RESEARCH PAPER

# Controlled hypotension in anesthesia: Principles, applications, and perioperative considerations

**Adel Rizk Botros, Farahat Ibrahim Ahmed, Mohamed Ibrahim Ramadan Ismail ElAtfy, Ayman Eskander Tawfeek**

Anesthesia, intensive care and pain management department, Faculty of Medicine, Zagazig University, Egypt

***Corresponding author:** Mohamed Ibrahim Ramadan Ismail ElAtfy

**Email:** mohamedalatfy15@gmail.com

**Abstract:**

Controlled hypotension or hypotensive anesthesia is an anesthetic technique used to intentionally reduce arterial blood pressure in order to minimize intraoperative blood loss with subsequent decreasing the requirements of blood transfusion an/or improving surgical field visibility with subsequent meticulous surgical dissection and shortening of surgery time

This technique has been frequently applied in surgical procedures associated with significant bleeding, particularly neurosurgical maxillofacial, spinal, orthopedic, otolaryngologic, plastic and endoscopic sinus surgeries.

The technique can be achieved through pharmacological method via using various specific hypotensive pharmacological agents and non pharmacological method via various maneuvers as patient head up positioning, high level neuraxial block , and deepening of general anesthesia,.

The decision to induce hypotensive anesthesia should be based according to the patient's general condition, the extent of the surgery, and in coordination with the operating surgeon. The target blood pressure should be adjusted according to the patient's preoperative status and coexisting illness. The risk of organ hypoperfusion should be kept in mind. Understanding the physiological basis of controlled hypotension, available techniques, and pharmacological agents used for induced hypotension, careful patient selection and close monitoring with adequate intraoperative volume replacement are mandatory for its safe implementation in surgical cases.

The aim of this review article is to through the light on the physiological basis of controlled hypotension, its indications, contraindications, the commonly used techniques, and the potential associated complications.

**Keywords:** Controlled hypotension; Hypotensive anesthesia; Hypotensive drugs; Management of hypotensive anesthesia; Methods of reduction of intraoperative blood loss.

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## .Introduction

Maintenance of a patient's blood pressure within normal ranges during surgery (i.e. normotensive anesthesia) is the routine standard practice for maintaining perfusion to vital organs. However, in some surgical cases, the technique of deliberate or controlled hypotension is applied for reduction of blood loss.[1]

This technique was firstly introduced in 1946 by **Gardner** who used arteriotomy to reduce arterial blood pressure during surgery.[2] After that, the concept of hypotensive anesthesia has revolutionized anesthesia practice.

Controlled hypotension is used during general anesthesia for lowering blood loss in bloody operations with subsequent decreasing the requirements of blood transfusion an/or improving surgical field visibility with subsequent meticulous surgical dissection and shortening of surgery time.[3]

It is generally accepted that in healthy patients, mean arterial pressure (MAP) can be reduced to 50-65 mmHg without apparent complications.[4]

The objective of the controlled hypotension is a controlled blood pressure reduction while maintaining sufficient organ perfusion rather than creating true hypotension.[5]

However, the risk of decreased perfusion to vital organs and tissues, particularly the brain, heart, and kidneys, is linked to the use of hypotensive anesthesia. Therefore, the hypotensive method is not appropriate for all patients and may be dangerous for some.[6]

This article mainly reviews the idea of controlled hypotension during anesthesia, from various aspects as definition, physiological basis, indications, contraindications, techniques, monitoring, and complications.

## Definition

Controlled hypotension is defined as a controlled blood pressure reduction to 80 to 90 mm Hg and mean arterial pressure (MAP) by at least 30% of preoperative blood pressure or keeping a minimum MAP of 50–65 mmHg.[7,8]

**Indications of controlled hypotension**

The main indications for induced hypotension are to decrease blood loss with subsequent transfusion requirements especially in rare blood group, and to improve surgical field visibility with subsequent meticulous surgical dissection and shortening of surgery time.

