# The patient with hypertension undergoing surgery

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**Purpose of review**
General recommendations for the perioperative management of patients with hypertensive disease have not evolved much over the past 20 years, yet new pathophysiological concepts have emerged and new monitoring techniques are available today. In this review, we will discuss their significance and potential role in the modern perioperative care of hypertensive patients.

**Recent findings**
For hypertensive patients, total cardiovascular risk rather than blood pressure (BP) alone should determine the preoperative strategy. Except for grade 3 hypertension, surgery should not be deferred on the basis of an elevated BP in the preoperative assessment.
New data suggest that even brief hypotensive episodes during surgery may have significant impact on outcome. Isolated systolic hypertension is the predominant phenotype in elderly patients who may be particularly vulnerable to hypoperfusion in the perioperative setting.
New monitoring techniques such as echocardiography and near-infrared spectroscopy may provide crucial information to optimize intraoperative control of BP based on an individual patient's pathophysiology.

**Summary**
Hypertension is highly prevalent in patients presenting for surgery yet its impact on surgical outcome is still debated. Guidelines on risk stratification and perioperative hemodynamic management of patients with hypertensive disease remain sparse and cannot rely much on solid new evidence. Target organ damage associated with hypertensive disease rather than high BP *per se* appears to determine perioperative risk. In the absence of new data, an individualized and pathophysiology-based approach to control BP may be the best option to guide these patients through the perioperative period.

**Keywords**
blood pressure management, cardiovascular risk, hypertension, perioperative medicine

## INTRODUCTION

Hypertension is a progressive cardiovascular disease that affects about 30–45% of the adult population in Europe. Its prevalence increases steeply with ageing. The European societies of Hypertension and Cardiology define hypertension as persistent SBP at least 140 mmHg and/or DBP at least 90 mmHg [1]. Blood pressure (BP) ranges in adults are classified into seven categories, with three grades of hypertension severity and a separate category for isolated systolic hypertension (Table 1). Hypertensive emergency and hypertensive urgency are defined as an acutely elevated SBP at least 180 mmHg or DBP at least 110 mmHg, with and without the presence of end-organ damage, respectively.

There is a continuous and independent relationship between BP and the incidence of stroke, myocardial infarction, sudden death, heart failure, peripheral artery disease, and renal disease. The majority of patients with hypertensive disease have additional risk factors for cardiovascular and renal events, which modify this relationship. Recent guidelines, therefore, no longer focus on BP values only, but take total cardiovascular risk as the primary determinant for selecting a specific antihypertensive drug treatment [2].

The importance of tight BP control in the long-term prevention of cardiovascular events is well established and based on strong evidence. This does not apply to the perioperative period. Although there is little evidence that raised preoperative BP affects postoperative outcome, uncontrolled hypertension in the preoperative setting continues to

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## KEY POINTS

- Target organ damage associated with hypertensive disease and total cardiovascular risk, rather than high BP *per se* appear to determine perioperative risk.
- The phenotype of isolated systolic hypertension with increased pulse pressure and diastolic dysfunction predominates in the elderly and constitutes a particular perioperative risk profile that calls for more scientific and clinical attention.
- In the absence of evidence-based guidelines, an individualized and pathophysiology-based approach to BP control may be the best option to guide hypertensive patients through the perioperative period.
- Monitoring techniques based on near-infrared spectroscopy show promise for real time assessment of autoregulation limits as a basis for individualized pressure management.

be one of the major reasons for cancellation of surgery [3].

Guidelines on how to target intraoperative BPs in patients with hypertensive disease are also vague. In the absence of well controlled studies, it seems prudent to base hemodynamic management on a thorough understanding of the pathophysiology of the disease. New monitoring techniques such as near-infrared spectroscopy are expected to provide better guidance in optimizing BP control for individual patients [4■■].

