Hypoxemia Requiring Venovenous Extracorporeal Membrane Oxygenation after Tricuspid Valvulectomy for Infective Endocarditis

Julian Macedo, MD, and Erin S. Grawe, MD, *Cincinnati, Ohio*

INTRODUCTION

Heroin and intravenous drug use (IVDU) has become a national health crisis in the United States. More than 169,000 persons became heroin initiates in 2013.[1] Tricuspid valve infective endocarditis (IE) has grown proportionally with increasing IVDU.[2] Surgery is currently performed in approximately half of all cases of IE and is associated with improved outcomes relating to heart failure and preventing embolic sequelae.[3] Surgical management strategies for tricuspid valve (TV) IE include TV repair, TV replacement, and, less commonly, tricuspid valvulectomy. The surgical approach is often driven by the severity of valve destruction and degree of involvement of the perivalvular apparatus.

Previous studies and guidelines have considered ongoing sepsis or metastatic infection, severe tricuspid regurgitation with evidence of heart failure, and large vegetation size (>1 cm) as potential indications for surgical intervention,[3-9] but consensus is lacking. Furthermore, isolated TV endocarditis associated with IVDU carries a poor long-term prognosis, especially when associated with *Staphylococcus aureus* infection.[10]

Tricuspid valvulectomy has been advocated in managing TV IE in IVDU cases refractory to medical therapy.[11] The physiologic and anatomic consequences of valvulectomy can result in increased atrial preload, which must be compensated for by the right heart. This altered physiology on the right heart can lead to unanticipated clinical complications.

CASE PRESENTATION

We report the case of a 30-year-old woman with a history of IVDU admitted to an outside hospital in stable condition for bacterial pneumonia. IE was suspected after computed tomography of her chest revealed septic pulmonary emboli.

Transesophageal echocardiography (TEE) was performed, confirming IE. By report, TEE was significant for a ravaged TV with fenestrations, wide-open tricuspid regurgitation with flail segments, and multiple mobile TV vegetations. Left ventricular ejection fraction was preserved. No other significant findings were noted on the report (images from an outlying hospital were unavailable). The patient was managed in a multidisciplinary fashion, including consultations with cardiology, cardiac surgery, and infectious disease. The decision was made to proceed with tricuspid valvulectomy. Blood and valve cultures confirmed presence of methicillin-susceptible *S aureus*.

In the immediate postoperative period, the patient developed refractory hypoxemia (partial pressure of oxygen 60 mm Hg on 100% fraction of inspired oxygen with mechanical ventilation). Chest radiography showed no evidence of hemopneumothorax, pulmonary edema, or lung consolidation. Attempts were made to aggressively diurese the patient. Inhaled epoprostenol was initiated without improvement in oxygenation. Neuromuscular blockade was initiated and the patient placed in a prone position with no improvement.

On-site cardiac surgery cannulated the patient to venovenous (VV) extracorporeal membrane oxygenation (ECMO) on the basis of marginal oxygenation despite multiple salvage interventions. Adequate oxygenation (partial pressure of oxygen 145–165 mm Hg) was obtained with ECMO support using a Maquet Cardiohelp system with right internal jugular (19 Fr) into the superior vena cava and right common femoral vein (21 Fr) cannula configuration.

An ECMO specialty transport team from our institution was sent to retrieve the patient. The patient was safely transferred, and VV ECMO support continued in our cardiovascular intensive care unit.

Subsequent transthoracic echocardiography and TEE performed at our institution demonstrated several findings that enabled diagnosis of the etiology of hypoxemia. The patient had undergone tricuspid valvulectomy with "ventricularization" of the right heart with wide-open systolic regurgitant flow from the anatomic right ventricle to the right atrium through the remnant TV (Figure 1, Videos 1 and 2). The right ventricle was dilated with interatrial septum bowing from right to left, indicative of increased right atrial pressures (Video 3). VV ECMO cannulas were correctly positioned. The return cannula was located at the junction of the right atrium and superior vena cava, with the outflow jet directed into the right atrium in close proximity to the interatrial septum (Figure 2). The drainage cannula was located at the junction of the right atrium and inferior vena cava. There was reversal of hepatic vein flow around the ECMO cannula supporting severe tricuspid regurgitation (Figure 3). A new interatrial communication was found, consistent with a patent foramen ovale (PFO) with significant right-to-left flow, previously unreported by the outside hospital (Figure 4, Video 4).

