GUIDELINES AND RECOMMENDATIONS

Indications for echocardiography of replacement heart valves: a joint statement from the British Heart Valve Society and British Society of Echocardiography

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Abstract

Echocardiography plays a vital role in the follow-up of patients with replacement heart valves. However, there is considerable variation in international guidelines regarding the recommended time points after implantation at which routine echocardiography should be performed. The purpose of routine echocardiography is to detect early structural valve deterioration in biological valves to improve the timing of redo interventions. However, the risk of valve deterioration depends on many valve-related factors (valve design and patient prosthesis mismatch) and patient-related factors (age, diabetes, systemic hypertension, renal dysfunction and smoking). In this statement, the British Heart Valve Society and the British Society of Echocardiography suggest practical guidance. A plan should be made soon after implantation, but this may need to be modified for individual patients and as circumstances change. It is important that patients are managed in a multidisciplinary valve clinic.

Key Words

- valve replacement
- echocardiography
- valve clinic
- structural valve deterioration

Introduction

All guidelines (1, 2, 3, 4, 5) agree that echocardiography should be routine soon after heart valve surgery to record baseline replacement valve function. After this further echocardiography is indicated by the presence of complications of the replacement valve, coexistent cardiac abnormalities or the clinical suspicion of new pathology, for example, infective endocarditis. All guidelines also agree that routine annual echocardiography is indicated to detect early structural valve deterioration (SVD) in biological replacement valves. This is to prompt closer follow-up and is expected to lead to optimal timing of redo intervention if this is clinically indicated. However, the guidelines do

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not agree when routine echocardiography should start (Table 1) (1, 2, 3, 4, 5) giving a range from immediately (1) after implantation to beyond 10 years (2). Guidance for mechanical valves is provided in some, (3, 5) but not other (1, 2, 4) guidelines and biological mitral and tricuspid valves are not discussed in any guideline.

These limitations and conflicts in the international guidelines make it difficult for clinical echocardiography departments to plan standards of care and may contribute to inconsistent clinical follow-up and frequency of echocardiography (6). The aim of this combined statement from the British Heart Valve Society and British Society of Echocardiography is to consider the various guidelines in the light of existing evidence to propose a pragmatic guide to the timing of echocardiographic follow-up in patients with replacement valves.

Routine echocardiography immediately after surgery

A point-of-care pre-discharge study may be performed to detect any problem requiring immediate management for example pericardial tamponade, a large dehiscence or severe LV dysfunction. However, a formal baseline echocardiogram is essential against which to compare future studies to detect structural valve deterioration (SVD) and complications. This may not be possible pre-discharge because image quality is often suboptimal due to subcutaneous edema and difficulty in positioning the patient adequately because of pain and immobility. Furthermore, LV function may not have recovered fully leading to temporarily reduced velocity measurements. It may therefore be better to perform the baseline study around 6–8 weeks post discharge, for example, at the first postoperative surgical outpatient visit. The patient should be in a stable rhythm with a controlled ventricular rate at the time of the study and if this is not the case, the study should be repeated as soon as possible after this has been corrected.

It is reasonable to repeat echocardiography in the early postoperative period to confirm resolution of a pericardial effusion or recovery of severe new LV dysfunction.

Table 1 Onset after implantation of routine annual echocardiography: summary of international guidelines.

Guideline	Mechanical	Biological aortic	Biological mitral or any tricuspid
ESC valve 2017 (1)	–	Immediate	–
AHA 2014 (2)	–	>10 years	–
ESC valve council 2015 (3)	Not routinely	>5–10 years	–
ESC valve 2012 (4)	–	>5 years[a]	–
ASE/EAE 2009 (5)	Not routinely	>5 years	–

[a]Earlier in young patients.

Long-term transthoracic echocardiographic follow-up in asymptomatic, well patients

The purpose of routine echocardiography is to detect early SVD in order to observe the patient more frequently both clinically and echocardiographically and plan a redo procedure. However, SVD of modern mechanical valves is exceptionally rare (7) and happens suddenly with critical hemodynamic deterioration. Routine echocardiographic follow-up of mechanical valve prostheses in asymptomatic patients with no coexistent pathology is therefore not usually needed. However, patients with a mechanical mitral valve should have a routine echocardiogram at 5 years to assess for tricuspid regurgitation or worsening RV dysfunction if they did not undergo concomitant TV repair.

