Intraoperative controlled hypotension-60 years of personal experience from the point of view of Anesthesiologists: A brief review.

Hanna Perez-Chrzanowska*, Patricia Serrano Méndez and Ricardo Pintado Otero

Department of Anesthesia and Critical Care, Hospital Universitario La Paz, Madrid, Spain

Abstract

Intraoperative controlled hypotension was introduced a century ago with the aim of reducing blood loss and decreasing the transfusion rates. It consists of intentionally lowering the blood pressure of the patient to a predetermined level, always under the strict supervision of an experienced anesthesiologist. It offers the surgeon improved operating field visibility conditions, increasing surgical precision and thus decreasing complications and operating time. It is a versatile technique used in diverse surgical specialties although it is not without controversies. At present, the discovery of drugs with predictable and easily titratable effects, simple administration and improved safety profiles, as well as sophisticated non-invasive monitorization, allow this technique to be performed with total security. In this article we will review the pharmacology of drugs that have been used to produce controlled hypotension over the last 100 years, its indications and complications. We will describe the pathophysiological basis, the monitoring required to perform it safely and we will make recommendations based on the personal experience of the authors whose practice of this technique spans 60 years.

Keywords: Controlled hypotension, Profound hypotension, Induced hypotension, Permissive hypotension, Deliberate hypotension, Intraoperative blood loss, Patient blood management, Bloodless surgery, Operating field visibility.

Introduccion

At the beginning of the 20th century, intraoperative controlled hypotension was first introduced as an anesthetic technique which could significantly reduce surgical blood loss. It has been studied, developed and perfected during the last 100 years, to offer important benefits to patients, surgeons and the healthcare system.

The surgeon benefits from a clean, bloodless operating field with improved visibility which leads to more precise and rapid operations. The patient experiences decreased blood loss and shorter intraoperative times, less postoperative anemia and lower transfusion requirements. The healthcare system saves money by avoiding blood product use and the accompanying complications costs. Theater occupation times and in hospital length of stay are reduced leading to a better distribution of scarce resources.

This article reviews, the different pharmacologic options which have been used and the physiologic techniques which aid the decrease in intraoperative bleeding and the effects of controlled hypotension on the cardiac, pulmonary, renal, splanchnic, skin and muscle circulation.

We explore the applications, indications, contraindications, possible complications and the monitoring needed to carry out this sophisticated technique safely.

Definition

Intraoperative hypotension, also known as profound hypotension, induced hypotension, permissive hypotension and deliberate hypotension, is defined as the intentional reduction of the systolic blood pressure (SBP) to 80-90 mmHg or of the mean blood pressure (MBP) to 50-65 mmHg, in normotensive patients. There is controversy as to what level of blood pressure (BP) reduction is acceptable and safe, especially for hypertensive patients, where a 30% decrease of the baseline BP is proposed [1,2]. So far no safety limit has been established for the duration of intraoperative controlled hypotension.

Historical Background

Intraoperative controlled hypotension was first proposed by Cushing in 1917 [3] to decrease surgical blood loss in intracranial operations. It appears in the literature in 1946 described by Gardner [4]. In 1948 Griffits and Gilles [5] publish what they call “hypotensive spinal anesthesia”.

During the 1950s there is a boom in the investigation of the pathophysiology and pharmacology of controlled hypotension. Enderby [6] describes “ganglionar blockade” with pentamethonium to decrease MBP. Halogenated inhalational agents [7] are used because of their diminishing effect on the cardiac output (CO) and BP. Nitroglycerine [8]

***Correspondence to:** Perez-Chrzanowska Hanna, Department of Anesthesia and Critical Care, Hospital Universitario La Paz, Madrid, Spain, E-mail: hannaperez@hotmail.com

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is introduced, followed by nitroprussiate [9] as vasodilators, beta blockers [10], ganglionar blockers such as trimetaphan [11], and the combination of alpha and beta blockers. Later the purines [9], alpha agonists and calcium channel antagonists are added to the anesthesiology arsenal.

Fluid therapy investigation of intraoperative blood loss under controlled hypotension focus on the importance of fluid therapy as a necessary component to maintain adequate CO; normocapnic mechanical ventilation to preserve cerebral blood flow dynamics and patient positioning to maintain the surgical field above the level of the heart favouring venous blood return [6].

