Review Article

Perioperative management of hypertension

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Abstract: Hypertension has a very high prevalence, affecting 46% of the population in the US; it is a major culprit for adverse cardiovascular outcomes, renal disease and stroke; it also carries a substantial impact in the perioperative period. It is frequently encountered in the perioperative time, and its presence can potentially affect the hemodynamic control during anesthesia. Intraoperatively, hypotension may be present associated with anesthesia; however hypertension may predominate postoperatively. The presence of uncontrolled hypertension preoperatively may lead to cancellation of surgical procedures with consequent adverse impact in multiple domains (psychological, social and financial) for patients and their families, as well as operational for the healthcare system. There is paucity of data providing guidance on ideal blood pressure values for elective anesthesia and surgery. We consider a reasonable goal to aim for a systolic pressure 140 mmHg or less and diastolic pressure 90 or less preoperatively. In patients with systolic pressure of 180 mmHg or higher or diastolic pressure of 110 mmHg or higher, we recommend postponing the surgery until achieving a better blood pressure control, given the associated increased risk for adverse perioperative cardiovascular outcomes. Most antihypertensive medications need to be continued perioperatively. We have reviewed the recommendations on perioperative management of different antihypertensive medications.

Keywords: Perioperative; preoperative; intraoperative; postoperative; hypertension; surgery; anesthesia

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Introduction

Hypertension is one of the most common and prevalent diseases, affecting 46% of the current population in the USA, and it is defined as a blood pressure greater than 130 mmHg over 80 mmHg, according to the most recent guidelines that applies to the ambulatory patients (1,2). Hypertension will likely develop in most people associated with aging of the population. In general, despite diverse and effective treatment options, the blood pressure in the general population remains uncontrolled (3).

Hypertension in the preoperative period can occur in at least 25% of patients undergoing major surgery. Patients with underlying high blood pressure are at increased risk of perioperative hypertensive episodes and more likely to have labile hemodynamics during a procedure (4). An important issue to consider when treating blood pressure in surgical patient is that hypertension should be defined by the patient's preoperative blood pressure, for treating systolic or diastolic hypertension, a 20% increase over the baseline often defines a treatment threshold (5).

Hypertensive events occur more commonly in patients undergoing surgery of the carotids, followed by abdominal aorta, peripheral vascular procedures, intraperitoneal, and intrathoracic surgery (6). Acute post-operative hypertension is defined as SBP above 190 mmHg and/or DBP of 100 mmHg on two consecutive readings after surgical intervention, and this can occur in the first 20 minutes of the postoperative period, and its resolution can require up to 3 hours (7-9). Despite the lack of compelling evidence to support a stringent preoperative blood pressure control to prevent perioperative morbidity or mortality, clinicians

use an arbitrary threshold of systolic pressure 180 mmHg or more and/or a diastolic pressure 110 mmHg or more as a guideline to cancel a surgical procedure (10,11). The etiology of uncontrolled hypertension in the perioperative period is multifactorial; however, an attributable cause is the early discontinuation of long term antihypertensive regimen. No clear guidelines exist on the optimal blood pressure in the preoperative period, ideally the clinician need to use target blood pressure in the general population in the ambulatory settings. Our goal is to review the pathophysiology of perioperative hypertension, identify optimal perioperative blood pressure goals and to present treatment options to assist in safe and effective management of blood pressure in the critical period around the time of non-cardiac surgery. Since the intraoperative hypertension is managed mainly by the anesthesia team, it will be beyond the focus of this review.

Pathophysiology and etiologies

Perioperative hypertension presents at different times around the surgery: induction of anesthesia (especially if no opioid analgesia is used), intraoperatively (associated with acute pain-induced sympathetic stimulation that leads to vasoconstriction), or in the early post anesthesia period (associated with pain-induced sympathetic stimulation, hypothermia, hypoxia, or as a result of intravascular volume overload from excessive intraoperative intravenous fluid therapy). Post anesthesia hypertension associated with volume overload can remain for 24–48 hours until adequate mobilization of fluid from the extravascular space occurs. As stated previously, elevation of blood pressure is also associated to preoperative discontinuation of antihypertensive medications (4).

The increased activity of the sympathetic nervous system is the main driver of intraoperative hypertension, and this is associated with tachycardia and arrhythmia. And this might be a result of inadequate analgesia or anesthesia, surgical stimulation, or due to airway manipulation from the laryngoscopy and extubation. Other causes of hypertension during anesthesia are related to the hypoxemia and hypercapnia, or related to overdose of the drugs being used intraoperatively such as vasoconstrictors and inotropes. However, all instances of intraoperative hypertension must prompt exclusion of awareness and malignant hyperthermia as the cause (12).