In contrast, SVD is common in all biological replacement valves. It usually develops and progresses gradually by a process of fibrosis and calcification leading in general to dominant stenosis in 40%, dominant regurgitation in 30% or mixed stenosis/regurgitation in 30% (8), although these proportions vary with valve design. Some designs (e.g. Cryolife-O'Brien) are prone to sudden tearing at the base of a cusp leading to relatively rapid symptomatic decline.

The timing and frequency of TTE depends on the likelihood of the particular valve prosthesis developing SVD. The main types of bio-prosthetic valves are outlined in Fig. 1 (8, 9) In general, the rate of SVD is 20% at 10 years for xenograft valves in the aortic position (7). However, the rate of SVD rate depends on a number of factors including valve design, position, patient–prosthesis mismatch, age at implantation (Fig. 2), systemic hypertension, renal function and diabetes (10) (see the 'Factors determining durability of a biological replacement valve' section below). The initiation and frequency of routine echocardiography must therefore take account of these factors.

A suggested framework for routine echocardiography is given in Table 2 and Fig. 3. We suggest that an individual plan should be agreed early after implantation for

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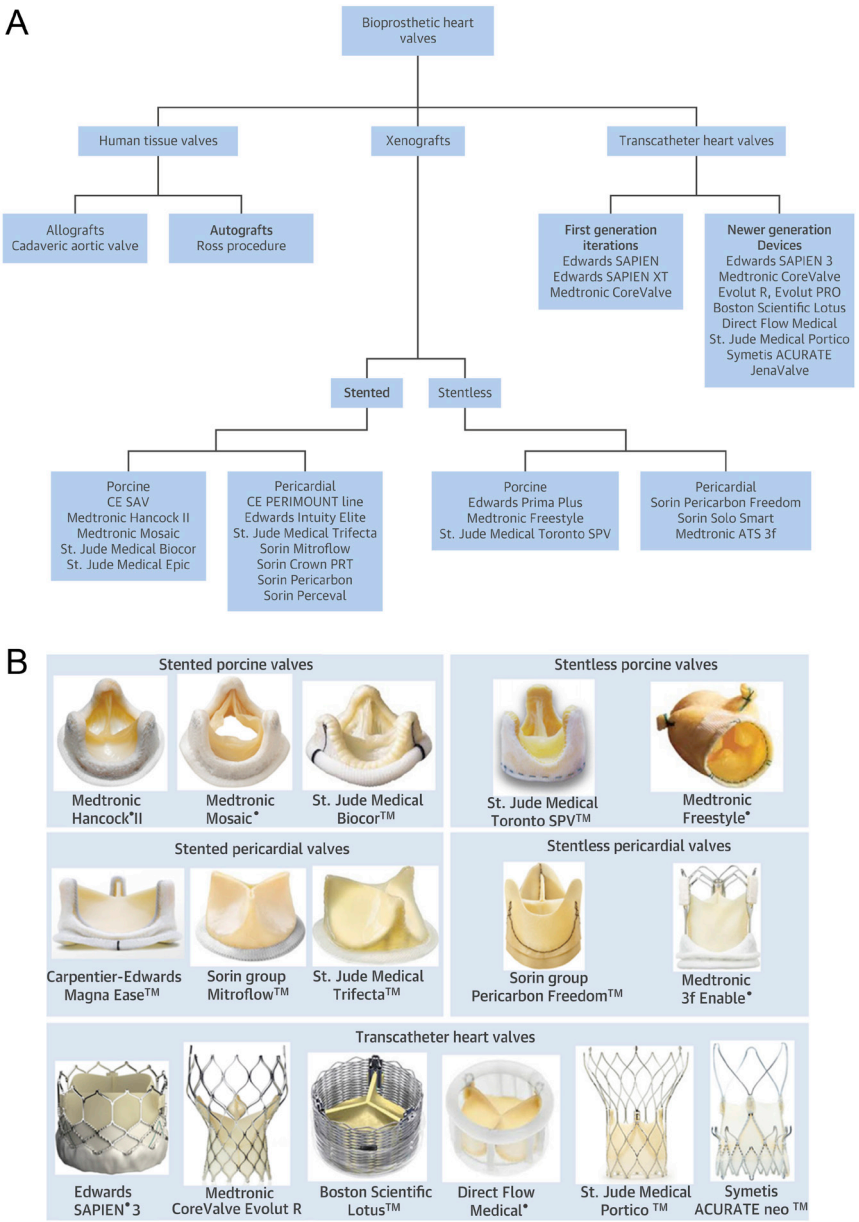