## IMPORTANCE OF PREOPERATIVE HYPERTENSION

The effect of chronic hypertension on perioperative risk is determined primarily by the presence of long-term consequences, that is, coronary artery disease, stroke, heart failure, and renal failure, all of which are known to affect perioperative morbidity and mortality [5]. It is not clear if increased BP has an independent effect. The updated European societies Cardiology/European Society of Anaesthesiology guidelines on cardiovascular assessment and management in noncardiac surgery state that clinicians may consider 'not' deferring noncardiac surgery in patients with grade 1 and 2 hypertension. Nevertheless, patients with a new diagnosis of hypertension should be screened for end-organ damage and cardiovascular risk factors. A preoperative electrocardiogram and serum creatinine level is required, whereas further testing is directed by a focused medical history and clinical examination. B-type natriuretic peptide was shown to correlate with markers of cardiac inflammatory processes and remodeling in asymptomatic hypertensive patients [6]. Preoperative B-type natriuretic peptide could be a useful adjunct for risk stratification but there is insufficient evidence at present for its use as a routine screening test in hypertensive patients. Valid reasons for delaying surgery are BP of grade 3, discovery of end-organ damage that has not previously been evaluated or treated, or suspicion of secondary hypertension without properly documented cause [7■]. Importantly, a single BP measurement in the preoperative assessment clinics may be an inaccurate estimate of baseline BP. A recent consensus document of the Association of Anaesthetists of Great Britain and Ireland and the British Hypertension Society highlights the important role of primary care physicians to ensure that patients admitted to the hospital for elective surgery are known to have BPs below grade 2 [8].

## CARDIOVASCULAR PATHOPHYSIOLOGY

Primary hypertension is a complex syndrome involving overactivity of the sympathetic nervous system [9], hormonal and metabolic abnormalities, and activation of the immune system [10]. The close association between hypertension and type 2

**Table 1.** Definitions and classification of office blood pressure levels

| Category | SBP (mmHg) | | DBP (mmHg) |
|---|---|---|---|
| Optimal | <120 | and | <80 |
| Normal | 120–129 | and/or | 80–84 |
| High normal | 130–139 | and/or | 85–89 |
| Grade 1 hypertension | 140–159 | and/or | 90–99 |
| Grade 2 hypertension | 160–179 | and/or | 100–109 |
| Grade 3 hypertension | ≥180 | and/or | ≥110 |
| Isolated systolic hypertension | ≥140 | and | <90 |

The highest level defines the blood pressure category, whether SBP or DBP. Isolated systolic hypertension should be graded 1–3 according to systolic values in the range indicated. Adapted with permission from [1].

diabetes has been attributed to the fact that both diseases share common risk factors but recent data suggest that there is a more complex and possibly pathogenic relationship [11].

It is long known that a persistent increase in BP induces structural remodeling of smaller resistance arteries early in the development of hypertension. To compensate for the increased vascular wall tension, the medial layer of the vascular wall thickens and the wall-to-lumen ratio increases at the expense of luminal diameter. This vascular adaptation, termed eutrophic inward remodeling, creates a chronic elevation of vascular resistance. It may also explain the exaggerated response to vasopressors typically observed in hypertensive patients [12,13]. Increased myogenic tone and arteriolar vasoconstriction protect capillaries from continuous exposure to high pressures but also cause functional and, eventually, even structural capillary rarefaction [14]. The latter is thought to occur through cell apoptosis, induced by low shear stress conditions in the nonperfused microvessels.

In recent years, attention has focused more on degenerative changes that occur in larger conduit arteries. Such vessels normally serve to buffer stroke volume and pressure during cardiac systole and release this energy during diastole so as to preserve continuous organ perfusion. Hypertension is associated with a loss of compliance in such conduit arteries, a process called arterial stiffening [15]. As a result of this pathophysiological process, the transformation of cyclic cardiac stroke volumes into a smooth continuous forward flow (the Windkessel effect) becomes less efficient and arterial pressure waves typically show an increased amplitude with larger pulse pressures, that is, an increased difference between SBP and DBP [16▪].

