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CASE SERIES
Valvular heart disease

Mechanical circulatory support for high-risk surgical aortic valve and ascending aortic replacement in severe bicuspid aortic valve stenosis: a case series

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Background Bicuspid aortic valve (BAV) is the most common congenital heart defect (reported incidence of 0.5%–2%) and is commonly associated with proximal aortic dilation. Patients with severe aortic stenosis (AS) of BAV have been shown to have worse pre-operative left ventricular (LV) function as well as a higher incidence of post-operative heart failure hospitalization when compared with analogous patients with tri-leaflet aortic valve disease. While surgical aortic valve replacement (SAVR) may be favoured over transcatheter aortic valve implantation (TAVI) due to anatomical factors or concomitant aortopathy and coronary artery disease, surgical candidacy is often limited by prohibitive operative risk.

Case summary We report on three cases of severe AS in BAV with concomitant aortopathy and severe left ventricular dysfunction in whom we proceeded with SAVR with *a priori* planned venoarterial extracorporeal membrane oxygenation (VA-ECMO) support and inotrope-assisted wean. All patients had severe LV dysfunction (ejection fraction < 25%) at baseline with gradual substantial improvement or normalization after successful SAVR.

Discussion These cases demonstrate the utility of planned VA-ECMO with SAVR and aortic root replacement as an integral component of the operative strategy for high surgical risk patients with severe BAV AS not amenable to TAVI. Appropriate pre-operative planning and consent for VA-ECMO as well as a multi-disciplinary approach involving anaesthesia, intensive care, and heart failure cardiology are the key to offering this option as an alternative to palliative medical therapy to a selected group of patients.

Keywords Bicuspid aortic valve • Severe aortic stenosis • Mechanical circulatory support • Aortic valve replacement • Case report

ESC curriculum 4.2 Aortic stenosis • 6.1 Symptoms and signs of heart failure • 6.2 Heart failure with reduced ejection fraction • 9.1 Aortic disease

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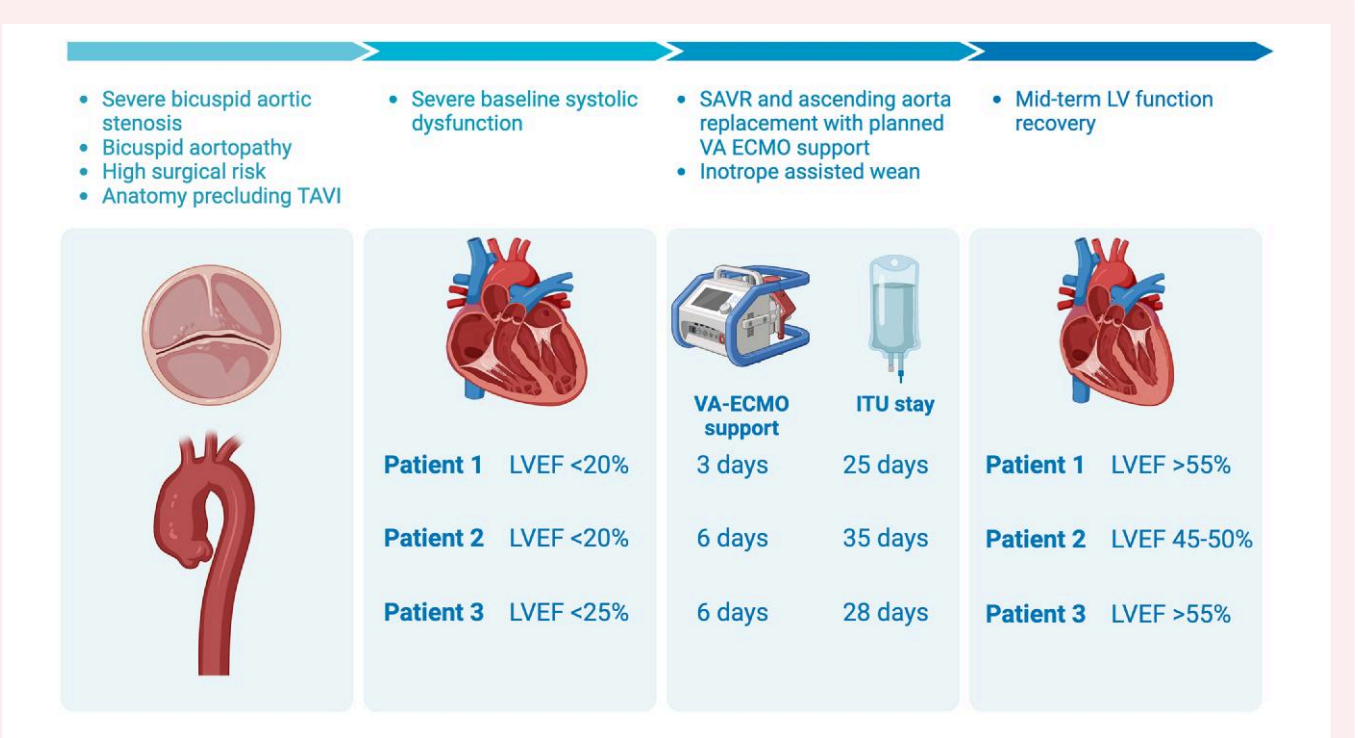
Learning points