Indications

The first and foremost aim of this technique is to benefit the patient. This is achieved by reducing the intraoperative blood loss by up to 50% compared to normotensive anesthesia. Postoperative anemia, blood transfusions and operating times are decreased [12-15].

Controlled hypotension has been used successfully in multiple surgical specialties [15]:

1. In surgeries which cannot be performed without hypotension such as cardiovascular o cerebrovascular surgeries
2. Surgeries with massive blood loss such as mayor oncologic and orthopedic operations
3. Surgeries where even minimal blood loss makes the procedure inviable such as plastic, ENT and arthroscopic surgery

Surgical specialties where controlled hypotension has demonstrated effectiveness (Table 1).

When controlled hypotension is used, the surgeon needs to take exquisite care with surgical hemostasis and rebound hypertension upon emergence must be avoided. Insufficient hemostasis and defective management of the BP when emerging from hypotension increase the incidence of postoperative hematomas.

Table 1. *Surgical specialties where controlled hypotension has demonstrated effectiveness.*

Surgical Specialities Where Controlled Hypotension has Demonstrated Effectiveness
Plastic and reconstructive surgery
Severe burns surgery
Ear, nose and throat surgery (especially middle ear, rhinoseptoplasty, major oncological resections)
Ophthalmology (ocular microsurgery)
Tracheal and endobronchial surgery
Neurosurgery (tumors, aneurisms, craneosynesthesis)
Orthopedics (shoulder, hip, and spine, surgeries where ischemia tourniquet cannot be applied: arthroscopy, arthroplasty, bone tumors)
Polytrauma surgery
Maxilofacial surgery (orthognatic surgery and oncological resections)
Porto-cava and spleno-renale derivations
Oncological surgery
Major abdominal, pelvic and urologic resections (exenterations)

The Ideal Drug

The pioneers of controlled hypotension embarked upon the search of the ideal drug. They defined its characteristics [2,16-20].

Ideal drug characteristics (Table 2)

With the passage of time, the investigators and the clinicians came to the conclusion that such a drug does not exist yet. However, with the combination of different drugs and anesthetic techniques, a close approximation can be made. At present the following can be found in the literature:

Table 2. *Ideal drug characteristics.*

Ideal Drug Characteristics
Easy administration and titration
Predictable effect
Easy to control effect
Rapid onset of effect
Effect steadily maintained during the administration of the drug
Dose-dependent effect
Rapid cessation of effect when the administration of the drug is interrupted
Easy, quick, and predictable elimination
Metabolism independent of hepatic and renal function
Absence of active and toxic metabolite
Preservation of blood flow, O_2 and metabolic substrate supply to vital organs
Does not affect the autoregulation of blood flow in vital organs

1. Neuroaxial anesthesia (spinal or epidural) associated with sedation or general anesthesia (GA) which improve the tolerance of the awake patient in the hypotensive state and coadjuvates the BP lowering effect.
2. Total intravenous anesthesia (TIVA) associating propofol and remifentanyl with other hypotensive drugs.
3. Balanced GA with halogenated inhalational agents, opioids and other hypotensive drugs
4. Direct action vasodilators such as nitroprussiate, nitroglycerin, the purines, or hydralazine combined with ganglionar blockers (trimetaphan), alpha blockers (phentolamine, urapidyl), beta blockers (propranolol, esmolol), mixed alpha and beta blockers (labetalol), calcium channels antagonists (nicardipine, clevidipine), prostaglandins (PGE1), alpha agonists (clonidine, dexmedetomidine) and magnesium sulphate, always associated with GA

Neuroaxial Blockade

In 1948 Griffiths and Gilles described "pharmacologic sympathectomy" through neuroaxial anesthesia. Spinal anesthesia has quick onset and the baricity of the local anesthetic used offers the advantage of allowing adjustments of lateralization, block level and duration of the anesthesia. On the other hand, epidural anesthesia has a gradual onset which offers better BP control and has the advantage of permitting lasting blockade through the use of an epidural catheter in long surgeries [21-24].

"Pharmacologic sympathectomy" acts by vasodilating arterioles and veins, decreasing venous return and CO. Its

safety depends on adequate intravascular volume replacement and meticulous maintenance [25]. If the sympathetic innervation of the heart is blocked (T_1-T_2), the appearance of compensatory tachycardia is contrarested.

