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CASE SERIES
Heart failure

Obstruction of the inferior vena cava following bicaval orthotopic heart transplantation: a case series

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Background Inferior vena cava (IVC) obstruction is a rare complication of orthotopic heart transplantation (OHT) and is unique to bicaval surgical technique. The clinical significance, diagnosis, complications, and management of post-operative IVC anastomotic obstruction have not been adequately described.

Case summary Two patients with end-stage heart failure presented for bicaval OHT. Post-operative course was complicated with shock refractory to fluid resuscitation and inotropic/vasopressor support. Obstruction at the IVC-right atrial (RA) anastomosis was diagnosed on transoesophageal echocardiography (TOE), prompting emergent reoperation. In both cases, a large donor Eustachian valve was found to be restricting flow across the IVC-RA anastomosis. Resection of the valve resulted in relief of obstruction across the anastomosis and subsequent improvement in haemodynamics and clinical outcome.

Discussion Presumably rare, we present two cases of IVC obstruction post-bicaval OHT. Inferior vena cava obstruction is an under-recognized cause of refractory hypotension and shock in the post-operative setting. Prompt recognition using TOE is crucial for immediate surgical correction and prevention of multi-organ failure. Obstruction can be caused by a thickened Eustachian valve caught in the suture line at the IVC anastomosis, which would require surgical resection.

Keywords Heart transplantation • Transoesophageal echocardiography • Obstruction • , inferior vena cava • Bicaval technique • Case series

Learning Points

- Inferior vena cava (IVC) obstruction is an under-recognized cause of refractory hypotension in the post-operative setting following bicaval orthotopic heart transplantation
- Prompt recognition of obstruction at the IVC anastomosis by transoesophageal echocardiography is crucial for immediate surgical correction and prevention of multi-organ system failure
- A thickened donor Eustachian valve can be a cause of IVC obstruction. Surgical resection is required to resolve this

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Introduction

Bicaval anastomosis is the most adopted surgical technique for orthotopic heart transplantation (OHT). Unlike the standard biatrial technique which requires only two anastomoses to the atria of the recipient, bicaval technique requires a single left atrial anastomosis and separate caval suture lines. Compared to the biatrial technique, the bicaval technique has demonstrated improved outcomes in post-transplant survival, reduction in tricuspid regurgitation, and preservation of sinus nodal function.[1] However, inferior vena cava (IVC) obstruction is a rare but catastrophic complication unique to bicaval OHT. Herein, we present two cases of IVC obstruction following bicaval OHT.

Timeline

Case	Age	Transplant surgical approach	Clinical manifestations/ findings	Diagnosis	Management	Outcome
1	59	Bicaval	Refractory hypotension Abdominal distension Decreased cardiac index and low intracardiac filling pressures	Transoesophageal echocardiography (TOE) demonstrating flow acceleration across inferior vena cava (IVC)-right atrial (RA) junction Catheter-based measurements demonstrating RA-IVC pressure gradient	Reoperation and resection of prominent Eustachian valve	Resolution of shock Good graft function on Follow-up
2	49	Bicaval	Refractory hypotension Oliguria Shock liver Elevated lactate Decreased cardiac index and low intracardiac filling pressures	TOE demonstrating flow acceleration across IVC-RA junction	Reoperation and resection of prominent Eustachian valve	Resolution of shock Good graft function on Follow-up

Case presentation

Case 1

A 59-year-old woman with ischaemic cardiomyopathy presented for OHT. She has a past medical history of Stage D heart failure (EF 20%) on home milrinone therapy, coronary artery disease with PCI to right coronary artery, hypertension, insulin-dependent diabetes mellitus, and Stage 3 chronic kidney disease. She was admitted from home for prospective heart transplantation. She was in her usual state of health without worsening shortness of breath, orthopnoea, or paroxysmal nocturnal dyspnoea. The induction of anaesthesia, sternotomy, and commencement of cardiopulmonary bypass (CPB) were without complications. She underwent cardiectomy and implantation of donor heart in the usual fashion. She had an unremarkable intraoperative course.