The pressures and pressure waveforms in any part of the arterial circulation are a summation of the forward pressures, generated by cyclic cardiac ejection of blood into the system, and reflecting pressure waves that bounce back from peripheral arterioles. In normal conditions, these reflecting waves add up to the diastolic component of the forward pressure waves at the level of the central arteries and augment diastolic pressure. At more peripheral locations of the arterial circulation, the phase between forward and reflecting waves is much smaller so the summation of pressures shifts toward systole. It explains the typical changes in the waveform pattern of BPs registered at increasing distance from the central aorta. With arterial stiffening, pressure waves travel at higher speed and bounce back to arrive earlier in the central aorta. Systolic pressure summation and the loss of diastolic augmentation amplify the already augmented pulse pressures in the central conduit arteries of patients with arterial stiffening. (Fig. 1) These pathologically increased pulse pressures cause a double burden to the heart. Firstly, there is a continuous increase in cardiac afterload, as the heart must now eject against augmented systolic pressures. The increased workload on the heart induces left ventricle (LV) hypertrophy to compensate for higher wall tensions but this goes at the expense of LV compliance and diastolic function. Secondly, decreased DBPs impair myocardial

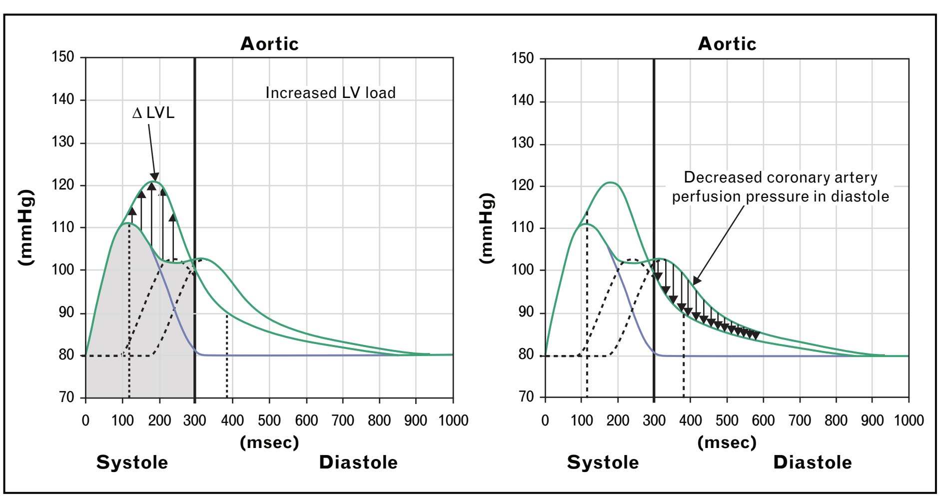


**FIGURE 1.** Panels indicate blood pressure composed of a forward and backward travelling pressure wave: full green line shows pressure signal in central aorta composed of forward (purple) and backward travelling (dotted lines) pressure waves. Left panel: arrows indicate systolic augmentation when backward pressure wave travels at increased speed [2] as compared with normal [1] because of arterial stiffening. Right panel: arrows indicate loss of diastolic augmentation because of early arrival of backward travelling pressure wave [2].

perfusion and render the hypertrophic myocardium sensitive to myocardial ischemia.

## PULSE PRESSURE AND ISOLATED SYSTOLIC HYPERTENSION

Arterial stiffening is typically seen in elderly patients since aging induces a progressive loss of elastin in conduit arteries [17,18]. Hence, isolated systolic hypertension, with low or normal DBPs and increased pulse pressures, is the predominant phenotype in this population. Patients with isolated systolic hypertension may be particularly vulnerable during surgery and anesthesia: antihypertensive drugs and anesthetics invariably decrease both SBP and DBP. Attempts to decrease SBP toward 'normal' ranges may cause diastolic hypotension and organ hypoperfusion. In elderly hypertensive patients, an excessive reduction of BP was reported to deteriorate cognitive function [19].

