Use of microaxial flow pumps in adolescents

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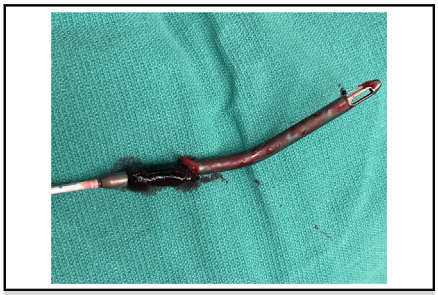
ABSTRACT

Objectives: The Impella 5.5 has been successfully used in the adult population; however, safety and efficacy data in patients aged less than 18 years are limited.

Methods: Six pediatric patients, aged 13 to 16 years and weighing 45 to 113 kg, underwent axillary artery graft placement and attempted placement of the Impella 5.5 device at our institution between August 2020 and March 2023.

Results: Indications for implantation were heart failure secondary to myocarditis (2), rejection of prior orthotopic heart transplant, idiopathic dilated cardiomyopathy (2), and heart failure after transposition of the great arteries repair. Placement was unsuccessful in a 13.8-year-old female patient due to prohibitively acute angulation of the right subclavian artery, and venoarterial extracorporeal membrane oxygenation cannulation was performed via the axillary graft. In 5 patients with successful Impella 5.5 placement, median duration of support was 13.5 days (range, 7-42 days). One experienced cardiac arrest secondary to coagulation-associated device failure, requiring temporary HeartMate3 implantation. Four patients were bridged to transplant; 3 patients received a transplant directly from Impella 5.5, and 1 patient received a transplant after HeartMate3. The final patient received the HeartMate3 on Impella day 42 and is awaiting transplant.

Conclusions: Although exact size cutoffs and anatomy are still being determined, our experience provides a framework for use of the Impella 5.5 in adolescents. (JTCVS Techniques 2023;21:188-94)



Impella 5.5 device with clot obstructing outflow.

CENTRAL MESSAGE

The Impella 5.5 can used as minimally invasive mechanical circulatory support in selected adolescent patients.

PERSPECTIVE

The prospect of using the Impella 5.5 in adolescent patients as total circulatory support for bridge to transplant is attractive. However, important considerations, including axillary artery dimensions, bony chest wall diameter, and risk of thrombosis, must be carefully considered. Failed Impella 5.5 placement can be rescued by initiating VA-ECMO at the axillary artery graft.

The Impella 5.5 (Abiomed) is a minimally invasive option for mechanical circulatory support (MCS) in patients with advanced heart failure, with the ability to provide up to 5.5 L/min of flow. This offers a minimally invasive option for left ventricular support, enabling recovery, or serving as a bridge to transplantation or durable left ventricular assist device (LVAD) placement. The advantages of a high-flow, minimally invasive MCS are numerous. These devices may avoid multiple sternotomies in patients likely to receive transplant, while still offering functional benefits of more durable devices. In addition, axillary insertion of the Impella 5.5 may enable patients to participate in physical therapy earlier and more rigorously in the postoperative period and avoid deconditioning before heart transplantation or durable LVAD placement.

These advances in minimally invasive MCS have transformed adult heart failure therapy; however, widespread use in young patients is inherently limited by the discrepancy between device and patient size. Although options for MCS in children have expanded with Food and Drug Administration approval of the RotaFlow (Maquet), CentriMag (Abbott), and PediMag (Abbott) centrifugal flow pumps, there are fewer options for minimally invasive circulatory support in the adolescent population. Previous versions of the Impella devices, including the Impella CP, Impella 2.5, and Impella 5.0, have been implemented in

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Abbreviations and Acronyms

BSA = body surface area
CT = computed tomography
CVP = central venous pressure
IABP = intra-aortic balloon pump
ICU = intensive care unit
LV = left ventricle
LVAD = left ventricular assist device
MCS = mechanical circulatory support
PCWP = pulmonary capillary wedge pressure
PVR = pulmonary vascular resistance
VA-ECMO = venoarterial extracorporeal membrane oxygenation

patients as young as 9 years old, with promising results.[1-12] However, use of the Impella 5.5 in the adolescent population is limited to a single case report describing a 14-year-old patient who received the Impella 5.5 as a bridge to heart transplant.[8] The Impella 5.5 not only provides greater circulatory support than past iterations of the device but also has different mechanical properties including a stiffer body and lack of pigtail to better facilitate axillary insertion. Further, the Impella 5.5 is the only iteration of Impella devices approved for total circulatory support in children. In this case series, we describe our institutional experience with the Impella 5.5 in 6 adolescent patients.