Controlled hypotension is a suitable anesthetic technique for those patients who will be undergoing oromaxillofacial surgery (mandibular osteotomy, facial repair), endoscopic sinus or middle ear microsurgery, spinal surgery and other neurosurgery (aneurysm), major orthopaedic surgery (hip or knee replacement, spinal), prostatectomy, cardiovascular surgery and liver transplant surgery.[13-15] and it may be the only available option for Jehovah's Witnesses because of religious beliefs.[16]

**Contraindications of controlled hypotension**

The main danger of lowering blood pressure is tissue hypoperfusion. Therefore, controlled hypotension is **absolutely contraindicated in** peripheral vascular disease, cerebrovascular disease with severe carotid stenosis**,** symptomatic or severe aortic or mitral stenosis**,** severe hypertension, respiratory failure, renal failure, and hepatic failure**,** known drug allergy, and lack of experience or knowledge in this technique Also it is **relatively contraindicated** in benign hypertension, uncontrolled diabetes mellitus**, ,** coronary artery disease**,** anemia, hemoglobinopathies, polycythaemia**,** hepatic disease.**,** renal disease**,** bronchial asthma**,** elderly, pregnancy.**,** hypovolemia and inadequate monitoring.[17]

**Methods for achieving hypotensive anesthesia**

**A. Pharmacologic methods**

There are various drugs for achieving hypotensive anesthesia. The ideal drug should be short-acting, dose-dependent, with minimal effect on vital organs, and quick excretion without any residual toxic metabolites.[7]

The commonly used drugs for achieving hypotensive anesthesia **(Tab. 1)** are the following:

**Inhalational anesthetic agents:**

The commonly used Inhalational anesthetic agents are isoflurane, halothane, sevoflurane, and desflurane. They are primarily vasodilators, thus decreasing systemic vascular

**Physiology basis of autoregulation of organ blood flow**

Mean arterial pressure (MAP**)** is the result of multiplication of cardiac output (CO) by systemic vascular resistance (SVR). By reducing SVR, CO, or both, pharmacologic drugs cause hypotension. The phrase "controlled hypotension" may be medically deceptive because the clinical goal is to preserve organ perfusion while lowering MAP; the technique is meant to accomplish a controlled MAP reduction that stays within each patient's autoregulatory limits. Normally, organ blood flow is maintained within autoregulatory limits. In chronic hypertension, the autoregulatory curve moves to the right **(Fig 1)** requiring a higher MAP to maintain cerebral and renal perfusion.[9]

Blood flow becomes pressure-dependent when MAP falls below the lower limit of autoregulation **(Fig, 1)** increasing the risk of ischemic damage and hypoperfusion.[8,10]

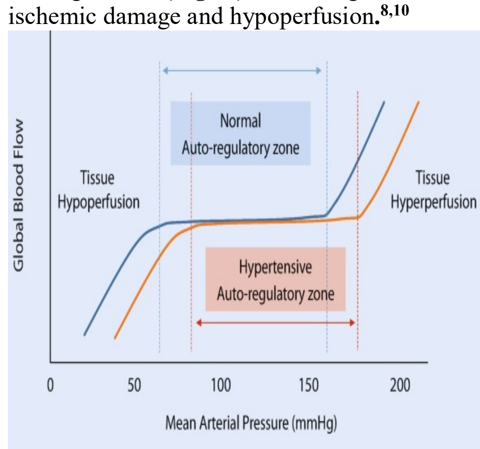


**Figure (1):** Limits of autoregulation of organ blood flow in normal blood pressure and in chronic hypertension. Autoregulation allows relatively constant organ blood flow across a range of mean arterial pressures (MAP). In patients with chronic hypertension, the autoregulatory curve shifts to the right, so lower MAPs may be poorly tolerated and increase the risk of ischemia at "normal" hypotensive targets.[11]

**Target blood pressure level in controlled hypotension**

Each individual has a range of blood pressures to which the individual's body is accustomed and within which it functions optimally. In hypotensive anesthesia, the patient's baseline mean arterial pressure (MAP) is reduced by 30%.[12]

Consequently, the systolic blood pressure values are about 80–90 mmHg and the MAP is reduced to 50–65 mmHg.[7]

glycerine in comparison with sodium nitroprusside has a slightly slower onset of action, but it does not cause myocardial ischemia, rebound hypertension, or any toxic metabolites.[21]

**Beta blockers**

These are commonly used for reducing blood pressure during surgery either alone or in combination with other agents. The commonly used beta blockers are Labetalol and Esmolol.

