BJA

British Journal of Anaesthesia, 122 (5): 552–562 (2019)

doi: 10.1016/j.bja.2019.01.018
Advance Access Publication Date: 2 March 2019
Special Article

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

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This article is accompanied by an editorial: Consensus Statements and Expert Guidance: Interpret with Care by S.J. Howell, *Br J Anaesth* 2019:122, doi: https://doi.org/10.1016/j.bja.2019.03.013.

Abstract

Background: A multidisciplinary international working subgroup of the third Perioperative Quality Initiative consensus meeting appraised the evidence on the influence of preoperative arterial blood pressure and community cardiovascular medications on perioperative risk.

Methods: A modified Delphi technique was used, evaluating papers published in MEDLINE on associations between preoperative numerical arterial pressure values or cardiovascular medications and perioperative outcomes. The strength of the recommendations was graded by National Institute for Health and Care Excellence guidelines.

Editorial decision date: 1 January 2019; **Accepted:** 1 January 2019

Results: Significant heterogeneity in study design, including arterial pressure measures and perioperative outcomes, hampered the comparison of studies. Nonetheless, consensus recommendations were that (i) preoperative arterial pressure measures may be used to define targets for perioperative management; (ii) elective surgery should not be cancelled based solely upon a preoperative arterial pressure value; (iii) there is insufficient evidence to support lowering arterial pressure in the immediate preoperative period to minimise perioperative risk; and (iv) there is insufficient evidence that any one measure of arterial pressure (systolic, diastolic, mean, or pulse) is better than any other for risk prediction of adverse perioperative events.

Conclusions: Future research should define which preoperative arterial pressure values best correlate with adverse outcomes, and whether modifying arterial pressure in the preoperative setting will change the perioperative morbidity or mortality. Additional research should define optimum strategies for continuation or discontinuation of preoperative cardiovascular medications.

Keywords: arterial pressure; haemodynamics; perioperative care; preoperative blood pressure; surgical risk

Editor's key points

- Numerous studies have suggested that preoperative hypertension is associated with increased perioperative risk.
- An expert consensus meeting reviewed the relationships between preoperative arterial pressure, cardiovascular medications, and postoperative outcomes using a modified Delphi approach to create recommendations.
- There are insufficient data to suggest that monitoring of preoperative arterial pressure should alter decisions to proceed with surgery or not.
- Further studies are required to define optimal perioperative management of chronic cardiovascular medications.

Preoperative risk stratification involves synthesis of patient, anaesthetic, and operative factors to determine the optimal approach to patient care. Of patient factors, vital signs provide relevant physiological information and, appropriately, are widely monitored. However, the value of individual measurements is unclear. In this consensus paper, we consider the importance of preoperative arterial pressure values for risk stratification and planning perioperative management. Numerous studies have suggested that preoperative hypertension is associated with increased perioperative risk, although other reports suggest that this is not always the case. Reflecting this, different risk stratification tools either use (e.g. National Surgical Quality Improvement Program) or do not use (e.g. Revised Cardiac Risk Index) preoperative arterial pressure as a risk measure. In this context, 'risk' relates to different postoperative outcomes: a specific morbidity, a group of morbidities, or mortality. It may be that this variation in outcomes studied in part explains the predictive utility of arterial pressure measures. This complexity is compounded by the variability of the measure itself, both in terms of measurement error of the value and in terms of fluctuation in the measured values of resting arterial pressure. Despite these limitations, we consider it valuable to understand the relationships between preoperative arterial pressure and postoperative mortality and morbidity; in particular, whether these relationships are linear or non-linear (with potential for risk escalation at specific values) requires clarification.

The predictive value of arterial pressure may also be modulated by antihypertensive medications and the patient co-morbidities that may result from arterial pressure changes. Hence, consideration of the differential impact of cardiovascular medications and the interaction with co-morbidities on perioperative risk is also warranted. For example, if certain arterial pressures are associated with increased risk, it would be useful to know if treating arterial pressure before an operation improved perioperative risk, how long (if at all) treatment should occur, and whether surgery should be deferred or non-surgical options explored. Similarly, it would be useful to know if specific medications would be preferred in this context, and whether discontinuing certain medications may be helpful to reduce perioperative risk. Discontinuation of medications may also have consequences on arterial pressure important for consideration of perioperative risk. These issues are clearly complex, and hence, we sought to reach consensus on core statements, and practice and research recommendations, relating to preoperative blood pressure and the associations with risk and outcomes from 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.[1–5] The participants in the POQI consensus meeting were recruited based on their expertise in perioperative medicine and blood pressure management (Supplementary Appendix S1). Conference participants were divided into four work groups. Group 1 reviewed the physiology and measurement of blood pressure with relevance to the perioperative setting.[1] Groups 2–4 were focused on pre- (this paper), intra-,[2] and postoperative[3] arterial pressure, respectively; see Ackland and colleagues[1] for detailed methods. The groups indicated the strength of evidence underlying practice recommendations using a structure consistent with the UK National Institute for Health and Care Excellence guidance (Supplementary Appendix S2).