MATERIALS AND METHODS

Ethical Statement

This study was approved by the institutional review board of Duke University Medical Center (PRO00101472), approved January 2, 2019. Individual patient consent was waived.

Patient Population and Data Collection

This retrospective observational study identified all patients aged less than 18 years who underwent Impella 5.5 placement from August 2020 to March 2023. Data were obtained from a prospectively maintained institutional database and manual chart review. Demographic data, including age, sex, height, weight, body mass index, body surface area (BSA), and family history of cardiomyopathy or congenital heart disease, were recorded. Bony chest wall width was measured at the level of the diaphragm on chest x-ray. Information regarding clinical course and outcomes was recorded. All data were maintained in protected servers.

Statistical Analysis and Visualization

Data were analyzed and visualized in GraphPad Prism (Dotmatics). Data are expressed as median (interquartile range) or mean ± standard deviation as indicated.

Operative Technique

Impella 5.5 insertion in the adolescent population presents unique operative considerations. Before incision, we inspect with echocardiogram for 5 key characteristics: (1) left ventricular thrombus, (2) right heart function, (3) significant septal defects, (4) aortic valve competency, and (5) device fit. For device fit, the cage must be inside the ventricle and the outflow must be above the aortic valve, and the device must fit through the aortic valve without occluding coronary or other arterial flow. Manufacturer contraindications include aortic valve diameter less than 1.5 cm and ventricular long axis length less than 7 cm. A 4- to 6-cm right subclavian incision facilitates exposure of the right axillary artery. After administration of 5000 units of heparin, the right axillary artery is then clamped. A longitudinal arteriotomy is made, and we anastomose an 8-mm or 10-mm beveled (~45°-60°) Dacron chimney graft to the axillary artery, regardless of the patient's axillary artery diameter. The graft is tunneled superficial to the chest wall muscles and out through a separate incision inferior on the axilla. After clamp removal and assurance of hemostasis at the anastomosis, additional heparin is administered to achieve a goal activated clotting time of greater than 250 seconds. With assistance of transesophageal echocardiography and fluoroscopy, a 0.035-inch diagnostic J-wire is manually placed through the graft and advanced to the ascending aorta. An AL-1 catheter advances the J-wire through the aortic valve and into the left ventricle (LV). After exchanging the J-wire for a 0.018-inch placement guidewire, the Impella 5.5 is advanced over the wire into the LV pointing toward the apex, with the bend below the aortic valve. This often requires graft palpation under fluoroscopy to guide the rigid motor housing through the vascular graft anastomosis, along the curvature of the subclavian and innominate, and into the ascending aorta then ventricular apex. Additional maneuvers that can be helpful include (1) papaverine solution topically on the axillary artery, (2) exchange for a stiffer wire such as a 0.027-inch size, (3) dilator passage along the subclavian artery with fluoroscopic guidance, or (4) moving the arm up above the head.

After removal of the wire, positioning of the device in the LV is assessed with fluoroscopy and transesophageal echocardiography. Generally, the distance from the center of the inlet cage to the aortic valve annulus is approximately 5 cm. After ensuring appropriate positioning, the device is started, and further adjustments to device position are made as needed. The Dacron graft is then cut to the appropriate size, and the insertion sheath is advanced, and the device is secured in place. The right subclavian incision is then closed, and sterile dressings are applied. In cases where the device cannot be placed due to small artery size or acute angulation of the great vessels, options include aborting to left-sided axillary placement, direct aortic placement via partial or full sternotomy, or conversion to venoarterial extracorporeal membrane oxygenation (VA-ECMO) with a cannula placed within the Dacron graft as described in case 3 of this report.