The response to sympathetic activation during induction of anesthesia can be more pronounced in patients with untreated hypertension, as the systolic blood pressure can increase by 90 mmHg and the heart rate by 40 beats per minutes contrasting to the response in normotensive individuals where the blood pressure tends to rise by 20 to 30 mmHg and the heart rate to increase by 15 to 20 beats per minutes (13).

Prys-Roberts and colleagues found greater absolute decreases in intraoperative blood pressures in patients with higher preoperative values, at first lower values reported among untreated hypertensive patients. However subsequent report showed no significance difference between the treated and untreated hypertensive patient groups at any time after induction of anesthesia (14).

Patients with renal or cerebrovascular complication of hypertension, had higher intraoperative systolic pressure nadirs, this finding was independent of the preoperative in-hospital blood pressure. While patients whose hypertension was complicated by heart failure or ischemic heart disease had neither higher intraoperative systolic pressure nadirs nor more frequent treatment with a fluid challenge or adrenergic agents intraoperatively than did those with uncomplicated hypertension. It is possible that patients with renal or cerebrovascular complication hypertension have more inherent resistance to intraoperative deceases in blood pressure than do other hypertensive patients (15).

On the other hand, hypotension is the most encountered complication after spinal anesthesia (16); among the contributory factors are age, anatomical level of spinal puncture, baseline blood pressure, peak block height, combination with general anesthesia, and addition of phenylephrine to the local anesthetic (17) (*Table 1*).

Blood pressure goal

Guidelines for ambulatory blood pressure management have been published; however there is paucity of recommendations for hypertension management specifically in the perioperative setting. The latest 2014 ACC/AHA perioperative guidelines do not address the management of hypertension (18).

The 2007 version of ACC/AHA perioperative guidelines reported that Stage 1 or Stage 2 hypertension is not an independent risk factor for perioperative cardiovascular complications (19). However, uncontrolled stage 3 hypertension (systolic blood pressure ≥180 mmHg or diastolic blood pressure ≥110 mmHg), constitutes a risk factor for perioperative ischemic events (20,21).

Preoperative hypertension might present secondarily

Table 1 Causes of perioperative hypertension

Patient related factors
Undiagnosed or poorly controlled hypertension
Pregnancy-induced hypertension
Withdrawal of antihypertensive medication
Anxiety
White coat syndrome
Increased sympathetic tone
Pain induced leading to vasoconstriction
Inadequate analgesia
Inadequate anesthesia
Hypoxemia
Hypercapnia
Hypothermia
Airway manipulation
Surgical stimulation
Drug overdose
Vasoconstrictors
Inotropes
Ketamine
Ergometrine
Intravenous fluids
Other
Aortic cross-clamping
Pheochromocytoma
Malignant hyperthermia

to anxiety and/or "white coat syndrome", to prevent this phenomenon, it is beneficial allowing the patient to sit in a comfortable and relaxed environment before rechecking the blood pressure; a calm, relaxed patient is less likely to experience intraoperative hypertension, so consideration should be given to anxiolytic premedication (22). Values higher than 180/110 without symptoms of end-organ damage can be considered hypertensive urgencies in preoperative patients. If any home antihypertensive medications were withheld or missed, either these can be resumed a few hours prior to surgery, or a similar dose of a parenteral antihypertensive medication may be administered preoperatively (23).

Chronic control of the hypertension prior to the procedure is desirable to allow time for the body's auto-regulatory control of mean arterial pressure to recalibrate prior to the swings in perioperative blood pressure. The general perioperative strategy suggested is to maintain blood pressure within 20% of preoperative values with the purpose to prevent end organ hypoperfusion (10). Two important issues should be considered when treating the blood pressure in surgical patients. First, hypertension should be defined by the patient's preoperative blood pressure. For treating systolic or diastolic hypertension, a 20% increase over the baseline often defines a treatment threshold. Second, due to the shift in the autoregulatory system with chronic hypertension, these patients are often able to tolerate a higher blood pressure level but unable to tolerate significant degrees of hypotension compared with usually normotensive individuals (5).

While it is difficult to find convincing prospective data that prove the importance of preoperative control of hypertension to prevent perioperative morbidity and mortality, many clinicians use a threshold of systolic pressure 180 mmHg and/or diastolic pressure of 110 mmHg to decide whether to cancel or postpone a procedure. It has been shown that patients with elevated blood pressure in the preoperative period carry a greater risk for wide blood pressure variations intraoperatively, thus leading to periods of hypoperfusion and end-organ ischemia (24). Physiologically, this may be due to hyper-dynamic vasoconstriction being abruptly disrupted on a large scale by the induction of anesthesia.