This workgroup of the POQI-3 consensus meeting reviewed the importance of preoperative arterial pressure thresholds in determining perioperative risk, and related to this primary aim, considered the potential effects of concomitant cardiovascular medications. We did not seek to evaluate whether diagnoses of hypertension *per se* were associated with perioperative risk, but rather to evaluate the data based on numerical pressure values and their association with risk.

We focused *a priori* on the following questions: (i) what is the risk associated with different preoperative arterial pressure values?; (ii) what is the importance of community cardiovascular medications in influencing perioperative risk? If there are risks, are these arterial pressure dependent?; (iii) what is the evidence guiding whether surgery should be deferred in patients with specific arterial pressure values and, if surgery is deferred, how should risk be optimised?; and (iv) is there evidence to support the use of preoperative arterial pressure to inform perioperative management, including intraoperative arterial pressure?

Before the meeting, a literature search was conducted in PubMed from 1966 to June 2017 using the following terms: preoperative AND hypotension AND elective AND surgery AND mortality OR preoperative AND hypertension AND elective AND surgery AND mortality OR preoperative AND blood pressure AND threshold AND surgical AND mortality OR preoperative blood pressure AND elective AND surgery AND mortality OR preoperative blood pressure AND elective AND surgery AND myocardial infarction OR preoperative blood pressure AND elective AND surgery AND stroke OR preoperative blood pressure AND elective AND surgery AND renal failure. All were with the added filters: *Humans *Ages 19+. This literature search was supplemented by reading the relevant references of the papers identified. After our meeting in July 2017, the American College of Cardiology (ACC) and the American Heart Association (AHA) released updated hypertension guidelines that included perioperative recommendations.[6] Therefore, we sought to compare our recommendations with those of that body and with those from the Association of Anaesthetists of Great Britain and Ireland/British Hypertension Society (AAGBI/BHS) guidelines that were in existence at the time of the meeting.

Results

Consensus statements

Consensus statement 1: *Preoperative arterial pressure values may be used to define targets for perioperative management; however, these should ideally reflect the patient's usual preoperative blood pressure*.

Recent studies have evaluated the use of target arterial pressure thresholds based on preoperative values, and suggest that this approach may improve outcomes.[7–9] Results from a recent randomised controlled trial suggested that patients who were randomised to tight systolic arterial pressure control, aiming for maintenance within 10% of baseline, may be at reduced risk of brain dysfunction and infection.[7] Observational data support tight control of intraoperative arterial pressure based on preoperative risk thresholds (within 20%[8] or 50%[9] of mean arterial pressure), but it remains unclear whether this is superior to a specific mean arterial pressure threshold.[2] Nonetheless, it appears that, in many centres, setting intraoperative arterial pressure targets based upon preoperative arterial pressure is routine.

We propose that, when available, ambulatory (as opposed to single office or clinic reading) arterial pressure[10] should be used to establish the relevant preoperative arterial pressure to avoid white coat hypertension and inaccurate readings.[1] Acting on isolated clinic arterial pressure readings brings a substantial risk of either overdiagnosing hypertension, or missing—and undertreating—true hypertension.[11] Both scenarios are associated with adverse outcomes,[12] and multiple hypertension guidelines now recommend ambulatory arterial pressure readings before a diagnosis of hypertension is made.[13] An ambulatory value will typically be a daytime average of readings from an automated device measuring arterial pressure at repeated intervals through the day and night whilst the patient continues routine activities. In the absence of a recent ambulatory arterial pressure measurement, we propose that a clinic (or office) baseline measure should be obtained (ideally within 30 days) before the day of surgery to limit the effects of white coat hypertension.[14] These preoperative measures may be used for setting intraoperative arterial pressure targets. However, we acknowledge that the optimal preoperative measure is unclear, and we recommend further research to identify this metric (see research recommendations).

Consensus statement 2: *Although extremes of preoperative blood pressure may be associated with increased perioperative risk, there is insufficient evidence to recommend a specific threshold of blood pressure upon which to decide whether or not to proceed with surgery, unless the extreme arterial pressure is associated with a medical emergency*.