Post-operatively, she was on stable doses of inotropes/vasopressors in the form of epinephrine at 0.1 mcg/kg/min, milrinone at 0.25 mcg/kg/min, and vasopressin at 1.2 units/h. Swan-Ganz catheter monitoring revealed low cardiac indices and low filling pressures. On physical examination, she was intubated and sedated, cardiac examination revealed normal S1/S2 with no additional sounds, murmurs, rubs, or gallops. It was difficult to assess JVP due to the presence of Swan-Ganz catheter. Laboratory evaluation revealed an acute kidney injury with a creatinine of 1.6 mg/dL, elevated lactic acid up to 14 mmol/L, with decrease in bicarbonate down to 14. AST was elevated to 397 and ALT up to 262. Four hours later, she remained tachycardic and hypotensive requiring escalating doses of norepinephrine, epinephrine, and vasopressin. She was resuscitated with 5 L of crystalloid and albumin without improvement in hypotension. She notably developed progressive abdominal distention corresponding with fluid resuscitation.

Transoesophageal echocardiography (TOE) showed a small hyperdynamic left ventricle with diastolic internal diameter of 2.57 cm. Transgastric right ventricular (RV) view showed a small underfilled RV (*Figure 1A*). At the IVC-RA junction, there was an area of flow acceleration with a near-constant flow with velocity 2 m/s (*Figure 1B*). Intrahepatic IVC was 3 cm in diameter while SVC

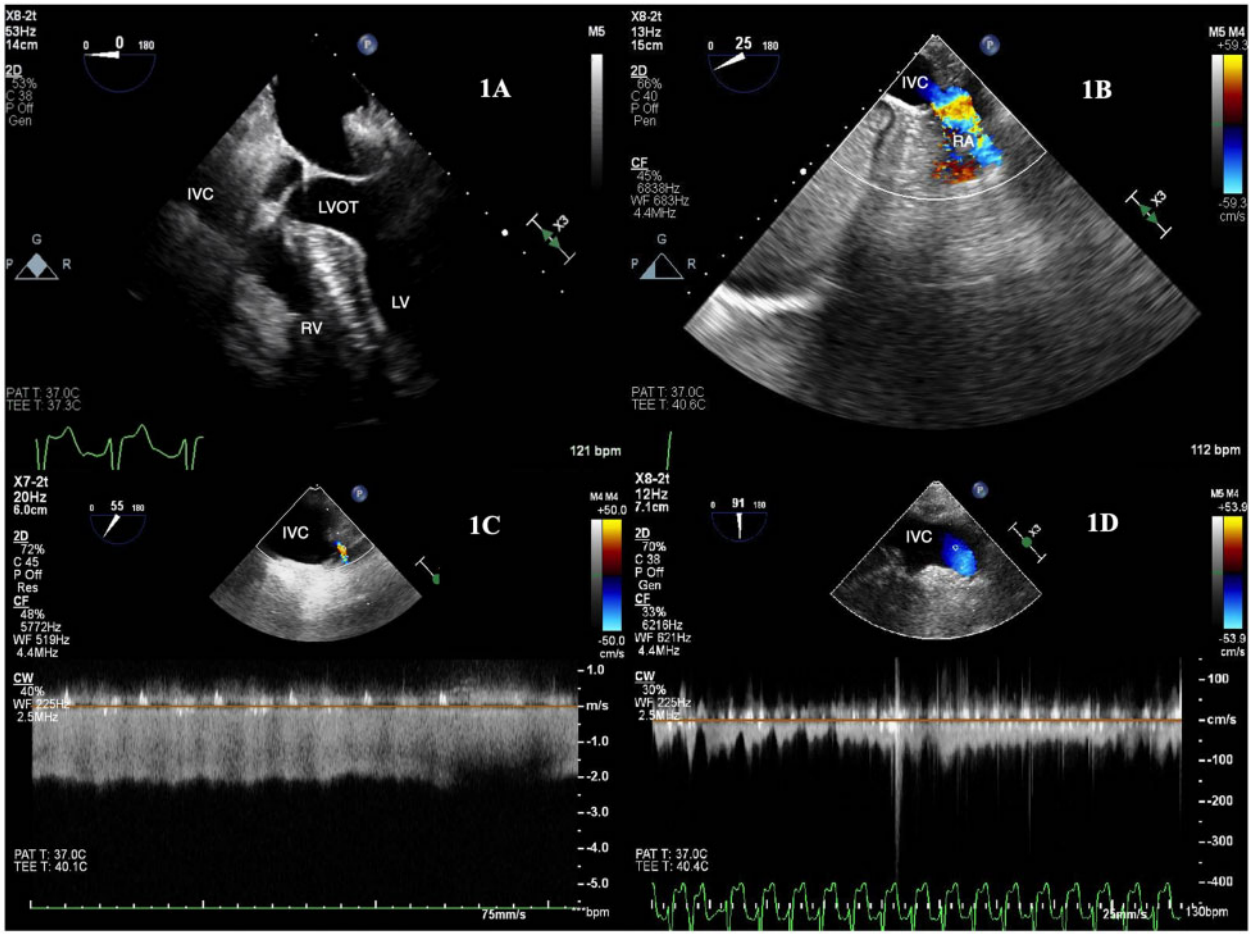
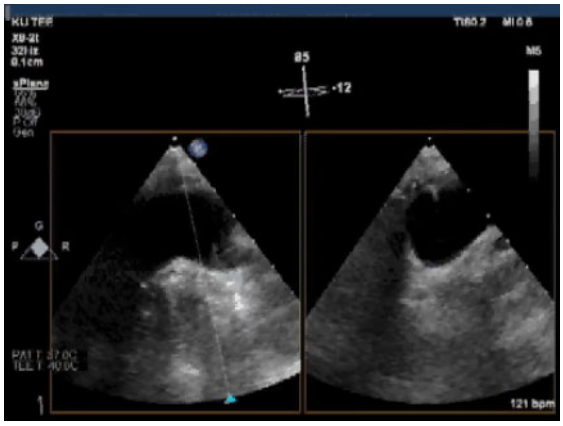