- Surgical aortic valve replacement (SAVR) remains more appropriate in aortic stenosis in bicuspid aortic valve especially in the context of attendant features (aortopathy, complex coronary artery disease, or severe mitral regurgitation).
- In cases where concomitant left ventricular dysfunction results in prohibitive surgical risk, transcatheter aortic valve implantation (TAVI) assessment is justified.
- If TAVI proves not feasible, SAVR with upfront planning for perioperative extracorporeal membrane oxygenation followed by gradual, inotrope-assisted wean can provide an alternative to palliative medical therapy.

Introduction

Bicuspid aortic valve (BAV) is the most common congenital heart defect (reported incidence 0.5%–2%) and is commonly associated with proximal aortic dilation.[1] The congenital nature of BAV may aid in our understanding of the observation that patients with an isolated severe aortic stenosis (AS) 'phenotype' of BAV have worse preoperative left ventricular function as well as a higher incidence of postoperative heart failure hospitalization when compared to analogous patients with tricuspid aortic valve disease.[2] Our case series incorporates an interesting subset of patients not clearly captured by the 2017 appropriate use criteria for the treatment of patients with severe AS.[3]

Summary figure



Created in BioRender. Karatasakis, A. (2025) https://BioRender.com/a61i392.

Case presentation

Patient 1

A 66-year-old woman presented with symptoms of dizziness and increasing dyspnoea on exertion over a period of 4 weeks. She confirmed variable symptoms of paroxysmal nocturnal dyspnoea and orthopnoea. On physical examination, notable findings were an ejection systolic murmur and bi-basal crepitations in the lungs. Her medical history was significant for Crohn's disease, advanced osteoporosis, right breast cancer treated with mastectomy and breast reconstruction, and being a current smoker with a smoking history in excess of 40 pack-years.

Computed tomography pulmonary angiography (CTPA) performed due to suspected PE confirmed an anterior segmental PE of the left upper lobe for which she was commenced on rivaroxaban. The CTPA further depicted the presence of a hypertrophied LV with dense calcifications of the AV, ascending aortic aneurysm approximating 5 cm, and a large left diaphragmatic hernia. Echocardiography identified severe bicuspid AV [aortic valve area (AVA): 0.38 cm^2, and mean gradient: 44 mmHg] with an LVEF <20%. Logistic EuroSCORE was calculated at 24.42.

The patient was discussed in the Heart Team valve meeting and was deemed not a favourable candidate for transcatheter aortic valve implantation (TAVI) on the anatomical grounds of irregular pattern of dense valvular/annular calcification and ascending aorta aneurysm with options being high-risk surgery or palliation. Following discussion with the patient, she provided informed consent to proceed with

conventional aortic valve replacement with ascending aortic replacement under hypothermic circulatory arrest with planned postoperative temporary mechanical circulatory support if required.