For urgent or emergency operations, the risks of uncontrolled hypertension during general anesthesia and surgery must be weighed against the risk of end organ hypoperfusion caused by the need to decrease blood pressure acutely allowing safe performance of surgery. This situation mandates careful and precise titration of a rapid-acting antihypertensive agent with close monitoring of arterial pressure and end organ function to minimize the risk of adverse cardiovascular events (25).

Deferring elective surgeries

In preoperative evaluation of hypertension, it is important to know whether the blood pressure is controlled with medications or not. Delaying surgeries only for blood pressure control might not be necessary unless there is a target-organ damage (26) or when the diastolic blood pressure is above 110 mm, especially given the concomitant

increased risk of perioperative arrhythmias, myocardial ischemia and stroke that affects patients with uncontrolled hypertension (13,27-29).

Weksler *et al.* (30) did a randomized study in which they randomized patients coming in for elective non-cardiac surgeries, with diastolic blood pressure between 110 and 130 mmHg to two groups: 400 patients in the control group and 589 patients as the study group. The control group had their surgery postponed and they remained in hospital for BP control, and the study patients received 10 mg of Nifedipine intranasally delivered. The patients were observed for cardiovascular and neurological complications during the intraoperative period and over the first three postoperative days. There were no statistically significant differences in postoperative complications. The hospitalization time was considerable shorter in the study group than in the control group. This practice of using intranasal Nifedipine is not done in our institution.

When BP is mildly elevated at the time of surgery (<180/110), rapid reduction in BP is not necessary, and studies have been unable to remonstrate a benefit to delaying surgery (30). However, when BP is ≥180/110 mmHg preoperatively, antihypertensive medications should be administered, and intraoperative blood pressure monitored closely. There is a lack of data to support delay of surgery (13) .

Some guidelines were made using the JNCDET V classification of arterial pressure (stage 1, stage 2, stage 3 etc.), it is important to note that these stages were changed in 2017 by ACC/AHA and included new categories (31).

Therefore, patients with stage 1 and stage 2 hypertension may proceed with anesthesia and surgery, as an association with cardiac complication was not demonstrated before (15) and deferring surgery in theses patient has little justification because surgeries cancellations have been a major problem in healthcare worldwide, with resulting psychological, social and financial implications for patients and their families In patients with stage 3 hypertension, deferring surgery was recommended, especially with other cardiovascular risk factors and target organ damage that may further increase the perioperative risk. Patients with stage 4 hypertension have severe disease and anesthesia and surgery should be deferred whenever possible and the blood pressure treated (32).

Pharmacological therapy

Intraoperative pharmacological therapy is usually done using parenteral agents, and this handled by anesthesia team and it is beyond the scope of this review. We have focused on preoperative and postoperative medications management.

Preoperative period

As mentioned above, it is reasonable to aim for blood pressure control of systolic pressure 140 mmHg or less and diastolic pressure 90 or less. In patients with systolic pressure of 180 mmHg or higher or diastolic pressure of 110 mmHg or higher, deferring surgery until blood pressure is better controlled can be considered (10,11).

In patients with hypertension undergoing major surgery, it is reasonable to continue most antihypertensive medications until surgery, including the morning of surgery with sips of water (2). Listed below are recommendations involving different antihypertensive medication groups and administration of these medications prior to non-cardiac surgery.

Beta blockers:

- In patients already on beta blockers, the medication should be continued, including the morning of surgery with sips of water (2,33);
- Discontinuation of beta blockers prior to surgery may be harmful (33,34);
- Beta blocker initiation before non-cardiac surgery to reduce perioperative medical risk is controversial. A cardiac benefit is present, but increased complications such as increased death, stroke, and sepsis are present, especially when high dose beta blockers are initiated immediately before surgery (35);
- Beta blockers can be initiated when preoperative testing reveals an intermediate or high cardiovascular risk (36). In patients with 3 or more revised cardiac risk index (RCRI) risk factors (*Table 2*), it may be reasonable to begin beta blockers before surgery: Class IIB recommendation from 2014 ACC/AHA guidelines of Perioperative Cardiovascular Evaluation and Management of Patients Undergoing Non-cardiac Surgery (18);
- Beta blocker initiation should begin at least 1 day prior to surgery and ideally 1 week or more before surgery: beta blockers should never be started on the morning of surgery (2,35);
- Choice of Beta blocker: all studies that have reported a cardiovascular benefit of perioperative beta blockers have used agents that are moderately

Table 2 Six independent predictors of major cardiac complications

RCRI (37)
High-risk type of surgery (examples include vascular surgery and any open intraperitoneal or intrathoracic procedures)
History of ischemic heart disease (history of myocardial infarction or a positive exercise test, current complaint of chest pain considered to be secondary to myocardial ischemia, use of nitrate therapy, or ECG with pathological Q waves; do not count prior coronary revascularization procedure unless one of the other criteria for ischemic heart disease is present)
History of heart failure
History of cerebrovascular disease
Diabetes mellitus requiring treatment with insulin
Preoperative serum creatinine >2.0 mg/dL (177 micromol/L)

RCRI, revised cardiac risk index.

