroencephalograms
indicate that the circulation within vital organs may be reduced to such an extent that
severe hypoxia can result. This was particularly true of the elevated portions of the
body. Postural drainage in combination with hypotension, as is employed occasionally
to further decrease the blood pressure, was found to be more deleterious when the
patient was in Fowler’s position. The impression obtained from Van Bergen’s studies
is that serious hypoxia can occur to the heart and to the brain during deliberate hypo­
tension if those areas of the body are placed in such a position that venous return
to the heart is deficient and gravity offsets any normal tendency for the increased blood
flow seen by reason of vasodilation. Hence the dangers of hypotension which are
always potential are certainly magnified if the patient is in the head-up position.

Stone and Mackrell have studied the effect of deliberate hypotension on cerebral
blood flow. Hypotension was induced with hexamethonium, histamine, and proto­
veratrine. They found that a fall of 44% of the arterial blood pressure with a con­
comitant 46% reduction in cerebral vascular resistance failed to produce significant
changes in cerebral blood flow or metabolism. Cerebral blood flow was maintained
despite falls in the arterial blood pressure because of the decrease in cerebral vascular
resistance. Their conclusions indicate that adjustment was not good in the aged patient
because of sclerotic vessels which can not adjust to a decrease in cerebral vascular resistance. The oxygen consumption was not changed. Palmore\textsuperscript{9} indicates that the slow awakening of patients undergoing deliberate hypotension is due to a lower basal metabolic rate and to slower elimination of drugs rather than one of brain hypoxia.

Renal function is nearly always decreased during anesthesia and surgery. During periods of hexamethonium hypotension however the fall in blood pressure does not cause a decrease in renal blood flow, according to De Wardener.\textsuperscript{11} More studies on this aspect are needed. The two organs which seem to be most seriously affected by the least amount of deviation from normal would appear to be the heart and the liver.

\textit{Methods of Induced Hypotension}

I. Arteriotomy

The use of arteriotomy was abandoned by most investigators because hypotension thus produced was like that of hemorrhagic shock. Hale\textsuperscript{13} states “It may seem and it may be true that hypotension with vasodilatation is safer than hypotension with vasoconstriction. Every animal organism which suffers hemorrhage, however, responds by preserving as well as possible the blood supply to the vital areas while temporarily denying it to other regions. If in hypotension by vasodilatation all tissues are supplied equally without regard for the greater needs of some, this method may not be safer than hypotension with vasoconstriction.” The bulk of published data would indicate that the safety of deliberate hypotension in surgery depends on HOW the pressure is lowered rather than the actual levels obtained. Most investigators feel that the method of arteriotomy can cause over-constriction leading to tissue hypoxia. It is also felt to deprive the patient of hemoglobin thus hindering oxygen transport.

II. Mechanical means

Positioning the patient with the operative site uppermost while under normotensive anesthesia may occasionally decrease wound bleeding but results are unpredictable, and at times dangerous. Special chambers have been devised in which the legs may be encased and kept in a dependent position. Suction is applied to these chambers in order to pool blood in the legs. These methods alone are not used extensively but are adjuncts to other methods.

III. Spinal Sympathetic Blockade

In this technique the usual vasopressor support of blood pressure is omitted, the legs are placed in a dependent position and general anesthesia is usually added. The peripheral arterioles are thus dilated by a preganglionic sympathetic block. This method is often very effective and can be fairly well controlled by use of catheter spinal techniques using short acting procaine and vasopressors for termination of the period of hypotension. It is probably the preferred technique for procedures below the diaphragm since it not only lowers blood pressure but likewise produces analgesia and muscular relaxation. Light general anesthesia is added for patient comfort and to insure an adequate respiratory exchange.

IV. Ganglionic Blocking Agents

Those drugs chosen are usually paralysants to autonomic ganglia without any specificity. Predominantly they produce arteriolar dilatation and consequent lowering of peripheral resistance. Such drugs have effects other than lowering of blood pressure; such as cycloplegia and a minimal curariform activity. These drugs should not be
preferentially employed where profound relaxation is required, such as in major abdo-
dinal procedures because these drugs used with deep general anesthesia or added curare for relaxation may be additive. Patients may not breathe for hours postoperatively or have prolonged vasomotor depression. Most frequently used are hexamethonium compounds and Arfonad®, (trade name) a thiophanium compound. Hexamethonium drugs are administered by intermittent injection but the results are often unpredictable as to effect and duration. Arfonad is the preferred drug since its effects are transient enough to require a titrated intravenous drip. Young people are more resistant to these drugs than the older age groups. Some patients get no response until large quantities have been given and then remain severely hypotensive for long periods. In other patients an initial satisfactory response is obtained but they then become refractory to subsequent doses. With Arfonad it is probably wise not to exceed one gram total dose irrespective of the procedures duration. If a satisfactory fall in blood pressure is not obtained with 75 to 100 mgm. in 10 to 15 minutes the use of this drug as well as the hypotensive tech-
nique in the patient should be abandoned.