Perioperative Considerations

Given that use of the Impella 5.5 is not widespread in the adolescent population, there are several perioperative considerations when caring for these patients. All adolescent patients undergoing nonemergency evaluation for Impella 5.5 therapy received preoperative computed tomography (CT) or ultrasound imaging to exclude aberrant right subclavian artery, which is not uncommon in patients with congenital heart disease (Table 1). Further, caring for these patients requires nursing staff to be familiar with Impella 5.5 management. Initially, all patients aged less than 18 years with the Impella 5.5 were cared for in the adult cardiothoracic surgical intensive care unit (ICU); however, with implementation of programmatic training of congenital nursing staff, these patients now remain in the pediatric cardiac ICU. After device placement, our patients are carefully monitored for hemolysis and initially receive twice-daily hemolysis laboratory tests, which include plasma-free hemoglobin, lactate dehydrogenase, and haptoglobin (Table 2). Anticoagulation is also carefully monitored. Ensuring proper placement of the device is critical to optimize function and avoid arrhythmia, and daily echocardiograms are performed to confirm device placement and facilitate any necessary repositioning. Generally, pulmonary artery catheters are used to monitor device-assisted output

TABLE 1. Cohort demographics and preoperative measurements

Variable	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Age (y)	13.2	13.3	13.7	13.8	16.8	16.9
Sex	M	M	M	F	M	F
Height (cm)	152.0	171.0	167.6	153	185.4	167.6
Weight (kg)	52.4	51.0	72.5	45.0	113.2	81.4
BMI	22.68	20.92	29.66	19.22	32.93	29.0
BSA	1.48	1.59	1.83	1.37	2.41	1.95
LVIDd (Z-score)	7.97 (8.37)	8.55 (9.52)	7.7 (5.33)	6.53 (6.63)		4.1 (−2.8)
LVIDs (Z-score)	6.52 (11.58)	6.91	6.25 (8.35)	5.77 (9.74)		3.7 (0.93)
IVSd (Z-score)	0.61 (−0.67)	0.68 (−0.09)	0.95 (1.57)	0.45 (−3.09)	0.91 (1.87)	0.82 (−1.23)
IVSs (Z-score)		0.78		0.51 (−4.29)	1.34 (−0.88)	
LVPWd (Z-score)	0.69 (0.17)	0.47 (−1.94)	0.86 (0.92)	0.62 (−1.55)	0.94 (2.26)	0.87 (−0.61)
LVPWs (Z-score)	0.76 (−3.95)	0.82		0.93 (−2.69)	1.21 (−2.29)	
FS%	18	19	18		14	10.4
EF%	43	18		10	21	15
Right axillary artery diameter (mm)	4.1	4.5	5.3	4.0 estimated, no available imaging	13.6	7.9
Aortic annulus (cm)	1.5	2.0	1.5	1.59	2.4	2.9
Distance from aortic annulus to LV apex (cm)	10.0	9.9	11.6	8.2	11.4	9.3
Bony chest wall width at diaphragm (cm)	32	28	30	23	37	28

BMI, Body mass index; *BSA*, body surface area; *LVIDd*, left ventricular end-diastolic internal dimension; *LVIDs*, left ventricular end-systolic internal dimension; *IVSd*, interventricular septal end-diastolic thickness; *IVSs*, interventricular septal end-systolic thickness; *LVPWd*, left ventricular end-diastolic posterior wall thickness; *LVPWs*, left ventricular end-systolic posterior wall thickness; *EF*, ejection fraction; *FS*, fractional shortening; *LV*, left ventricle.

and volume status, but in smaller patients this is not always possible, and we have been satisfied with the flow estimations of the device in combination with routine clinical noninvasive parameters.

RESULTS

Case 1

A 13-year-old male patient (59.6 kg, BSA 1.58 m^2) with a history of Coxsackie myocarditis complicated by dilated cardiomyopathy, severe pulmonary hypertension, and severe mitral regurgitation presented with acute on chronic systolic dysfunction. An intra-aortic balloon pump (IABP) was placed; however, ongoing cardiogenic shock led to placement of femoral VA-ECMO on post-IABP day 4. The patient was transferred to our institution, and the IABP was removed. Given worsening pulmonary hypertension and concern for left atrial hypertension, right heart catheterization was performed, which revealed elevated pulmonary pressures (pulmonary capillary wedge pressure [PCWP] 38 mm Hg, pulmonary vascular resistance [PVR] 108 dynes/sec/cm^{-5}, central venous pressure [CVP] 10 mm Hg). Balloon atrial septostomy was performed to alleviate left atrial hypertension and left atrial pressure at