Data suggest that both preoperative hypo- and hypertension are associated with increased risk, although study findings on this are not consistent.[15–18] We emphasise that the following description is based on observational data, and therefore, causality is not established between the exposure (arterial pressure value) and clinical outcome. First, we consider mortality. In patients more than 65 yr of age undergoing non-cardiac surgery, Venkatesan and colleagues[15] found evidence that *low* preoperative arterial pressure is more strongly associated with increased postoperative risk of mortality than high pressure using primary care data. In this large study (n=251 567), increased mortality risk was identified in patients with a preoperative systolic arterial pressure <119 mm Hg, diastolic <63 mm Hg, and pulse pressure <37 mm Hg. The change in odds ratio was non-linear, demonstrating escalating risk as arterial pressure decreased. The apparent effect of low preoperative pulse pressure is consistent with a recent analysis of the prospective Vascular Events in Noncardiac Surgery Cohort Evaluation (VISION) cohort in non-cardiac surgery patients that suggested that low pulse pressure (<45 mm Hg) may be associated with increased mortality.[18] The influence of preoperative hypertension appears less clear. After risk adjustment for age and a range of co-morbidities, Venkatesan and colleagues[15] identified that high preoperative diastolic pressure was associated with increasing mortality risk. This indicates a J-shaped association between diastolic arterial pressure and mortality risk, with increasing risk at both extreme low and high values. The lack of relationship found between systolic hypertension and mortality may be explained by a number of factors. These include the presence of unmeasured confounders in observational studies, or the possibility that the secondary effects of systolic hypertension, which were included in the multivariable model, have a greater effect on perioperative risk. These and other data suggest that raised diastolic or pulse pressure may be more important than systolic hypertension in the non-cardiac perioperative period, although these findings should be confirmed in future studies.[19,20]

In contrast, in cardiac surgery, there are data to suggest that systolic hypertension and a high pulse pressure are associated with increased mortality.[21,22] It is possible that methodological differences in risk adjustment and uncontrolled confounding contribute to this apparent inconsistency between cardiac and non-cardiac populations. Another explanation is that these patient cohorts have different levels of risk and undergo different types of injury. However, in these studies, no clear numerical risk threshold was identified limiting the clinical impact of the work.

Accumulating data from both cardiac and non-cardiac surgical studies suggest that preoperative high arterial pressure values are associated with increased cerebral, cardiac, and renal morbidities.[18,22–29] In seminal studies, Howell and colleagues[30,31] demonstrated relationships between systolic hypertension and postoperative cardiovascular morbidity, suggesting a linear relationship between preoperative systolic blood pressure and risk of ischaemic events after non-cardiac surgery.[26] Similar studies have been completed in cardiac surgery; for example, Wolman and colleagues[29] reported that systolic hypertension (>145 mm Hg) was a risk factor for a diverse group of postoperative cerebral adverse events. Fontes and colleagues[22] found that raised preoperative pulse pressure was associated with all-cause mortality and cerebral and cardiac events after cardiac surgery. Abbott and colleagues[18] found that raised preoperative pulse pressure was associated with increased risk of myocardial injury after non-cardiac surgery, even when systolic pressure was controlled for. However, they also found that intermediate pulse pressure (46–53 mm Hg) was associated with reduced risk of myocardial injury. This latter finding was also echoed by Venkatesan and colleagues,[15] who showed that pulse pressures from 42 to 58 mm Hg were associated with lower postoperative mortality. Ackland and colleagues[32] also found that a *low* preoperative pulse pressure was associated with increased postoperative morbidity, assessed by the PostOperative Morbidity Survey, in patients with low cardiopulmonary reserve undergoing non-cardiac surgery, consistent with the mortality findings.[15,18] It is plausible that the association of low pulse pressure with adverse outcomes involves heart failure events or pathophysiology, and high pulse pressure is associated with acute vascular events or pathophysiology. This requires further study.

No study has identified clear thresholds of arterial pressure (for hypotension or hypertension) beyond which risk rapidly escalates. Rather, whilst the (unadjusted) relationships between risk and blood pressure may be J shaped (Fig. 1), and thus, non-linear, there is no consensus on the threshold at which patients would be deemed at an increased risk, and hence, their surgery should be deferred. The ACC/AHA and AAGBI/BHS guidelines suggest that elective surgery in patients with arterial pressure >180/110 mm Hg may be deferred; however, this appears to be driven largely by expert opinion (Table 1). We were unable to identify consistent evidence that patients who underwent operations with preoperative arterial pressure above these values experienced increased harm. However, it is important to note that the data evaluated largely came from a period that was likely influenced by the expert opinion recommending deferral of surgery,[33] potentially resulting in a lack of operations in patients with very high preoperative arterial pressure and a resultant lack of evidence. In 1971, Prys-Roberts and colleagues[28] showed that patients with untreated hypertension, with mean arterial pressures of ~130 mm Hg, were associated with intraoperative hypotension, and five of seven of these patients sustained myocardial ischaemia associated with mean arterial pressure changes greater than 50% from baseline. This not only suggests that extremely high arterial pressure may be a perioperative risk factor, but also that the harm may be mediated by intraoperative pressure changes. Whether pre- or intraoperative treatment may modify this putative relationship remains unclear.

