Case Reports

Titanium Plug Closure

after HeartWare Ventricular Assist Device Explantation in a 15-Year-Old Girl: First U.S. Experience

Diego A. Lara, MD, MPH
Aamir Jeewa, MD
Barbara A. Elias, RN, CCRN
Elizabeth O. McCullum, PhD
Susan W. Denfield, MD
William J. Dreyer, MD
Iki Adachi, MD

We describe the case of a teenage girl with anthracycline-induced cardiomyopathy who received a HeartWare ventricular assist device and underwent successful device explantation after cardiac recovery.

During device support, the patient's cardiac function returned to normal. Twelve months after implantation, we explanted the device via repeat median sternotomy. To close the hole in the left ventricular apex and preserve the sewing ring in case future device support is needed, we used a German-manufactured titanium plug, developed specifically for this purpose. To our knowledge, this is the first use of this plug in the United States.

The patient recovered uneventfully and was discharged from the hospital on postoperative day 11. Left ventricular biopsy specimens at explantation revealed the resolution of previous degenerative sarcomeric changes.

Our patient did well clinically; however, recurrent late anthracycline cardiotoxicity might subsequently cause her cardiac function to deteriorate. In this event, our use of the titanium plug to preserve the left ventricular sewing ring would enable easier device replacement than would other explantation options. ***(Tex Heart Inst J 2017;44(1):66-9)***

Key words: *Adolescent; cardiomyopathies/chemically induced; cardiovascular surgical procedures/instrumentation/methods; device removal/methods; equipment design; heart failure/therapy; heart-assist devices/utilization; recovery of function; titanium; treatment outcome*

From: *Section of Pediatric Cardiology (Drs. Denfield, Dreyer, Jeewa, and Lara) and Division of Congenital Heart Surgery (Drs. Adachi and McCullum, and Ms Elias), Baylor College of Medicine; and Department of Surgery (Drs. Adachi and McCullum, and Ms Elias), Texas Children's Hospital; Houston, Texas 77030*

Address for reprints: *Diego A. Lara, MD, MPH, Ochsner Hospital for Children, 1514 Jefferson Hwy., New Orleans, LA 70121*

E-mail: *diego.lara@ochsner.org*

The number of children supported with implantable continuous-flow ventricular assist devices (VADs) has steadily increased.[1] In adults, VAD therapy has been established as a bridge to recovery.[2-8] However, cardiac recovery with subsequent VAD explantation has been reported only infrequently in the pediatric population, and research into pediatric cardiac recovery lags behind that of adults.[9-17] Among proposed surgical options for explanting VADs, the most ideal for children and adolescents is to remove as much foreign material from the body as possible while enabling later VAD reinstitution.

We report the case of a 15-year-old girl with anthracycline-induced cardiomyopathy who was successfully bridged to recovery after 12 months of support from a HeartWare HVAD® (HeartWare, Inc.; Framingham, Mass). The VAD was removed via repeat sternotomy, and the sewing ring was preserved with use of a titanium plug manufactured by Steffan Fittkau GmbH, a metallurgy and engineering firm in Berlin, Germany.[18] Because the titanium plug had not been approved by the U.S. Food and Drug Administration, we had multiple lengthy discussions with that agency before its clinical use. To our knowledge, we are the first to use this plug in the U.S.

Case Report

A 14-year-old girl (weight, 51 kg; body surface area, 1.4 m^2) with a history of acute myeloid leukemia developed severe congestive heart failure 3 months after the termination of chemotherapy. Her left ventricular (LV) ejection fraction (EF) was 0.10, her right ventricular systolic function was moderately depressed, and her brain natriuretic peptide level was 1,900 pg/mL. She could not be weaned from inotropic agents. Support from a VAD was deemed necessary as a bridge to candidacy for transplantation, because she had been in remission for only 3 months.

In January 2013, the patient underwent HeartWare HVAD implantation with use of a modified technique—necessitating a median sternotomy—wherein the VAD was placed in an infradiaphragmatic position to lessen compression of the lower lobe of the left lung.[19] She recovered uneventfully and was discharged from the hospital 11 days later. Her medications included enalapril, nadolol, furosemide twice daily, and a stable warfarin dose.