*Labetalol* blocks both $\alpha$ and $\beta$ receptors. $\alpha$-receptors blockage leads to vasodilatation, of blood vessels, thus causing hypotension, while $\beta$-receptor blockage prevents reflex increase in heart rate.[22]

*Esmolol* is a short-acting cardio-selective drug with antagonist action on the $\beta$-1 receptor. It has negative chronotropic and inotropic action, thus reducing CO, and heart rate, with subsequent decreasing blood pressure. Its ability to prevent reflex tachycardia and rebound hypertension makes it a good choice among $\beta$-blockers for hypotensive anesthesia. However, $\beta$-blockers need to be avoided in patients with a history of asthma due to the risk of bronchospasm associated with them.[23]

**Alpha-2 agonists**

These are commonly used for reducing blood pressure during surgery either alone or in combination with other agents. The commonly used alpha 2 agonists are clonidine and dexmedetomidine. Clonidine is commonly used to treat hypertension, migraine and menopausal flushing. It is less selective to $\alpha$-2 receptor as compared to dexmedetomidine (220:1 vs. 1620:1).[24]

Dexmedetomidine offers a promising role in hypotensive anesthesia. This is due to its wide spectrum of properties which includes sedation, analgesia, anxiolysis, and sympatholytic action at both central and peripheral levels. It preserves cardiovascular and respiratory functions and lacks any major side effects. Besides this, it is easy to administer and quite predictable with other anesthetic agents.[25]

**Magnesium sulfate**

Its mechanism of action includes antagonism of the non-competitive N-methyl-resistance. However, volatile anesthetics when used alone in high doses for controlled hypotension can cause hepatic or renal injury and delayed recovery from anesthesia.[18]

Overall, the use of inhalation anesthetic agents solely as hypotensive agent is controversial, and an adjuvant is required to induce truly controlled hypotension.
The commonly used adjuvant to inhalation anesthetics for achieving controlled hypotension are nitroglycerine, adenosine, morphine, labetalol, and esmolol. These adjuvant reduce the concentration and side effects of each drug.[18]

**Intravenous anesthetic agents**

Propofol is the most commonly used intravenous anesthetic agent. It acts by enhancing the inhibitory neurotransmitter gamma-aminobutyric acid (GABA) through GABA type A (GABAA) receptors. Hypotension is one of the associated side effects of propofol. This side effect is often desirable in surgeries requiring deliberate hypotension. Propofol has rapid onset and recovery, hence, mostly used as a part of total intravenous anesthesia (TIVA). Complete and smooth recovery without any residual effects makes it a good choice for day-care surgery.[19]

**Opioids**

These are commonly used in anesthesia for their analgesic effects, few opioids can induce hypotension which may not be desirable routinely. However, they have been used successfully as adjuvant to other hypotensive agents where controlled hypotension is indicated. Out of the commonly available opioids like morphine, fentanyl, alfentanil, sufentanil, and remifentanil, the latter has gained popularity due to its rapid onset and very short elimination half-life which is about 5 min.[20]

**Vasodilators**

Sodium nitroprusside and nitro-glycerine (NTG) are commonly used for rapid control blood pressure because of their short onset and duration of action. They produce nitric oxide which causes relaxation of vascular smooth muscle.. For a long time, sodium nitroprusside has been a drug of choice for hypotensive anesthesia. However, side effects like tachyphylaxis and cyanide toxicity impose challenges in its administration. Nitro-

