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Review Article

Pre-operative cardiac optimisation: a directed review

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Summary

Cardiac events remain the leading cause of peri-operative morbidity and mortality, and patients undergoing major surgery are exposed to significant risks which may be preventable and modifiable. Proper assessment and management of various cardiac conditions in the peri-operative period by anaesthetists can markedly improve patient safety, especially in high-risk patient populations. This involves understanding and applying current evidence-based practice and international guidelines on the main aspects of cardiac optimisation, including management of patients with hypertension, chronic heart failure, valvular heart diseases and cardiac implantable electronic devices. Peri-operative management of antihypertensive drugs in keeping with the current best evidence is discussed. Pre-operative cardiac risk assessment and cardiac biomarkers can be used to help predict and quantify peri-operative adverse cardiac events. There is an increasing need for anaesthetist-led services, including focused transthoracic echocardiography and management of implantable cardiac electronic devices. Anaesthetists should be encouraged to play a proactive role in pre-operative risk stratification and make timely multidisciplinary referrals if necessary. A personalised approach to pre-operative cardiac optimisation enables a safer peri-operative journey for at-risk patients undergoing major surgery.

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Introduction

It is estimated that around 200 million major operations are performed every year worldwide [1]. Overall complication rates vary among different countries but are probably around 10% [2], with cardiac complications now one of the leading causes of all morbidity and mortality [3, 4], accounting for 40% of postoperative mortality in one study utilising troponin levels [3]. Major adverse cardiac events comprise: acute myocardial ischaemia or infarction; angina; congestive heart failure; atrioventricular block; arrhythmias; and cardiac arrest [5]. This has a significant impact on immediate and long-term prognosis, and adds to the burden on the healthcare system by increasing the utilisation of intensive care facilities, drugs and equipment and prolonging the length of hospital stay [6, 7].

Thorough assessment of cardiac morbidity is particularly important for high-risk surgical patients. Although many risk scoring systems are available, the most validated one is the revised cardiac risk index, which consists of one procedural and five clinical risk factors

Table 1 Revised cardiac risk index [8].

Risk factor	Points
Cerebrovascular disease	1
Congestive heart failure	1
Creatinine level > 2.0 mg.dl^{-1}	1
Diabetes mellitus requiring insulin	1
Ischaemic cardiac disease	1
Supra-inguinal vascular surgery, intrathoracic surgery or intra-abdominal surgery	1
Risk of major cardiac event	
Points	Percentage risk (95%CI)
0	0.4 (0.05–1.5)%
1	0.9 (0.3–2.1)%
2	6.6 (3.9–10.3)%
≥ 3	≥ 11 (5.8–18.4)%

(Table 1) [8]. A systematic review has proven a linear relationship between the score and the likelihood of peri-operative cardiac complications [9], but it is still debatable as to whether at-risk patients can benefit from such stratification approaches.

Surgical patients present with various cardiac conditions and the peri-operative management strategies are, therefore, diverse. The common ones are addressed below. The level of evidence and the strength of recommendation of particular management options are graded according to a pre-defined scale (Table 2).

Hypertension

Hypertension alone is only a minor independent risk factor for adverse cardiac events in non-cardiac surgery [10], but patients with uncontrolled hypertension tend to have volatile intra-operative blood pressure which can increase risk. In the context of isolated hypertension, delaying or cancelling surgery for additional cardiac testing is usually neither necessary nor desirable. The potential benefit of delaying surgery for optimisation must be weighed against the risks of postponing surgery. Despite the availability of guidelines that recommend elective surgery should not be deferred if the blood pressure is below 180 mmHg systolic and 110 mmHg diastolic [11], cancellation of surgery due to 'suboptimal' peri-operative control of hypertension is still encountered occasionally. The American College of Cardiology (ACC) and American Heart Association (AHA) published an updated guideline in 2017 on the definition of hypertension (Table 3) and recommendations for hypertensive patients undergoing surgical interventions (Table 4) [12].