(Atenolol or Metoprolol) or highly (Bisoprolol) beta-1 cardioselective (38);

- ❖ There is evidence from the POISE trial (39) about the increased rate of stroke and all-cause mortality due to hypotension associated with prophylactic beta blocker in the perioperative settings, however that study did not enroll patients on long-term beta blockers and the pervious observation cannot be directly applicable to patients on long-term therapy. Therefore, physician will have to individualize the perioperative management of each patient who is chronically on a beta blocker. Reduction of the dose of beta blocker should be considered in the patient with systolic blood pressure <115 mmHg. This recommendation is based on expert opinion rather than evidence.

Based on the above data, it is optimal to continue beta blockers in patients who are already taking these medications. If patients are at intermediate or high cardiovascular risk, consideration is given to begin a beta blocker in the preoperative period. This medication should be started at least 1 day prior to surgery, and ideally 1 week prior to the surgical intervention. A low dose should be initiated and carefully up titrated. Beta blockers should not be started on the morning of surgery. The clinician can use for example, Metoprolol 12.5 twice a day, or Bisoprolol 2.5 mg daily.

Alpha-2 agonists (Clonidine):

- ❖ These medications should not be initiated for the purpose of cardiac perioperative protection. In the POISE 2 (40) Trial when Clonidine was started in the preoperative period, an increased risk of nonfatal cardiac arrest and hypotension was present, and no cardiac benefit was present (41);
- ❖ In patients already on Alpha-2 agonists they should be continued, including the morning of surgery. Discontinuation of Alpha-2 agonists prior to surgery may be harmful due to the risk of clonidine withdrawal syndrome (39).

Based on the above data, it is optimal to continue clonidine in those patients who are already taking this medication. This medication should not be initiated in the preoperative period with the intent of providing cardiac protection.

Calcium channel blockers: it is ideal to continue these medications in the perioperative period, including the morning of surgery. As these medications are usually well tolerated in the perioperative settings, and do not results in an exaggerated hypotensive response after induction of anesthesia (26). Limited data revealed a decreased incidence of myocardial ischemia and supraventricular tachycardia, especially with Diltiazem (42). Both Dihydropyridines and Non-Dihydropyridines can be continued with the caveat that the latter can cause bradycardia. Patients receiving calcium channel blockers may have an increased incidence of postoperative bleeding, probably due to inhibition of platelet aggregation (43). The multiple benefits of these drugs probably outweigh the small risk of continued therapy.

Diuretics: there is no supportive data to guide dosing this group of medications in the perioperative period. Due to potential for volume depletion and electrolyte disturbance, it is ideal to hold these medications on the morning of surgery in most cases. In patients undergoing carotid endarterectomy under general anesthesia, preoperative diuretic therapy is associated with an increased vasopressor requirement to maintain blood pressure when

used as a single antihypertensive or as a part of a multiple-antihypertensive regimen (44).

ACE inhibitors (ACE-I) and Angiotensin receptor blockers (ARBs):

- The use of these medications on the morning of surgery is controversial. The American Heart Association guidelines on perioperative cardiovascular evaluation and management from 2014 recommend that continuation of ACE-I and ARBs in the immediate preoperative period is reasonable (33,45);
- ACE-I/ARBs increase the rate of hypotension requiring vasopressor agents, usually at the time of anesthesia induction. A meta-analysis by Rosenman et al. revealed a relative risk of 1.5 in the incidence of hypotension requiring vasopressor agents, but no difference in perioperative myocardial infarctions or cardiac outcomes was noted (45-47);
- In patients undergoing major orthopedic surgery, ACE-I and ARBs given on the AM of surgery increase the risk of acute kidney injury. Nielson *et al.* measured an incidence of acute kidney injury of 8.3% in patients who received angiotensin blockade medications the morning of surgery versus 1.7% in those patients who did not receive these medications on the morning of surgery. There was no difference in mortality or progression to renal replacement therapy over a 2-year period. However, in those patients who developed acute kidney injury, the length of hospitalization was nearly doubled (47);
- If ACE-I medications are held prior to surgery, it is imperative to resume them postoperatively. A recent retrospective review by Mudumbai *et al.* revealed that failure to resume ACE-I medications within 2 weeks of surgery was associated with a 2.5-fold increase in mortality at 30 days (48);
- A recent review of withholding ACE-I/ARBs before surgery was associated with lower risk of all cause death, stroke and myocardial injury after non-cardiac surgery (MINS) (49).