The patient was taken to the operating room for closure of the PFO and TV replacement with a 31-mm St. Jude Epic porcine bioprosthetic valve (Figure 5A, Video 5). Intraoperative TEE of the new valve revealed no residual tricuspid regurgitation (Figure 5B, Video 6) and no residual right-to-left shunt by bubble study (Video 7). She was deccannulated from ECMO intraoperatively and extubated the same day. The patient remained in the hospital for an additional 19 days for IV antibiotic therapy and treatment with an addiction specialist. Unfortunately, she left the hospital against medical advice

From the University of Cincinnati Medical Center, Cincinnati, Ohio.

Keywords: Infective endocarditis, Tricuspid valvulectomy, Intracardiac shunt, Extracorporeal membrane oxygenation, ECMO, Post–cardiac surgery hypoxemia

Conflicts of interest: The authors report no actual or potential conflicts of interest relative to this document.

2468-6441

https://doi.org/10.1016/j.case.2019.04.002

VIDEO HIGHLIGHTS

Video 1: Midesophageal four-chamber view showing surgical valvulectomy, ventricularized right heart, dilated right ventricle and right atria, and atrial septal bowing.
Video 2: Midesophageal four-chamber view with color flow Doppler of right ventricle shows wide-open regurgitant flow through remnant TV.
Video 3: Midesophageal right ventricular inflow-outflow view showing tricuspid valvulectomy, dilated right ventricle, and atrial septal bowing.
Video 4: Midesophageal bicaval view with color flow Doppler showing significant right-to-left shunt through patent foramen ovale.
Video 5: Midesophageal four-chamber view. Patient is status post patent foramen ovale closure and TV replacement with a 31-mm St. Jude Epic porcine bioprosthetic valve.
Video 6: Midesophageal RV inflow-outflow view showing TV replacement with no residual tricuspid regurgitation by color flow Doppler.
Video 7: Midesophageal view of right atrium and ventricle after TV replacement and patent foramen ovale closure showing negative bubble study with no residual shunt.

View the video content online at www.cvcasejournal.com.

before completing treatment and has been lost to follow-up. Opioid dependence is the primary contributing factor to this outcome.

DISCUSSION

TV endocarditis due to IVDU is a clinically challenging condition. Surgical management can include TV repair, TV replacement, or, as in this case, tricuspid valvulectomy. No clinical guidelines are currently available to guide which patient should receive which intervention, so decisions are made on a case-by-case basis taking into consideration the severity of valve destruction, the degree of involvement of the perivalvular apparatus, and the patient's risk for reinfection. Valvulectomy is often chosen in intravenous drug users because of concern for prosthesis reinfection with ongoing substance abuse. Arbulu *et al.*[11] published a case series of 55 patients undergoing tricuspid valvulectomy over a 20-year period for IE. This approach was tolerated in the majority of patients, but 11% required repeat surgery secondary to right heart failure. There have been additional case reports validating this procedure.[6] However, we would recommend caution in the use of this approach if there is preoperative evidence of pulmonary hypertension, as this would place the patient at risk for right heart failure in the immediate postoperative period.

In our case, we suspect that a series of clinical factors led to the patient's presentation of hypoxemia. Likely, a conditionally susceptible foramen ovale was present preoperatively, but not yet patent (or, if patent, lacked sufficient flow to be readily identified on imaging). Factors causing pulmonary hypertension (positive pressure ventilation, pulmonary emboli) served to "prime" the patient for the development of right-to-left shunting through the foramen ovale. Following valvulectomy, acutely increased pressures within the remnant right atrium created a sufficient gradient between the right atrium and left atrium to overcome the opening pressure threshold necessary to activate the foramen ovale. We were able to appreciate clear signs of increased right heart pressures on TEE (atrial septal bowing, dilation of the right heart structure), which predisposed the patient to developing a right-to-left shunt. With replacement of the TV and PFO closure, the patient demonstrated rapid clinical improvement and normalization of echocardiographic findings, thus confirming our diagnosis.