| | | | | | |
|---|---|---|---|---|---|
| | | | and cyanide toxicity (rare) | anemia | tive airway disease (COPD) |
| **Labetalol** | 2-5 min | 4-8 hours | Bradycardia, heart block | Severe bradycardia, Bronchial asthma, heart block | May have long duration of action in patients with liver and renal dysfunction due to slow metabolismCaution in asthma |
| **Esmolol** | 1–2 min | 10–20 min | Bradycardia, heart block | Severe asthmatics | Caution in asthma |
| **Dexmedetomidine** | 5–10 min | 15–30 min | Hypotension, bradycardia, dry mouth, and nausea decrease lacrimation | Current high cost relative to generic medications | In patients with heart block or ventricular dysfunction (ejection fraction <30) – continuous monitoring of ECG, BP, SPO2 is essential |
| **Magnesium sulfate** | 1–2 min Pe | 30 min-1 h afte | Bradycardia, Respiratory depress | Severe renal impairment Myast | Reduced dose in renal disease , |

D-aspartate (NMDA) receptors, decrease catecholamine release, and anti-nociceptor action, thus decreasing response to noxious stimuli. It is a vasodilator and decreases systemic vascular resistance, thus producing hypotensive effects. Besides this, it has also anti-arrhythmic action. Hence, it can be used as an adjuvant for controlled hypotension.[26]

**Lidocaine**

It is a commonly used amide local anesthetic agent. It is also used to treat ventricular arrythmia and blunt the hypertensive response of laryngoscopy. Its negative inotropic action on the heart along with the sympatholytic effect may contribute to hypotension.[27]

**Table (1):** The pharmacological features of the commonly used drugs for controlled hypotension.[17]

| Drug | Onset time | Duration of action | Side effects | Patient contraindications | Adjustment for special population |
|---|---|---|---|---|---|
| **Propofol** | 30 sec-1 min | 5–10 min | Propofol infusion syndrome after prolong infusion, bradycardia | Severe renal or hepatic disease | Dose reduction in elderly patients, liver disease, heart failure |
| **Remifentanil** | 1–3 min | 5–10 min | Respiratory depression (dose-dependent) | Obstructive sleep apnea | Dose reduction in elderly patients, and respiratory disease |
| **NTG** | 1–2 min | 10–30 min | reflex tachycardia, venous congestion methemoglobinemia | Patients with increase intracranial tension, Severe | Decrease dose in patients with heart failure, chronic obstruc |

Over a MAP range of 60 to 150 mm Hg, cerebral blood flow typically stays constant. The autoregulation curve shifts to the right in individuals with long-term hypertension. The curve tends to return to normal in patients whose blood pressure is under control and they are receiving antihypertensive medication. Maintaining the patient in a state of normocapnia ($CO_2$ partial pressure ($PaCO_2$) between 35 and 40 mmHg) is advised.[17]

### Renal

Recent research indicates a high correlation between postoperative acute kidney damage (AKI) and intraoperative hypotension. Furthermore, even mild drop in arterial blood pressure damages renal blood flow, and general anesthesia impairs the autoregulation of renal blood flow. Maintaining MAP >65 mmHg is therefore advised.[31]

### Cardiovascular system.

Any increase in myocardial oxygen demand necessitates an increase in coronary artery blood flow at the same time. Hypotensive anesthesia may make this more difficult by lowering coronary blood flow as a result of decreased afterload or preload. Therefore, there is a considerable intraoperative risk of myocardial infarction with hypotensive anesthesia.[30]

### Monitoring during controlled hypotension

Under hypotensive anesthesia, the recommended monitoring are blood pressure, electrocardiography (ECG), arterial oxygen saturation, end tidal carbon dioxide ($EtCO_2$), urine output, core temperature, blood loss., cardiac out put and pressure points.