Consensus statement 3: *There is insufficient evidence to support lowering blood pressure in the immediate preoperative period to reduce perioperative risk.*

The only randomised trial of acute preoperative lowering of arterial pressure identified no difference in postoperative complications after non-cardiac surgery in patients at low cardiovascular risk with raised preoperative diastolic pressure (>110 mm Hg).[34] However, it is unclear whether a sufficient decrease in arterial pressure was achieved, or for long enough, to induce a change in outcome. A small subgroup analysis of another study found similar event rates for postoperative myocardial injury and death in hypertensive patients deferred for surgery compared with those not deferred.[35] Importantly, a reduction in arterial pressure was not achieved by deferring surgery. Consequently, there is currently no evidence that deferring patients for better arterial pressure control changes their risk unless they are manifesting acute pathological symptoms (defined as new onset end-organ damage) requiring urgent medical therapy (see ACC/AHA guidelines[6]). We acknowledge that, for specific surgeries, for example, neurosurgery or endocrine surgery, specific pressure parameters may be recommended; however, this was considered beyond the scope of these general guidelines.

Consensus statement 4: *There is insufficient evidence that any one measure of blood pressure (systolic pressure, diastolic pressure, MAP, or pulse pressure) is better than any other for risk prediction of adverse perioperative events.*

There are limited data comparing the utility of different preoperative arterial pressure measures for predicting perioperative risk.[15,18,22] Fontes and colleagues[22] found that raised preoperative pulse pressure was associated with all-cause mortality and cerebral and cardiac events after cardiac surgery. A comprehensive comparison with similar metrics from systolic and diastolic pressures was not conducted, making inference about the relative importance of all variables difficult. In particular, systolic and diastolic pressures were analysed as continuous variables, and pulse pressure was analysed in 10 mm Hg increments. Methodological differences, such as these, make direct comparison of the variables problematic. Nonetheless, Fontes and colleagues[22] did attempt to control for systolic and diastolic changes in their analyses, suggesting that pulse pressure may be predictive, independent of these other pressure metrics. Abbott and colleagues[18] also showed that the association of pulse pressure with myocardial injury was independent of systolic pressure in non-cardiac surgery. Venkatesan and colleagues[15] analysed all three variables as continuous data and found similar findings with each measure: low systolic, diastolic, and pulse pressures were each associated with increased postoperative mortality. In sum, these data show that arterial pressure can provide important prognostic information; however, the relative value of each measure has been inadequately explored. A thorough analysis of several data sets should be undertaken to rigorously compare the different metrics. Of course, interpretation of any arterial pressure value is dependent on the clinical context. It is also likely that the data sets investigated do not capture all of the relevant variables. Referral to the POQI-3 physiology report[1] is recommended for discussion of clinical context.

The consensus statements are summarised in Figure 2.