Unfortunately, as is the case in actual clinical medicine, no pre- or intraoperative transesophageal echocardiographic images from the outside hospital were available for review. However, reporting from the transferring institution made no mention of PFO. The patient had no hypoxemia pre- or intraoperatively, so we assume that the PFO would have been closed or with a minimal shunt and therefore not visible until symptoms manifested in the postoperative period.

Perhaps most important is the need for serial echocardiographic evaluations as a means of achieving diagnostic clarity when questions remain. It was on repeat TEE at our institution that a PFO was identified as culprit of patient's condition.

Although Doppler imaging was adequate in diagnosing the right-to-left intracardiac shunt in our patient, it is worth mention that agitated

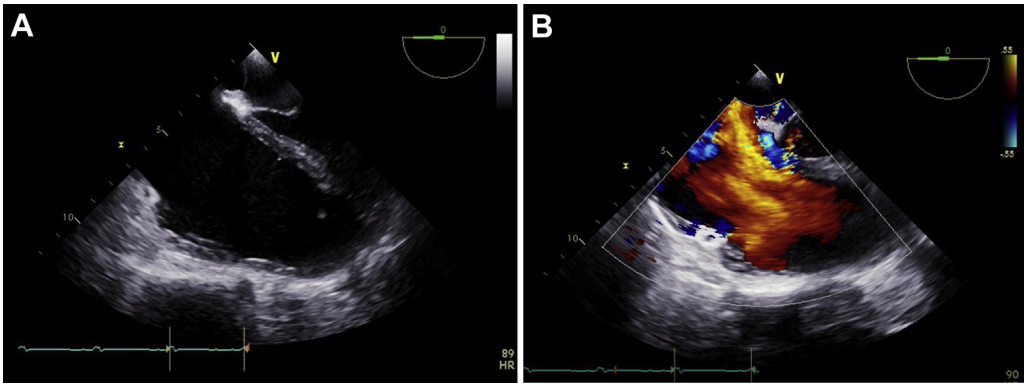

Figure 1 **(A)** Midesophageal four-chamber view showing surgical valvulectomy, ventricularized right heart, dilated right ventricle and right atrium, and interatrial septal bowing. **(B)** Color flow Doppler of right ventricle shows wide-open regurgitant flow through remnant TV.

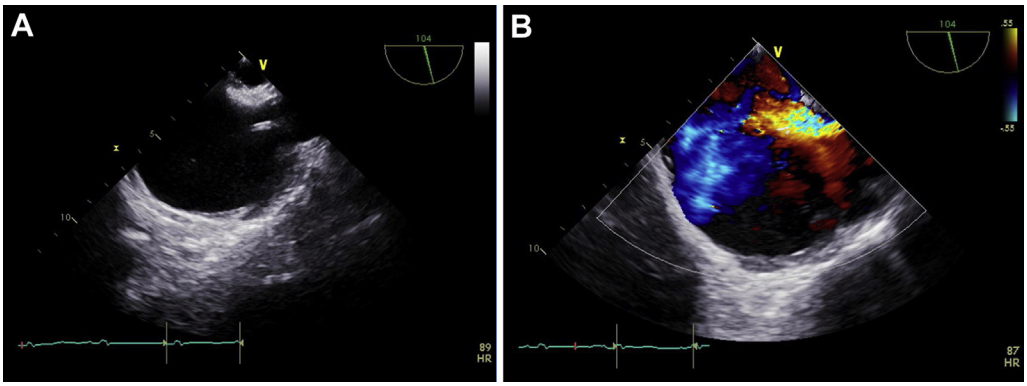

Figure 2 **(A)** Midesophageal bicaval view of the right atrium–superior vena cava junction with the extracorporeal membrane oxygenation (ECMO) return cannula positioned at this junction. **(B)** Color flow Doppler of ECMO cannula shows return flow jet directed toward the right atrium in close proximity to the interatrial septum.