The disadvantages of this technique are the difficulty in standardization of the block level (considerable inter patient variation) which implies that the anesthesiologist must be very experienced, and an unpredictable hypotensive effect (due once again to inter patient variation) [26]. It's extremely important to avoid hypovolemia by carefully adjusting fluid management. In order to improve patient tolerance of high blocks, it is recommended that neuroaxial anesthesia be accompanied by sedation or GA which also coadjuvate the degree of intraoperative hypotension achieved [27].

Halogenated Inhalational Agents

The effect of halogenated inhalational agents is totally dose dependent [28]. The greater the alveolar concentration, the deeper myocardial depression with the consequent decrease in CO, BP and systolic volume. The right heart filling pressures increase, there is vasodilatation of the skin (increasing body heat loss and the risk of hypothermia if protective measures are not taken), muscle and brain vasculature. Total peripheral resistances (PR) increase in kidney and musculoskeletal beds [29-30]. The vasodilatation in the brain causes augmented intracranial pressure (ICP) and production of cephalospinal fluid (CSF). Once again, the overall intravascular volume status of the patient at the moment of induction is crucial to allow for controlled lowering of the BP [31,32].

The disadvantages of these agents are: their unpredictable effect over PR, a prolonged emergence time when high doses are used and the effect on autoregulation which can lead to cerebral ischemia. At present the sole use of inhalation halogenated agents at high doses for controlled hypotension is contraindicated [33]. Currently their use as coadjuvants, at low doses and as part of balanced GA is admitted.

Intravenous Drugs

Nitroprussiate

Nitroprusside was the first intravenous drug used to induce controlled hypotension. It is the golden standard against which all other drugs and anesthetic techniques are compared. It is a rapid onset arteriolar vasodilator which is administered via continuous intravenous infusion and whose dosing requires minute by minute adjustments. Its effects are short lived and it is very potent. It increases the heart rate (HR) and the CO in normovolemic patients. In hypovolemic patients the CO drops notably. It is not a cardiac contractility depressant. The cardiovascular response driver is the intravascular volume status of the patient. Unfortunately it has toxicity due to cyanide which causes tissue hypoxia and contraindicates its use at high doses and prolonged infusion times. It is metabolized by the liver and excreted by the kidneys. It undergoes photodegradation maintaining its biological activity and generating free cyanide which makes it even more toxic. Patients resistant to its effect have been described. The phenomenon of tachyphylaxis has been observed. It occurs through the activation of catecholamines and of the renin-angiotensin system. Rebound hypertension upon discontinuation of its administration is a problem. It alters the cerebral blood flow autoregulation and currently is no longer used in developed countries where more effective and safer drugs are available [34-36].

It has been employed in combination with propanolol as premedication since the latter prevents the appearance of reflex compensatory tachycardia and allows the lowering of the total dose of nitroprussiate needed to reach the target BP. Premedication with captopril has also been described [12,22]. Once again, it allows the decrease of the doses of nitroprussiate, diminishing its toxicity and attenuating the rebound hypertension which occurs when nitroprussiate is used as the only hypotensive agent [2].

Nitroglycerin

Nitroglycerin is a direct dilator of the venous capacitance vessels. It has a rapid onset of action and a short life time ($t_{1/2}$). It has no toxic metabolites. Its effect on the CO depends on the intravascular volume status of the patient [37]. It causes an activation of the baroreceptors which increases sympathetic activity, HR, cardiac contractility and O_2 consumption. It is a vasoconstrictor of the mesenteric, iliac, coronary and systemic circulations. This response is attenuated under GA but continues being a potential cause of complications. Currently nitroglycerin is not being used for controlled hypotension. The cessation of its administration causes a prolonged period of vasodilatation and residual hypotension.

Hydralazine

Hydralazine is a smooth muscle relaxant, very effective in combination with inhalational halogenated anesthetics. It does not cause rebound hypertension [38]. The biggest problem is the increase in ICP and possible cerebral ischemia. Currently it is no longer in use.

The Purines

Adenosine and adenosintriphosphate degrade rapidly to phosphate and free adenosine which is the active component. They are very potent vasodilators which decrease PR and lead to rapid and profound hypotension. They do not cause rebound hypertension [39]. They are no longer in use because of the high risk of heart block, increased ICP (cerebral vasodilatation, increased blood flow and cerebral autoregulation disruption). They are also coronary vasodilators but they lead to disfavorable shunts which may lead to ischemia.