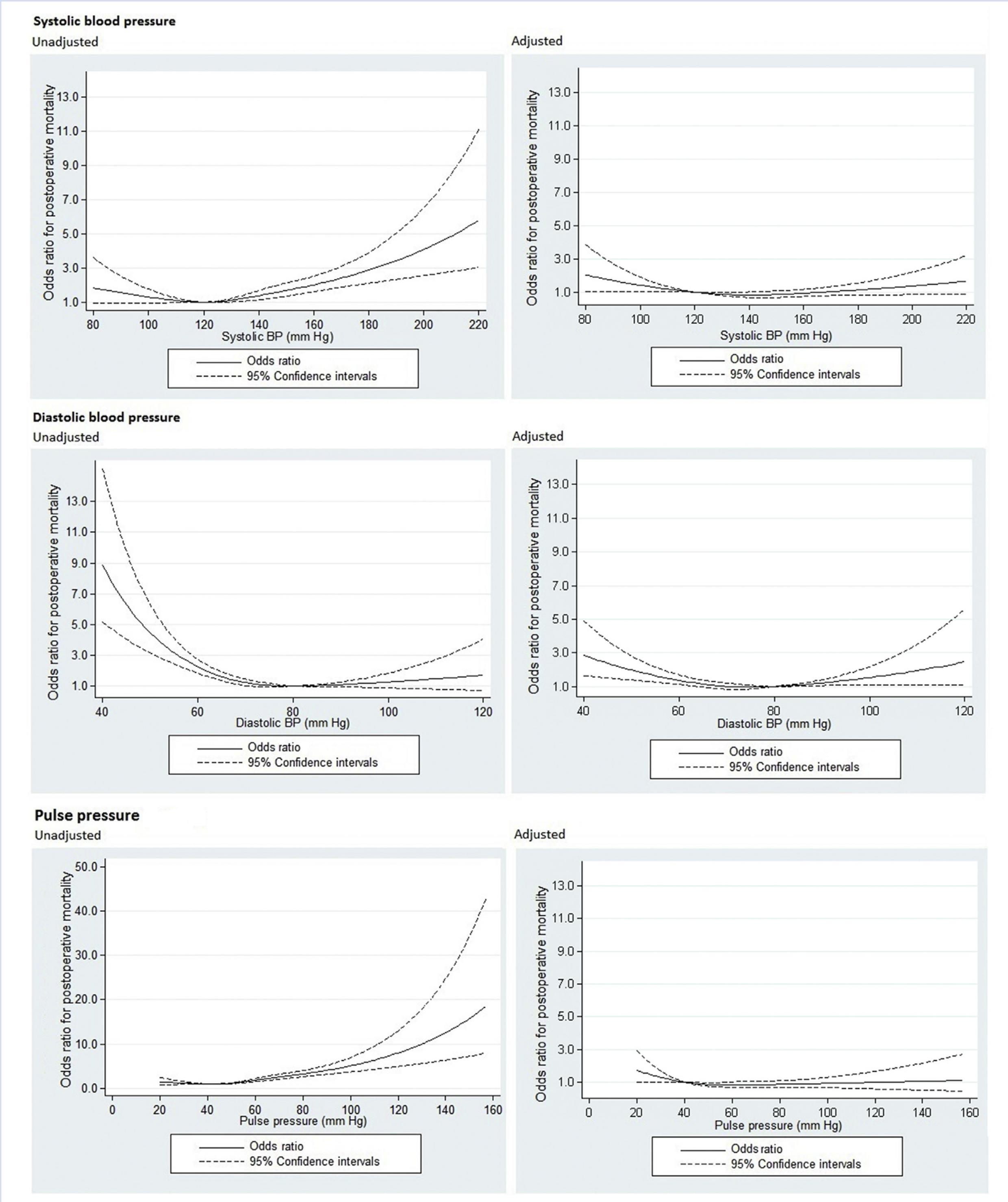

Fig 1. Examples of the association of preoperative arterial pressure and postoperative mortality. The unadjusted data on the left demonstrate the J-curve phenomenon for the association between preoperative systolic, diastolic, and pulse pressures, and postoperative mortality. On the right, the fully adjusted spline curves do not demonstrate the J-curve phenomenon clearly. Fully adjusted model adjusted for age; gender; atrial fibrillation; unstable angina; valvular heart disease; myocardial infarction; congestive heart failure; peripheral vascular disease; cerebrovascular disease; chronic obstructive pulmonary disease; liver disease; diabetes mellitus; renal disease; cancer; Charlson's comorbidity score; smoking; alcohol; surgical risk scale; socioeconomic status (Index of Multiple Deprivation 2010); number of arterial pressure measurements; and use of statins, beta blockers, calcium channel blockers, angiotensin-converting enzyme inhibitors, alpha-2 agonists, loop diuretics, thiazide diuretics, aspirin, other antiplatelet drugs, and selective serotonin reuptake inhibitors. Reproduced from Venkatesan and colleagues[17] with permission.

Table 1 Contrast between two recent guidelines concerning preoperative blood pressure. ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker

High blood pressure clinical practice guideline (Whelton and colleagues[6])			Perioperative quality Initiative[XX]	Discussion on discordance
COR	LOE	Statements	Statements	
I	B-NR	In patients with hypertension undergoing major surgery who have been on beta blockers chronically, beta blockers should be continued.	For patients on chronic beta blockade for high-risk indications (such as congestive heart failure or recent myocardial infarction within the last 2 yr), beta blockers should be continued.	Recent evidence suggests that beta blockers exert protective effects in patients with high-risk indications, but not for those patients solely taking beta blockers for hypertension. It remains unclear whether beta-blocker drug withdrawal is safe in patients with low-risk indications or not.
IIa	C-EO	In patients with hypertension undergoing planned elective major surgery, it is reasonable to continue medical therapy for hypertension until surgery.	Currently, there is limited evidence to withhold thiazide diuretics or calcium channel blockers in the preoperative period. Continuation or stopping of loop diuretics should be considered on a per-patient basis.	
IIb	B-NR	In patients with hypertension undergoing major surgery, discontinuation of ACEIs or ARBs perioperatively may be considered.	Unless clinically contraindicated, withhold ACEIs/ARBs 24 h before surgery with attention to restarting the medications within 48 h after operation where appropriate.	
IIb	C-LD	In patients with planned elective major surgery and SBP of 180 mm Hg or higher, or DBP of 110 mm Hg or higher, deferring surgery may be considered.	Unless associated with a medical emergency, there is insufficient evidence to recommend a specific threshold of blood pressure upon which to decide whether or not to proceed with surgery.	The limited data available do not suggest that deferring surgery for blood pressure control is effective or reduces risk. Unless there is a medical emergency, surgery need not be deferred based solely on the blood pressure value.
III: Harm	B-NR	For patients undergoing surgery, abrupt preoperative discontinuation of beta blockers or clonidine is potentially harmful.	For patients on chronic beta blockade for high-risk indications (such as congestive heart failure or recent myocardial infarction within the last 2 yr), beta blockers should be continued.	See above. Recent data have suggested there may be less morbidity with beta blocker withdrawal, but continue to show increased mortality. This discordance requires further investigation.
III: Harm	B-NR	Beta blockers should not be started on the day of surgery in beta-blocker-naïve patients.	Beta blockers should not be initiated in the preoperative period solely to reduce perioperative risk.	