Figure 1
Main types of surgical and transcatheter bioprosthetic heart valve. Reproduced from *Journal of the American College of Cardiology*, vol **69**, Puri R, Auffret V & Rodés-Cabau J, Bioprosthetic valve thrombosis, pages 2193–2211, Copyright (2017), with permission from Elsevier (9).

patients with particular risk factors and that this should be recorded in the case-file. All patients should undergo clinical follow-up in a specialist valve clinic (11, 12). In a multidisciplinary valve clinic, a nurse will usually see patients after surgery who do not require echocardiography (13). The valve clinic setting allows immediate discussion of individual cases to agree changes to the initial plan for example extending follow-up to every 2 years if the valve is morphologically and functionally normal or cessation of echocardiography if the patient is not a candidate for further invasive intervention.

Factors determining durability of a biological replacement valve

Valve position

SVD occurs more commonly for valves implanted in the mitral position with a failure rate of approximately 40% at 10 years (14) compared to <10% for valves implanted in the aortic position in patients aged >60 years. There is relatively little information for valves inserted in the tricuspid position but annualized rates as high as 5% per patient year have been reported (15).

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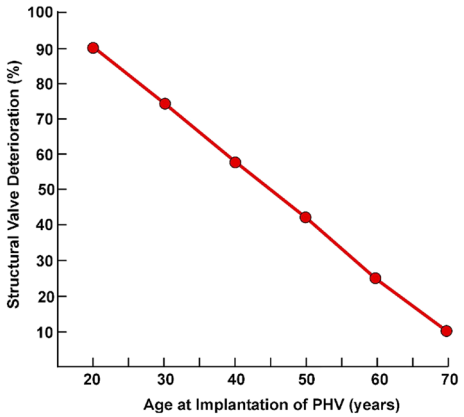

Figure 2
Graph of structural valve deterioration in biological valves at 15–20 years according to the age at implantation. Constructed with data from multiple studies. Reproduced from *Journal of the American College of Cardiology*, vol **55**, Rahimtoola SH, Choice of prosthetic heart valve in adults: an update., pages 2413–2426, Copyright (2010), with permission from Elsevier (16).

Valve design

Valve design affects durability in a number of ways including the quality of tissue preservation, anti-calcification treatment and the stresses between the stent and cusps. In a recent study (10), stentless valves were less likely to develop SVD than stented valves and porcine-stented less likely than pericardial-stented valves. However, within these broad categories individual designs differ widely. A stentless valve, the Cryolife O'Brien and a stented pericardial valve, the Sorin More were withdrawn as a result of early failures. The Medtronic Mosaic, a stented porcine valve, may be more likely to fail early than the Edwards Perimount, a stented pericardial valve (16). Furthermore, long-term durability data are strongest for the Edwards Perimount stented pericardial valve (7) and the Medtronic Hancock II porcine-stented (17) valves with mean survival of 20 years for patients aged >60 years at implantation. In a series of 1387 biological replacement valves of 13 different designs including the now withdrawn Cryolife O'Brien, 52 (3.7%) developed SVD before 2 years, 129 (9.3%) between 2 and 5 years, 158 (11.4%) between 5 and 10 years and 89 (6.4%) beyond 10 years. Consequently, it is recommended to perform more frequent follow-up in patients, even aged >60 years at implantation, who have valve designs for which follow-up data are lacking. Newly introduced valve designs should be followed annually from implantation. The durability of transcatheter valves is also uncertain and these should also be followed annually. By contrast, patients aged >60 years at implantation with a Perimount series valve or Hancock II or another valve design with demonstrable good durability can reasonably have routine echocardiography only at 10 years and beyond as suggested by the American Heart Association guideline (2).

Patient prosthesis mismatch

A mean gradient ≥15 mmHg was one of the many factors predicting SVD in a series of 1387 biological aortic valves (10). Flameng *et al.* (18) showed that SVD started at 2 years in the presence of patient prosthesis mismatch compared to 9 years without mismatch. This effect may be because of increased stresses on the valve cusps and there may also be less reserve before symptoms develop if the effective orifice area is already small immediately after implantation.

