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Special Article

Perioperative Quality Initiative consensus statement on postoperative blood pressure, risk and outcomes for elective surgery

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Abstract

Background: Postoperative hypotension and hypertension are frequent events associated with increased risk of adverse outcomes. However, proper assessment and management is often poorly understood. As a part of the PeriOperative Quality Improvement (POQI) 3 workgroup meeting, we developed a consensus document addressing this topic. The target population includes adult, non-cardiac surgical patients in the postoperative phase outside of the ICU.

Methods: A modified Delphi technique was used, evaluating papers published in MEDLINE examining postoperative blood pressure monitoring, management, and outcomes. Practice recommendations were developed in line with National Institute for Health and Care Excellence guidelines.

Results: Consensus recommendations were that (i) there is evidence of harm associated with postoperative systolic arterial pressure <90 mm Hg; (ii) for patients with preoperative hypertension, the threshold at which harm occurs may be higher than a systolic arterial pressure of 90 mm Hg; (iii) there is insufficient evidence to precisely define the level of postoperative *hypertension* above which harm will occur; (iv) a greater frequency of postoperative blood pressure measurement is likely to identify risk of harm and clinical deterioration earlier; and (v) there is evidence of harm from withholding beta-blockers, angiotensin receptor blockers, and angiotensin-converting enzyme inhibitors in the postoperative period.

Conclusions: Despite evidence of associations with postoperative hypotension or hypertension with worse postoperative outcome, further research is needed to define the optimal levels at which intervention is beneficial, to identify the best methods and timing of postoperative blood pressure measurement, and to refine the management of long-term antihypertensive treatment in the postoperative phase.

Keywords: antihypertensive drugs; postoperative; hypotension; hypertension; blood pressure; outcomes; myocardial infarction; surgery

Editor's key points

- An expert consensus meeting reviewed the relationships between postoperative arterial pressure and postoperative outcomes using a modified Delphi approach to create recommendations.
- There is evidence of harm associated with postoperative systolic arterial pressure <90 mm Hg, and higher with preoperative hypertension.
- There is insufficient evidence to precisely define the level of postoperative hypertension above which harm will occur.
- Further studies are required to define the optimal thresholds for intervention, the best methods and timing of blood pressure measurement, and management antihypertensive drugs in the postoperative phase.

Postoperative blood pressure regulation is complex and can be affected by a variety of factors including patient, procedure, and perioperative care.[1] Postoperative hypotension and hypertension are frequent events and are associated with an increased risk of adverse outcomes.[2] However, the proper assessment and management of postoperative hypotension and hypertension is often poorly understood.[3] Accordingly, we present the latest data concerning risks associated with postoperative hypotension and hypertension and evidence for postoperative monitoring of vital signs. As this topic is both complex and important for patient outcomes, we sought to propose evidence-based consensus statements and practice and research recommendations relating to postoperative blood pressure and the associations with risk and outcomes after elective surgery.

Methods

The Perioperative Quality Initiative (POQI) is an international, multidisciplinary non-profit organisation that organises consensus conferences on clinical topics related to perioperative medicine. Each conference assembles a collaborative group of diverse international experts from multiple healthcare disciplines who are tasked with using a modified Delphi technique to develop consensus-based recommendations in perioperative medicine.[4–8] The participants in the POQI consensus meeting were recruited based on their expertise in perioperative medicine and blood pressure management (Supplementary material, Appendix 1). Conference participants were divided into four work groups; Group 1 reviewed the physiology and measurement of blood pressure with relevance to the perioperative setting,[4] whereas Groups 2, 3, and 4 were focused on preoperative,[5] intraoperative,[6] and postoperative blood pressure (this paper), respectively; see Ackland and colleagues[4] for detailed methods. The POQI process is based on an established modified Delphi process used in the Acute Dialysis Quality Initiative (ADQI) conferences.[9–11] Groups indicated the strength of evidence underlying practice recommendations using a structure consistent with UK National Institute for Health and Care Excellence (NICE) guidance (Supplementary Table S1).

This workgroup of POQI-3 meeting sought to develop a consensus document addressing postoperative blood pressure assessment and management. Our target population included adult, non-cardiac surgical patients in the postoperative phase who go through the PACU or high-dependency unit (HDU) and continue to the hospital ward. This consensus statement does not apply to ICU-based care of surgical patients or to postoperative cardiac surgery patients. We focused *a priori* on the following questions regarding adult postsurgical patients:

1. What arterial pressure readings should trigger a bedside assessment?
2. How should clinicians determine the *intensity* of postoperative blood pressure monitoring and *location* of postoperative care?
3. What treatment options are available for postoperative hypotension and when should an escalation of care be considered?
4. What treatment options are available for postoperative hypertension and when should an escalation of care be considered?
5. When should home antihypertensive medications be resumed in the postoperative period?