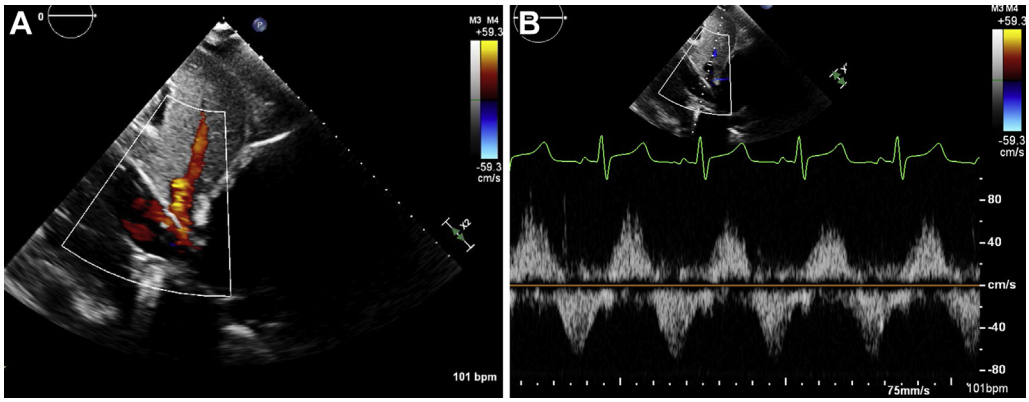

Figure 3 **(A)** Subcostal view of inferior vena cava (IVC) showing extracorporeal membrane oxygenation inflow cannula at the junction of the IVC and right atrium with reversal of blood flow through hepatic veins, indicating increased right atrial pressure. **(B)** Pulsed-wave Doppler over hepatic vein showing biphasic pattern with retrograde systolic flow reversal supporting severe tricuspid regurgitation and possible right ventricular dysfunction.

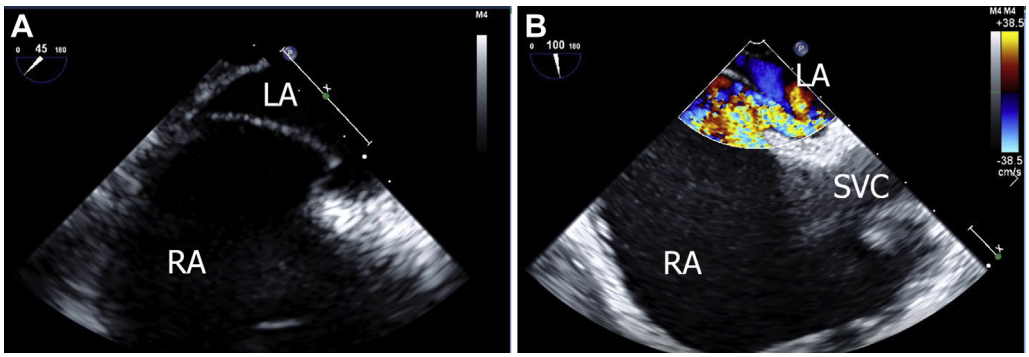

Figure 4 **(A)** Midesophageal four-chamber view with zoom on interatrial septum to show bowing of from the right atrium (RA) to the left atrium (LA). **(B)** Midesophageal bicaval view with color flow Doppler showing significant right-to-left shunt through patent foramen ovale. *SVC*, Superior vena cava.

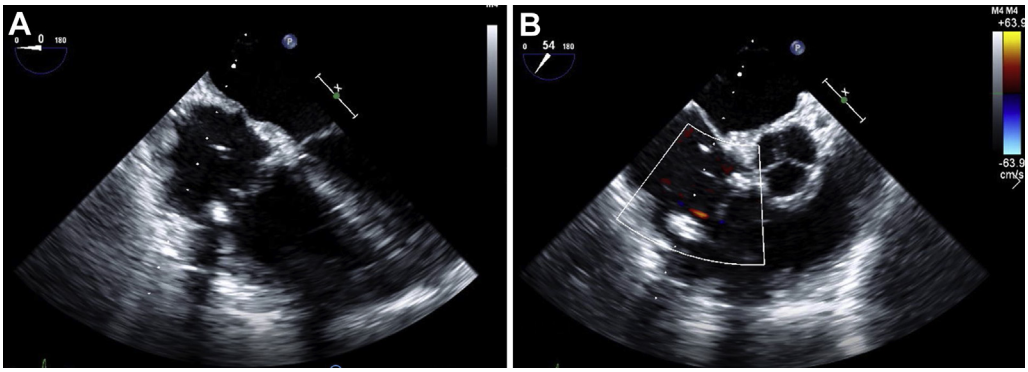

Figure 5 **(A)** Midesophageal four-chamber view. Patient is status post patent foramen ovale closure and TV replacement with a 31-mm St. Jude Epic porcine bioprosthetic valve. **(B)** Midesophageal right ventricular inflow-outflow view showing TV replacement with no residual tricuspid regurgitation by color flow Doppler.

saline is well suited for this purpose. Because microbubbles are unable to access the left heart because of diffusion into the lungs, appearance of left heart bubbles within five beats after opacification of the right heart structure strongly suggests intracardiac shunt.