In cardiac surgery, high preoperative pulse pressures have been associated with a three-fold increase in perioperative mortality, an increased incidence of renal impairment, and with reduced long-term survival [20,21]. This has not been consistently observed in patients undergoing noncardiac surgery. Increased pulse pressures are not invariably the result of arterial stiffening as exercise also transiently increases systolic pressure with no change or a slight decrease in diastolic pressure. In search for an objective method to diagnose and quantify arterial stiffening several techniques have been proposed from which assessment of pulse wave velocity is currently considered the gold standard. An increase in pulse wave velocity by 1 m/s was reported to cause a 15% adjusted risk increase in cardiovascular mortality in the general population [16▪]. The validity of this index in perioperative medicine has not been clearly established but it may prove a valuable risk indicator in the preoperative assessment of hypertensive patients.

## LEFT VENTRICULAR HYPERTROPHY AND DIASTOLIC DYSFUNCTION IN HYPERTENSIVE PATIENTS

Hypertension is the primary cause of left ventricular hypertrophy (LVH). Until recently, little attention was paid to a diagnosis of LVH on a preoperative ECG except for considering it the result of chronic hypertension or as a potential indicator of aortic stenosis. In the past few years however, it has become increasingly clear that diastolic dysfunction, typically present in LVH, is a specific syndrome that affects cardiovascular reserve and may evolve to a distinct type of heart failure with preserved ejection fraction [22]. Importantly, even asymptomatic diastolic dysfunction has been associated with higher 30-day and long-term cardiovascular morbidity in patients undergoing vascular surgery [23]. Echocardiography-based Doppler interrogation of transmitral flow and mitral annular velocity has become the standard technique to assess diastolic function. It has gradually replaced invasive catheterization for LV pressure measurements [24] and has also been used for the estimation of LV filling pressures during surgery as well as in critically ill patients with variable success [25]. There are few concrete guidelines for perioperative management of patients with diastolic dysfunction. With poor tolerance to hypovolemia, and at the same time an increased risk for fluid overload, these patients have very narrow margins for fluid optimization [26]. New monitoring techniques such as echocardiography and dynamic preload assessment can be helpful in guiding volume therapy during major surgery.

## INTRAOPERATIVE BLOOD PRESSURE MANAGEMENT

BP variations outside the physiological range are common during surgery and are associated with poor postoperative cardiovascular outcome [27]. Interestingly, there is little agreement on the definition of intraoperative hypotension and hypertension [28]. In a retrospective cohort study, Monk *et al.* used three different definitions for abnormal BPs and consistently found an association between hypotension and 30-day mortality. There was no association between hypertension and mortality in that study [29▪▪]. The proportion of patients with known hypertensive disease was not specified, however, and no stratification was made for the use of antihypertensive drugs. Previous studies have shown a higher incidence of intraoperative hypotension when angiotensin-converting enzyme (ACE) inhibitors were continued prior to surgery. More recently, these findings were questioned and it was argued that withdrawal of ACE inhibitors in the perioperative period deteriorates outcome [30]. β-Blockers should be continued but initiation of β-blockade therapy shortly before surgery is no longer recommended since the perioperative ischemic evaluation study found an increased incidence of stroke after high-dose metoprolol.

Hypertensive patients are considered to be at particular risk for hypoperfusion and organ damage during hypotensive episodes. The pressure range for autoregulation is shifted rightward so that pressure-dependency of organ perfusion occurs at higher mean arterial BPs than normal. As the lower limits of safety for arterial BP vary unpredictably between patients it is common practice to use the awake