Cardiopulmonary bypass (CPB) was established via cannulation of the ascending aorta [20 Fr EOPA® arterial cannula (Medtronic, Inc, Minneapolis, MN, USA)] and right femoral vein [23Fr HLS cannula® (Maquet Getinge, Rastatt, Germany)]. Intraoperative findings included a BAV (Sievers type I R-L) and dilated and thin-walled, 5 cm ascending aortic aneurysm (see Supplementary material online, *Video S1*, left). We proceeded with extensive annular decalcification and bioprosthetic AVR [23 mm Trifecta GT (Abbott Vascular, Santa Clara, CA)] whilst the patient was cooled. Under moderate hypothermic circulatory arrest with the adjunct of bilateral selective antegrade cerebral protection, ascending aortic replacement was carried out [30 mm Vascutek Anteflow Gelweave (Vascutek Terumo Corporation, Glasgow, UK)].

As anticipated, despite good prosthetic AV function, weaning from CPB proved unsuccessful despite appropriate inotropic support due to severe left ventricular impairment (see Supplementary material online, *Video S1*, middle); VA-ECMO was initiated via the side arm branch of the ascending aortic graft and the percutaneous femoral venous cannula (*Figure 1*). The skin only was approximated, and the patient transferred in a hemodynamically stable condition to the cardiac surgical intensive care unit.

The patient was successfully weaned on postoperative day three with an EF estimated on transoesophageal echocardiography (TOE) of 35%–40%. Her impaired preoperative respiratory function necessitated tracheostomy with prolonged respiratory wean. Following a total ITU (intensive therapy unit) stay of 25 days, she was discharged home on day 56 with specialist heart failure follow-up. Interestingly, the patient was diagnosed with *Streptococcus mitis* prosthetic aortic valve endocarditis 5 months post-discharge that was successfully managed with culture-directed antibiotic therapy. She remains clinically asymptomatic with an excellent exercise performance and a follow-up LVEF > 55% (see Supplementary material online, *Video S1*, right).

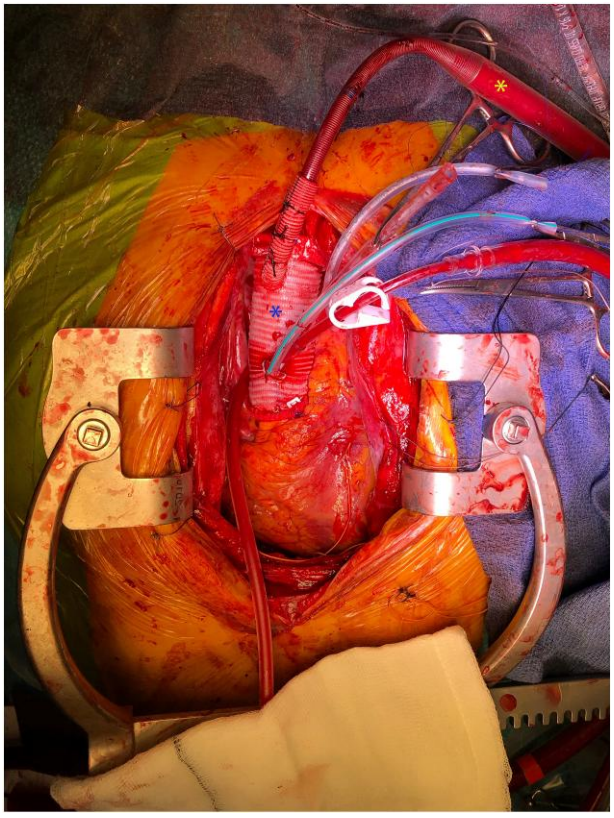


Figure 1 Intraoperative image demonstrating ascending aortic replacement (blue asterisk) with arterial limb of subsequent venoarterial extracorporeal membrane oxygenation (yellow asterisk) attached to sidearm of prosthesis. (Venous limb of venoarterial extracorporeal membrane oxygenation via percutaneous femoral cannula not seen in this image.)