For content to be included in the paper, we searched PubMed from 1966 to June 2017 using the following search terms with the filters of 'human', 'age 18+', and 'published in English' selected: postoperative AND hypotension AND mortality OR postoperative AND hypertension AND mortality OR postoperative AND hypotension AND morbidity OR postoperative AND hypertension AND morbidity OR postoperative AND blood pressure AND outcomes OR postoperative AND blood pressure AND mortality OR postoperative AND blood pressure AND morbidity OR postoperative AND blood pressure AND threshold AND risk OR postoperative blood pressure AND myocardial infarction OR postoperative blood pressure AND myocardial injury OR postoperative blood pressure AND major adverse cardiac event OR postoperative blood pressure AND stroke OR postoperative blood pressure AND renal failure OR postoperative blood pressure AND acute kidney injury OR postoperative blood pressure AND delirium OR postoperative AND hypotension AND treatment OR postoperative AND hypertension AND treatment OR postoperative blood pressure AND treatment. Based on a review of the reference lists of papers, one citation was included from 1957. This literature search was supplemented by reading the relevant references of the journals identified.

Results

Consensus statements

Consensus statement 1: *There is evidence of harm associated with postoperative systolic arterial blood pressure* <90 mm *Hg. However, there is insufficient evidence to precisely define the levels of postoperative pressure below which harm will occur. The level of risk is increased with longer durations of hypotension.*

Consensus statement 2: *For patients with preoperative hypertension, the threshold at which harm occurs may be higher than a systolic pressure of* 90 mm *Hg.*

Postoperative hypotension is a common occurrence.[12,13] Roshanov and collegues[12] recently reported that 20% of the 14 687 patients in the VISION (Vascular events In noncardiac Surgery patIents cOhort evaluatioN) cohort experienced at least one episode of clinically significant hypotension in the perioperative period (systolic pressure <90 mm Hg with an intervention given to raise blood pressure), with 95% of those events occurring from postoperative day (POD) 0–3 and the largest percentage on POD1.[12] These events occurred in a patient population with an average baseline preoperative mean arterial pressure of 93 mm Hg, which corresponds to a blood pressure of about 120/80, so it is difficult to draw conclusions from these data about patients with significant preoperative hypertension. There is emerging evidence from the POISE-II (PeriOperative Ischemic Evaluation-2) cohort that systolic pressures of <90 mm Hg in the postoperative period are associated with increased risk of all-cause death, myocardial injury after non-cardiac surgery (MINS), and stroke.[13] This risk increased for each 10 min epoch of hypotension during the intraoperative period and POD0. Furthermore, the odds ratio of poor outcomes with hypotension was almost three times as high if it occurred on POD1–4, a time when extended periods of hypotension can occur, particularly if vital signs are only checked every 4–6 h on the surgical ward (Fig. 1). Thus, a systolic pressure <90 mm Hg or <30% below baseline is likely to put most patients at risk of end organ injury.

These findings are in line with the literature on intraoperative blood pressure control where recent reports have identified a mean arterial pressure <65 mm Hg as an independent risk factor for postoperative MINS and acute kidney injury (AKI). The risk of harm increased with the duration of hypotension (with increasing risk accruing with increasing time of hypotension).[14] Salmasi and colleagues[14] reported that mean arterial pressure reductions of 25–30% or more are associated with increased risk of harm. The effects of 20% reductions from baseline were less clear. This study is in keeping with previous literature reporting an association between intraoperative hypotension and postoperative renal and cardiac injury and 30 day mortality.[15–18] It also agrees with a systematic review that found avoidance of hypotension as a key strategy for reducing AKI.[19]

Beyond these data on surgical patients from the intraoperative period, the Modified Early Warning System (MEWS) provides further indirect support for the importance of postoperative blood pressure in determining surgical outcomes.[20–23] Blood pressure is an important element of the MEWS score with systolic arterial pressure <100 or <90 mm Hg equating to medium or high-risk scores, respectively. Although data are mixed concerning the effect of MEWS scoring in general ward patients,[20,21] postoperative MEWS scores are strongly associated with postoperative outcome.[22] Patients with high MEWS scores, or a trend of increasing MEWS scores, had an increased risk of complications. Conversely, low scores or a trend of decreasing scores were associated with favourable surgical outcomes. This corresponds with other studies that have further confirmed the importance of hypotension (defined as systolic arterial pressure <90 mm Hg) as an antecedent to adverse patient outcomes. In one study, systolic pressure <90 mm Hg was the most common cause (25%) for emergency team activation on the ward after orthopaedic or general surgery.[24] This is similar to the finding from the ACADEMIA study from 90 hospitals in the UK, Australia, and New Zealand in which a systolic arterial pressure <90 mm Hg was the most common antecedent event of patient deterioration in the inpatient setting.[25]

In order to interpret postoperative blood pressure, it is important to understand variations with circadian rhythm. Although the majority of patients experience a 10–20% reduction compared with their awake blood pressure when asleep, some do not show a decrease at all and some have increased blood pressure.[26] Consequently, tolerating prolonged periods of postoperative hypotension during sleep may not be appropriate and may put patients at risk unless it can be shown that they achieve these pressures when not in the hospital setting.