Patient factors

The most important factors in the longevity of valve prosthesis is the age of implantation (19) (Fig. 2). The rate of SVD at 10 years is typically <10% in patients over the age of 60 years but is significantly higher with rates of 20–30% in patients <40 years of age (17, 20, 21, 22). The reason for this is uncertain but may be related to the higher levels of physical stress during periods of exertion in younger cohorts. Despite this, 25% of people aged

Table 2 Suggested frequency of routine echocardiography.

Valve type	Indications	Frequency
Mechanical valve in aortic, mitral or tricuspid position	Baseline echocardiogram normal	No routine follow-up usually required
Biological valve	TAVI, new designs for which adequate durability data do not exist, Ross procedure	Annual from implantation
Biological valve	Mitral or tricuspid position, aortic xenograft age <60 at implantation (or other major risk factors, e.g. renal failure, severe patient–prosthesis mismatch)	Annual from 5 years after implantation
Biological valve	Designs in the aortic position with proven longevity e.g. Edwards Perimount, Medtronic Hancock II in patients aged ≥60 at implantation	Annual from 10 years after implantation

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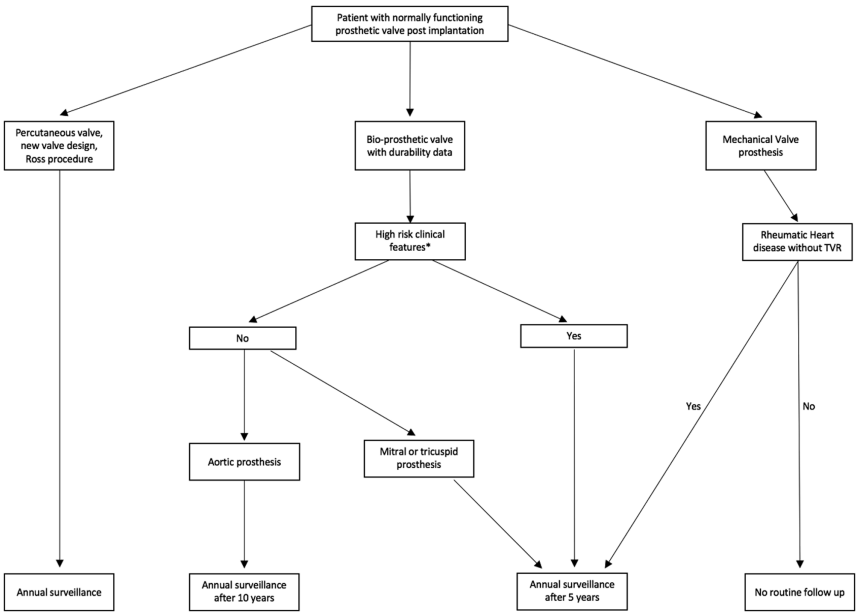

Figure 3
Recommendations for echocardiographic follow-up of normally functioning prosthetic valves post-implantation. TVR, tricuspid valve replacement. *High-risk features include age <60 years, patient–prosthesis mismatch, renal failure, type 2 diabetes.

<56 years had biological valve implanted in the UK in 2008 (23). In addition, the presence of systemic hypertension, increased BMI, diabetes, renal failure and smoking have all been shown to accelerate the rate of SVD (10, 24, 25).

Signs of early failure of a biological replacement valve

The key to detecting early SVD is a change in the appearance of the valve accompanied by an increase in the gradient and/or the development of or worsening of transvalvar regurgitation. This definition has been unnecessarily confused by the recent EACTS guideline for aortic replacement valves (26), which allows the definition of SVD based on an absolute gradient (mean gradient >20 mmHg) with no requirement for a morphological abnormality nor for an increase in gradient. This conflates SVD and patient–prosthesis mismatch and means that SVD as defined is often present at implantation. A better definition (10, 27) is

Thickening and reduced opening of the cusps associated with either (1) an increase in mean gradient from the last study by ≥10 mmHg associated with a fall in EOA or (2) an increase in regurgitation from baseline by one grade provided that the current grade is at least moderate.