Figure 1 Case 1: Transoesophageal echocardiogram images following bicaval heart transplantation. (*A*) Underfilled right ventricle (*B*) Colour Doppler demonstrating flow acceleration across inferior vena cava-RA anastomosis (*C*) Continuous wave Doppler analysis demonstrating a significant pressure gradient across the inferior vena cava anastomosis (*D*) Continuous wave Doppler showing resolution of pressure gradient following resection of Eustachian valve.

diameter was 1.4 cm. The suspicion of IVC obstruction was confirmed after volume resuscitation; the IVC-RA flow acceleration increased and became more phasic with respiration with peak velocity of 2 m/s, with gradient across the IVC and RA of approximately 16 mmHg (*Figure 1C*).

A central venous catheter was inserted into the left femoral vein and transduced to measure the pressure in the IVC which was found to be 26 mmHg. The transduced gradient across the SVC and IVC was ~18 mmHg; consistent with the measured TOE gradient of 16 mmHg.

She was emergently taken back to the operating room. Following the initiation of CPB and right atriotomy, it was immediately evident that an obstruction existed at the IVC anastomosis with a thickened Eustachian valve and the existing sutures. The Eustachian valve was completely excised. The IVC orifice and anastomosis were confirmed as widely patent and the anterior wall of the anastomosis was closed. Transoesophageal echocardiography following Eustachian valve resection showed resolution of IVC-RA pressure gradient (*Figure 1D*).



Video 1 Case 1: Difficulty crossing IVC-RA anastomosis during cannulation for cardiopulmonary bypass due to obstruction.

Post-operatively, her haemodynamics showed hypervolaemia reflected by a CVP >15 mmHg. Aggressive diuresis with furosemide was initiated. Hours later, she was weaned off inotropic and vasopressor support. Her cardiac index improved to >2.0 with a mixed venous oxygen saturation (SvO2) of 72.7%. She subsequently had an uncomplicated post-operative course and overall recovery. During her follow-up visit, she had excellent graft function with no signs or symptoms of heart failure and was leading an excellent quality of life.