TABLE 2. Operative outcomes

Variable	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Implant duration (d)	17	21	42	0 – Failed Impella (Abiomed) placement, VA-ECMO placed as bridge to recovery	5	10
Bridge to LVAD	N	N	Y	N/A	Y	N
Time to LVAD (d)			42			
Bridge to transplant	Y	Y	Pending PRA desensitization	N/A	Y	Y
Time to transplant (d)	17	21			36	10
ICU LOS (d)	26	36	99	65, deceased	47	21
Hospital LOS (d)	30	43	99	65, deceased	50	24

VA-ECMO, Venoarterial extracorporeal membrane oxygenation; *LVAD*, left ventricular assist device; *N/A*, not available; *PRA*, panel-reactive antibody; *ICU*, intensive care unit; *LOS*, length of stay.

the time of septostomy was 43 mm Hg, with a left-to-right gradient of 14 mm Hg after septostomy creation. On ECMO day 11, an acute upper gastrointestinal bleed was identified, and the patient was taken to the operating room for ECMO decannulation and placement of a right axillary Impella 5.5. Preoperative imaging identified axillary artery diameter of 4.1 mm, aortic annulus diameter of 1.5 cm, aortic annulus to LV apex distance of 10.0 cm, and bony chest width of 32 cm. There were no operative complications, and postoperative care was completed in the adult cardiothoracic surgical ICU. The patient was extubated on postoperative day 1, and the upper gastrointestinal bleed resolved after decreasing anticoagulation while on the Impella 5.5. On postoperative day 17, a suitable donor was identified, and the patient underwent orthotopic heart transplantation and removal of the Impella 5.5. The patient's pulmonary hypertension resolved with continued inotropic support and diuresis, and catheterization on post-transplant day 7 demonstrated favorable hemodynamics (PCWP 10, CVP 5), and all inotropic support was weaned. Post-transplant course was complicated by positive crossmatch requiring 5 plasmapheresis sessions and intravenous immunoglobulins given signs of antibody-mediated rejection on initial cardiac biopsy. He was discharged on post-Impella 5.5 day 30. Eight days after discharge, he was briefly readmitted after routine cardiac catheterization demonstrated decreased cardiac function, raising concern for continued antibody-mediated rejection. However, endomyocardial biopsy did not demonstrate signs of cell- or antibody-mediated rejection, and cardiac function improved with diuresis. He continues to do well with routine outpatient management.

Case 2

A 13-year-old male patient (52.5 kg, BSA 1.59 m^2) with a history of dilated cardiomyopathy diagnosed at birth presented with emesis, poor oral intake, and radiating chest pain after 1 week of viral symptoms. On arrival to the emergency department, the electrocardiogram demonstrated no ST changes, and infectious workup was positive for parainfluenza virus. His echocardiogram demonstrated acutely decompensated heart failure, with an ejection fraction of 18% from a baseline of 28%. He was transferred to our institution for further evaluation. The patient demonstrated some improvement in hypotension and cardiac output with milrinone and epinephrine but experienced refractory atrial fibrillation/flutter requiring rate control with diltiazem. Given persistently inadequate cardiac output and refractory arrhythmia, the team decided to pursue Impella 5.5 therapy to support electrical cardioversion and assist in possible functional recovery or as bridge to durable ventricular assist device or transplant. Preoperative imaging revealed an aortic annulus of 2.0 cm, right axillary artery diameter of 7.5 mm, aortic annulus to LV apex distance of 9.9 cm, and bony chest wall width of 28 cm. The Impella 5.5 was placed successfully and permitted electrical cardioversion. He was extubated on post-Impella day 1 and subsequently listed status 1A for heart transplantation. On post-Impella day 7, the patient experienced ventricular tachycardia that resolved after Impella repositioning. The patient underwent transplantation on Impella day 21 and continues to do well.

Case 3

A 13-year-old male patient (72.5 kg, BSA 1.82 m^2) with a history of D-transposition of the great arteries, status post-aortic translocation and right ventricle to pulmonary conduit in infancy, and pulmonary valve replacement with a 23-mm Sapien valve (Edwards Lifesciences) at 10 years of age. He developed progressive systolic and diastolic dysfunction with ventricular tachycardia. After the patient experienced pulseless cardiac arrest with return of spontaneous circulation achieved after defibrillation, the decision was made to proceed with advanced MCS while the patient was evaluated for cardiac transplantation. Preoperative imaging revealed an aortic annulus of 1.5 cm, right axillary artery diameter of 5.3 mm, aortic annulus to LV apex distance of 12.3 cm, and bony chest wall width of 30 cm. The patient was listed status 1A for cardiac transplantation, however, was unable to receive offers due to prohibitively high panel reactive antibodies requiring desensitization. The patient was extubated on Impella day 15 and underwent Impella 5.5 removal and durable LVAD placement on Impella 5.5 day 42. He is undergoing desensitization for plasma reactive antibodies before transplant.