COR, class of recommendation; LOE, level of evidence; B-NR, moderate quality of evidence from non-randomized studies; C-LD, evidence from randomized or non-randomized studies with limitations in design or execution.

Recommendations for practice

Based on the original questions, the consensus group discussed practice recommendations.

Practice recommendation 1: *Unless clinically contraindicated, withhold angiotensin-converting enzyme inhibitors/angiotensin receptor blockers (ACEIs/ARBs) 24 h before surgery with attention to restarting the medications within 48 h after operation where appropriate.*

A recent analysis of the VISION study of non-cardiac surgery suggested that withholding ACEIs/ARBs before surgery may reduce the risk of mortality, stroke, and myocardial injury,[36] supporting prior concerns that these drugs may be associated with intraoperative haemodynamic instability.[37] It is likely that these drugs should be restarted after operation as soon as is reasonable, as delayed or omitted reinstitution of ACEIs/ARBs has been associated with increased postoperative mortality.[38] We believe that a prospective randomised controlled trial is needed to confirm whether ACEI/ARB withdrawal improves outcomes, including attention to when the medications are restarted. However, based on the present

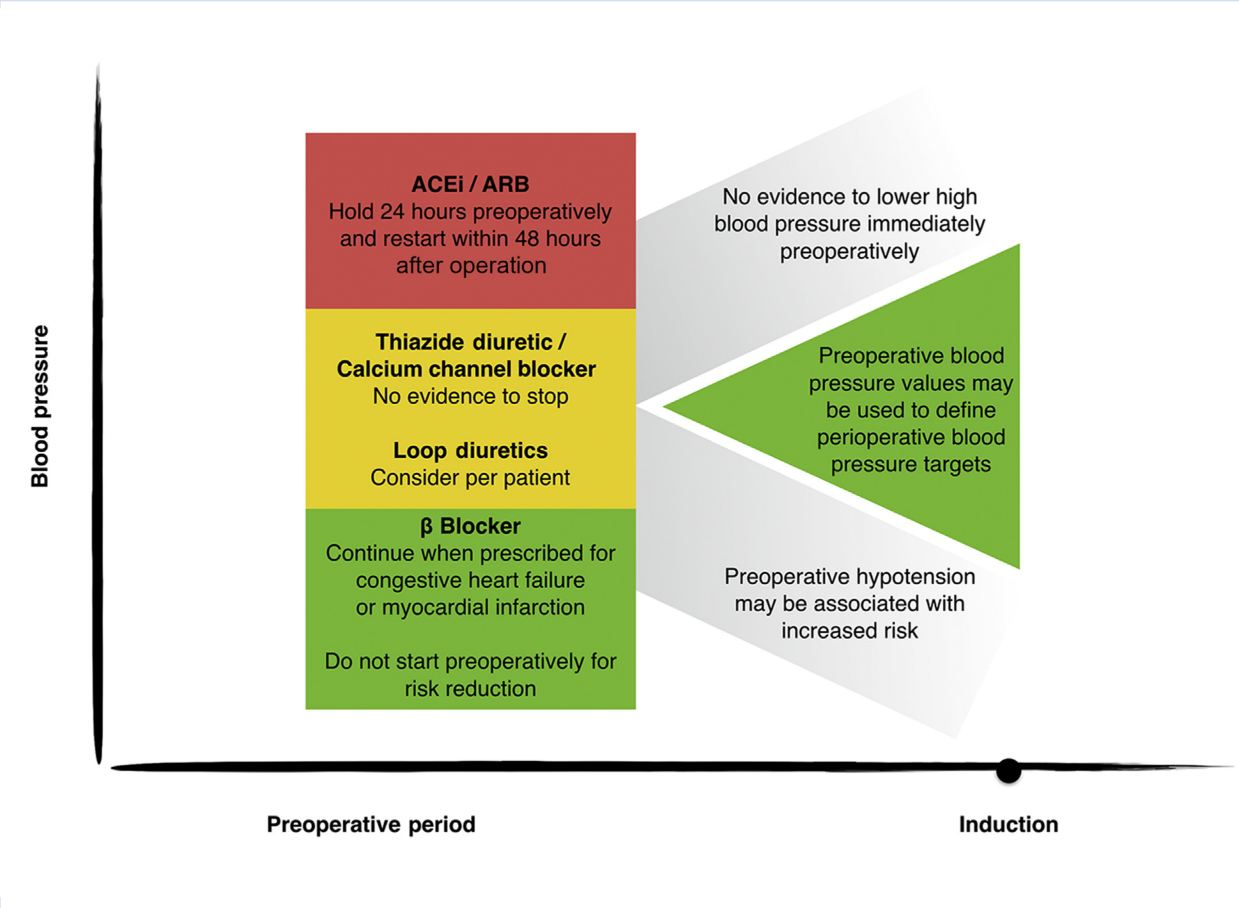

Fig 2. Infographic demonstrating the consensus recommendations. Figure reused with the permission of the Perioperative Quality Initiative (POQI). For permission requests, contact info@poqi.org.

data, our consensus was that withholding ACEIs/ARBs before surgery is reasonable, consistent with prior guidance.[6]

The data for cardiac surgery are less clear; whilst similar concerns over haemodynamic instability have been noted,[37] discontinuation of ACEIs/ARBs before surgery was associated with increased mortality.[39] Whether this represents failure to reinstitute therapy is unclear.