**Table 2.** Recommendations for the perioperative management of patients with hypertensive disease (opinion based)

| Preoperative | Intraoperative | Postoperative |
|---|---|---|
| SAP ≤ 180 mmHg, DAP ≤ 110 mmHg | MAP not lower than 25–30% of awake | Resume antihypertensive drugs upon oral intake or substitute i.v. |
| ECG, serum creatinine, electrolytes (diuretics) search for target organ damage (heart, brain, kidney) | Attenuate sympathetic response to laryngoscopy (or use laryngeal mask) | Measure blood pressure every 5–15 min first hour then every 30 min until 3 h postoperative |
| Antihypertensive drugs; continue DOS: β-blockers, CCB; Stop DOS: diuretics, ACE-inhibitor, sartanes | Consider use of noninvasive cardiac output monitoring and NIRS | Treat postoperative hypertension to MAP > 100 and < 130 mmHg and HR ≥ 50 bpm; Metoprolol: repeat 2–5 mg bolus i.v.; labetolol: repeat 10–20 mg bolus i.v.; nicardipine: 0.5–1 μg/kg/min i.v.; nitroglycerine: 0.1–5 μg/kg/min i.v. |

CCB, calcium channel blocker; DOS, day of surgery; i.v., intravenously; MAP, mean arterial pressure; SAP, systolic arterial pressure.

preoperative pressures as a reference for an individual and not to deviate more than 25–30% during anesthesia and surgery [7▪].

In general, recommendations on the perioperative management of hypertensive patients are opinion based. A summary is provided in Table 2.

## MONITORING TOOLS

Pulse contour analysis has become a popular technique to measure cardiac output from an arterial pressure line. Algorithms estimating compliance from population nomograms, however, do not account for arterial stiffening. Such systems may be prone to error in patients with isolated systolic hypertension unless calibrated against an independent method. Similarly, dynamic preload assessment, a concept based on BP variation because of cardiopulmonary interaction in mechanical ventilation, has not been validated in hypertensive patients. If diastolic dysfunction is present the sensitivity to ventilation-induced changes of LV filling is more pronounced and this may translate in different cut-off values for fluid responsiveness. Validation of the concept in this specific population seems warranted.

Near-infrared spectroscopy is now finding its way beyond the field of neuromonitoring as a noninvasive monitor of global hemodynamic status, as it reflects venous oxygen concentrations, and a unique way to dynamically evaluate regional tissue and organ perfusion [31]. Recent studies show that processed near-infrared spectroscopy (NIRS) information in relation to changes in BP allows for noninvasive assessment of autoregulation of cerebral perfusion. This approach shows great clinical potential since real-time assessment of autoregulation limits would allow for individualized pressure management. Preliminary data in cardiac surgery showed that BP below the limits of autoregulation as determined with NIRS was independently associated with major morbidity and operative mortality after cardiac surgery [32]. NIRS was also shown to detect the loss of autoregulation in spinal perfusion after repair of a thoracic aneurysm [33]. Further studies in noncardiac surgery are awaited as this could determine our strategy to BP management in hypertensive patients in the future.

New imaging modalities have made the microcirculation a visible target for bedside clinical research [34]. Preliminary studies in hypertensive patients show pathophysiological changes in resistance vessels and precapillary arterioles, and capillary rarefaction. Although still at an experimental stage, the technique shows promise as a tool to monitor the effects of therapeutic interventions at the microcirculatory level.

## CONCLUSION

Hypertensive disease causes pathophysiological changes to the cardiovascular system and is associated with target organ damage that affects perioperative outcome. Assessment in the preoperative clinic should focus on a patient's complete risk profile and perhaps less on instantaneous BP.

In the elderly population, the phenotype of isolated systolic hypertension with increased pulse pressure and diastolic dysfunction constitutes a particular entity at risk in the perioperative period, which calls for more scientific and clinical interest.

In the absence of new outcome data, an individualized and pathophysiology-based approach to control intraoperative BP may be the best option to guide hypertensive patients through the perioperative period. New monitoring tools such as echocardiography, noninvasive cardiac output devices, and NIRS do provide incremental information on cardiovascular status and may turn out important to achieve this goal.

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## Conflicts of interest

*There are no conflicts of interest.*

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■■ of outstanding interest

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