Treatment of pre-operative hypertension can be complicated, and the condition is further compounded by the phenomena known as 'masked hypertension' and 'white coat hypertension' [13, 14]. White coat hypertension is an elevated blood pressure in the clinical setting with a normal pressure at home. Masked hypertension is defined as a normal blood pressure in the clinic, but an elevated blood pressure out of the clinic. It may occur in as much as 10% of the general population, and is important because it is not diagnosed by routine medical examinations, but carries an adverse prognosis, both in terms of increased target organ damage and cardiovascular events. Patients are frequently relatively young and male, with stress or increased physical activity during the daytime, and are often smokers or have excessive alcohol consumption. Masked hypertension has also been described in treated hypertensive patients and in

Table 2 Definitions of class of recommendation and level of evidence.

Class of recommendations	Definition	Suggested wording to use
Class I	Evidence and/or general agreement that a given treatment or procedure is beneficial, useful, effective	Is recommended/is indicated
Class II	Conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of the given treatment or procedure	
Class IIa	Weight of evidence/opinion is in favour of usefulness/efficacy	Should be considered
Class IIb	Usefulness/efficacy is less well established by evidence/opinion	May be considered
Class III	Evidence or general agreement that the given treatment or procedure is not useful/effective, and in some cases may be harmful	Is not recommended
Level of evidence	**Definition**	
Level A	Data derived from multiple randomised clinical trials or meta-analyses	
Level B	Data derived from a single randomised clinical trial or large non-randomised studies	
Level C	Consensus of opinion of the experts and/or small studies, retrospective studies, registries	

Table 3 Definition of hypertension in adults [12].

Category	Systolic blood pressure		Diastolic blood pressure
Normal	< 120 mmHg	and	< 80 mmHg
Elevated	120–129 mmHg	and	< 80 mmHg
Hypertension			
Stage 1	130–139 mmHg	or	80–89 mmHg
Stage 2	≥ 140 mmHg	or	≥ 90 mmHg

An individual with systolic blood pressure and diastolic blood pressure in two different categories should be assigned to the higher category.

children, in whom it may be a precursor of sustained hypertension. It may be suspected in individuals who have a history of occasional high blood pressure readings, but who are apparently normotensive when checked in the clinic.

There is a wide range of medications available to reduce blood pressure to the desired target before surgery. Hypertensive subjects have more arterial pressure lability intra-operatively, although this has not been shown to be associated with increased 30-day mortality [15]. Anaesthetists can monitor intra-operative haemodynamic fluctuation either directly or indirectly and have a range of drugs at their disposal to maintain blood pressure within an acceptable range. Anaesthetic drugs will also affect blood pressure but should only be used to maintain an optimum depth of anaesthesia, not to control blood pressure. Therefore, it is the treatment of cardiovascular risk, not hypertension per se, that is important.

Table 4 Recommendations for hypertensive patients undergoing surgical interventions [12].

Pre-operative	
1	In patients with hypertension undergoing major surgery who have been on beta-blockers chronically, beta-blockers should be continued. (Class I, level B evidence)
2	In patients with hypertension undergoing planned elective major surgery, it is reasonable to continue medical therapy for hypertension until surgery. (Class IIa, level C evidence)
3	In patients with hypertension undergoing major surgery, discontinuation of angiotensin-converting enzyme inhibitors or angiotensin II receptor blockers peri-operatively may be considered. (Class IIb, level B evidence)
4	In patients with planned elective major surgery and SBP of ≥ 180 mmHg or DBP of ≥ 110 mmHg, deferring surgery may be considered. (Class IIb, level C evidence)
5	For patients undergoing surgery, abrupt pre-operative discontinuation of beta-blockers or clonidine is potentially harmful. (Class III, level B evidence)
6	Beta-blockers should not be started on the day of surgery in beta-blocker naïve patients. (Class III, level B evidence)
Intra-operative	
7	Patients with intra-operative hypertension should be managed with intravenous medications until such time as oral medications can be resumed. (Class I, level C evidence)

Class, recommendation class; level, level of evidence (see Table 2); DBP, diastolic blood pressure; SBP, systolic blood pressure.