Practice recommendation 2: *Beta blockers should not be initiated in the preoperative period solely to reduce perioperative risk.*

Beta blockers have been associated with increased risk in the perioperative period, particularly increasing the risk of stroke and mortality when initiated just for surgery.[40–42] In line with present guidelines,[6,43] we conclude that there is limited evidence that *de novo* initiation in the perioperative period is warranted.

Practice recommendation 3: *For patients on chronic beta blockade for high-risk indications (such as congestive heart failure or recent myocardial infarction within the past 2 yr), beta blockers should be continued.*

Observational data suggest that beta blockers should not be withdrawn from these 'higher-risk' patients in the perioperative period.[44,45] Beta blockers may exert protective effects in those with congestive heart failure or recent myocardial infarction in particular,[46] but have been associated with increased harm in lower-risk individuals,[44,47] such as those on beta blockers for hypertension control[47] or ASA physical status 1–2.[44] This is in concordance with the present guidelines.[6,43]

Practice recommendation 4: Currently, there is limited evidence supporting withholding thiazide diuretics or calcium channel blockers in the preoperative period; continuation or stopping of loop diuretics should be considered on a per-patient basis.

There have been few studies of the effects of diuretics and calcium channel blockers on perioperative outcomes. For diuretics, thiazides have not been associated with harm,[47] and data from small randomised controlled trials suggest that calcium channel blockers may be associated with improved outcomes.[48,49] There are limited data to suggest these drugs are harmful in the perioperative period. Continuation or stopping of loop diuretics should be considered on a per-patient basis; definitive data that these drugs are harmful are lacking.[50]

Recommendations for research

Folllowing the consensus statements and practice recommendations, the group sought to identify important remaining research recommendations.

Research recommendation 1: *What is the best time and setting in which to measure blood pressure in the preoperative period? Studies addressing environment, technique, equipment, and reproducibility are required. The blood pressure measure that best predicts* *perioperative risk is unknown, and this question may be addressed via large-scale pragmatic observational and interventional trials.*

Intraoperative relative reductions in arterial pressure of >20% of baseline are associated with increased risk of perioperative myocardial ischaemia, acute kidney injury, and stroke.[7,9] The definition of this baseline has not been formalised, and no single metric is consistently used (systolic, diastolic, mean, or pulse pressure). White coat hypertension in both the primary care setting and on the morning of surgery may yield falsely high baseline pressure measurements. The clinical significance of this is unknown, particularly when these measurements are used to set intraoperative arterial pressure targets.[14] Measurements taken in the primary care setting from 1 to 52 weeks before surgery have been found to be predictive of postoperative risk, with increased risk in patients with preoperative arterial pressure <119/63 mm Hg in one study.[15] However, it is unclear whether this is the best available measure. Whilst ambulatory monitoring may provide the best index for establishing baseline arterial pressure, it is unlikely this is feasible in every patient before operation. Prospective studies are required to investigate which method, and time point, of blood pressure measurement is both predictive of adverse perioperative outcomes and feasible.

Research recommendation 2: *Whether or not correction of preoperative hypo- or hypertension improves outcomes is unknown, and requires answering given the numbers of patients who have surgery deferred based on preoperative arterial pressure readings.*[43]

Outside the settings of shock or hypertensive emergency, the value and feasibility of preoperative arterial pressure optimisation are unknown. It is unclear whether deferring surgery for better control of arterial pressure leads to lower arterial pressure on the day of the rescheduled surgery. It is also unclear how long surgery should be deferred in order to reduce perioperative risk, if it does at all.

Research recommendation 3: *The effect of preoperative discontinuation of ACEIs and the relative effects of ACEIs vs ARBs need clarifying, with emphasis on time of withdrawal and reinstitution of therapy.*

Withholding ACEIs/ARBs 24 h before non-cardiac surgery was associated with reduced risk of all-cause mortality, myocardial injury, and stroke in an observational study[36]; however, this is yet to be shown in a randomised controlled trial. In cardiac surgery, the benefits of withholding ACEIs/ARBs are less clear.[39] Randomised controlled trials are required to assess the benefit of ACEI/ARB continuation or withdrawal, and the timing of withdrawal and reinstitution of therapy (e.g. ISRCTN17251494).