Patient 2

A 67-year-old man was admitted to a local general hospital whilst working away from home with paroxysmal nocturnal dyspnoea on the background of a 4-week history of worsening breathlessness on exertion. He was previously fit and well with no relevant medical history. The patient was diagnosed with an NSTEMI on biochemical grounds of a small troponin rise and was initiated on treatment for acute coronary syndrome (ACS). On examination, a loud ejection systolic murmur was identified with diffuse bi-basal crackles in the lung fields. Subsequent investigations revealed no significant coronary artery disease but severe BAV stenosis (peak aortic jet velocity: 4 m/s; AVA: 0.75 cm^2; and mean gradient: 38 mmHg) with severe LV impairment (LV end-diastolic diameter 7.5 cm, EF < 20%; Supplementary material online, *Video S2*, left); ACS treatment was subsequently discontinued. Logistic EuroSCORE was calculated at 19.88.

On transfer to our centre, he underwent further optimization of his overt heart failure by our heart failure specialists. Following Heart Team discussion and review of investigations, he was consented for high-risk surgery. Transcatheter aortic valve implantation was not considered in view of the short distance between valve and coronary ostia, irregular pattern of dense valvular/annular calcification, and ascending aorta aneurysm. Cardiopulmonary bypass was established via cannulation of the ascending aorta and right atrium. Intraoperative findings included a BAV (Sievers type I R-N) and dilated and thin-walled ascending aortic aneurysm up to 4.6 cm. We proceeded with annular decalcification and bioprosthetic aortic valve replacement [29 mm INSPIRIS RESILIA (Edwards Life- sciences, Irvine, CA, USA)] whilst the patient was cooled. Under moderate hypothermic circulatory arrest with the adjunct of bilateral selective antegrade cerebral protection, ascending aortic replacement was carried out [28 mm Vascutek Anteflow Gelweave (Vascutek Terumo Corporation, Glasgow, UK)].

The patient was weaned off CPB with appropriate inotropic support and intra-aortic balloon pump (IABP) and transferred in a haemodynamically stable condition to the cardiac surgical intensive care unit. However, he became haemodynamically unstable later that evening with increasing inotropic requirements and worsening biventricular function on TOE and returned to the operating theatre for institution of VA-ECMO.

He was weaned off successfully after 6 days with minimal inotropic support and chest was closed. He had an extended stay on the ITU secondary to prolonged ventilatory wean with a tracheostomy, and postoperative hypoactive delirium. Following a total ITU stay of 35 days, he was discharged home on day 68 with specialist heart failure follow-up (social issues delayed discharge). He remains clinically asymptomatic with an excellent exercise performance enjoying daily walks >4 miles and reassuring echocardiographic follow-up with normalization of LV chamber size and borderline normal EF (see Supplementary material online, *Video S2*, right).

Patient 3

A 66-year-old man previously hospitalized for decompensated heart and diagnosed with severe bicuspid AS and impaired LV function. Following optimization, he was discharged on medical treatment and scheduled urgent outpatient surgical follow-up, during which he described ongoing symptoms of orthopnoea and paroxysmal nocturnal

dyspnoea with an exercise tolerance of ≈50 yards. He was subsequently admitted from clinic for optimization and further management. His medical history included chronic kidney disease, left-sided nephrectomy, hypertension, and well-controlled asthma.

On systemic review, there was evidence of lower limb pitting oedema and a loud ejection systolic murmur, grade 4/6. Investigations revealed no significant coronary artery disease but severe bicuspid aortic valve stenosis (AVA: 0.78 cm^2 and mean gradient: 51 mmHg) with severe LV impairment (5.9 cm; EF <25%; Supplementary material online, *Video S3*, left). In addition, the right ventricle was dilated with impaired systolic function, and systolic pulmonary artery pressure was estimated at 70 mmHg. The ascending aorta on CT measured ≈4.5 cm. Logistic EuroSCORE was calculated at 20.3.