Nowadays, anaesthetists have more opportunity to assess and optimise hypertension in the outpatient assessment clinic before surgery. Firstly, the patient's baseline blood pressure should be determined, either by checking their self-monitoring record, or the record from their primary care physician [11]. If long-standing hypertension is suspected, there should be an assessment of possible end-organ damage including left ventricular hypertrophy, diastolic dysfunction, atherosclerotic coronary artery disease, heart failure, glomerular injury, renal tubular ischaemia and end-stage renal failure [16].

For patients with systolic blood pressure < 180 mmHg and diastolic blood pressure < 110 mmHg, antihypertensives should be continued in the peri-operative period [11]. In patients with planned elective major surgery and a documented systolic pressure of ≥ 180 mmHg or diastolic pressure of ≥ 110 mmHg, surgery should be postponed [12], and blood pressure-lowering treatment should be discussed and commenced by following the National Institute for Health and Care Excellence/British Heart Society CG127 algorithm [11]. In particular, patients with diastolic pressure ≥ 110 mmHg immediately before surgery have been shown to have increased risk of complications including myocardial infarction and renal failure [17].

Earlier clinical trials alluded to a possible beneficial effect of beta-blockers in prevention of peri-operative cardiac risks [18, 19]. However, the peri-operative ischemic evaluation (POISE) trial and a subsequent meta-analysis showed that although initiation of beta-blockers one day or less in patients before non-cardiac surgery will decrease rates of nonfatal myocardial infarction, it paradoxically increases the risk of stroke, hypotension, bradycardia and death [20, 21]. The POISE trial was criticised for not using a titrated dose of beta-blocker, because initiating and titrating beta-blockers to heart rate weeks before surgery

Table 5 Recommendation for peri-operative beta-blocker therapy [23, 24].

ESC/ESA guideline 2014 [23]	ACC/AHA guideline 2014 [24]
Class I	Class I
Peri-operative continuation of beta-blockers is recommended in patients currently receiving this medication (Class I, level B†)	Peri-operative continuation of beta-blockers is recommended in patients currently receiving this medication (Class I, level B)
Class II	Class II
Pre-operative initiation of beta-blockers may be considered 1 In patients scheduled for high-risk surgery and who have ≥ 2 clinical risk factors or ASA status ≥ 3 (Class IIb, level B) 2 In patients who have known IHD or myocardial ischaemia (Class IIb, level B) When oral beta-blockade is initiated in patients who undergo non-cardiac surgery, the use of atenolol or bisoprolol as a first choice may be considered (Class IIb, level B)	Guide management of beta-blockers after surgery by clinical circumstances (Class IIa, level B) It may be reasonable to begin beta-blockers 1 In patients with intermediate- or high-risk pre-operative tests (Class IIb, level C) 2 In patients with > 3 revised cardiac risk index factors (Class IIb, level B) 3 Long enough in advance to assess safety and tolerability, preferably > 1 day before surgery (Class IIb, level B) Initiating beta-blockers in the peri-operative setting as an approach to reduce peri-operative risk is of uncertain benefit in those with a long-term indication but no other revised cardiac risk index risk factors (Class IIb, level B)
Class III	Class III
Beta-blockers not recommended 1 Peri-operative high dose beta-blockers without titration (Class III, level B) 2 Patients scheduled for low-risk surgery (Class III, level B)	Beta-blockers should not be started on the day of surgery (Class III, level B)

Class, recommendation class; level, level of evidence; ESC, European Society of Cardiology; ESA, European Society of Anaesthesiology; ACC, American College of Cardiology; AHA, American Heart Association.

has been advocated as there is significant pharmacogenetic variability in response [22]. Table 5 summarises the current recommendations for peri-operative beta-blocker therapy [23, 24]. However, this strategy is limited by the timing of assessment before surgery [25]. Step-wise titration of beta-blockers in the pre-anaesthetic clinic allows optimisation of blood pressure and heart rate control, which may reduce peri-operative adverse cardiac events without increasing other risks [26]. Patients on chronic treatment with beta-blockers for ischaemic heart disease, arrhythmias or hypertension should be maintained on this medication throughout the peri-operative period (Class I recommendation) [23, 24].