Research recommendation 4: *The role of beta blockers and alpha-2 agonists in the perioperative setting remains uncertain; further data are required on the perioperative withdrawal of beta blockers in low-risk patients.*

Observational data suggest that beta blockers may be harmful in low-risk patients.[44,47] However, epidemiological data often lack accurate recording of drug withdrawal and physiological data, and are insufficient to estimate whether beta blocker withdrawal may benefit some patients. A recent observational study found that beta blocker withdrawal was associated with increased mortality, but paradoxically shorter PACU stays and less vasopressor support.[51] The discordance in these findings needs to be resolved, especially as the reported mortality rates were very low in both groups. Despite the limitations of observational data, including selection bias for one group or another, before conducting a randomised controlled trial, we recommend a prospective cohort study to evaluate the potential benefit/harm of beta blocker withdrawal in patients at a low risk of cardiac mortality or morbidity.

Less commonly used antihypertensives have similarly not been studied on a suitable scale to fully define perioperative management. However, it should be noted that acute cessation of chronic alpha-2 agonists (e.g. clonidine) may cause acute rebound hypertension.[52] There are inadequate data to comment on the perioperative cessation/continuation of alpha-blockers (e.g. doxazosin).

Research recommendation 5: *Investigation of the potential benefit of loop diuretic withdrawal is required in the perioperative setting.*

Diuretics are often withheld on the day of surgery based on the rationale that their use is associated with a risk of intraoperative hypotension. The withdrawal of loop diuretics, in a relatively small randomised controlled trial of non-cardiac surgical patients, led to no reduction in the incidence of intraoperative hypotension and cardiac morbidity.[50] This study did show a small trend to increased harm from loop diuretic continuation that warrants evaluation in a large randomised controlled trial.

Research recommendation 6: *Evaluation of perioperative diltiazem use in a large randomised controlled trial.*

The use of non-dihydropyridine calcium channel blockers may reduce the risk of perioperative myocardial ischaemia and arrhythmias.[48,49] A meta-analysis of several small studies shows a reduction in myocardial ischaemia when diltiazem is administered perioperatively.[48,49] An adequately powered, well-designed randomised controlled trial investigating the effect of diltiazem on perioperative myocardial ischaemia and mortality should be undertaken.

Strengths and limitations

POQI uses an established modified Delphi process, which has been used in more than 25 Acute Dialysis Quality Initiative[53,54] and POQI conferences in the last 20 yr. 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 statements and 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

Despite widespread monitoring of preoperative arterial pressure, there are insufficient data to suggest that this should alter decisions to proceed with surgery or not. However, the use of preoperative arterial pressure to guide intraoperative management appears promising. Further observational studies and randomised controlled trials are required to define optimal perioperative management of chronic cardiovascular medications. Our consensus statements broadly agree with recent hypertension guidelines; however, there is some discordance, as summarised in Table 1. Ultimately, this topic requires investment in novel research approaches to resolve ambiguities in the evidence.

Authors' contributions

Writing first draft: RDS.
Infographic design: FH.
Final version approval: all authors.

Declarations of interest

AS: member of the Scientific Advisory Board, Edwards Lifesciences. MGM: University Chair Sponsored by Smiths; director, UCL Discovery Lab; co-director, Duke-UCL Morpheus Consortium; consultant for Edwards Lifesciences; director, Bloomsbury Innovation Group (BiG); shareholder and scientific advisor, Medical Defense Technologies LLC; shareholder and director, Clinical Hydration Solutions Ltd (Patent holder 'QUENCH'); editorial board, BJA; editorial board Critical Care; founding editor-in-chief of Perioperative Medicine; chair, Advisory Board American Society of Enhanced Recovery. TEM: research funding and consultant for Edwards Lifesciences and consultant for Mallinckrodt. MRE: has received an honorarium for lecturing for Edwards Lifesciences. He is deputy Chief Investigator for the OPTIMISE II trial, which is part-funded by Edwards Lifesciences, although he does not receive financial support in this role. MPWG: National Specialty Lead for Anaesthesia, Perioperative Medicine and Pain within the UK National Institute of Heath Research Clinical Research Network, an elected council member of the Royal College of Anaesthetists and president of the Critical Care Medicine section of the Royal Society of Medicine. MPWG serves on the board of ERAS UK, Oxygen Control Systems Ltd, the Evidence Based Perioperative Medicine (EBPOM) social enterprise and the medical advisory board of Sphere Medical Ltd and the international advisory board of the American Society of Enhanced Recovery (ASER). MPWG has received honoraria for speaking and/or travel expenses from Edwards Lifesciences, Fresenius-Kabi, BOC Medical (Linde Group), Eli Lilly Critical Care, and Cortex GmBH. MPWG is executive chair of the Xtreme-Everest Oxygen Research Consortium. RDS, FH, AT, AB, AH, DAW: none.

Funding

EBPOM CiC and Edwards Lifesciences (to Perioperative Quality Initiative-3).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bja.2019.01.018.

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Handling editor: H.C. Hemmings Jr