Case 2

A 49-year-old man with ischaemic cardiomyopathy was admitted for atrial and ventricular arrhythmias. His past medical history is relevant for Stage D heart failure (EF 20%) with a defibrillator in place, coronary artery disease and CABG, atrial fibrillation on anticoagulation, hypertension, and Stage 2 chronic kidney disease. He initially presented with palpitations, shortness of breath, dizziness. This was shortly followed by multiple defibrillator shocks for ventricular tachycardia. His ventricular arrhythmias continued and were refractory to medical therapy. He was listed as United Network for Organ Sharing (UNOS) status 3 with exception for heart transplant. Once a suitable organ donor was available, he was taken to the operating room. His intraoperative course was unremarkable and OHT was successful. Intraoperative TOE demonstrated mild impairment in global heart function with flow acceleration at the IVC-RA anastomosis (*Figure 2*).

Post-operatively, he was on epinephrine and norepinephrine. SvO2 was 69% with a cardiac index of 1.6 L/min/m^2. Dobutamine 5 mcg/kg/min was added as a result. On physical examination, he was intubated and sedated, his sternal incision was intact with pacer wires present, cardiac auscultation revealed tachycardia with normal S1/S2 and no additional sounds or murmurs. Over the next 24 hours, he was aggressively volume resuscitated with 5 L of crystalloids. Despite this, his hypotension worsened requiring the addition of vasopressin. He developed acute kidney injury (Creatinine 1.64 mg/dL), worsening lactic acidosis (up to 21 mmol/L), and shock liver (AST 1460, ALT 1351). The rest of his laboratory values were within normal limits. His cardiac index remained low near 1.8 L/min/m^2.

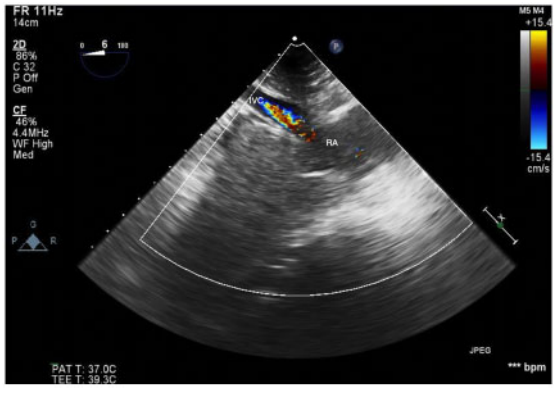


Figure 2 Case 2: Transoesophageal echocardiogram demonstrating flow acceleration across the inferior vena cava-right atrial anastomosis.

He returned to the operating room for reexploration. A prominent area of the Eustachian valve on the donor's native tissue was seen to be restricting flow from IVC to RA. The atrial cuff was trimmed and the anastomosis was redone. The anastomosis was rechecked with TOE and was found to be patent. Post-operatively, his cardiac index improved to 2.3 L/min/m^2. CVP was elevated at 12 and diuresis was initiated. His creatinine, liver function tests, and lactate rapidly improved. Over the course of 7 days, he was weaned off vasopressor and inotropic support. He was transferred to the floor on post-operative day (POD) 8 and ultimately discharged on POD 14. Graft function on subsequent follow-up was excellent. During follow-up over a year, he was admitted once for cardiac rejection requiring glucocorticoid therapy but has otherwise continued to have a good quality of life without signs/symptoms of heart failure.

Discussion

Bicaval OHT requires separate anastomoses of recipient IVC and SVC to donor RA. This is in contrast to the biatrial technique, which instead connects the donor's right atrium to the recipient's RA, leaving the recipient's IVC and SVC intact. The exact incidence of IVC obstruction with the bicaval technique is unclear, as it is infrequently reported in the literature.[2–6] In our series, we describe two cases whereby inferior vena cava obstruction was caused by the presence of a thickened donor Eustachian valve. Prompt recognition of this obstruction resulted in reoperation and complete recovery for both patients. In other published cases, the aetiology of caval obstruction was secondary to haemostatic suture[5] or IVC thrombus formation.[2] The presence of donor-recipient mismatch has also been associated with caval obstruction.[7] A summary of previously published case reports, including their clinical presentation, cause of obstruction, and definitive management is illustrated in *Table 1*.