There is some controversy over whether it is appropriate to continue angiotensin-converting enzyme inhibitors/angiotensin-II receptor blockers in the peri-operative period. There is an increased risk of intra-operative hypotension when they are continued [27, 28] and clinically-significant hypotension is independently associated with increased myocardial infarction, stroke and death, leading to the recommendation towards withholding them at least 24 h before major surgery [12, 21, 29, 30]. However, other studies show conflicting results with no sufficient available evidence to recommend discontinuing the drugs on the day of surgery [31–33]. Anaesthetists should be aware of the potential risk of intra-operative hypotension in patients receiving the drugs and be prepared to manage it [33]. In patients on chronic treatment, it is reasonable to continue them under supervision (Class IIa recommendation) [23, 24]. Likewise, if the drugs are discontinued before surgery for fear of intra-operative hypotension, it is reasonable to resume them after surgery as soon as possible (Class IIa recommendation) [23, 24].

Calcium channel blockers should be continued. There is little evidence to support their initiation pre-operatively for cardioprotection and, in a meta-analysis of studies investigating this, most of the benefits shown were attributed to diltiazem [34].

Alpha-2 agonists reduce central sympathetic activity and peripheral noradrenaline release, which can attenuate the adrenergic stress response to surgery, and the reduction in heart rate can improve myocardial oxygen balance. A meta-analysis had suggested that alpha-2 agonists reduce mortality and myocardial infarction after vascular surgery [35] but another meta-analysis, restricted to dexmedetomidine, did not show a significant improvement in cardiac outcomes, although hypotension and bradycardia were increased [36]. The more definitive POISE-2 trial suggests that alpha-2 agonists should

probably not be used for 'cardioprotection' in non-cardiac surgery [37], and this opinion is reflected in the most recent guidelines from North American and European bodies (Class III recommendation) [23, 24].

Nitrates are known to attentuate myocardial ischaemia. However, a 2016 Cochrane systematic review found no role for any preparation of nitrate in the prevention of peri-operative cardiac events, although only 3 trials recruiting a total of 149 patients, reported the all-cause mortality at 30 days [38]. To date, prophylactic use of nitrates is not recommended, as they may pose a significant risk with pre-load reduction [23]. A general approach for peri-operative management in the high-risk population would be to advise the patient to continue usual doses as needed, especially in case of symptom control in angina pectoris. No guidelines have been published concerning this topic.

At present, the recommended frequency of blood pressure monitoring varies hugely among different international guidelines, ranging from every primary care visit to every 5 years [39–41]. A specialist-led pre-operative assessment clinic [42] provides opportunity to stratify patients based on risks, to make timely referrals and prescribe medications according to latest ACC/ESC guidelines [23, 24]. The referring physician should be informed for patients with newly diagnosed hypertension.

Chronic heart failure

Heart failure is a global problem, with at least 26 million people affected [43, 44]. The prevalence of heart failure is also increasing as the population ages, and more patients with congestive heart failure will present for surgery [45]. Ejection fraction is the stroke volume divided by the end-diastolic volume and can be used in classification. Current terminology distinguishes: heart failure with preserved ejection fraction; heart failure with mid-range ejection fraction; and heart failure with reduced ejection fraction, based on the ejection fraction, natriuretic peptide levels and the presence of structural heart disease and diastolic dysfunction [46] (Table 6).

When assessing these patients, a detailed history and clinical examination are crucial to determine the cause and quantify its severity (Tables 7 and 8). Patients with current or previous history of heart failure are well known to have more peri-operative complications and this is an independent prognostic variable for all cardiac risk scores [8]. The revised cardiac risk index is the most validated clinical risk score and has been used as a tool to assess the risk of cardiac complications after non-cardiac surgery [8]. A 12-lead ECG should be done to look for myocardial ischaemia and arrhythmia. There is a consensus among international guidelines [23, 24, 47–49] that patients with active cardiovascular signs or symptoms should have an ECG, especially those undergoing high-risk surgery (Table 9). A pre-operative ECG is recommended for patients who have risk factor(s) and are scheduled for intermediate or high-risk surgery (Class I, level C evidence; it may also be considered for patients who have risk factor(s) identified by revised cardiac risk index and are scheduled for low-risk surgery (Class IIb, level C evidence) [23].