Although current evidence suggests that postoperative hypotension is associated with increased risk of patient harm, it is yet to be definitively shown that using postoperative arterial pressure as a therapeutic target improves outcome. The optimal strategy to achieve blood pressure targets is also

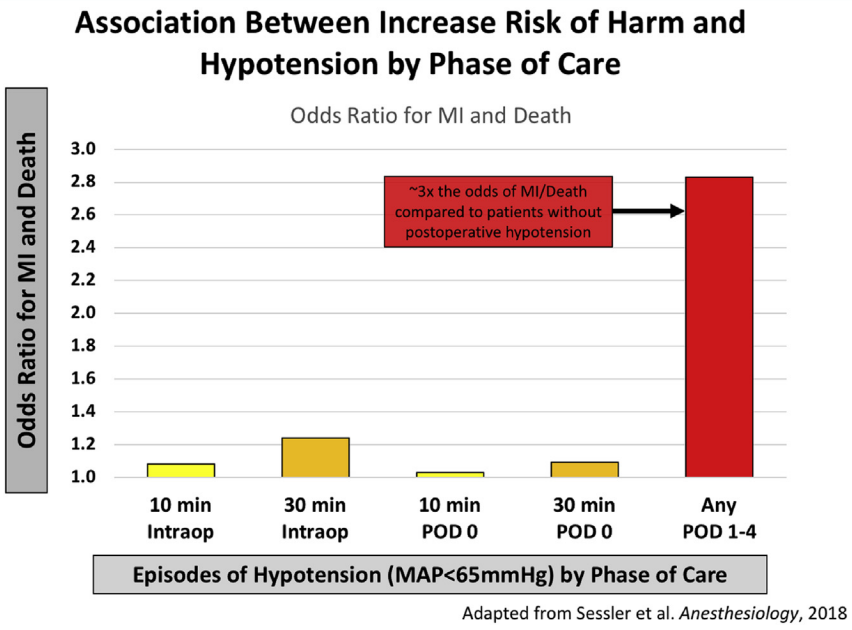

Fig 1. This figure demonstrates the association of perioperative hypotension with myocardial infarction (MI) and death, showing that each 10-minute episode of hypotension of postoperative day (POD) 0 is associated with a 3% increase in risk, and *any* episodes of hypotension on POD 1-4 are associated with almost a doubling or risk. The actual incidence of the composite outcome (MI and death) was 7.2%. [Adapted from Sessler DI, et al. Period-dependent Associations between Hypotension during and for Four Days after Noncardiac Surgery and a Composite of Myocardial Infarction and Death: A Substudy of the POISE-2 Trial. *Anesthesiology*, 2018 128:317-327.] Figure reused with the permission of the Perioperative Quality Initiative (POQI).

unclear. For instance, the INPRESS (Intraoperative Noradrenaline to Control Arterial Pressure) trial suggested that tight blood pressure control achieved using a norepinephrine infusion during and for 4 h after surgery improves outcome compared with standard care when used in addition to a stroke volume maximisation algorithm intraoperatively.[27] Although this trial further highlights the potential role for blood pressure control as a perioperative target, the relative contribution from the intra- and postoperative phases of treatment is not clear. Overall, it should be noted that relatively few studies have been performed in this arena, and none of the studies to date have *a priori* used postoperative blood pressure as a primary outcome. Non-standardisation in data collection methods and measurement bias surrounding blood pressure might impact the results of these studies. As such, although the association between postoperative hypotension and adverse patient outcomes has clinical plausibility and appears robust, further research is needed.

Consensus statement 3: *There is insufficient evidence to precisely define the level of postoperative hypertension above which harm will occur.*

Postoperative hypertension is common and independently associated with adverse events after non-cardiac surgery, including stroke, myocardial injury and infarction, and bleeding.[2,3,28,29] Its frequency varies in different types of surgery: carotid endarterectomy (9–58%),[30–35] abdominal aortic aneurysm surgery (25–85%),[36,37] intracranial neurosurgery (57–91%),[38,39] and elective non-cardiac surgery (5–20%).[40–42] The accepted definition of acute postoperative hypertension is 'a significant elevation in blood pressure during the immediate postoperative period that may lead to serious neurologic, cardiovascular, or surgical-site complications and that requires urgent management'.[43] However, a precise consensus definition of postoperative hypertension does not exist.[3,42,43] One source defined postoperative hypertension as a systolic pressure >190 mm Hg, diastolic pressure >100 mm Hg, or both on two consecutive readings after surgical intervention, whereas a recent publication that linked postoperative hypertension with cardiovascular complications used a cut-off of systolic pressure >180 mm Hg and diastolic pressure >110 mm Hg. The latter is in accord with the modified and national early warning systems (MEWS and NEWS, respectively), which have shown good validity and predictive ability.[21,22,43,44] It is worth noting that hypertension after carotid endarterectomy and intracranial neurosurgery have specific considerations not present with other cases. Specifically, post-carotid endarterectomy hypertension may be attributable to altered baroreceptor sensitivity and is associated with cerebral hyperaemia and poor neurologic outcomes.[45,46] Hypertension after intracranial neurosurgery with craniotomy is common and places the patient at risk of intracranial bleeding and worse neurologic outcomes.[47,48] Hypertension in these cases should be rapidly treated while considering whether surgical intervention to address haematoma or haemorrhage is required.