Invasive blood pressure monitoring is recommended as it provides beat to beat monitoring of the blood pressure and it also permits sampling for arterial blood gases analysis and estimation of the amount of hemoglobin. ECG monitoring especially the V5 lead with ST segment analysis helps to detect cardiac ischemia. Oxygen saturation must be monitored because of the risk of hypoxemia due to the mismatch of ventilation and perfusion. $EtCO_2$ is recommended for prevention of hypercarbia and hypo-capnia are essential. Because the relationship between EtCO2 and PaCO2 will be changed with hypotension, so that arterial blood gas determination should be carried out intermittently to make sure that the PaCO2 is within the desired range. Core temperature

| | | | | | |
|---|---|---|---|---|---|
| | ak effect within 5-10 min | r a single iv dose | ion Muscle weakness | henia gravis Heart block | elderly patient |
| **Lidocaine** | 3–5 min | 1–2 hours | C.N.S and cardiovascular toxicity | Severe heart block and liver disease | Reduced dose in liver disease, elderly patient |

**B. Nonpharmacologic methods**

These include head up or reverse Trendelenburg position (15 degrees from horizontal line) in head and neck surgery to allow venous drainage from the surgical field. **(28) ,** high neuraxial anesthesia that reduce SVR via sympathetic blockade., mild hyperventilation in selected neurosurgical patients, usage of Tourniquet for u limbs' orthopedic surgeries and optimal pneumoperitoneum pressures in laparoscopic surgeries.[8,29]

### Effect of controlled hypotension on various organs

### 1. Lungs

In head-up position, pulmonary blood flow tends to favor the dependent areas. Dead space increases as a result of non-dependent lungs being vented but not sufficiently perfused. The hypoxic pulmonary vasoconstriction response is eliminated by using vasodilators to cause hypotension, which increases intra-pulmonary shunt. When these elements come together, they cause hypoxia, hypercarbia, and a rise in the arterial-end tidal carbon dioxide ($etCO_2$) gradient. As a result, during controlled hypotension, it is crucial to regularly evaluate the partial pressure of carbon dioxide ($PaCO_2$).[30]

For the same reason, hypotension may also result in a decrease in arterial oxygen tension (PaO2). Therefore, during hypotensive anesthesia, a larger fraction of inspired oxygen (FiO2) might be required to keep the oxygen saturation within normal bounds.[17]

### Central nervous system

monitoring is essential because body heat dissipates very quickly from dilated vessels with subsequent hypothermia. Hypothermia should be avoided because it impairs the function of platelets and coagulation factors which are essential in hemostasis and also may decrease the effectiveness of vasodilators and increase the dose requirements if compensatory vasoconstriction occurs. The physiological response to blood loss may be lost during hypotensive anesthesia. Therefore, blood loss should be carefully estimated using swab weighing and measuring blood volume in suction bottles. Blood loss must be replaced with an equal amount of colloid or three to four times the amount of crystalloid. If the blood loss exceeds a predetermined level (e.g. 20–25% of the patient's total blood volume), a blood transfusion should be given.[32]

If available, cardiac output (CO) monitoring can also be used to guarantee sufficient perfusion of critical organs under hypotensive anesthesia. via either Lithium dilution cardiac output or Flowtrac technique.[33]

To avoid skin necrosis, the nasotracheal tube should be securely fastened with the least amount of pressure on the nares, and to avoid pressure sores, air cushions should be positioned under the pressure points like the sacrum.[34]

**Complications of controlled hypotension:**

Complications of controlled hypotension generally occur when MAP is reduced beyond the patient's autoregulatory capacity, resulting in true hypotension rather than a controlled MAP reduction. The potential complications of controlled hypotension include cerebral hypoperfusion, cerebral stroke, postoperative neurocognitive dysfunction, myocardial ischemia, acute kidney injury, visual loss and prolonged postprocedural hypotension.[29,35,36]

**Conclusion**

Controlled hypotension during surgery is beneficial because it can minimize the amount of intraoperative blood loss with subsequent decreasing the requirements of blood transfusion an/or improving surgical field visibility with subsequent meticulous surgical dissection and shortening of surgery time However, hypotension carries the risk of hypoperfusion in vital organs and is unsafe in certain patients. The level of the blood pressure reduction during controlled hypotension should be adjusted according to the patient's general condition, age, and coexisting conditions. Careful patient selection and close monitoring with adequate intraoperative volume replacement are mandatory for safe implementation of controlled hypotension in patients who are scheduled for known bloody surgical procedures.

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