With all hypotensive techniques young people are often more refractory, with falls in blood pressure more difficult to obtain. Less anesthesia is required during the hypotensive period and awakening time may be delayed. Cycloplegia often persists 24 hours when ganglioplegics are used. Reactionary hemorrhage must be prevented by raising the blood pressure toward normal before body cavities are closed. Two points of paramount importance are: (a) Normal blood volume preoperatively, and replacement of blood loss the instant it occurs during surgery. Hence sponges must be weighed. (b) Maintenance of maximal respiratory exchange. This requires continuous use of oxygen and frequently assisted or controlled respiration. The blood pressure is lowered to that point where bleeding is considerably lessened. Often this can be achieved at 80 mm. Hg. but on occasions it has been carried as low as 50 mgm. Hg. Theoretically anything above capillary perfusion pressure (32 - 40 mm. Hg.) would be adequate but this risk is not justified; hence pressures are usually sought in the 70 - 80 mgm. range.

Hazards of Deliberate Hypotension in Surgery and Contraindications

Hampton and Little reporting the results of a questionnaire sent to various anesthes-
thetists in Great Britain and the U. S. in 1953 indicated that 322 physicians employed the technique of controlled hypotension in a total of 27,930 cases. Complications were noted to be higher when the blood pressure was reduced below 80 mm. The overall incidence of complications was 1 in every 31 cases. Suppression of kidney function in the form of anuria or oliguria occurred 106 times. Thrombosis of the various essential arterial vessels such as the cerebral vessels, retinal vessels and coronary arteries were reported in 50 cases. Cardiac arrest or cardiovascular collapse in general occurred in 58 cases, and was frequently followed by death. The most frequent complication which occurred was that of reactionary hemorrhage, occurring 243 times. There were 96 deaths or 1 in 291 cases. Since this early report it has been the impression of careful investigators that the mortality for comparable surgery is no greater than with normotensive techniques of anesthesia and surgery with massive transfusions. In this country little has been said of reactionary hemorrhage since the technique here is to insure a normal pressure prior to wound closure. The author's own experience would agree that morbidity and mortality are no higher with induced hypotension where care in the selectivity of patients is exercised. Unfortunately the elderly hypertensive cardiac
patient who should be spared massive transfusions and prolonged surgery should be
denied this technique. Likewise it should not be used on those with moderately ad­
vanced arteriosclerosis, hepatic, renal, or cerebral disorders.

**Indications for Induced Hypotension in Surgery**

(a) Major surgery on large blood vessels and cardiac operations: In these cases
hypotension can be achieved by deliberate hypothermia which in addition to lowering
body temperature and oxygen utilization also lowers the blood pressure. (b) Certain
neurosurgical procedures, i.e. the ligation of intracranial aneurysms. Here hypotension
should be produced only at the time the surgeon has the greatest need for it. (c) Ex­
tensive surgical dissections where many planes of tissue are to be dissected and the
predicted blood loss will be in excess of 2000 cc. Here the sparing in transfusions to
the patient is of considerable importance as well as providing greater facility for surgical
dissection.

In general, induced hypotension should be used on carefully selected patients where
the risks without hypotensive techniques exceeds those of normotensive procedures with
massive transfusions.

**SUMMARY**

Induced hypotension in surgery is accomplished by deliberately lowering the blood
pressure to 70 or 80 mm. Hg. systolic by means of ganglioplegics or spinal anesthesia
wherein the peripheral arterioles are dilatated and capillary permeability remains un­
changed. If the patient has and is maintained with an adequate blood volume, is
adequately ventilated with oxygen enriched atmospheres, and is kept in a level or
Trendelenburg position, the safety to the patient is no less than comparable procedures
done with massive transfusions. Blood loss is decreased but the reduction is such as
to question its use in other than selected cases. Complications which follow the use
of deliberate hypotension are more frequently associated with blood pressures that
are kept below 70 mm. Hg. systolic and occur in those patients in whom selectivity
has not been exercised.

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