The timing of postoperative hypertension is also relevant. Many episodes occur in the first 20 min of the postoperative period and are relatively short-lived; however, resolution can require 3 h or longer.[41,42] Untreated postoperative hypertension increases the risk of myocardial ischaemia, myocardial

infarction, arrhythmia, pulmonary oedema, stroke, and surgical site bleeding.[42,43] Postoperative hypertension is characterised by sympathetic stimulation resulting in catecholamine release, vasoconstriction, tachycardia, and impaired baroreceptor sensitivity. Rose and colleagues[1] found that patients who had intraoperative hypertension, excessive pain, and inadequate ventilation had a higher risk of developing postoperative hypertension, and also noted that these patients had more critical care admissions and a higher risk of mortality. Accordingly, bedside evaluation of the patient with acute postoperative hypertension is important to address the adequacy of ventilation and analgesia before considering specific blood pressure therapy.

In addition to direct evidence of harm as summarised above, use of MEWS with a systolic pressure >180 mm Hg indicating high-risk has been validated in numerous acute care situations, including the emergency department, medical ward, and surgical patients.[20–22] This level of hypertension is predictive of end organ dysfunction and harm and should be immediately assessed and treated according to the underlying cause. Most of the studies of MEWS to date have been retrospective in nature; however, prospective studies related to implementing EWSs, including MEWS and NEWS, have shown that these systems can predict worse outcomes. It is not clear whether treatment regimens given in response to these systems are beneficial, or whether intervention for postoperative hypertension with systolic pressure <180 mm Hg would be of benefit.

Consensus statement 4: *A greater frequency of postoperative blood pressure measurement is likely to identify risk of harm and clinical deterioration earlier.*

There currently exists no direct evidence to specifically address the optimal intensity of postoperative blood pressure monitoring. The standard of care is typically to measure and record vital signs every 4 h, although studies show that it is often less frequent in clinical practice.[49–52] Audits of vital sign recording on postoperative general care wards display significant deficits in applying this standard in routine care.[53,54] Continuous monitoring of other vital signs reveals concerning trends that are not picked up with the current standard of care. Continuous monitoring of ventilatory frequency for the first 6 h on a general care ward after PACU discharge revealed that in patients ≥60 yr old who underwent elective intra-abdominal or orthopaedic surgery under general anaesthesia, almost 80% had at least one episode of bradypnoea (1–6 breaths min^{-1}) and almost 60% had at least one episode of apnoea (cessation of inspiratory flow for >60 s).[49] A recent trial of continuous monitoring of oxygen saturation on the postoperative general care ward revealed that 21% of patients had ≥10 min h^{-1} of SpO_2 readings <90%, 8% had ≥20 min h^{-1} <90%, and 8% had ≥5 min h^{-1} <85%.[50] Nursing records only documented hypoxaemia in 5% of patients, and 90% of hypoxaemic episodes (SpO_2 <90% for at least 1 h) were missed. In a randomised trial setting, continuous measurement of oxygen saturation significantly reduces the amount of hypoxaemia in the PACU.[55,56]

There is also evidence that vital sign disturbances in one phase of care can predict further perturbations or complications later in the perioperative course. For instance, hypoxaemia or bradypnoea in the PACU is strongly associated with similar events on the postoperative ward for elderly patients and for those with sleep apnoea.[49,57] For patients with sleep apnoea, respiratory events in the PACU are strongly associated with use of naloxone within 12 h after PACU discharge.[58] The Surgical Apgar score, a rapid scoring system based on intraoperative vital signs and blood loss, is highly predictive of postoperative complications and death after major surgery.[59–64]

Taken together, the evidence shows that disturbances in vital signs on the postoperative ward are common and often missed. Given that clinical deterioration is often preceded by changes in physiologic parameters, more frequent or continuous ward monitoring may improve patient care.[20,21,23,65] Given that disturbances in one phase of care can predict events in subsequent phases, clear guidelines for moving patients between levels of care and a structured assessment at those transition points may be of benefit (Fig. 2).

As noted above, NEWS[66] and MEWS[20] are validated patient screening systems that can predict deterioration in clinical status earlier than traditional means of assessment. These systems have a scoring algorithm that takes into account