There is no high-quality evidence on the use of routine pre-operative chest radiography and it is not mandatory in patients with stable chronic heart failure [47]. Resting echocardiography is also not routinely recommended in patients with chronic and stable heart failure [50]. However, patients with signs and symptoms of worsening heart failure require investigations to assess the severity of systolic or diastolic dysfunction which will guide peri-operative management. In patients with acutely decompensated heart failure (New York Heart Association class IV), surgery should be postponed, if possible, and the opinion of a cardiologist sought for titration of heart failure medication [24]. Cardiac biomarkers have been used to predict the risk

Table 6 Diagnosis of heart failure[46].

Type of HF	HFrEF	HFmrEF	HFpEF
Criteria			
1	Symptoms ± signs[a]	Symptoms ± signs[a]	Symptoms ± signs[a]
2	LVEF < 40%	LVEF 40–49%	LVEF > 50%
3	–	1 Elevated levels of natriuretic peptides; 2 At least one additional criterion: a A relevant structural heart disease (LVH and/or LAE) Diastolic dysfunction	1 Elevated levels of natriuretic peptides; 2 At least one additional criterion: a A relevant structural heart disease (LVH and/or LAE) Diastolic dysfunction

HF, heart failure; HFrEF, heart failure with a reduced ejection fraction; HFmrEF, heart failure with mid-range ejection fraction; HFpEF, heart failure with a preserved ejection fraction; LAE, left atrial enlargement; LVH, left ventricular hypertrophy; LVEF, left ventricular ejection fraction.
[a]Signs may not be present in the early stages of HF (especially in HFpEF) and in patients treated with diuretics.

Table 7 Modified Framingham criteria for congestive heart failure [108].

Major criteria	Minor criteria
Paroxysmal nocturnal dyspnoea or orthopnoea	Bilateral ankle oedema
Central venous pressure > 16 cmH_2O	Nocturnal cough
Pulmonary rales	Dyspnoea on exertion
Cardiomegaly	Hepatomegaly
Acute pulmonary oedema	Pleural effusion
Third heart sound gallop	Tachycardia (heart rate ≥ 120 beats/min)
Weight loss > 4.5 kg in 5 days in response to treatment	Weight loss > 4.5 kg in 5 days in response to treatment

The diagnosis of heart failure requires that either two major or one major and two minor criteria are met.

Table 8 New York Heart Association (NYHA) Functional Classification [109].

NYHA functional classification	
Class I	No limitation of physical activity. Ordinary physical activity does not cause undue fatigue, palpitation or dyspnoea
Class II	Slight limitation of physical activity. Comfortable at rest. Ordinary physical activity results in fatigue, palpitation or dyspnoea
Class III	Marked limitation of physical activity. Comfortable at rest. Less than ordinary physical activity results in fatigue, palpitation or dyspnoea
Class IV	Unable to carry on any physical activity without discomfort. Symptoms at rest. If any physical activity is undertaken, discomfort is increased

Table 9 Cardiac risk stratification for non-cardiac surgical procedures [110].

Risk of procedure	Examples
High (> 5%)	Aortic and major vascular surgery, peripheral vascular surgery
Intermediate (1–5%)	Intraperitoneal and intrathoracic surgery, carotid endarterectomy, head and neck surgery, orthopaedic surgery, prostate surgery
Low (< 1%)	Endoscopic procedures, superficial procedures, cataract surgery, breast surgery, ambulatory surgery

'Cardiac risk' denotes combined incidence of cardiac death and nonfatal myocardial infarction.

of post operative major adverse cardiac events. Myofibrillar proteins, such as troponin T and troponin I, and natriuretic peptides such as brain natriuretic peptide (BNP) and N-terminal fragment of proBNP (NT-proBNP), are released into the circulation as a result of myocyte injury and stress. Several studies have investigated the prognostic values of BNP and NT-proBNP to predict major cardiovascular events after non-cardiac surgery [51–58]. The European Society of Cardiology and European Society of Anaesthesiology guidelines for pre-operative cardiac risk assessment have recommended the measurement of natriuretic peptides in high-risk patients (Class IIa, level B evidence) [59]. Post-operative raised levels of BNP or NT-proBNP compared with pre-operative levels has been shown to be associated with increased adverse cardiac events [60]. However, it is not clear how to tailor the peri-operative management to improve outcomes in patients with raised plasma BNP or NT-proBNP. Apart from natriuretic peptides, a raised postoperative troponin level has also been shown to be a very strong predictor of 30-day mortality and long-term outcomes for patients undergoing non-cardiac surgery [3, 61]. Post operative myocardial infarction is notoriously difficult to diagnose, as most patients have no symptoms and such myocardial injury could only be detected by serial serum troponin monitoring [3]. Therefore, it is recommended for at-risk patients to have their troponin levels monitored in the first few postoperative days, although further studies are required to define how cardiac optimisation should be performed in the most vulnerable group.