Based on the above data, ACE-I/ARBs should be held on the morning of surgery in most cases. It is imperative to resume these medications in the postoperative period no later than 2 weeks following surgery.

Additional antihypertensive medication groups: medications such as Hydralazine, Alpha blockers, and Methyldopa can be continued in the perioperative period and can be administered on the morning of surgery.

Although not considered as a true antihypertensive medication, Nitrates can be given on the morning of surgery with sips of water.

Intraoperative period

Patients with intraoperative hypertension should be managed with intravenous medications with close titration of the blood pressure response (2). These medication orders and adjustments are handled by the Anesthesia team and not discussed here.

Postoperative period

Acute postoperative hypertension usually develops within 2 hours of surgery and can resolve within a few hours after treatment, however persistent blood pressure elevations may occur in the postoperative period. This can be associated with myocardial ischemia, MI, arrhythmia, congestive heart failure and cerebral ischemia in addition to hemorrhagic stroke (50). As noted above, uncontrolled preoperative hypertension is a predictor for postoperative blood pressure elevations.

When oral intake is resumed, antihypertensive medications can be resumed as the physiology dictates. It is important to resume beta blockers and alpha-2 agonists without prolonged interruption to avoid rebound hypertension and tachycardia (39). Calcium channel blockers can be resumed as the blood pressure stabilizes. Diuretics and ACE-I/ARBs can be resumed on postoperative days 1 to 3, as blood pressure and fluid status dictate. Hydralazine, nitrates, and alpha blockers should be resumed postoperatively as the physiological status dictates. In all situations, ordering "holding parameters" on all antihypertensive will prevent overmedication when the blood pressure may be too low.

While there are no clear guidelines about what holding parameters to use, the clinicians need to individualize the parameters based on the patient comorbidities and the current status. For example, patients with systolic heart failure or Liver cirrhosis have baseline low blood pressure and the holding parameters may need to be higher than other hypertensive patients. Similarly, patients with postoperative cerebrovascular accidents need to use different holding parameters for their blood pressure medications.

When oral intake cannot be immediately resumed in the post-operative period, intravenous fluids are essential to maintain proper electrolyte and fluid balance. Until

oral intake is resumed, antihypertensive medications used prior to surgery can be resumed in intravenous or topical formulations. Listed below are recommendations involving different antihypertensive medication groups and alternatives to oral dosing in the postoperative period.

For diuretics:

- Intravenous Furosemide or Bumetanide can be substituted for any oral diuretic. At our institution we prefer furosemide and begin this medication on postoperative day 2–3 unless urgent situations arise prompting earlier dosing. Intravenous fluids are continued with close attention to fluid balance, electrolytes, and blood pressure control. The correct dose is dependent on preoperative dose, current volume status and the appropriate intravenous conversion;
- As oral intake is resumed, oral diuretics are restarted with dose adjustments based on fluid balance and blood pressure.

For Beta blockers:

- Intravenous Metoprolol can be substituted for any oral beta blocker: (Atenolol, Propranolol, Carvedilol, and Bisoprolol);
- When the preoperative beta blocker dose is low, intravenous Metoprolol can be started at 2.5 mg intravenously every 6 hours on a scheduled basis. When the beta blocker dose is moderate to high, a reasonable starting dose is 5 mg intravenously every 6 hours on a scheduled basis;
- The dose of intravenous Metoprolol can be titrated upward as needed, but should not exceed 10 mg every 6 hours;
- Appropriate "holding parameters" should always be placed to prevent overmedication when the blood pressure or heart rate is too low;
- Intravenous labetalol is often used to acutely lower blood pressure in patients with hypertensive urgency; and the clinician need to be aware about the alpha antagonist property of this agent in addition to the beta blocking one;
- As oral intake resumes, the intravenous beta blocker can be stopped, and the oral dose resumed. Starting at a lower initial oral dose of the beta blocker compared with the home dosage for 1 to 2 days provides a safer transition to oral medications with less chance of hypotension or bradycardia.

For any ACE-I or ARB:

- Intravenous Enalaprilat can be given on a scheduled basis in place of any ACE-I/ARB medication with "holding parameters" to prevent overmedication when the blood pressure may be too low;
- This can be initiated as intravenous Enalaprilat on post-operative day 1 or 2;
- The dose range is 0.625 to 2.5 mg intravenous and this is preferably given as infusion with a diluted solution;
- A reasonable starting dose for all doses of ACE-I/ARBs is 0.625 mg every 6 hours;
- The dose can be titrated upward as needed, but should not exceed 2.5 mg every 6 hours;
- Close attention to blood pressure, renal function and potassium levels is needed;
- As oral intake resumes, the intravenous Enalaprilat can be stopped and the oral dose of the ACE-I/ARB medication resumed. And again, starting with a lower initial oral dose of the ACE-I/ARB compared with the home dosage for 1 to 2 days provides a safer transition to oral medications with less chance of hypotension.