Analogous to RV failure, the presentation of IVC obstruction is characterized by reduced cardiac output and high venous pressure. In our series, we describe how caval obstruction can present with hypotension refractory to fluid resuscitation requiring escalating need for vasoactive drugs. This can lead to signs of end-organ malperfusion, evidenced by acute kidney injury simulating type 1 cardiorenal syndrome, metabolic acidosis, and elevated liver enzymes. In addition, IVC obstruction may present with clinical features of congestion, including pleural effusions, hepatomegaly, and lower extremity oedema. A continuous murmur at the right lung base has been described with IVC obstruction.[3] In our case series, the clinical syndrome and time to diagnosis occurred less than 24 h post-operatively. One case report described a late IVC obstruction presentation at 2 months post-operatively, whereby the patient presented with pleural effusions, hepatomegaly, and peripheral oedema and was found to have an extensive thrombus of the IVC that also involved the hepatic, renal, and iliac veins.[2] The cases we present here, in addition to previously published cases summarized in *Table 1*, highlight the diverse onset and presentation of IVC obstruction following heart transplantation. Therefore, clinicians should have a high index of suspicion for IVC obstruction following OHT when the exact cause of venous congestion or shock is unclear.

Common aetiologies for shock need to be considered including graft failure, hypovolaemia, or vasoplegia. However, it is

Table 1 Summary of previously published case reports of inferior vena cava (IVC) obstruction following heart transplantation

	Patient characteristics	Surgery	Onset	Clinical findings	Cause of obstruction	Definitive treatment	Post-operative course
Santise *et al.*	45-year-old male	Bicaval OHT (Pericardial conduit used to connect IVC to RA due to donor-recipient size mismatch)	2 months post-operatively	Peripheral oedema, pleural effusion, hepatomegaly. RHC and cavography revealed severe stenosis with a gradient of 40 mmHg. CT Abdomen with severe thrombosis of IVC	Retracted and severely stenosed pericardial conduit	Surgical removal of intracaval thrombi and deployment of stent at IVC-RA junction	Uneventful. Discharged on anticoagulation and low dose diuretics
Bleasdale *et al.*	3-year-old male with cystic fibrosis	Heart–lung transplantation	POD 5	Bilateral ankle oedema, murmur at right lung base. TTE with turbulent blood flow at IVC-RA junction. RHC (POD 13): IVC pressure 14 mmHg, RAP 1 mmHg. Catheter withdrawn confirming a gradient of 13 mmHg at level of IVC-RA junction. IVC angiogram: Severe narrowing at level of surgical anastomosis	Presumed oedema and haematoma surrounding suture line	Percutaneous dilation of anastomosis via right femoral approach using a balloon catheter	Complete resolution of oedema and discontinuation of diuretics.
Abrams *et al.*	45-year-old male with familial non-ischaemic restrictive cardiomyopathy	Bicaval OHT	Intraoperative—following weaning from CPB	Need for significant vasopressor doses to maintain adequate blood pressure. TOE: Flow acceleration from IVC to RA. Colour wave Doppler measurements revealed a gradient through anastomosis of approximately 19 mmHg.	Large Eustachian valve obstructing flow from IVC to RA	Resection of substantial area of Eustachian valve	Overall recovery with excellent graft function and quality of life at follow-up

Continued

Table 1 *Continued*

	Patient characteristics	Surgery	Onset	Clinical findings	Cause of obstruction	Definitive treatment	Post-operative course
Jacobsohn *et al.*	42-year-old female with idiopathic dilated cardiomyopathy	Bicaval OHT	POD 0	Shock liver and oliguric renal failure. TOE confirmed IVC-RA anastomotic stenosis RHC via femoral approach: Femoral vein pressure 25 mmHg, RAP 12 mmHg (sharp drop)	Haemostatic suture at RA cannulation site causing constriction of anastomosis	Surgical repair and removal of haemostatic suture	Overall recovery with improved urine output and serum creatinine on post-operative day 1 and normalization of transaminases and INR
Chaney *et al.*	57 year-old female with non-ischaemic cardiomyopathy	Bicaval OHT	POD 1	Decreased MVO2, Marginal CI and increased serum lactate that resolve intermittently with volume resuscitation. RHC (POD 7): IVC pressure 23 mmHg, RAP 13 mmHg. 10 mmHg gradient suggestive of stenosis. TOE turbulent flow from IVC to RA.	Stiff scarring at previous IVC cannulation site narrowing lumen to 5 mm.	Surgical reanastomosis using a pericardial patch at the IVC-RA junction	Rapid weaning of inotropic support and overall recovery.