Case 4

A 13-year-old female patient (45.0 kg, BSA 1.37 m^2) presented with 5 days of upper respiratory symptoms and 1 day of altered mental status. Laboratory results indicated multiorgan failure, and echocardiogram revealed severely decreased biventricular function, with thrombus in the LV. The patient was intubated and placed on high-intensity inotropes and transferred to our institution for transplant evaluation. Preoperative CT imaging could not be completed because of the urgent need for surgical intervention. Intraoperatively, the right axillary artery diameter was approximately 4 mm. The aortic annulus measured 1.59 cm, and bony chest wall width was 23 cm. She was taken to the operating room immediately upon arrival to our institution for Impella 5.5 placement. In the operating room, an axillary cutdown was performed and a 10-mm Dacron graft was anastomosed to the axillary artery. The Impella 5.5 was inserted into the Dacron graft and through the axillary artery; however, subclavian artery angulation was too acute to facilitate Impella 5.5 passage. We elected to place the patient on VA-ECMO via the axillary artery graft, followed by atrial septostomy for left atrial decompression. Postseptoplasty right heart catheterization demonstrated

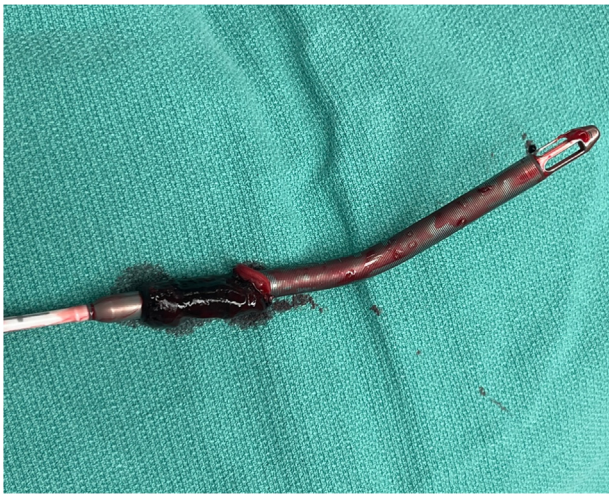

FIGURE 1. Operative image demonstrating occlusive clot at the Impella 5.5 (Abiomed) outflow tract in case 5.

persistently elevated left atrial pressure, and a percutaneous left atrial vent was placed. Continuous renal replacement therapy was initiated on VA-ECMO day 8 for anuric renal failure. VA-ECMO and left atrial ventilation were discontinued after 11 days, and echocardiogram demonstrated mild to moderate LV dysfunction. Unfortunately, 53 days after ECMO decannulation, the patient had acutely decompensated cardiac function, resulting in hypotensive arrest. Given persistent renal failure and worsening cardiac function, this patient transitioned to comfort care and died 54 days after ECMO decannulation.