For any Calcium channel blocker:

- Intravenous Nicardipine or Diltiazem can be substituted for any calcium channel blocker. At our institution, this requires a transfer to a higher level of care on a dedicated cardiac unit or an intensive care unit. For this reason, we do not routinely administer intravenous calcium channel blockers in the postoperative period for control of hypertension;
- As oral intake is resumed, the calcium channel blocker is restarted at the same dose as prior to surgery. Appropriate "holding parameters" on these medications should be placed to prevent overmedication when the blood pressure may be too low.

For Alpha-2 agonists (Clonidine):

- Clonidine can be administered in a patch form known as Catapres TTS;
- The TTS patch requires 2 to 3 days to reach a steady state;
- The patch is applied to the skin and the duration of antihypertensive effect is 1 week. The clinician can use the suggested conversion below:
  - Clonidine 0.1 mg BID to TID = Catapres patch TTS-1;
  - Clonidine 0.2 mg BID to TID = Catapres patch TTS-2;
  - Clonidine 0.3 mg BID to TID = Catapres patch TTS-3.

- ❖ As oral intake resumes, the patch is removed, and the oral dose of clonidine is restarted no less than 8 hours after patch removal. The oral dose of clonidine should be 50% of the home dose on postoperative days 1 to 2, with an increase to the full dose on postoperative day 3. Appropriate "holding parameters" on these medications should be placed to prevent overmedication when the blood pressure may be too low.

For Nitrates:

- ❖ Although not consider an antihypertensive in the purest sense, it will induce vasodilation of both arterioles and veins. And it is being used as the treatment of choice in angina. Chronic nitrate therapy is used to prevent recurrent angina episodes, and in patients with heart failure. Therefore, it is optimal to continue these meds in the post-operative period, and if the oral route cannot be used, then a conversion to a patch from can be done and this is a suggested conversion:
  - ◆ Isosorbide less than 60 mg per day = Nitroglycerin patch 0.2 mg/hour;
  - ◆ Isosorbide 60 mg or more per day = Nitroglycerin patch 0.3 to 0.4 mg/hour.
- ❖ The patch is placed for 12 hours each day and then removed for 12 hours at night to avoid nitrate tolerance.
- ❖ As oral intake is resumed, the patch is discontinued, and the oral dose of nitrate medication is resumed.

For Alpha blockers:

- ❖ These meds are resumed as the blood pressure and physiology allows.

For Hydralazine:

- ❖ When moderate to high doses of oral Hydralazine are used preoperatively, intravenous Hydralazine at a dose of 5–10 mg every 6 hours on a scheduled basis may be reasonable with very close attention to blood pressure and heart rate;
- ❖ As oral intake resumes, the intravenous Hydralazine can be stopped, and the oral dose of the medication resumed. This author has found that a lower initial oral dose of Hydralazine compared with the home dosage for 1 to 2 days provides a safer transition to oral medications with less chance of hypotension;
- ❖ We avoid the use of intravenous Hydralazine for as needed treatment of acute elevations of blood pressure in the postoperative period due to potential for harm and lack of benefit (50).

Conclusions

Adequate blood pressure control must be maintained in all three perioperative (pre, intra and postoperative) settings, as its instability is associated with multiple adverse events. Careful assessment of the adequacy of chronic blood pressure control and early identification of target organ damage is paramount. Looking at all causes of hypertension in the three perioperative settings should be done prior to pharmacological therapy. Patient with preoperative uncontrolled stage 3 hypertension pose the greatest risk for perioperative cardiovascular complications. The goal is to maintain mean arterial pressure within 20% of baseline values when possible. Several therapeutic options are available to be used perioperatively, and when the oral intake cannot be resumed postoperatively, options are available in intravenous or patch form. The ideal antihypertensive agent should provide immediate onset of action, act selectively on the arterial circulation, and be easy to titrate precisely. Antihypertensive medications should be continued until the day of surgery with exception of renin-angiotensin-blocking agents, which may be continued and not to be given on the day of the surgery and to be resumed after the surgery.