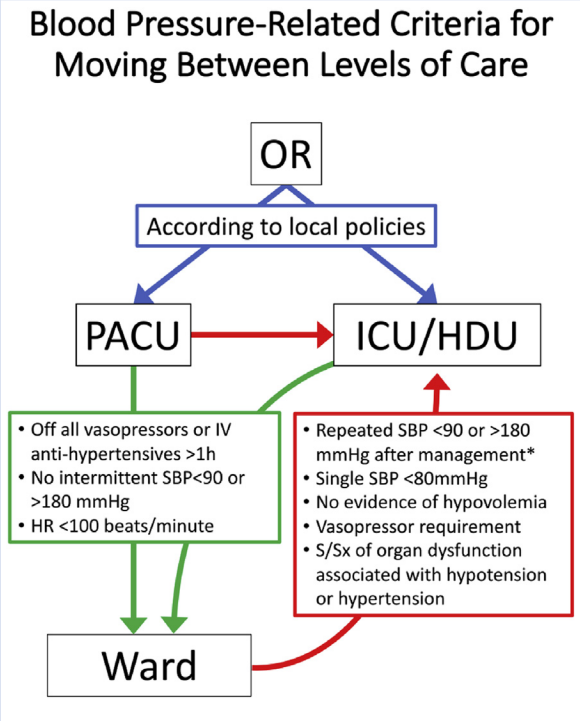

Fig 2. This figure represents structured criteria for moving patients between levels of care based upon postoperative blood pressure. If the patient meets all criteria in the green box, then they would be cleared to move from PACU or the ICU/HDU to the ward based upon blood pressure (other vital signs or care issues may prevent such change in level of care). If the patient meets criteria in the red box, then they should move from the ward to a higher level of care, such as ICU/HDU. Figure reused with the permission of the Perioperative Quality Initiative (POQI). *Of note, this algorithm assumes that the bedside assessment and initial management shown in Figure 4 has occurred and the patient remains hypotensive or hypertensive after appropriate initial therapies have been undertaken that are possible on the postoperative ward. [OR = operating room/theater; PACU = post-anesthesia care unit; ICU = intensive care unit; HDU = high-dependency unit; IV = intravenous; SBP = systolic blood pressure; HR = heart rate; S/Sx = signs and symptoms].

parameters such as systolic arterial pressure, heart rate, ventilatory frequency, oxygen saturation, temperature, and mental state.[21,44] Although composite scores from EWSs may perform better than single components,[66] the most common antecedent finding 15 min to 24 h before in-hospital death, cardiac arrest, or unanticipated ICU admissions was a systolic pressure <90 mm Hg, which was present in more than 30% of events.[25] Thus, increased frequency of arterial pressure monitoring is likely to improve detection of risk of harm. The significant resource implications of increased frequency of monitoring should be considered.[66] It is possible that new products (e.g. wearable and wireless sensors) designed specifically for ward monitoring will aid in providing continuous vital signs monitoring until the patient shows a sustained return to baseline cardiopulmonary physiologic status.[52,65,67,68]

Consensus statement 5: *There is evidence of harm from withholding beta-blockers, angiotensin receptor blockers (ARBs), and angiotensin-converting enzyme (ACE) inhibitors in the postoperative period.*

There is strong evidence that resuming beta-blockers after operation decreases morbidity and mortality. Wallace and colleagues[69] demonstrated that continuation of a beta-blocker decreases both short-term (30 days) and long-term (1 yr) mortality in the perioperative period. In a retrospective cohort analysis of more than 136 000 patients, London and colleagues[70] noted a two-fold increase in mortality when a patient was not continued on a beta-blocker after operation. In addition, Hoeks and colleagues[71] reported direct evidence that withdrawal of beta-blockers increased both in-hospital mortality and 1 yr mortality in vascular surgery patients as opposed to continuation of beta-blockers throughout the perioperative period. Although evidence has shown that prophylactic treatment with beta-blockade for -blocker naïve patients is not of benefit, it is clear that continuing beta-blockers throughout the perioperative period is of benefit for those on chronic therapy.[72,73]

We know from the POISE trial that fixed dosing of beta-blockers can be harmful, particularly in large doses.[72] Therefore, we urge caution when restarting a beta-blocker at the chronic preoperative dose. A smaller dose and titration to heart rate and blood pressure may be more appropriate in the perioperative setting to avoid hypotension. Beta-blockers should not be resumed in patients who develop an absolute contraindication (i.e. third-degree atrioventricular block without a pacemaker).[73] Therefore, we recommend that beta-blockers be resumed as soon as possible after operation with titration or holding if clinically indicated for hypotension or severe bradycardia.

The evidence surrounding cessation of ACE inhibitors/ARBs before surgery is presented in the POQI-3 paper from the Preoperative Blood Pressure Group.[ref - Sanders R, et al.][6] Failure to restart ACE inhibitor or ARB medications within 48 h after operation has been shown to increase all-cause 30 day mortality and the incidence of postoperative complications, with the largest effect on those <60 yr old.[74,75] Caution is warranted in patients with postoperative increases in creatinine or low/borderline low blood pressure.

There is little direct evidence on the resumption of calcium channel blockers after surgery. However, calcium channel blockers have been shown to reduce ischaemia and arrhythmias in patients undergoing non-cardiac surgery when patients take them throughout the perioperative setting.[76] In the cardiac surgery population, calcium channel blockers have been shown to reduce overall mortality, but it is unknown if this can be extrapolated to all perioperative patients.[77]

There is a lack of evidence about when to resume a chronic clonidine therapy, but withdrawal from clonidine is associated with rebound hypertension in non-surgical patients.[78]

At present, there is little evidence to guide reintroduction of diuretics in the postoperative period.

Practice recommendations

Practice recommendation 1: *Patient-specific postoperative blood pressure target ranges should be created based on baseline preoperative blood pressure measurements and clinical context.*

Practice recommendation 2: *A clinical assessment should be conducted in response to high or low postoperative blood pressure. Trigger blood pressure values should allow enough time for assessment in cases where blood pressure is trending downward or upward.*

Maintaining systolic pressure >90 and <160 mm Hg is a reasonable therapeutic target for a broad range of adult post-surgical patients with normal preoperative baseline blood pressure. These targets should be adapted for patients with abnormal baseline values (e.g. systolic pressure >140 or <100 mm Hg); observational data suggest that intraoperative systolic pressures >70% of preoperative baseline are associated with less harm.[14] Other targets may be chosen depending on other co-morbidities and clinical context, for example after vascular surgery or neurosurgery.