Case 5

A 16-year-old male patient (113.2 kg, BSA 2.41 m^2) with a history of mild COVID-19 infection 1 month before symptom onset presented with vomiting, syncope, and ventricular ectopy. He was diagnosed with dilated cardiomyopathy and transferred to our institution for transplant evaluation. His heart failure was refractory to medical therapy, including carvedilol, lisinopril, milrinone, and sotalol, and progressed to the development of persistent nonsustained ventricular tachycardia. Cardiac magnetic resonance imaging demonstrated diffuse epicardial scarring consistent with a chronic, progressive cardiomyopathy rather than an acute COVID-19–associated myocarditis. Cardiac catheterization showed significantly elevated right-sided pressures (PCWP 34 mm Hg, PVR 560 dynes/sec/cm^{-5}, CVP 6 mm Hg). Preoperative imaging revealed an aortic annulus of 1.36 cm, right axillary artery diameter of 13.6 mm, aortic annulus to LV apex distance of 11.4 cm, and bony chest wall width of 37 cm. After multidisciplinary discussion, the team elected to proceed with MCS and Impella 5.5 implantation as a bridge to transplantation. Unfortunately, on postoperative day 5, the patient had ventricular fibrillation cardiac arrest requiring defibrillation due to device failure secondary to coagulopathy. The ICU and cardiac surgery teams proceeded with intracorporeal LVAD implantation as a bridge to transplantation. After Impella 5.5 explant, the team observed a complete occlusion of the outflow tract by clot (Figure 1). Repeat catheterization 26 days after durable LVAD insertion showed significant improvement in right-sided heart pressures and permissive of transplant. The patient received cardiac transplantation on post-Impella 5.5 day 36. Post-transplant course was initially complicated by low cardiac output, which improved with diuresis and inotropic support. A filling defect in the transverse aorta was observed on left heart catheterization, which prompted CT angiography and identification of a small, contained transverse aortic arch dissection that is being managed with labetalol to a blood pressure goal of less than 135/85 mm Hg and regular CT angiograms to evaluate dissection progression. He was discharged on post-Impella day 50 and continues to do well with outpatient management.

Case 6

A 16-year-old female patient (81.4 kg, BSA 1.95 m^2) with a history of TNNT2-positive dilated cardiomyopathy status post-orthotopic heart transplantation at age 14 years presented with allograft rejection. Transthoracic echocardiography showed severely decreased LV ejection fraction (20%) and severe right ventricle dysfunction. She was transferred to our institution for retransplant evaluation. After right heart catheterization showing reduced cardiac index and elevated filling pressures, the cardiothoracic surgery team elected to proceed with femoral VA-ECMO cannulation. Preoperative imaging revealed an aortic annulus of 2.9 cm, right axillary artery diameter of 7.9 mm, aortic annulus to LV apex distance of 9.3 cm, and bony chest wall width of 28 cm. ECMO course was complicated by cannulation site bleeding and compartment syndrome on ECMO day 3 leading to Impella 5.5 implantation on ECMO decannulation. A suitable donor was identified, and she underwent a repeat heart transplantation 10 days after insertion of the Impella 5.5. Cardiac catheterization on post-transplant day 7 showed improved hemodynamics and no evidence of rejection. Her hospital course was complicated by a generalized seizure expected to be posterior reversible encephalopathy syndrome related to post-transplant hypertension. She was discharged on post-Impella day 24 and continues to do well with routine outpatient management.

DISCUSSION

In this article, we describe our institutional experience with the Impella 5.5 in 6 adolescent patients. Four patients were successfully bridged to transplant, with 1 requiring initial bridge to LVAD due to Impella device failure. One

patient remains on HeartMate3 (Abbott) support awaiting cardiac transplantation. One patient had failed Impella 5.5 insertion due to acute subclavian artery angulation and instead was placed on VA-ECMO via the axillary artery graft. This patient highlights challenges with Impella 5.5 use in small adolescent patients. Bony chest wall diameter may provide a crude estimation of great vessel angulation and contour without axial imaging, although we do not have enough patients to determine a threshold for insertion. This case illustrates the alternative approach of using the already-placed axillary artery Dacron graft as a conduit for VA-ECMO.

The most notable adverse event in this patient cohort was in case 3. This patient experienced Impella 5.5 outflow thrombosis, resulting in complete outflow occlusion, ventricular tachycardia cardiac arrest, and subsequent conversion to intracorporeal LVAD. This patient had a history of presumed COVID-19 infection approximately 1 month before the onset of heart failure symptoms, given several members of his household were symptomatic, although only 1 sibling had COVID-19 testing at this time, which was positive. The patient's COVID-19 symptoms were reportedly mild, with only 1 day of fever and no respiratory symptoms. The patient did test positive for COVID-19 at the time he presented with symptoms of heart failure. Thus, it is possible that this patient's coagulopathy was related to recent COVID-19 infection. We also considered insufficient anticoagulation or heparin-induced thrombocytopenia; however, heparin-induced thrombocytopenia panels were negative and activated prothrombin time ranged from 40.7 to 44.6 seconds 24 hours before thrombosis. The most likely etiology is device malpositioning; this patient experienced significant ectopy secondary to presumed arrhythmogenic cardiomyopathy, and the Impella 5.5 was repositioned multiple times to avoid triggering ventricular arrhythmia. It is possible that repositioning to avoid ectopy inadvertently caused the Impella 5.5 outflow cannula to push against the aortic wall, leading to stasis and serving as a nidus for clot formation or aspiration. Notably, we have not observed this complication in the more than 100 Impella 5.5 devices we have placed in adults at our institution. Although the etiology remains uncertain, this underscores the importance of regular positioning verification with echocardiogram and routine lab monitoring in the immediate postoperative period.