SVD does not necessarily lead immediately to redo intervention. In one series (10) of 1387 biological replacement valves, 428 (31%) developed SVD but only 159 (11.5%) had a redo procedure. However, once signs of SVD are found, it is reasonable to restudy in 6 months in case there is rapid progression. If the change is minor and there is no progression after 6 months, it may then be reasonable to revert to annual follow-up. If there is moderate or severe SVD (mean gradient >40 mmHg or moderate or worse regurgitation) 6 monthly follow-up is usual. These decisions should be discussed with the cardiologist supervising the valve clinic.

Often the patient may become frail during a long follow-up and find it increasingly hard to attend regular outpatient visits. He or she may not want to undergo further procedures or it may only be appropriate to consider these in the presence of severe symptoms. The scientist or nurse who sees the patient regularly together with the cardiologist may suggest that the patient stops attending regularly but remains free to re-establish contact. Sometimes a patient may still prefer to be seen

Table 3 Indications for non-routine echocardiography if the baseline study is abnormal.

Indication	Frequency
Moderate valve disease including paraprosthetic regurgitation	1–2 years (1, 2)
Severe valve disease (if not requiring redo surgery)	6 months (1, 2)
Significant LV dysfunction	1 year
Aortic dilatation >41 mm or >21 mm/m^2	1 year (28)

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clinically even if it is no longer appropriate to undergo routine echocardiography.

Indications for non-routine serial echocardiography

If the baseline, postoperative transthoracic echocardiogram is abnormal, repeated echocardiograms are indicated at a frequency depending on the pathology (Table 3). Echocardiography is also indicated on the suspicion of pathology either because of a symptom (typically breathlessness), the suspicion of endocarditis (e.g. unremitting fever, weight loss, malaise), an event (e.g. TIA) or a change in clinical signs including the murmur.

Conclusion

Defining the timing of and frequency of echocardiographic follow-up of patients with replacement valves can be complex and may depend on a variety of valve and patient-related factors. This statement from the British Heart Valve Society and the British Society of Echocardiography suggests general guidelines but stresses that these may have to be modified for individual patients. A follow-up plan should be made after implantation but may have to be reviewed as circumstances change. This complexity underlines the need for these patients to be followed in a specialist multidisciplinary valve clinic.

Declaration of interest

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References

1 Baumgartner H, Falk V, Bax JJ, De Bonis M, Hamm C, Holm PJ, Iung B, Lancellotti P, Lansac E, Muñoz DR, *et al*. 2017 ESC/EACTS Guidelines for the management of valvular heart disease. *European Heart Journal* 2017 **38** 2739–2791. (https://doi.org/10.1093/eurheartj/ehx391)

2 Nishimura RA, Otto CM, Bonow RO, Carabello BA, Erwin JP, Guyton RA, O'Gara PT, Ruiz CE, Skubas NJ, Sorajje P, *et al*. 2014 AHA/ACC guideline for the management of patients with valvular heart disease: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *Journal of the American College of Cardiology* 2014 **63** e57–e185. (https://doi.org/10.1016/j.jacc.2014.02.536)

3 Chambers JB, Garbi M, Nieman K, Myerson S, Pierard LA, Habib G, Zamorano JL, Edvardsen T, Lancellotti P, *et al*. Appropriateness criteria for the use of cardiovascular imaging in heart valve disease in adults: a European Association of Cardiovascular Imaging report of literature review and current practice. *European Heart Journal Cardiovascular Imaging* 2017 **18** 489–498. (https://doi.org/10.1093/ehjci/jew309)

4 Vahanian A, Alfieri O, Andreotti F, Antunes MJ, Baron-Esquivias G, Baumgartner H, Borger MA, Carrel TP, De Bonis M, Evangelista A, *et al*. Guidelines on the management of valvular heart disease (version 2012). *European Heart Journal* 2012 **33** 2451–2496. (https://doi.org/10.1093/eurheartj/ehs109)