Trimetaphan

This drug produces a non-selective ganglionar blockade. By blocking both the sympathetic and the parasympathetic systems it causes tachycardia, mydriasis (which can be interpreted as cerebral ischemia by the unexperienced anesthesiologist), cycloplegia, decreased gastrointestinal motility and acute urinary retention. It is degraded by plasmatic cholinesterases which confer it an ultra-short half life time ($t_{1/2}$ minutes). It is excreted by the kidneys. It offers an easy BP control and does not affect cerebral circulation. Its main problems are:

tachyphylaxis, liberation of histamine and potentiation of succinylcholine muscle blockade. Although it is not being used at present, its combination with nitroprussiate has been described when prolonged periods of hypotension are required [40].

Antagonists of the Sympathetic Nervous System

Urapidil

Urapidil is a peripheral alpha1 and alpha2 blocker. It also blocks cerebral 5-hydroxytryptamine serotoninergic receptors. It produces vasodilatation without sympathetic activation. It does not cause changes in cerebral autoregulation. Its action has rapid onset and is dose dependent [41]. It does not cause rebound hypertension. It is very useful to induce moderate levels of hypotension, especially in combination with other drugs (inhalational halogenated agents, TIVA o neuroaxial anesthesia).

Esmolol

Esmolol is a selective beta blocker with a rapid onset and short duration of action. Its effects are dose dependent and cease upon discontinuing its infusion [1,42]. The biggest obstacle to its use is the profound myocardial depression which it causes and the increase in PR.

Labetalol

This drug is an alpha1 and beta 1 and 2 blocker It decreases CO and PR. Its effect reaches peak 5 minutes after intravenous administration. Its half-life is long ($t_{1/2}$ 4 hours) which is its biggest problem. It has an intense synergism with inhalational halogenated anesthetics, not so with the intravenous ones. It preserves renal blood flow and does not affect CBF [43].

Calcium Channel Antagonists

The action of calcium channel antagonists is peripheral, coronary and cerebral vasodilatation. They do not affect cardiac contractility, CO or HR.

Nicardipine

The action of calcium channel antagonists is peripheral, coronary and cerebral vasodilatation. They do not affect cardiac contractility, CO or HR. The main drawback of this drug is that the hypotension induced by it needs minute by minute monitoring because it is resistant to the corrective treatment with the usual drugs such as ephedrine or phenylephrine.

Clevidipine

This is a new, ultra-short acting drug. It is degraded by non-specific tissue and plasma esterases resulting in a $t_{1/2}$ of 1 to 2 minutes. It is being used successfully as a coadjuvant for controlled hypotension in the context of TIVA with propofol, remifentanyl and dexmedetomidine, and with balanced GA with sevoflurane, desflurane and remifentanyl [44]. It is very potent, easily titratable and well tolerated by the anesthetized patient. It has rapid onset and offset of action. Clevedipine does not cause rebound hypertension. It causes tachycardia which may necessitate correction with a beta blocker.

Angiotensin Converting Enzyme Inhibitors

Captopril

Captopril is a highly selective, competitive drug which inhibits the conversion of angiotensin I to angiotensin II. Secondarily it decreases the levels of aldosterone. It blocks the degradation of bradykinin, a potent vasodilator. It has been used as premedication, allowing the administration of smaller doses of nitroprussiate to achieve controlled hypotension [45,46].

Prostaglandins

PGE1 has a moderate effects on BP. Patients resistant to its effects have been reported. No gastrointestinal side effects are observed in patients under GA.

Propofol

This intravenous anesthetic appeared on the market in 1977 and brought with it an authentic revolution for anesthesiologists. It is an excellent hypnotic and sedative induction and maintenance agent. It causes venous vasodilatation and a fall in PR [35,47]. It has a short half-life and rapid onset of action. It undergoes hepatic metabolism and renal excretion. During long infusions it accumulates in the fat tissue. Although the mechanism of action is still not clear, it affects the gabaergic system. It potentiates cardiodepressors and hypotensive agents and is widely used in controlled hypotension [48].