Finally, VV ECMO was deployed in rapid fashion when refractory hypoxemia developed. In this scenario, it served as a bridge to diagnosis and corrective surgery. The patient did not experience any long-term sequelae of prolonged hypoxemia, as measures were taken to cannulate in a rapid and systematic fashion, with echocardiography serving to provide precise evaluation of cannula position and ECMO flow, even when complex anatomy existed.

CONCLUSION

Echocardiography was critical in the diagnosis and treatment of this patient's uncommon clinical scenario. IVDU populations are at high risk for cardiac complications, not only related to IE but also arising from complications of corrective cardiac surgery. With an increasing burden of heroin-related IE cases, valvulectomy may become a more common procedure. As such, providers must be increasingly aware and able to diagnose and manage complications related to this approach. These complexities are diagnosable by echocardiography; its importance cannot be understated.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.case.2019.04.002.

REFERENCES

1. Substance Abuse and Mental Health Services Administration. Results from the 2013 National Survey on Drug Use and Health: summary of national findings. NSDUH Series H-48, HHS Publication No. (SMA) 14-4863. Rockville, MD: Substance Abuse and Mental Health Services Administration; 2014.
2. Wurcel AG, Anderson JE, Chui KK, Skinner S, Knox TA, Sydman DR, et al. Increasing infectious endocarditis admissions among young people who inject drugs. Open Forum Infect Dis 2016;3:ofw157.
3. Chu VH, Park LP, Athan E, Delahaye F, Freiberger T, Lamas C, et al. Association between surgical indications, operative risk, and clinical outcome in infective endocarditis: a prospective study from the International Collaboration on Endocarditis. Circulation 2015;131:131-40.
4. Baddour LM, Wilson WR, Bayer AS, Fowler VG Jr, Bolger AF, Levison ME, et al. Infective endocarditis: diagnosis, antimicrobial therapy, and management of complications: a statement for healthcare professionals from the Committee on Rheumatic Fever, Endocarditis, and Kawasaki Disease, Council on Cardiovascular Disease in the Young, and the Councils on Clinical Cardiology, Stroke, and Cardiovascular Surgery and Anesthesia, American Heart Association: endorsed by the Infectious Diseases Society of America. Circulation 2005;111:e394-434.
5. Horstkotte D, Follath F, Gutschik E, Lengyel M, Oto A, Pavie A, et al. Guidelines on prevention, diagnosis and treatment of infective endocarditis executive summary; the Task Force on Infective Endocarditis of the European Society of Cardiology. Eur Heart J 2004;25:267-76.
6. Akinosoglou K, Apostolakis E, Koutsogiannis N, Leivaditis V, Gogos CA. Right-sided infective endocarditis: surgical management. Eur J Cardiothorac Surg 2012;42:470-9.
7. Nishimura RA, Otto CM, Bonow RO, Carabello BA, Erwin JP III, Guyton RA, 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. Circulation 2014;129:e521-643.
8. Rabkin DG, Mokadam NA, Miller DW, Goetz RR, Verrier ED, Aldea GS. Long term outcomes for the surgical treatment of infective endocarditis with focus on intravenous drug users. Ann Thorac Surg 2012;93:51-7.
9. Manne MB, Shrestha NK, Lytle BW, Nowicki ER, Blackstone E, Gordon SM, et al. Outcomes after surgical treatment of native and prosthetic valve infective endocarditis. Ann Thorac Surg 2012;93:489-93.
10. Shetty N, Nagpal D, Koivu S, Mrkobrada M. Surgical and medical management of isolated tricuspid valve infective endocarditis in intravenous drug users. J Card Surg 2016;31:83-8.
11. Arbulu A, Holmes RJ, Asfaw I. Tricuspid valvulectomy without replacement. Twenty years' experience. J Thorac Cardiovasc Surg 1991;102:917-22.