A narrower range of 'trigger' values should provide a safety margin in alerting clinicians to abnormal blood pressures. This provides an opportunity for assessment before pressures on a down- or upward trend reach levels associated with harm. Suggested trigger values for assessment are therefore systolic pressure <100 mm Hg (or <75% of baseline, whichever is higher) or >160 mm Hg (or >140% of baseline, whichever is lower). These trigger values may be further adapted to clinical context.

Practice recommendation 3: *The frequency of postoperative surveillance, including blood pressure monitoring, should be determined by the patient status and clinical context.*

We recommend that the frequency of postoperative blood pressure surveillance be determined by patient status and clinical context. Although routine current practice for many patients may be intermittent measurement of vital signs every 4–6 h, we recommend increased frequency of blood pressure monitoring in certain settings (Fig. 3), such as patients with a decreasing or increasing trend in blood pressure or those requiring tighter targets. Non-invasive continuous blood pressure monitoring is becoming a reality with volume clamp methods and application tonometry with devices designed for operating room and ICU use. Future products (e.g. wearable and wireless sensors) will be designed specifically for ward monitoring in ambulatory patients.[67]

We recommend that clinicians consider use of a structured alert system, including an individualised alert for hypotension for postoperative patients on the general care ward. Such early warning systems have been shown to identify postoperative patients at risk of deterioration earlier than standard monitoring and has correlated with improved mortality in one study.[20–22,79] More intensive monitoring—through novel technology, alert systems, or both—is likely to have resource implications and should undergo thorough evaluation before its routine use can be more strongly recommended.

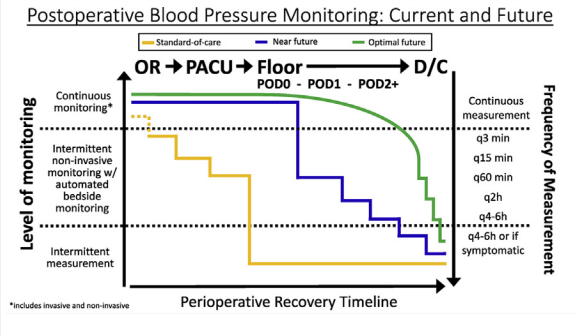

Fig 3. This figure illustrates the current standard of care for monitoring blood pressure in the perioperative period and also depicts how that may change in the near future based on available technologies and evolving evidence. Finally, we propose what may be present optimally in the future concerning the level of postoperative monitoring, anticipating that improved continuous monitoring in the first 48 hours after surgery may improve patient safety and reduce adverse events related to hypotension. Figure reused with the permission of the Perioperative Quality Initiative (POQI).

Practice recommendation 4: *A structured bedside assessment should be carried out in response to postoperative hypotension/hypertension in order to (a) determine aetiology, (b) select appropriate treatment if indicated, and (c) consider changing the intensity of future monitoring and care environment.*

A focused history and physical examination should be performed with an emphasis on characterising the hypotensive or hypertensive state as stable or unstable, as described in practice guidelines and recommendations (Fig. 4).[80–82] Unstable patients displaying signs and symptoms of end-organ dysfunction should be treated in a high acuity care setting (Fig. 2).

Hypotension

The most appropriate management for hypotensive, haemodynamically unstable patients is to perform a bedside assessment in order to define the cause and then treat accordingly as supported by a recent meta-analysis.[83] In that meta-analysis of 2260 patients, the mean prevalence of fluid responsiveness was 50%, and typical signs and symptoms of suspected hypovolaemia were not predictive of fluid responsiveness. However, an increase in cardiac output after passive leg raise (PLR) strongly predicted fluid responsiveness (positive likelihood ratio [LR]=11; 95% confidence interval [CI], 7.6–17; pooled specificity, 92%). No increase in cardiac output after PLR classified patients who most likely would not respond to fluid (negative LR=0.13; 95% CI, 0.07–0.22; pooled sensitivity, 88%).

To assess the situation of postoperative hypotension and better understand the most appropriate therapy, El Hadouti and colleagues[84] performed a prospective observational study on postsurgical patients with suspected hypovolaemia (systolic pressure <90 mm Hg, MAP <70 mm Hg, oliguria, or heart rate >100 beats min^{-1}) who were spontaneously breathing in the recovery room. The primary outcome was change in cardiac output before and after PLR and a 500 ml intravenous bolus of lactated Ringer's solution. Of the patients who met inclusion criteria for suspected hypovolaemia, only 54% responded to the fluid bolus. This suggests that the typical approach of correcting postoperative hypotension with intravenous fluid (preload correction) may be inappropriate ~50% of the time, with correction of vascular tone or inotropy being required in the remaining patients.

A PLR test should be considered for patients with postoperative hypotension.[83] Although the existing literature has specifically examined the effect of PLR on monitored cardiac output, it is likely to be useful in detecting whether inadequate preload is contributing to hypotension. If the PLR test does not correct hypotension, further management should focus on vascular tone and chronotropy/inotropy. In this setting, non-invasive cardiac output monitors and portable ultrasound devices may help in identifying the root cause of hypotension and hence in choosing the most appropriate treatment. Patient transfer to a higher level of care may be required in order to deliver appropriate therapies, dependent on local facilities and available resources.