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References

1. Muntner P, Carey RM, Gidding S, et al. Potential U.S. Population Impact of the 2017 ACC/AHA High Blood Pressure Guideline. J Am Coll Cardiol 2018;71:109-18.
2. Whelton PK, Carey RM, Aronow WS, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: Executive Summary. Available online: http://hyper.ahajournals.org/content/hypertensionaha/early/2017/11/10/HYP.0000000000000066.full.pdf
3. Chobanian AV. Shattuck Lecture. The hypertension paradox--more uncontrolled disease despite improved therapy. N Engl J Med 2009;361:878-87. Erratum in: N Engl J Med 2009;361:1516.
4. Varon J, Marik PE. Perioperative hypertension management. Vasc Health Risk Manag 2008;4:615-27.
5. Goldberg ME, Larijani GE, Pharm D, et al. Perioperative hypertension. Semin Anesth. 1998;17:87-92.
6. Goldman L, Caldera DL, Nussbaum SR, et al. Multifactorial index of cardiac risk in noncardiac surgical procedures. N Engl J Med 1977;297:845-50.
7. Gal TJ, Cooperman LH. Hypertension in the immediate postoperative period. Br J Anaesth 1975;47:70-4.
8. Seltzer JL, Gerson JI, Grogono AW. Hypertension in perioperative period. N Y State J Med 1980;80:29-31.
9. McGuirt WF, May JS. Postoperative hypertension associated with radical neck dissection. Arch Otolaryngol Head Neck Surg 1987;113:1098-100.
10. Dodson GM, Bentley WE 4th, Awad A, et al. Isolated perioperative hypertension: clinical implications & contemporary treatment strategies. Curr Hypertens Rev 2014;10:31-6.
11. Fleisher LA. Preoperative evaluation of the patient with hypertension. JAMA 2002;287:2043-6.
12. Graham SG, Aitkenhead AR, Alan R, et al. Complications during anaesthesia. Smith and Aitkenhead's Textbook of Anaesthesia 2013:853-86.
13. Wolfsthal SD. Is blood pressure control necessary before surgery? Med Clin North Am 1993;77:349-63.
14. Prys-Roberts C, Foëx P, Greene LT, et al. Studies of anaesthesia in relation to hypertension. IV. The effects of artificial ventilation on the circulation and pulmonary gas exchanges. Br J Anaesth 1972;44:335-49.
15. Goldman L, Caldera DL. Risks of general anesthesia and elective operation in the hypertensive patient. Anesthesiology 1979;50:285-92.
16. Tarkkila P. Complications Associated with Spinal Anesthesia. In: Complications of Regional Anesthesia. New York, NY: Springer New York, 2007:149-66.
17. Carpenter RL, Caplan RA, Brown DL, et al. Incidence and risk factors for side effects of spinal anesthesia. Anesthesiology 1992;76:906-16.
18. Fleisher LA, Fleischmann KE, Auerbach AD, et al. 2014 ACC/AHA guideline on perioperative cardiovascular evaluation and management of patients undergoing noncardiac surgery: a report of the American College of Cardiology/American Heart Association Task Force on practice guidelines. J Am Coll Cardiol 2014;64:e77-137.
19. Fleisher LA, Beckman JA, Brown KA, et al. ACC/AHA 2007 Guidelines on Perioperative Cardiovascular Evaluation and Care for Noncardiac Surgery: Executive Summary: A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery) Developed in Collaboration With the American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Rhythm Society, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, and Society for Vascular Surgery. J Am Coll Cardiol 2007;50:1707-32. Erratum in: J Am Coll Cardiol 2008;52:794-7.
20. Chobanian AV, Bakris GL, Black HR, et al. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure: the JNC 7 report. JAMA 2003;289:2560-72. Erratum in: JAMA 2003;290:197.
21. Eagle KA, Berger PB, Calkins H, et al. ACC/AHA guideline update for perioperative cardiovascular evaluation for noncardiac surgery---executive summary a report of the American College of Cardiology/American Heart Association Task Force on Practice