5 Zoghbi WA, Chambers JB, Dumesnil JG, Foster E, Gottdiener JS, Grayburn PA, Khandheria BK, Levine RA, Marx GR, Miller FA, *et al*. Recommendations for evaluation of prosthetic valves with echocardiography and Doppler ultrasound: a report From the American Society of Echocardiography's Guidelines and Standards Committee and the Task Force on Prosthetic Valves, developed in conjunction with the American College of Cardiology Cardiovascular Imaging Committee, Cardiac Imaging Committee of the American Heart Association, the European Association of Echocardiography, a registered branch of the European Society of Cardiology, the Japanese Society of Echocardiography and the Canadian Society of Echocardiography, endorsed by the American College of Cardiology Foundation, American Heart Association, European Association of Echocardiography, a registered branch of the European Society of Cardiology, the Japanese Society of Echocardiography, and Canadian Society of Echocardiography. *Journal of the American Society of Echocardiography* 2009 **22** 975–1014; quiz 1082. (https://doi.org/10.1016/j.echo.2009.07.013)

6 Alaour B, Menexi C & Shah BN. Clinical and echocardiographic follow-up of patients following surgical heart valve repair or replacement: a tertiary centre experience. *Echo Research and Practice* 2018 **5** 113–119. (https://doi.org/10.1530/ERP-18-0035)

7 Bourguignon T, Bouquiaux-Stablo AL, Candolfi P, Mirza A, Loardi C, May MA, El-Khoury R, Marchand M & Aupart M. Very long-term outcomes of the Carpentier-Edwards Perimount valve in aortic position. *Annals of Thoracic Surgery* 2015 **99** 831–837. (https://doi.org/10.1016/j.athoracsur.2014.09.030)

8 Côté N, Pibarot P & Clavel MA. Incidence, risk factors, clinical impact, and management of bioprosthesis structural valve degeneration. *Current Opinion in Cardiology* 2017 **32** 123–129. (https://doi.org/10.1097/HCO.0000000000000372)

9 Puri R, Auffret V & Rodés-Cabau J. Bioprosthetic valve thrombosis. *Journal of the American College of Cardiology* 2017 **69** 2193–2211. (https://doi.org/10.1016/j.jacc.2017.02.051)

10 Salaum E, Mahjoub H, Girerd N, Dagenais F, Voisine P, Mohammadi S, Yanagawa B, Kalavrouziotis D, Juni P, Verma S, *et al*. Rate, timing, correlates, and outcome of hemodynamic valve deterioration after bioprosthetic surgical aortic valve replacement. *Circulation* 2018 **138** 971–985. (https://doi.org/10.1161/CIRCULATIONAHA.118.035150)

11 Lancellotti P, Rosenhek R, Pibarot P, Iung B, Otto CM, Tornos P, Donal E, Prendergast B, Magne J, La Canna G, *et al*. Heart valve clinics: organisation, structure and experiences. *European Heart Journal* 2013 **34** 1597–1606. (https://doi.org/10.1093/eurheartj/ehs443)

12 Chambers JB, Ray S, Prendergast B, Taggart D, Westaby S, Grothier L, Arden C, Wilson J, Campbell B, Sandoe J, *et al*. Specialist valve