Hypotension should be treated immediately in the symptomatic patient. For a positive PLR test, intravenous fluid would be appropriate in many instances.[83,84] If preload augmentation is not needed, vasopressor or inotropic support is indicated. The side-effect profile of drugs used in the treatment of hypotension must be taken into account. For example, phenylephrine is best used in situations where the hypotension is accompanied by tachycardia because phenylephrine can result in a reflex bradycardia, especially in the preload independent state.[85]

Hypertension

For treatment for hypertension in the PACU setting, therapy should be individualised with a focus on the choice of agent based on the specific clinical situation, patient characteristics, and care setting. In the absence of a hypertensive emergency, attempts should be made to determine if there is a reversible underlying cause of the hypertension.[41,86] Common non-pharmacological interventions can be used depending on aetiology, such as supplemental oxygen for hypoxaemia, forced air warmer for hypothermia, catheterisation for urinary retention, and verbal reassurance/family presence/anxiolytic for anxiety. For postoperative hypertension from withdrawal of long-term antihypertensive therapy, administering a home dose of the antihypertensive drug is appropriate after other causes have been ruled out. In situations where this is not possible, rapid acting analogues with the same mechanism of action as the chronic medications are appropriate.

Generally, the treatment goal should be based on preoperative blood pressure with a target of ~10% above the baseline (although a more aggressive approach may be necessary for patients at very high risk of bleeding or with severe heart failure who would benefit from afterload reduction).[2,3,41] Adequate monitoring of the response to the chosen therapy, and appropriate adjustments to the treatment itself, are paramount to safe and effective treatment of postoperative hypertension. In the days after surgery, a careful transition ought to be planned to an effective oral antihypertensive regimen to manage the long-term risks of hypertension.

The side-effects of drugs used in the treatment of hypertension must be taken into account before administration. For example, isolated hypertension with a low heart rate (<60 beats min^{-1}) should not be treated with a non-selective beta blocker. Similarly, calcium channel blockers should be used with caution in conditions where such agents can have