Alpha Agonists

Clonidine

A derivative of imidazoline, with alpha adrenergic agonist properties which produces a fall in BP accompanied by bradycardia and decreased CO. The fall in SBP is greater than that of DBP. Postsynaptic adrenoreceptor stimulation contributes to its hypotensive action in the adrenal medulla and the stimulation of presynaptic alpha receptor at the central and peripheral nervous system potentiates this effect [49-52]. Cerebral receptor stimulation is the main reason for its hypotensive action. It is used as premedication in combination with beta blockers, propofol and halogenated inhalational anesthetics; however its effect is too long lasting and unpredictable.

Dexmedetomidine

Highly selective and potent alpha2 agonist, it has a rapid onset of action and $t_{1/2}$ of 6 minutes. It does not accumulate even in very long infusions. The offset is predictable. It causes sedation without respiratory depression, and moderate hypotension. Special care is required with bradycardia especially when used in combination with remifentanyl. Currently it is widely used as a coadjuvant of other anesthetic agents and opioids to achieve controlled hypotension.

Magnesium Sulphate

It is most known as an antihypertensive agent used to control BP during pregnancy. It stabilizes cellular membranes mediating the activation of key enzymes involved in the ionic transmembrane interchange during depolarization and repolarization. It also inhibits noradrenaline release from nerve

endings leading to moderate hypotension in normotensive, anesthetized patients. It has been used as coadjuvant for the induction and maintenance of controlled hypotension [51,53].

Opioids

Opioids act as analgesics and sedatives. They also cause hypotension, a side effect which is an advantage when planning to employ intraoperative controlled hypotension [2].

Fentanyl

Fentanyl is a potent mu antagonist, 50 to 100 times more potent than morphine. It is extremely useful in controlled hypotension due to its cardiostabilizing and hypotensive effect in combination with propofol or halogenated inhalational agents.

Remifentanyl

The most potent mu agonist known to date [1]. It has rapid onset and an ultra-short duration of action. It is degraded by plasmatic and tissular esterases to biologically inactive metabolites. Its $t_{1/2}$ is 1 to 20 minutes, rapid onset of action and 5 minutes offset time. It does not accumulate; its metabolism does not saturate. The effect is highly predictable, easy to control and can be used during long surgical times. It offers great hemodynamic stability and causes dose dependent bradycardia and hypotension. Remifentanyl was introduced in 1997 as a sedative and an analgesic, however its use was soon curtailed because of the severe hyperalgesia it causes when employed as the sole analgesic in long and painful procedures. This is due to its strong affinity for mu receptors. However, it is the perfect coadjuvant of other hypotensive drugs and is the one which comes closest to the description of the ideal controlled hypotension agent. Currently it is widely used in association with propofol and halogenated inhalational anesthetics.

How Controlled Hypotension Affects Body Organ Systems

The aim of decreasing BP levels to safe limits is to preserve sufficient CO to guarantee the correct supply of O_2 and energy substrates while maintaining the elimination of metabolic byproducts whose accumulation leads to cell damage when regional blood flow distribution changes under controlled hypotension [54]. Subjecting an anesthetized patient to controlled hypotension requires the constant optimization of intravascular volume status and mechanical ventilation parameters to maintain normocapnea. Both hypovolemia and fluid overload are deleterious and must be avoided. Hypercapnea has a cerebral vasodilating effect which leads to increased ICP, while hypocapnea produces vasoconstriction and the risk of ischemia.

The main potential side effect of profound hypotension is ischemia (cerebral, myocardial, renal and splanchnic). It is important to individualize the level of hypotension to be reached. The generic MAP of 50-65mmHg is based on experimental studies of blood flow autoregulation such as radioactive xenon clearance, electroencephalography (EEG), jugular gulf O_2 saturation and cerebral regional O_2 saturation. Once the MAP falls below the pre-established threshold, blood flow decreases in parallel with the BP.

In uncontrolled hypertensive patients, the autoregulation curve is displaced to the right, meaning that the lower limit where autoregulation can function is higher. In well controlled hypertensive patients the autoregulation curve returns to its physiological position. The most important factor influencing the effectiveness of autoregulation is the perfusion pressure (PP), not the BP per se. PP is the difference between the arteriolar supply pressure and the surrounding tissue pressure which under physiologic conditions depends mainly on the venous drainage pressure. Metabolic interchange occurs in the capillary beds. The optimization of oxygenation and free diffusion of metabolites at the tissular level is of utmost importance.