Following Heart Team valve discussion and review of investigations he was consented for high-risk surgery. Transcatheter aortic valve implantation was not considered in view of the irregular pattern of dense valvular/annular calcification and ascending aorta aneurysm. CPB was established via cannulation of the ascending aorta and right femoral vein. Intraoperative findings confirmed a BAV (Sievers type I R-N) and dilated and thin-walled ascending aortic aneurysm up to 4.5 cm. We proceeded with annular decalcification and bioprosthetic aortic valve replacement (25 mm INSPIRIS RESILIA, Edwards Life-sciences, Irvine, CA, USA) whilst the patient was cooled. Under moderate hypothermic circulatory arrest with the adjunct of bilateral selective antegrade cerebral protection ascending aortic replacement was carried out (26 mm Vascutek Anteflow Gelweave, Vascutek Terumo Corporation, Glasgow, UK).

Weaning from CPB proved unsuccessful despite appropriate inotropic support due to severe biventricular impairment; VA-ECMO was initiated via the side arm branch of the ascending aortic graft and a percutaneous femoral venous cannula. The skin only was approximated, and the patient transferred in a haemodynamically stable condition to the cardiac surgical intensive care unit.

He was weaned off successfully after 6 days with minimal inotropic support, and chest was closed. He had an extended stay on the ITU secondary to prolonged ventilatory wean with a tracheostomy, acute on chronic renal failure requiring temporary dialysis, and post-operative atrial fibrillation. Following a total ITU stay of 28 days, he was discharged home on day 36 with specialist heart failure follow-up. He remains clinically asymptomatic with an excellent exercise performance and normalization of biventricular function (see Supplementary material online, *Video S3*, right).

Discussion

Although aortic valve replacement has been associated with a large mortality benefit in patients with severe AS with EF 20% or less,[4] a growing body of evidence suggests that a significant proportion of contemporary patients with severe AS are not offered definitive treatment after heart team evaluation.[5–7] Glaser *et al.*[8] reported an excellent survival rate following aortic valve surgery in patients with BAV similar to that of the general population; however, only 16/865 (2.9%) of patients studied had an EF 0.30 or less. Transcatheter aortic valve implantation has allowed treatment to be extended safely to patients at high or even prohibitive risk for conventional surgical aortic valve replacement. All patients described herein were discussed in our weekly multidisciplinary heart-valve team meeting for which attendees include aortic surgeons, interventional TAVI operators, as well as specialist non-invasive cardiologists. All patients were deemed not suitable for TAVI due to one or more of the following factors: short distance between valve and coronary ostia, irregular pattern of dense valvular/annular calcification, and ascending aorta aneurysm requiring concomitant intervention and therefore treatment options were either high-risk surgery or palliative medical treatment.

A variety of devices are routinely used in clinical practice for post-cardiotomy cardiogenic shock support either as a single modality or in combination. Lorusso *et al.*[9] have shown prophylactic IABP to improve in-hospital and 30-day survival following high-risk cardiac surgery in a cohort of 478 patients that included >20% of patients with aortic pathology; once again, patients with an EF 35% or less were underrepresented at 58/478 (12.1%). Impella (Abiomed, Danvers, MA, USA) devices have been used in a variety of clinical situations pertaining to aortic stenosis including cardiogenic shock, high-risk percutaneous coronary intervention, balloon aortic valvuloplasty, and haemodynamic collapse during TAVI.[10] Although anecdotal evidence of utilizing Impella5.0 support following combined coronary artery bypass and bioprosthetic aortic valve replacement for post-cardiotomy failure has been reported,[11] there is anecdotal evidence of aortic valve leaflet mechanical injury associated with an indwelling Impella cannula.[12] The Leipzig group experience with perioperative Impella support in cardiac surgery patients reported a 30-day mortality and complication composite outcome of 60% and 40%, respectively for patients undergoing heart valve surgery.[13] Finally, veno-arterial extracorporeal membrane oxygenation (VA-ECMO) with central or peripheral cannulation is a well-established modality to provide cardiorespiratory support for post-cardiotomy low-output state. A recent meta-analysis assessing ECMO outcomes for post-cardiotomy cardiogenic shock in 2877 patients from 20 observational studies reported a pooled survival rate to hospital discharge of 34%.[14]

