

Guidelines for the Preoperative use of Echocardiography

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Summary and Key Recommendations

- TTE is most commonly requested to assess left ventricular function and valvular pathology
- There is no place for routine TTE in preoperative cardiac risk assessment
- Preoperative TTE is warranted if there are new clinical signs of cardiac failure
- Repeat TTE is not required in chronic stable cardiac failure
- Ejection fraction is poorly correlated with postoperative outcome
- Aortic stenosis is a significant risk factor which is often asymptomatic
- Preoperative TTE is indicated in a new finding of systolic murmur in those aged over 60 and in any patient if in addition the ECG is abnormal or there are cardiac symptoms
- Preoperative TTE is indicated in the assessment of known moderate or severe aortic stenosis if the valve has not been imaged within the last 1-2 years
- Preoperative TTE is indicated in the diagnosis and assessment of pulmonary hypertension
- Bedside focussed TTE shows promise in addressing availability when surgery is urgent

Introduction

Perioperative cardiac complications are a significant cause of morbidity and mortality in patients undergoing elective non-cardiac surgery. Consequently, such patients should be appropriately investigated to minimise their risk of complications and to improve shared decision making. Transthoracic echocardiography (TTE) is one such investigation which is usually easily available in the elective situation, is painless and has no apparent side effects.

Unfortunately there is little published guidance about which patients should (and which should not) have a TTE before elective non-cardiac surgery. The 2016 NICE guidelines on preoperative testing gives broad indications [1] and international guidelines give advice from a cardiologists viewpoint, rather than that of a focussed preoperative healthcare professional [2,3,4,5].

This article will focus primarily on the use of static transthoracic echocardiography in the preoperative assessment of patients undergoing non-cardiac elective surgery. Transoesophageal, 3D and stress echocardiography will not be discussed, nor shall special indications such as its use prior to solid organ transplantation.

What is a Transthoracic Echocardiogram (TTE)?

A TTE is a non-invasive imaging investigation of the heart and major blood vessels. It employs the use of ultrasound to image the cardiac structures in real time, so that dynamic images and measurements can be obtained. Doppler ultrasound is also used to measure blood flow and tissue movements. For TTEs performed in the UK, a standardised investigation procedure has been devised [5]. Recently, standards have also been developed for shorter, more focussed examinations in emergency situations [6]. In the elective preoperative setting, the commonest indications for requesting a TTE are to assess left ventricular function and to investigate the presence and severity of valvular heart disease.

What information does TTE provide and what are the indications for requesting a TTE?

1.1 Left Ventricular Function

Heart failure has long been identified as being a significant risk for non-cardiac surgical patients and is a feature of the most widely known risk scoring system, the revised cardiac risk index [7]. It has also been demonstrated as major risk factor in more recent studies [8,46]. It is therefore essential that the condition is recognised and controlled before proceeding to surgery. Even stable heart failure is a recognised risk factor for post-operative complications.

Left heart failure typically presents with increasing shortness of breath, worsened by physical activity. The patient may describe breathlessness on lying flat (orthopnoea) with severe episodes occurring during the night (paroxysmal nocturnal dyspnoea). Clinical examination may reveal a 3rd heart sound, and in more severe cases bilateral basal crepitations. Secondary right heart failure may also be present, giving rise to an elevated jugular venous pressure and lower limb oedema. Unfortunately, clinical symptoms and signs are neither sensitive nor specific for diagnosing chronic heart failure, and further investigation is warranted [9].

TTE can provide information as to both the cause and severity of myocardial dysfunction. The presence of regional wall motion abnormalities (RWMAs) would point to a likely ischaemic cause [10], which may influence further management and risk profile. Measurement of left ventricular dimensions in systole and diastole can also estimate the ejection fraction (EF). This is defined as the stroke volume divided by the LV end-diastolic volume X 100, with a normal value of >55%.