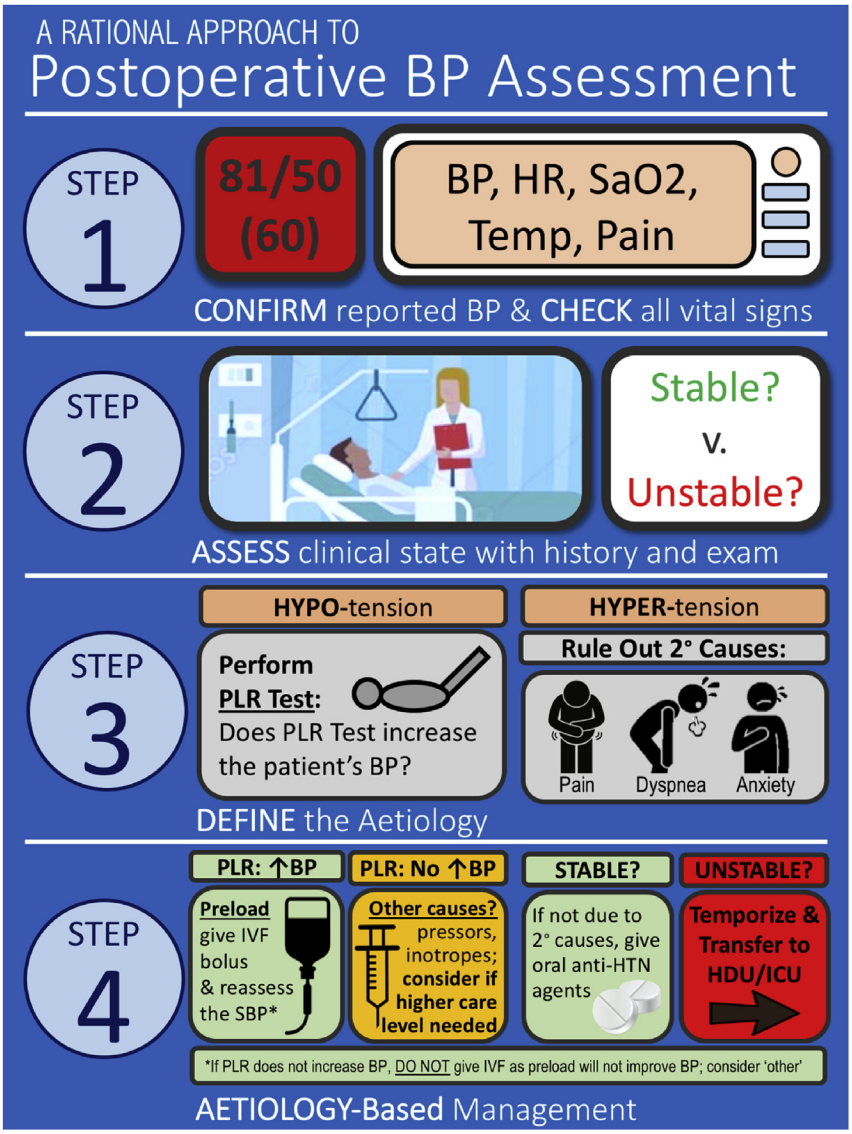

Fig 4. This figure illustrates our recommendations for a structured bedside assessment due to perturbations in postoperative blood pressure readings. *An unstable patient would be any patient who is displaying signs and symptoms of end organ dysfunction related to blood pressure (e.g. altered mental status, chest pain). [BP = blood pressure; PLR = passive leg raise; SV = stroke volume; TTE − transthoracic echocardiography; SVR = systemic vascular resistance; ECG = electrocardiogram; PACU = post-anesthesia care unit; HDU = high-dependency unit; ICU = intensive care unit] Figure reused with the permission of the Perioperative Quality Initiative (POQI).

harmful side-effects (i.e. Wolff–Parkinson–White syndrome). Drugs that lower blood pressure indirectly by anxiolysis and sedation must be used with caution in patients prone to rapid desaturation, such as those with obstructive sleep apnoea.

Practice recommendation 5: *Home antihypertensive medications should be restarted as soon as is appropriate in the clinical context.*

As noted in Consensus Statement 5 above, there is evidence of harm from withholding beta-blockers, ARBs, and ACE inhibitors in the postoperative period. Thus, beta-blockers should be continued in the postoperative period with specific criteria for withholding the drug to avoid hypotension and bradycardia.[69–71] ACE inhibitors or ARBs should be resumed within 48 h after surgery unless the patient has persistent hypotension or AKI.[75] Alpha-agonists can cause withdrawal hypertension, so we recommend resuming these after beta-blockers and ACE/ARBs if the patient is normotensive. We recommend resuming calcium channel blockers after the patient is on home doses of beta-blockers and ACE inhibitors/ARBs, although there is no direct evidence about the time of resumption after operation. Diuretics should be resumed based on the patient's volume status and the indication for the diuretic. All antihypertensive medications should be omitted if a patient is hypotensive.

Recommendations for research

The above consensus statements and practice recommendations concerning risks and outcomes associated with postoperative blood pressure regulation are based upon the latest evidence. However, the evidence base is far from conclusive and future research is needed to answer several important questions related to this topic.

First, large, observational studies are needed to identify the *relative* and *absolute* lower and upper limits of postoperative arterial blood pressure associated with optimal patient outcomes and risk of harm. Although current data demonstrate an association of harm with hypotension, the studies cited were not designed to evaluate postoperative blood pressure and patient outcomes specifically and thus further research is needed. Second, prospective studies are needed to identify a reliable reference blood pressure for postoperative management (i.e. ambulatory, immediately before surgery, PACU). Both absolute and relative changes in blood pressure have been associated with patient outcomes, so it is important to know the most reliable reference from which to build patient-specific postoperative management targets, especially for those with hypotension or hypertension who present for elective surgery. Third, prospective studies are needed to identify the best method and timing of postoperative blood pressure measurement, including use of continuous monitoring with wearable devices. Although more frequent measurement is likely to improve patient assessment and reduce the risk of unrecognised significant clinical deterioration and harm, the resource limitations that such a system would place upon nurses and other personnel are significant. Therefore, well-designed prospective studies need to be performed that include measurement of blood pressure and patient outcomes, provider workload, alarm fatigue, and related human factors. Fourth, research is needed to define the optimal treatment strategy for postoperative hypotension. Current evidence suggests that much postoperative hypotension is not caused by hypovolaemia, but treatment with a vasopressor or inotrope typically requires a high-intensity, monitored setting that has significant resource implications. Additionally, the optimal targets for blood pressure and how these are achieved is not yet known. Finally, prospective studies are needed to determine the optimal strategies of resuming chronic antihypertensive therapy. Although some studies suggest that continuing or quickly resuming some of these medications after surgery is associated with reduced risk of harm, it is important to know the optimal parameters for managing these medications.

Strengths and limitations

POQI uses an established modified Delphi process which has been used in more than 25 ADQI and POQI conferences in the past 20 yr.[9,10] The combination of a literature review with expert opinion aims to produce a practical consensus statement focusing on areas of clinical uncertainty. This methodology does not incorporate a formal systematic review or meta-analysis. However, as this process is based partly on expert opinion, there remains some risk of bias. Although a formal strength of evidence scoring system was not used, the wording of practice recommendations as defined here gives an indication of the group's opinion on the strength of evidence underlying those statements. Areas of uncertainty have been clearly signposted in the discussions accompanying each statement.

Conclusions

Perioperative blood pressure management has been an area of research for more than 70 yr.[87,88] Both hypotension and hypertension occur frequently in the postoperative period and both can place the patient at significant risk of complications and death. A clear definition is emerging for what defines postoperative hypotension and the risk associated with it. However, much remains to be done in terms of defining optimal blood pressure goals, monitoring strategies, and interventions to improve patient outcomes.

Authors' contributions

Conception and design of consensus document: all authors.
Analysis and interpretation of data in the literature: all authors.
Writing paper: all authors.

Declarations of interests

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Appendix A. Supplementary data

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