There is a growing body of evidence supporting outcome improvements in patients with better overall physical condition. Guidelines for the diagnosis and treatment of acute and chronic heart failure recommend supervised aerobic exercises to improve functional status and reduce the risk of hospital admission [46]. The evidence comes mostly from patients with heart failure and a reduced ejection fraction. The HF-ACTION trial is the largest multi-centre, randomised controlled trial so far to look at the efficacy and safety of aerobic exercise training among patients with heart failure; it enrolled more than 2000 patients [62]. For the primary composite end-point of all-cause mortality or all-cause hospitalisation, there was no significant difference between supervised exercise training and usual care (education and recommendation of regular exercise). However, after adjustment for prognostic baseline variables, there was a significant but modest reduction in all-cause mortality or all-cause hospitalisation in the exercise training group [62]. Other studies have shown improvements in functional status and quality of life after exercise training in patients with heart failure with reduced ejection fraction [63, 64]. In addition, it has been demonstrated that exercise training improves peak oxygen

uptake in patients with heart failure [64–66]. Apart from that, it improves cardiac structure and function, with significant improvements in left ventricular ejection fraction, end-diastolic and end-systolic volumes observed in patients receiving aerobic exercise training [67].

The clinical significance of cardiac rehabilitation is well described, especially in patients with heart failure. However, there is limited research about the use of pre-operative rehabilitation, also known as pre-habilitation, in this patient group. Preliminary evidence shows that pre-operative supervised exercise training enhances postoperative outcome in terms of shorter hospital stay and fewer postoperative complications [68, 69]. A systematic review has shown that pre-operative aerobic exercise training is effective in improving physical fitness in patients planned for intra-abdominal and intrathoracic surgery [70]. Pre-habilitation may well have a useful role but further large-scale studies will be needed to determine the best type of training to be prescribed for surgical patients with underlying heart failure. First of all, at-risk patients should be identified, and functional capacity and frailty are components of pre-operative evaluation. Biccard [71] provides evidence for predicting peri-operative complications associated with major non-cardiac surgery using stair-climbing capacity (four metabolic equivalents). Type of exercise and its duration is, as yet, undefined. It would be reasonable to initiate pre-habilitation during the waiting period for elective surgery, as patients tend to have little physical activity while waiting [72–74]. The PREHAB study [75], which hypothesises that an interdisciplinary pre-operative programme composed of an 8-week comprehensive exercise therapy and education programme will improve postoperative clinical outcome of frail elderly patients awaiting elective cardiac surgery, is still ongoing and results are expected to be released this year.

Cardiac murmurs

Systolic cardiac murmurs are common. In a study on an unselected cohort of elderly patients with fractured neck of femur, 30% had mild aortic stenosis or aortic sclerosis and 8% were found to have either moderate or severe aortic stenosis [76]. Yet, clinical examination alone is neither sensitive nor specific for evaluating undifferentiated murmurs, and valvular lesions are often missed with auscultation [77, 78]. In particular, it is unreliable in diagnosing combined disease in the aortic and mitral valves with a sensitivity of 55%, even in experienced hands [77]. The ability to detect diastolic heart murmurs is even worse, especially in the presence of a systolic murmur, with a sensitivity of only 20–40% [77, 79].