However, a significant number of patients with heart failure, particular in the older population, have a normal ejection fraction [11], so this reading alone can lead to false re-assurance. This is termed diastolic heart failure (i.e. impaired relaxation of the ventricle in diastole) and is becoming increasingly apparent as a common and significant predictor of adverse outcomes [12]. In one study, around 60% of surgical patients over the age of 65 had evidence of diastolic dysfunction on TTE despite a normal ejection fraction [13], and such patients have an increased incidence of post-operative cardiac complications and longer term mortality risk [14,15,47].

TTE can be used to assess the presence and severity of diastolic dysfunction in the preoperative setting using a variety of imaging techniques [16]. These include left ventricular inflow measured at the mitral leaflets and myocardial tissue movement at the base of the septum [17]. These allow the echocardiographer to define the severity of the dysfunction, with the terms mild, moderate and severe often interchangeable with grades 1, 2 and 3 respectively [3,19].

1.2 Preoperative TTE in heart failure

A TTE is recommended for patients in whom heart failure is suspected on clinical grounds but this applies all patients, irrespective of whether they are due for surgery. So who warrants a TTE preoperatively? If a member of the preoperative team suspects a new diagnosis of heart failure, then the NICE guidelines recommend measuring B-type Natriuretic Peptide (BNP) [9], a position echoed by guidelines from Canada [48]. If this is elevated or the patient is known to have had a previous myocardial infarction, then immediate referral to a specialist multidisciplinary heart failure team should be arranged. This may be better organised by primary care if surgery is not urgent, but a direct referral to cardiology may be required if surgery cannot be significantly delayed. Local referral rules will dictate practice.

For patients with an established diagnosis presenting for elective surgery, it is reasonable not to repeat a TTE if their symptoms are stable [18]. If they have deteriorated or they are unstable, an echocardiogram may be indicated but usually this should only be requested after discussion with the clinician who normally monitors the patient's cardiac function, who will also be able to advise on any changes in therapy required [9]. It is likely that in the near future, both BNP and cardiopulmonary exercise testing may be of increasing relevance in the perioperative assessment of heart failure [19,20,21].

2.1 Aortic Stenosis

Aortic stenosis (AS) is a significant concern in the perioperative setting. 4% of people over 75 will have significant AS and several published series have characterised AS as a high-risk index for peri-operative complications [22,23,44]. The grading of AS can be conflicting as it is dependent on which echo measurement is chosen as the most important factor. Minners et al. [24] in a large review of echocardiograms showed that 30% of patients with severe AS by aortic valve area (AVA) had non-severe stenosis by mean gradient and 25% had non-severe by peak velocity. ACC/AHA Guidelines 2020 [25] classify asymptomatic AS as severe if either peak velocity is $\geq 4\text{m/s}$ or mean gradient $\geq 40\text{mmHg}$. AVA although typically will be $\leq 1.0\text{cm}^2$, is not required to define severe AS. The guidelines further subdivide AS into whether the subject is symptomatic or not. For reference the table illustrates commonly used values to grade AS.

Degree of Stenosis	Peak Velocity (m/s)	Mean Pressure Drop (BH)	Peak Pressure Drop (mmHg)	Valve Area (cm ²)
Normal	1.4-2.2	-	8-20	>3
Trivial	2.2-2.5	-	20-25	1.8-3.0
Mild	2.5-3.2	12-25	25-40	1.2-1.8
Moderate	3.2-4.2	25-40	40-70	0.8-1.2
Severe	>4.2	40-50	>70	0.6-0.8
Critical	-	>50	-	<0.6

AS is often asymptomatic in its mild and moderate stages, and even severe cases may be symptom free [26]. If symptomatic, the patient may complain of exertional chest pain, syncope/presyncope or dyspnoea. The classical clinical sign is the presence of an ejection systolic murmur, loudest at the left sternal edge or in the right second intercostal space, radiating into the carotid region. Often an ECG will demonstrate left ventricular hypertrophy, although this is not seen in 15% of severe cases [27]. Nevertheless, clinical examination alone is poor at accurately diagnosing aortic stenosis, let alone assessing its severity [43]. In a series of 83 patients who had a murmur detected by auscultation in the preoperative clinic, only 27 (32%) had AS subsequently found at TTE and 25 (30%) had no valvular abnormality [28].