Guidelines (Committee to Update the 1996 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery). Circulation 2002;105:1257-67. Erratum in: Circulation 2006;113:e846.
22. Aitkenhead AR, Moppett IK, Thompson JP. Complications during anaesthesia. In: Smith and Aitkenhead's Textbook of Anaesthesia. Sixth Edit. 2013:853-86.
23. Papadakos PJ, Franklin KM. Management of Preoperative Hypertension. Available online: https://www.urmc.rochester.edu/MediaLibraries/URMCMedia/Anesthesiology/documents/Hypertension_Papadakos_Franklin.pdf
24. Prys-Roberts C, Meloche R, Foëx P. Studies of anaesthesia in relation to hypertension. I. Cardiovascular responses of treated and untreated patients. Br J Anaesth 1971;43:122-37.
25. Cheung AT. Exploring an optimum intra/postoperative management strategy for acute hypertension in the cardiac surgery patient. J Card Surg 2006;21 Suppl 1:S8-S14.
26. Sear JW. Perioperative control of hypertension: when will it adversely affect perioperative outcome? Curr Hypertens Rep 2008;10:480-7.
27. Roizen MF. Anesthetic Implications of Concurrent Diseases. In: Miller RD, editor. Anesthesia. 4th edition. New York: Churchill Livingstone, 2000:927-30.
28. Prisant LM, Houghton JL, Bottini PB, et al. Hypertensive heart disease. How does blood pressure affect left ventricular mass? Postgrad Med 1994;95:59-62, 66-76.
29. Vertes V, Goldberg G. The preoperative patient with hypertension. Med Clin North Am 1979;63:1299-308.
30. Weksler N, Klein M, Szendro G, et al. The dilemma of immediate preoperative hypertension: To treat and operate, or to postpone surgery? J Clin Anesth 2003;15:179-83.
31. Whelton PK, Carey RM, Aronow WS, et al. 2017 Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults. A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines 2017. Available online: http://hyper.ahajournals.org/content/early/2017/11/10/HYP.0000000000000065
32. Dix P, Howell S. Survey of cancellation rate of hypertensive patients undergoing anaesthesia and elective surgery. Br J Anaesth 2001;86:789-93.
33. Shammash JB, Trost JC, Gold JM, et al. Perioperative beta-blocker withdrawal and mortality in vascular surgical patients. Am Heart J 2001;141:148-53.
34. Houston MC. Abrupt discontinuation of antihypertensive therapy. South Med J 1981;74:1112-23.
35. London MJ, Hur K, Schwartz GG, et al. Association of perioperative β-blockade with mortality and cardiovascular morbidity following major noncardiac surgery. JAMA 2013;309:1704-13. Erratum in: JAMA 2015;314:188.
36. Devereaux PJ, Sessler DI, Leslie K, et al. Clonidine in patients undergoing noncardiac surgery. N Engl J Med 2014;370:1504-13.
37. Lee TH, Marcantonio ER, Mangione CM, et al. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. Circulation 1999;100:1043-9.
38. Auerbach AD, Goldman L. beta-Blockers and reduction of cardiac events in noncardiac surgery: scientific review. JAMA 2002;287:1435-44.
39. POISE Study Group, Devereaux PJ, Yang H, et al. Effects of extended-release metoprolol succinate in patients undergoing non-cardiac surgery (POISE trial): a randomised controlled trial. Lancet 2008;371:1839-47.
40. Devereaux PJ, Mrkobrada M, Sessler DI, et al. Aspirin in patients undergoing noncardiac surgery. N Engl J Med 2014;370:1494-503.
41. Wijeysundera DN, Beattie WS. Calcium channel blockers for reducing cardiac morbidity after noncardiac surgery: a meta-analysis. Anesth Analg 2003;97:634-41.
42. Turan A, You J, Shiba A, et al. Angiotensin converting enzyme inhibitors are not associated with respiratory complications or mortality after noncardiac surgery. Anesth Analg 2012;114:552-60.
43. Zuccalá G, Pahor M, Landi F, et al. Use of calcium antagonists and need for perioperative transfusion in older patients with hip fracture: observational study. BMJ 1997;314:643-4.
44. Anastasian ZH, Gaudet JG, Connolly ES Jr, et al. The effect of antihypertensive class on intraoperative pressor requirements during carotid endarterectomy. Anesth Analg 2011;112:1452-60.
45. Rosenman DJ, McDonald FS, Ebbert JO, et al. Clinical consequences of withholding versus administering renin-angiotensin-aldosterone system antagonists in the preoperative period. J Hosp Med 2008;3:319-25.
46. Mets B. Management of hypotension associated with angiotensin-axis blockade and general anesthesia administration. J Cardiothorac Vasc Anesth 2013;27:156-67.
47. Nielson E, Hennrikus E, Lehman E, et al. Angiotensin axis blockade, hypotension, and acute kidney injury in elective major orthopedic surgery. J Hosp Med 2014;9:283-8.
48. Mudumbai SC, Takemoto S, Cason BA, et al. Thirty-day mortality risk associated with the postoperative nonresumption of angiotensin-converting enzyme

inhibitors: a retrospective study of the Veterans Affairs Healthcare System. J Hosp Med 2014;9:289-96.
49. Roshanov PS, Rochwerg B, Patel A, et al. Withholding versus Continuing Angiotensin-converting Enzyme Inhibitors or Angiotensin II Receptor Blockers before Noncardiac Surgery: An Analysis of the Vascular events In noncardiac Surgery patIents cOhort evaluatioN Prospective Cohort. Anesthesiology 2017;126:16-27.
50. Lipari M, Moser LR, Petrovitch EA, et al. As-needed intravenous antihypertensive therapy and blood pressure control. J Hosp Med 2016;11:193-8.

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