Previously undetected cardiac murmurs are commonly found during pre-operative assessment [80, 81] and are among the most common reasons for referral to a cardiologist [82]. A comprehensive history and physical examination remains the cornerstone of assessment. Recently, especially with cheaper and more portable ultrasound devices, there has been an expansion of echocardiography use in the peri-operative period among anaesthetists [83–86]. This, however, also has created challenges. Ideally, operations should be postponed while waiting for formal echocardiography, which may be undesirable, especially in emergencies. In a patient presenting with an otherwise asymptomatic cardiac murmur, although it would be useful to have transthoracic echocardiography to exclude cardiac pathology, such expertise may not always be readily accessible. Fortunately, training in, and utilisation of, pre-operative focused transthoracic echocardiography is becoming more available to anaesthetists [87, 88]. The examination is non-invasive and can be completed within 10 min in an outpatient setting. It allows the detection of significant valvular lesions, assessment of left and right ventricular function and detection of pericardial effusion [84]. It has been shown that even relatively junior anaesthetists can diagnose aortic stenosis, and assess its severity, after limited training [89].

There is now widespread use of echocardiography in patient assessment and management [90], and recent studies on the impact of focused transthoracic echo in pre-operative assessment [91, 92]. Having said that, focused echocardiography cannot replace clinical assessment and physical examination, nor does it replace a formal echocardiogram. Despite an improvement in diagnostic accuracy, evidence showing a scientifically robust positive clinical outcome is lacking. A retrospective cohort involving more than 250,000 patients with elective, intermediate- to high-risk, non-cardiac surgery showed pre-operative echocardiography was not associated with improved survival or shorter hospital stay, which casts doubt on the value of pre-operative echocardiography for improving peri-operative care and outcomes [93]. However, pre-operative consultation by physicians is also common practice, and yet patient outcome improvement is not apparent. On the other hand, pre-operative medical consultation may paradoxically result in increased short and long-term mortality, prolonged hospital stay, increased pre-operative testing and increased pharmacological intervention [94]. Consequently, we encourage anaesthetists to play a more proactive role in pre-operative management.

Recent studies demonstrate the impact of focused echocardiography in enhancing peri-operative management and the predictive value of peri-operative cardiac events [91, 92, 95–97]. Nonetheless, anaesthetist-led focused echocardiography is not a substitute for detailed assessment by a cardiologist. Theoretically, a reduction in unnecessary medical consultations can help reduce the burden on the whole healthcare system and reinvest resources in improving patient care; however, the overall efficacy and cost-effectiveness of this anaesthetist-led service is still lacking and needs further evaluation in large-scale clinical trials [98].

Patients with a cardiac implantable electronic device

The use of implantable electronic cardiac devices, which include pacemakers, implanted cardioverter-defibrillators, cardiac resynchronisation devices and implantable cardiac monitors, is increasingly common [99, 100]. The use of cardiac implantable electronic devices has provided significant benefit, yet also creates considerable challenges to healthcare personnel. Of particular note, the majority of patients with the devices fall into a high-risk stratification group relative to their physical status. For instance, patients with advanced biventricular failure may receive cardiac resynchronisation therapy; both of these will make the peri-operative management challenging [101].

Cardiac implantable electronic devices are problematic intra-operatively because their functions can be hindered by electromagnetic interference. There are multiple sources of such radiation in the operating theatre including electrocautery, evoked potential monitors, nerve stimulators, radiofrequency ablation, extracorporeal shock wave lithotripsy and electroconvulsive therapy [102]. Different devices will behave differently when there is excessive electromagnetic interference, which may cause rate interference, pulse generator damage, lead tissue damage and switching to inappropriate electrical reset mode. For patients with an implanted pacemaker, interference can result in oversensing [103] which will, in turn, lead to inappropriate inhibition and then serious bradycardia or asystole. With implantable cardioverter-defibrillators, electromagnetic interference can lead to inappropriate delivery of a defibrillator shock. Mechanical interference can also affect the normal function of the pacemaker, for example, when a guidewire is advanced during insertion of a central venous catheter and results in ventricular oversensing [103]. When assessing these devices, a thorough cardiovascular history and activity tolerance should be obtained to determine the indication for implantation and look for signs and symptoms suggestive of malfunction such as dizziness, syncope and deteriorating functional status. The time when the device was last checked and the specific recommendation from a cardiologist should be carefully documented. It is recommended by the Heart Rhythm Society that device interrogation should be arranged for a pacemaker within 12 months, an implantable cardioverter-defibrillator within 6 months and a cardiac resynchronisation therapy device within 3–6 months before surgery [103, 104]. Review of the electrocardiograph or consultation with the cardiology team can determine whether the patient is device dependent, and information such as the type and site of the procedure, patient positioning and anticipated sources of intra-operative electromagnetic interference should be obtained [105].