Levosimendan is a calcium sensitizer and adenosine triphosphate–dependent potassium channel opener with positive inotropic, lusitropic, and vasodilatory effects.[15] Three randomized controlled trials—LICORN, CHEETAH, and LEVO CTS, failed to show a benefit of pre-operative levosimendan in high-risk cardiac surgery in terms of mortality reduction or need for post-operative mechanical circulatory support.[16–18] Only a small proportion of patients in these trials underwent aortic valve surgery with no improvement in outcomes noted in this subgroup. However, in a subsequent meta-analysis, patients with an ejection fraction of <30% exhibited a survival advantage with the use of pre-operative levosimendan.[19] Therefore, it remains unclear whether its use would have obviated the need for VA ECMO in our patients.

All of our patients exhibited a marked improvement in left ventricular function post-operatively. Prior studies have shown that surgical AVR for AS in patients with LV impairment leads to an improvement in ejection fraction in 72% of survivors, with a mean improvement in EF of 10%–17.5%.[20,21] Predictors of LV recovery include female sex, and lower burden of coronary artery disease. In those with AS and contractile reserve on dobutamine stress echocardiography, 83% show an improvement in EF of 10% or greater.[22] A comparison of AVR and TAVI in patients with LV dysfunction showed that normalization of LV function occurs in 20% treated with surgical AVR.[23] There are no published studies examining the impact of post-cardiotomy VA ECMO support on subsequent recovery of left ventricular function.

As a tertiary centre for cardiothoracic transplantation and mechanical circulatory support, we formulated a strategy of perioperative management to facilitate bridging to myocardial recovery. In order to provide sufficient support allowing for left ventricular ejection whilst minimizing the risk of mechanical injury as well as thrombosis to the implanted bioprostheses, we opted for central VA ECMO with IABP if no contraindication existed for the latter. Once protamine was administered and hemostasis secured, we proceeded with mediastinal packing and delayed chest closure. This measure was effective at mitigating postoperative bleeding prior to formal decannulation and sternal closure. We maintain partial flow support with an aim to wean gradually with appropriate haemometabolic/echocardiographic monitoring, inotropic support, and inhaled nitrous oxide over 48–72 h. The day prior to planned decannulation, we load patients with levosimendan as we have empirically found this as a useful adjunct to our weaning strategy.[24] Full wean is always performed in the operating room. What differentiates this strategy from majority of published data is that mechanical

circulatory support was an integral part of the operative strategy and all patients were appropriately consented.

Conclusion

As mechanical circulatory support continues to expand and be readily available in non-tertiary centres, algorithms will require development to risk stratify patient profiles at the preoperative stage. A close working relationship with heart failure cardiology specialists is of paramount importance during early postoperative recovery as well as outpatient basis to secure optimal medical management.

Lead author biography

Dr John Dimarakis MD, PhD, FRCS CTh held the post of Surgical Director of Cardiothoracic Transplantation at Wythenshawe Hospital when he carried out this work. His clinical interests include aortic surgery, redo cardiac surgery, cardiothoracic transplantation, and mechanical circulatory support. His research interests span from basic science to surgical database analysis. Stemming from his doctorate work investigating the regenerative potential of stem cell therapy in ischaemic heart disease, he maintains an active research interest in all aspects of regenerative medicine in heart disease. He currently holds the post of Associate Professor at the University of Washington within the Division of Cardiothoracic Surgery.

Supplementary material

Supplementary material is available at *European Heart Journal – Case Reports* online.

Consent: The authors confirm that written consent for submission and publication of this case report including images and associated text has been obtained from the patient in line with Committee on Publication Ethics (COPE) guidance.

Conflict of interest: None declared.

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Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

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