In addition to confirming whether aortic stenosis is present, TTE can provide information as to the cause and severity of the condition. 2D and M-mode imaging can determine the excursion of the valve leaflets and any thickening or abnormalities such as a bicuspid valve structure. Doppler imaging can measure blood flow across the valve, and from this peak and mean pressure gradients are derived. By measuring the diameter of the left ventricular outflow tract and the velocities through it, an estimation of the valve area can be derived. However, TTE usually under-estimates outflow tract diameter and thereby over-estimates the severity of AS based on AVA. Moreover, if there is a degree of left ventricular impairment, the gradient may underestimate the degree of stenosis.

2.2 Who needs a pre-operative echocardiogram?

The 2006 ACC/AHA guidelines recommend any patient with a Grade 3 murmur or above (a loud murmur, easily audible with a stethoscope) should proceed to echocardiography, and any patient with a Grade 2 murmur (faint) with symptoms or an abnormal ECG should also undergo TTE [24]. However, systolic murmurs in patients under 40 are very unlikely to be pathological unless there is a history of heart disease and even in the 40-60 age group, significant AS is unlikely without additional symptoms or comorbidities [28]. These authors therefore considered TTE not necessary in patients under 60 who have no symptoms and a normal ECG and this is in line with the new NICE guidelines on routine preoperative tests for elective surgery [1] which just advises considering TTE "if there is a heart murmur *and* any cardiac symptom". Symptoms or an abnormal ECG (e.g. LVH or AF) in conjunction with a murmur would mandate preoperative TTE.

Aortic stenosis is a progressive condition, and a number of patients presenting for elective surgery will be under regular review by a cardiologist. On average, peak pressure gradients increase by 7mmHg per year and valve area decreases by 0.1cm² per year. Therefore any patient previously diagnosed with moderately severe stenosis should have a repeat echocardiogram on a 1-2 yearly basis [10,24], and the development of any symptoms should prompt urgent referral. Patients with mild disease should also be considered for repeat TTE every 3-5 years [24]. Any patient with severe or critical stenosis undergoing elective non-cardiac surgery should be referred to a cardiologist, as valve replacement may be considered before surgery [4].

2.3 Assessment of perioperative risk

Kertai et al [22] found that AS increased the overall risk of death or non-fatal MI by a factor of 5 after adjusting for clinical factors. Risk increased with AS severity with severe AS associated with 3 times the risk of these outcomes over moderate AS. However, a recent publication by Samarendra and Mangione [29] critically examined the relationship between echo findings and surgical risk. They concluded that patients should only be labelled as high risk (for non-cardiac surgery) if the aortic valve area (AVA) is $<0.8\text{cm}^2$ and mean gradient is $>45\text{-}50\text{ mmHg}$. Asymptomatic patients with AVA $>0.8\text{cm}^2$, mean gradient $<45\text{-}50\text{mmHg}$ and preserved LV function should not be labelled as high risk [29]. Certainly the cardiac risk during non-cardiac surgery appears to have declined in recent years according to a recent report with mortality rates similar to controls without AS.[30]

Urgent surgery often presents a challenge in obtaining TTE, but a recent report showed that bedside focussed TTE identified AS in 14% of patients aged over 65 with a fractured neck of femur where it was not suspected clinically [31]. TTE was associated with a lower postoperative mortality and the place of routine focussed TTE in this patient group is currently being debated.

In summary, aortic stenosis is a significant risk factor in the perioperative period but only if severe or symptomatic. Indeed the 2014 ESC/ESA guidelines on cardiovascular assessment in non-cardiac surgery states "In asymptomatic patients, non-cardiac surgery of low to intermediate risk can be performed safely" [4]. However, it is important that the patient's primary care physician is involved as surveillance of the valve disease is likely to be needed.