Patients with an elevated ICP should never be subjected to controlled hypotension before the surgical liberation of the dura mater which corrects PP. Patients with systemic inflammatory Response Syndrome and the consequent tissue significant tissue edema also should not undergo controlled hypotension as regional blood flow is compromised by the increased outflow pressures.

It is important to note that the inhalational halogenated anesthetics have a protective cerebral and cardiac effect through the phenomenon of ischemic preconditioning.

Experimental studies have shown that the glomerular filtration rate is preserved down to MAP of 75mmHg. Below this level, blood flow is sufficient to satisfy the metabolic necessities of renal cells however oliguria can appear. This can be alarming for inexperienced clinicians. Normovolemic patients rapidly recover diuresis upon returning to basal MAP. As a consequence, urinary output measures during controlled hypotension are not reliable and not necessary.

The eyes are particularly vulnerable to the effects of reducing blood flow during controlled hypotension. The correct positioning of the head so as not to obstruct the correct blood supply to the eyes is of vital importance. So is the avoidance of applying external pressure to the eyes. Blood rheology must be attended to by correct fluid therapy to prevent central retinal vein thrombosis.

No significant changes in the microcirculation have been observed in muscle and skin, even though they are low priority organs in states of compromised oxygenation. Neither myoglobinuria nor muscle pain nor weaknesses have been observed. There have been no cases of skin necrosis or ischemic ulcerations. A sudden and unexplained fall in the peripheral O_2 saturation (SpO_2) measured in the fingertip, earlobe or the tongue while under controlled hypotension, is an alarming sign that must be attended to immediately.

Laminar Blood Flow, Rheology and Endothelial Function

A possible complication of controlled hypotension is the slowing of tissular blood flow leading to thrombotic events.

The careful conservation of correct endothelial function and laminar blood flow distribution inside the vessels by preserving rheology is achieved by the proper management of vascular filling and optimization of blood viscosity.

Contraindications

There are conditions that the anesthesiologist planning to subject a patient to controlled hypotension must be aware of as they constitute absolute contraindications to this technique [55] (Table 3).

Table 3. *Contraindications.*

Contraindications
Cerebrovascular disease
Coronary artery disease
Severe aortic or mitral valve stenosis
Renal insufficiency
Hepatic insufficiency
Intermittent claudication and peripheral arteriopathy disease
Severe anemia
Hypovolemia
Severe uncontrolled hypertension

Monitorization

There is no which when used alone parameter offers the anesthesiologist all the information that is needed. All of the monitors currently available provide some aspect of an organ system that another monitor does not provide. All are complementary and must be interpreted in the clinical context of the patient and the surgical procedure at any given time. In general, the trends are more important than isolated measurements. No monitor can substitute the integrating capacity of a trained anesthesiologist who interprets the pathophysiology of the situation to arriving at a diagnosis and taking the appropriate action at any given moment.

Peripheral Oxygen Saturation

The pulseoximeter is the basis of all patient monitorization. It may be placed on a finger/toe tip, earlobe or the tongue depending on the surgical situation. It provides multiple information: peripheral tissue oxygenation, HR, pulse pressure wave and the adequacy of CO to reach even the lowest priority organs.

Electrocardiography

The ECG detects possible alarming events such as myocardial hypoperfusion, ectopic beats, rhythm alterations or changes in the ST segment which may indicate ischemia.

Arterial Blood Pressure

In the beginnings of controlled hypotension when drugs difficult to titrate were in use and with limited additional monitorization, the invasive measurement of BP beat by beat was necessary. Currently with new drugs which offer easy dosification, predictable effect and full monitorization of the patient, it is sufficient to monitor BP every 3 to 5 minutes by a non-invasive inflatable cuff.

Capnography

The correlation between the end tidal CO_2 ($ETCO_2$) and the arterial partial pressure of CO_2 ($PaCO_2$) is altered during controlled hypotension due to changes in the physiological dead space, CO and systemic metabolism. However, the absolute value and the wave form of the capnograph, are of utmost importance to guide the correct mechanical ventilation of the anesthetized patient under controlled hypotension. It is fundamental to establish baseline normocapnea and then watch the tendencies. A sudden fall in the absolute value alerts to the possibility of an uncontrolled hypotensive state below the safety threshold, pulmonary thromboembolism or respirator disconnection. Wave and tendency changes alert to the possibility of a respiratory problem. It is vital to avoid hypo or hypercapnia.