In all circumstances, close communication is required with the surgeon and cardiologist, particularly if reprogramming is expected before and after surgery. Anaesthetists have the potential, and opportunity, to offer structured peri-operative management of implanted cardiac devices before surgery. A pilot anaesthetic device service, led by anaesthetists in the US, has been reported. These doctors were trained to provide basic management of cardiac implantable electronic devices, including interrogation and reprogramming, in the pre-operative holding areas and recovery area and the programme was shown to be safe with specialist support if necessary [106]. It has been postulated that, in collaboration with the electrophysiology and cardiology services, anaesthetists could be more proactive in managing these patients and, thereby, reducing interdepartmental consultations and patient waiting time before surgery [99, 106].

For patients who are pacemaker-dependent with a high chance of electromagnetic interference, temporary reprogramming to asynchronous (non-sensing) mode will usually be required. Similarly, for those with implantable cardioverter-defibrillators, the device should be reprogrammed to suspend the anti-tachycardia function and prevent delivery of an unwanted shock. Devices with advanced functions (i.e. rate response function, sleep/rest mode) should have these functions turned off [105].

In general, no device reprogramming is required for surgery below the umbilicus [103]. When reprogramming is required, it is usually performed by trained personnel with a device-specific programming machine. Classic teaching describes placing a magnet onto the device for temporary suspension of the function of cardiac implantable electronic devices, however, this approach is seldom employed nowadays. The responses of the different devices to the

Table 10 Recommendations for management of cardiac implantable electronic devices (adapted from [107]).

Procedure	Intra-operative pacemaker monitoring	Pacemaker reprogramming	Postoperative pacemaker check	Implantable cardioverter-defibrillator deactivation/ re-activation
Surgery below umbilicus or upper limb distal to elbow	+	–	–	+
Surgery above umbilicus or upper limb proximal to elbow	+	±[a]	±[a]	+
Cardiac surgery	+	+	+	+
Ophthalmic surgery (if unipolar diathermy anticipated)	+	±[a]	±[a]	+
Endoscopy procedure	+	±[a]	±[a]	+
Dental surgery (only if diathermy use is anticipated)	±	±[a]	±[a]	+
Lithotripsy	+	±[b]	±[b]	+[c]
Electroconvulsive therapy	+	±[b]	±[b]	+[c]
Nerve conduction studies	+	±[a]	±[a]	±

[a]±: Consider reprogramming if patient is pacemaker dependent; postoperative pacemaker check required if reprogrammed.
[b]±: Consider reprogramming if patient is pacemaker dependent; interrogate pacemaker within 1 month after procedure.
[c]+: Deactivate implantable cardioverter-defibrillators peri-operatively and reactivate postoperatively, carry out checks after procedure.

magnet vary and are, thus, unpredictable, but it is also challenging to keep it in the optimal position particularly, when the surgery is performed in the lateral or prone position. In circumstances when placing a magnet is required, it is crucial to clarify with the cardiologist what will be the exact response of the cardiac implantable electronic device [104]. The British Society of Heart Rhythm has published a guide on the actions required for device management during different clinical scenarios (Table 10) [107]. These scenarios can be diverse and there is a paucity of evidence for peri-operative management of these devices for every specific procedure. As mentioned above, it is still advisable to discuss with the parent team for patients either with a complex device implanted or those with complicated cardiac conditions.

Conclusion

Many of the conditions mentioned above can be optimised before surgery and, therefore, to some extent can be regarded as modifiable risk factors. Anaesthetists can play an important role both in stratifying the risks and in initiating or titrating management, as well as liaising with other specialists where appropriate. Ultimately, the objective of pre-operative cardiac optimisation is to identify and modify these conditions well in advance to avoid cancellation or postponement of surgery and reduce the likelihood of peri-operative complications.

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