clinics: recommendations from the British Heart Valve Society working group on improving quality in the delivery of care for patients with heart valve disease. *Heart* 2013 **99** 1714–1716. (https://doi.org/10.1136/heartjnl-2013-303754)
13 Parkin D & Chambers J. Routine follow-up for patients with prosthetic valves: the value of a nurse-led valve clinic. *British Journal of Cardiology* 2012 **19** 204–206. (https://doi.org/10.5837/bjc.2012.015)
14 Grunkemeier GL, Li HH, Naftel DC, Starr A & Rahimtoola SH. Long-term performance of heart valve prostheses. *Current Problems in Cardiology* 2000 **25** 73–154. (https://doi.org/10.1053/cd.2000.v25.a103682)
15 Kunadian B, Vijayalakshmi K, Balasubramanian S & Dunning J. Should the tricuspid valve be replaced with a mechanical or biological valve? *Interactive Cardiovascular and Thoracic Surgery* 2007 **7** 551–557. (https://doi.org/10.1510/icvts.2007.159277)
16 Webb J, Parkin D, Tøndel K, Simitsis P, Roxburgh J & Chambers JB. A comparison of early redo surgery rates in Mosaic porcine and Perimount bovine pericardial valves. *European Journal of Cardio-Thoracic Surgery* 2018 **54** 724–728. (https://doi.org/10.1093/ejcts/ezy113)
17 Chan V, Kulik A, Tran A, Hendry P, Masters R, Mesana TG & Ruel M. Long-term clinical and hemodynamic performance of the Hancock II versus the Perimount aortic bioprosthesis. *Circulation* 2010 **122** S10–S16. (https://doi.org/10.1161/CIRCULATIONAHA.109.928085)
18 Flameng W, Herregods MC, Vercalsteren M, Herijgers P, Bogaerts K & Meuris B. Prosthesis-patient mismatch predicts structural valve degeneration in bioprosthetic heart valves. *Circulation* 2010 **121** 2123–2129. (https://doi.org/10.1161/CIRCULATIONAHA.109.901272)
19 Rahimtoola SH. Choice of prosthetic heart valve in adults: an update. *Journal of the American College of Cardiology* 2010 **55** 2413–2426. (https://doi.org/10.1016/j.jacc.2009.10.085)
20 Forcillo J, Pellerin M, Perrault LP, Cartier R, Bouchard D, Demers P & Carrier M. Carpentier-Edwards pericardial valve in the aortic position: 25-years experience. *Annals of Thoracic Surgery* 2013 **96** 486–493. (https://doi.org/10.1016/j.athoracsur.2013.03.032)
21 Banbury MK, Cosgrove DM, White JA, Blackstone EH, Frater RWM & Okies JE. Age and valve size effect on the long-term durability of the Carpentier-Edwards aortic pericardial bioprosthesis. *Annals of Thoracic Surgery* 2001 **72** 753–757. (https://doi.org/10.1016/S0003-4975(01)02992-7)
22 Rodriguez-Gabella T, Voisine P, Puri R, Pibarot P & Rodés-Cabau J. Aortic bioprosthetic valve durability: incidence, mechanisms, predictors, and management of surgical and transcatheter valve degeneration. *Journal of the American College of Cardiology* 2017 **70** 1013–1028. (https://doi.org/10.1016/j.jacc.2017.07.715)
23 Bridgewater B, Keogh B, Kinsman R & Walton P. *Demonstrating Quality: the Sixth National Adult Cardiac Surgery Database Report 2008*. Henley-on-Thames, UK: Dendrite Clinical Systems Ltd, 2009. (available at: https://scts.org/_userfiles/resources/SixthNACSDreport2008withcovers.pdf)
24 Briand M, Pibarot P, Despres JP, Voisine P, Dumesnil JG, Dagenais F & Mathieu P. Metabolic syndrome is associated with faster degeneration of bioprosthetic valves. *Circulation* 2006 **114** I512–I517. (https://doi.org/10.1161/CIRCULATIONAHA.105.000422)
25 Lorusso R, Gelsomino S, Luca F, De Cicco G, Bille G, Carella R, Villa E, Troise G, Vigano M, Banfi C, *et al*. Type 2 diabetes mellitus is associated with faster degeneration of bioprosthetic valve: results from a propensity score-matched Italian multicenter study. *Circulation* 2012 **125** 604–614. (https://doi.org/10.1161/CIRCULATIONAHA.111.025064)
26 Capodanno D, Petronio AS, Prendergast B, Eltchaninoff H, Vahanian A, Modine T, Lancellotti P, Sondergaard L, Ludman PF, Tamburino C, *et al*. Standardized definitions of structural deterioration and valve failure in assessing long-term durability of transcatheter and surgical bioprosthetic valves. *European Heart Journal* 2017 **38** 3382–3390. (https://doi.org/10.1093/eurheartj/ehx303)
27 Dvir D, Bourgignon T, Otto CM, Hahn RT, Rosenhek R, Webb JG, Treede H, Sarano ME, Feldman T, Wijeysundera HC, *et al*. Standardized definition of structural valve degeneration for surgical and transcatheter bioprosthetic aortic valves. *Circulation* 2018 **137** 388–399. (https://doi.org/10.1161/CIRCULATIONAHA.117.030729)
28 Evangelista A, Flachskampf FA, Erbel R, Antonini-Canterin F, Vlachopoulos C, Rocchi G, Sicari R, Nihopyannopouls P, Zamorano J, European Association of Echocardiography, *et al*. Echocardiography in aortic diseases: EAE recommendations for clinical practice. *European Journal of Echocardiography* 2010 **11** 645–658. (https://doi.org/10.1093/ejechocard/jeq056)

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