Body Temperature Monitorization

The optimal range for the correct function of all bodily enzyme systems lies around 37°C. All patients suffer the risk of hypothermia during surgical operations; however, this problem is increased during controlled hypotension due to vasodilatation which speeds up heat loss and due to the altering effects on the central temperature homeostasis control centers. These become less sensible and the patient cannot mount compensatory reflex mechanisms such as shivering, which under physiologic conditions help generate and preserve body heat. It is very important to take all the possible measures to preserve normotermia such as convective warm air blankets and warm intravenous fluids. This in turn acts as prevention of excessive O_2 consumption.

Bispectral Index Monitoring and Entropy

These monitors help the anesthesiologist to quantify the anesthetic depth of the patient and protect from over and under dosification of the anesthetics thus preventing prolonged emergence times or intraoperative awareness. Both the trend and a sudden drop in the monitor value alerts to a possible problem in the cerebral circulation [56,57].

Cerebral Oxygen Saturation

This is the golden standard in current non-invasive monitorization of patients at high risk of suffering cerebral hypoxia. It alerts the anesthesiologist to possible deleterious changes in cerebral blood flow and orientates to the anatomical region involved [58]. As its use becomes more wide spread it has the potential to improve the safety of the patient under controlled hypotension and diminish possible complications.

Complications

There are many reports of the complications of hypotension during surgery. However most of the publications are outdated and either describs situations of uncontrolled hypotension during surgical complications and in compromised patients (polytrauma, massive hemorrhage) or in insufficiently monitored patients. Modern literature on deliberate, controlled hypotension in the adequately monitored, optimized patient is lacking [59,60].

The following complications have been described (Table 4):

Table 4: ***Complications***

Complications
Surgical field bleed, insufficient hemostasis
Postoperative hematoma
Delayed awakening from anesthesia
Postoperative delirium
Postoperative cognitive disfunction
Vertigo
Chronic neuropathic pain
Cerebral thrombosis
Cerebral or cerebellar ischemia
Permanent brain damage
Retinal thrombosis
Myocardial infarction
Renal failure and anuria
Hepatic failure
Death (0,055%)

The Authors´ Accumulated 60 Year Experience

The authors´ practice of controlled hypotension spans a great part of the evolution of this technique and all the surgical specialties where it has been used. Both the anesthesiologists and their surgeons are fully convinced of the advantages that controlled hypotension offers to the patient, the surgeons and the health care system, when it is done in correctly preoperatively selected and optimized patients.

Maintaining patient safety under controlled hypotension requires training, experience and constant vigilance on the part of the anesthesiologist. It is advisable to raise the BP gradually in the phase of final hemostasis to help avoid postoperative bleeding when the patient returns to their basal BP. Having seen the evolution of hypotensive intraoperative technique and the different drugs used to achieve it, from trimetophan and nitroprussiate to halogenated inhalational agents and labetalol, we now recommend TIVA with propofol and remifentanyl or epidural anesthesia associated with propofol sedation or GA, depending on the surgical procedure. We use the whole armament of patient monitoring and in the 60 years of accumulated experience we have not had any complications which can be attributed to controlled hypotension.

Conclusion

Intraoperative controlled hypotension has now been on the clinical scene for one century, helping to decrease surgical bleeding and improving the visibility conditions of the operative field. When performed by experts, it is a safe and effective technique which allows carrying out surgical operations with precision, shortening in theatre time and improving the results. Associated with other blood saving measures in the context of Patient Blood Management it is effective in decreasing the need for transfusions with their associated risks and complications. Although more difficult to quantificate, it helps to improve the efficiency of operating theatre programming. The body of knowledge of the complex physiopathological changes that occur at the level of homeostatic reflexes of the main organ systems, their blood flow and autoregulation has grown greatly since controlled hypotension has first been introduced. Given that this technique has potential risks and complications, it is necessary to carefully weigh its advantages and disadvantages individually in each patient and each surgical procedure. In young healthy patients and short operations, complications are practically inexistent. In elderly, pluripathological patients and operations of long durations, there are more risks. The successful use of this technique depends on the hands on training of future anesthesiologists and surgeons. Up to date prospective, multicentric, randomized studies are needed to document and quantifications the advantages and safety of controlled hypotension in the era of advanced science of its pathophysiology, better drugs and improved patient monitoring.

Conflicts of Interest

The authors declare no conflict of interest

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