CI, cardiac index; CPB, cardiopulmonary bypass; INR, international normalized ratio; MVO2, mixed venous oxygen; POD, post-operative day; RA, right atrium; RAP, right atrial pressure; RHC, right heart catheterization; TOE, transoesophageal echocardiography; TTE, transthoracic echocardiography.

important to keep anastomotic site obstruction in the differential diagnosis for shock following OHT. This is where the use of TOE can aid early recognition of anastomotic obstruction, allowing for timely intervention. Transoesophageal echocardiography features of IVC obstruction include biventricular underfilling and hyperdynamic ejection fraction from impaired preload. More specifically, flow acceleration at the IVC-RA anastomosis is most suggestive of obstruction. This is identified by the presence of a pressure gradient by spectral Doppler across the caval anastomosis as well as presence of turbulent flow on Colour Doppler. The intraoperative TOE can help in detecting IVC obstruction before the patient leaves the OR. This allows for prompt correction and avoids the need for surgical reexploration.

To confirm the diagnosis of caval obstruction, we have demonstrated in Case 1 that an RA-IVC gradient can be established using catheter-based pressure measurements. In our case, we have transduced a femoral central venous catheter to directly measure the pressure in the IVC and compared that to the RA pressure measured by the Swanz-Ganz catheter. A significant pressure gradient was found suggesting obstruction. Other case reports have demonstrated a gradient using a Swanz-Ganz catheter alone. A sudden drop in pressure as the catheter crosses the constriction and enters the right atrium is diagnostic of caval obstruction. This technique provides direct evidence of anastomotic obstruction and can corroborate TOE findings. In cases of complete obstruction or narrowing, passing the catheter across may not be feasible. Perhaps, venography can be used in these circumstances to directly visualize IVC narrowing/obstruction as has been done in previous case reports.[2,3]

We have opted for emergent surgical repair in our series due to the presence of profound hemodynamic compromise. Percutaneous endovascular repair is a feasible approach but was not sought due to the acuity of the obstruction in the immediate post-operative period and the presence of fresh sutures. In our series, the obstruction was caused by a large Eustachian valve of the donor heart, which had to be surgically resected. This finding highlights the importance of direct visualization of the Eustachian valve prior to dissection of the native heart. Pre-emptive resection of prominent Eustachian valves should be considered in some situations to reduce the risk of anastomotic obstruction.[4]

Following repair of IVC obstruction, signs of congestion tend to resolve rapidly along with improvement in cardiac indices. In our series, patients had a full recovery and graft function was excellent following timely diagnosis and repair.

Conclusion

Bicaval OHT can be complicated by post-operative IVC obstruction, which would present with refractory hypotension in the post-operative setting. Transoesophageal echocardiography is crucial for prompt diagnosis of obstruction. Operative intervention is often required to correct the underlying cause of IVC obstruction, which includes the presence of a prominent donor Eustachian valve.

Lead author biography

Anas Abudan, MBBS, is a third-year internal medicine resident at the University of Kansas Medical Center. He graduated from Alfaisal University in Saudi Arabia and thereafter completed a Postdoctoral Research Fellowship at the Mayo Clinic, MN. His research interests are within the fields of heart failure, heart transplantation and electrophysiology.

Supplementary material

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

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Slide sets: A fully edited slide set detailing these cases and suitable for local presentation is available online as Supplementary data.

Consent: The authors confirm that consent for submission and publication of this case report including images and associated text has been obtained from both patients in line with COPE guidance.

Conflict of interest: None declared.

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