Currently, only 1 adolescent patient supported with the Impella 5.5 is described in the literature: a 14-year-old with acute systolic dysfunction who was bridged to transplant after 21 days of Impella 5.5 support (Table 1).[8] Our case series adds to a growing body of literature describing minimally invasive MCS in adolescent patients. One limitation is that many of our patients aged less than 18 years

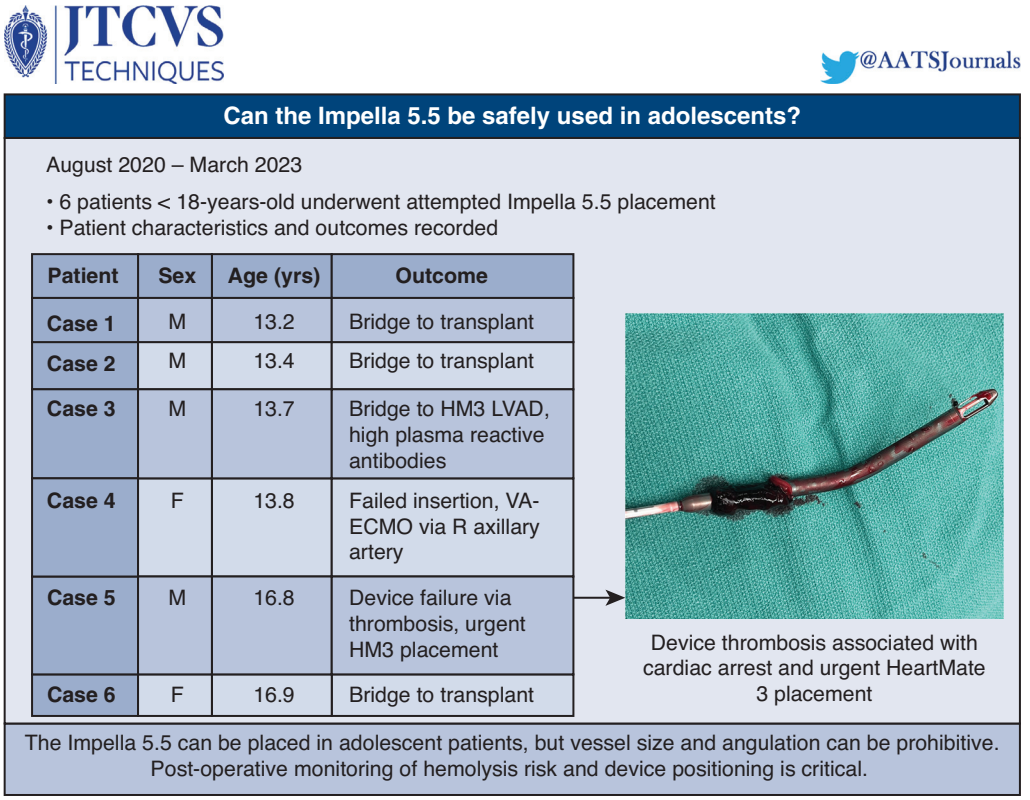

FIGURE 2. Graphical abstract: Can Impella 5.5 be safely used in adolescents? *HM3 LVAD*, HeartMate 3 left ventricular assist device; *R*, right; *VA-ECMO*, venoarterial extracorporeal membrane oxygenation.

could be considered adult sized, and our smallest successful insertion was in a patient weighing 51 kg. However, age is positively correlated with vessel diameter independent of weight, and body size may not always predict successful insertion.[13,14] Further studies are needed to determine exact measurement thresholds and guidelines for use of the Impella 5.5 in adolescent patients.

CONCLUSIONS

The Impella 5.5 can be used to bridge adolescent patients to cardiac transplantation (Figure 2). Although exact size cutoff and anatomic guidelines are still being determined, this article gives a framework for the use of the device in adolescents.

Conflict of Interest Statement

J.N.S. is a consultant for Abiomed. All other authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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