3. Other Conditions

A TTE may also be of use in a number of other conditions, such as aortic regurgitation, mitral regurgitation or stenosis or pulmonary hypertension. However, unlike aortic stenosis which can be severe and asymptomatic, patients with severe degrees of these conditions will usually be symptomatic and would warrant a TTE for investigation of dyspnoea as per the NICE guidelines for heart failure. Pulmonary hypertension is a particularly significant risk factor for adverse outcomes, both intra and postoperatively, and should be identified by TTE if suspected on clinical grounds [32]. Patients with long-standing obstructive sleep apnoea (especially if hypo-ventilating due to obesity), severe chronic obstructive pulmonary disease (COPD) and post pulmonary embolus are three groups which can develop pulmonary hypertension and this possibility should be borne in mind in the preoperative setting. In general however, provided the patient's symptoms are stable, then routine repeat TTE is unlikely to provide much more information [33].

4. What is the utility of TTE in risk assessment and does it alter outcomes?

As described previously it is clear that, with appropriate patient selection, a TTE can be an extremely important investigation. To improve its usefulness, it must be used and requested only after an appropriate history and clinical examination has been performed. However, there is conflicting evidence as to whether a more liberal use of TTE is beneficial. An intriguing retrospective cohort study from Toronto in 2011 found that a preoperative TTE was associated with increased 30 day mortality in those at low or intermediate risk [34]. Several hypotheses were put forward to explain this finding and it is always pertinent to bear in mind the potential harm from an investigation if it results in inappropriate treatment.

Halm et al [35] found no evidence to support the routine use of preoperative echocardiography for assessing cardiac risk, adding that TTE "provided no significant prognostic information in addition to that predicted by the cardiac risk indices". By contrast, Rohde et al [36] evaluated the place of preoperative TTE in predicting cardiac complications in 570 patients undergoing major non-cardiac

surgery. Systolic dysfunction was significantly associated with major cardiac complications (OR 2.4) including MI and pulmonary oedema and prediction models which included TTE variables were significantly better than clinical variables alone.

The 2014 ESC/ESA guidelines [4] state that *routine* TTE is not recommended for the preoperative evaluation of ventricular function and that LV function assessment has limited predictive value for postoperative outcomes. One explanation for this is that exercise performance, either self-reported or at cardiopulmonary exercise testing [37,38], shows little correlation with ejection fraction at rest. TTE is usually performed in a resting situation, and as such does not provide much insight into myocardial performance under stress (e.g. after surgery).

More recently there have been a number of publications looking at a simplified TTE, often performed at the bedside. Although a number of studies and correspondence have focussed on hip fractures in the elderly [31,39,40,41], one study has looked at TTE in the preoperative clinic [42]. In this study, a change in anaesthetic plan was made in 54 out of 100 patients; 62% of patients with suspected cardiac disease had their anaesthetic plan changed (23% had treatment increased, 39% decreased), whilst only 25% without suspected disease but over 65 years of age had a change (10% increased, 15% decreased).

Summary

TTE is a useful preoperative investigation but it is of proven benefit in only certain conditions which require a full history and examination to suspect – specifically aortic stenosis and cardiac failure. It is therefore reasonable to request a TTE in the following circumstances:

- 1) Where undiagnosed cardiac failure is suspected (usually secondary to left ventricular impairment, although valvular pathologies may cause similar symptoms) or there has been a clinical deterioration in known cardiac failure**
- 2) To exclude aortic stenosis if an undiagnosed systolic murmur is detected in patients over 60 and in any patient if in addition with an abnormal ECG or cardiac symptoms**
- 3) To assess progression of disease in patients with known aortic stenosis when coming for surgery without an echo or when it was done more than 1 year ago if moderate or severe or more than 2-3 years ago if mild. All patients with known aortic stenosis should be referred to cardiology if they become symptomatic or the echo findings suggest a severe or critical category.**
- 4) When pulmonary hypertension is suspected or previously diagnosed in order to assess progression of pulmonary pressures, bearing in mind that TTE can only estimate PAP from a tricuspid regurgitant jet. Accurate measurements of PAP require right heart catheterisation.**

Although these recommendations are similar to those made by another author [33], it must be realised that individual patients do not always fall easily into diagnostic groups, and that a pragmatic approach, based on a full history and clinical examination, should be used in all cases.

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