The patient's heart began to show signs of functional recovery after 3 months of VAD support: the LVEF returned to normal, and the LV diastolic dimension pro-

gressively decreased. We placed her on a VAD-weaning protocol developed at our center,[20] and she tolerated 2 pump-weaning tests well. Although device explantation was thought to be feasible, uncertainty remained about the sustainability of the patient's cardiac function: LV histologic results had shown moderate myocyte hypertrophy, mild-to-moderate interstitial fibrosis, degenerative myocytolysis, and decreased sarcomere density. In view of possibly recurrent heart failure, cancer, or both, we thought it best to explant as much foreign material as possible from the body while still enabling later reinstitution of VAD support.

The patient's young age and female sex influenced our decision to perform a repeat sternotomy, enabling the removal of the entire device. Thoracotomy would have necessitated making an additional operative incision and leaving the outflow-graft component in place.

In January 2014, 12 months after VAD implantation, the patient (now 15 years old) underwent explantation via repeat median sternotomy with cardiopulmonary bypass support. We removed a small mural thrombus from the LV cavity near the cannulation site. We used the titanium plug (Fig. 1) to cover the LV coring site. The plug—manufactured for this specific use—is made of a titanium alloy with titanium microsphere sintering, similar to the materials used in the HVAD itself. The diameter exactly matches that of the sewing ring. The center of the plug is hollow, to reduce weight. A special plug-holder device is supplied by the manufacturer to help position the plug during surgery.[18]

The patient was weaned from cardiopulmonary bypass without difficulty. Her biventricular systolic function remained normal, with an LVEF of 0.63 and normal LV dimensions. She recovered uneventfully and was discharged from the hospital on postoperative day 11 with instructions to take enalapril, nadolol, warfarin, and aspirin. She took warfarin and aspirin for 3 months and continued thereafter only with aspirin for anticoagulation. Post-explantation histologic results revealed improvement of the degenerative sarcomeric changes that had been seen previously. As of January 2017, the patient was doing well without recurrence of heart failure.

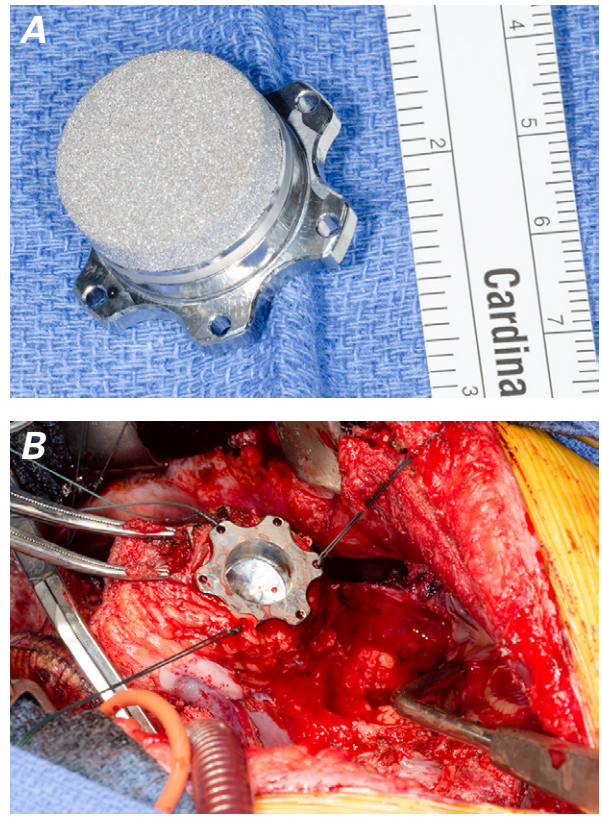

Fig. 1 ***A****) Photograph shows the titanium plug.* ***B****) Intraoperative photograph shows the plug in situ. (Printed with permission from Texas Children's Hospital.)*

Discussion

Myocardial recovery during long-term VAD support is infrequently reported in children, perhaps because of their substantially shorter waiting times on the transplant list in comparison with adults.[21] However, as the waiting time in children increases, myocardial recovery might occur in mechanically supported children.[22] In 2015, we reported that the pediatric myocardial response to VAD therapy differs from that in the adult myocardium at a subcellular level.[23] Improved understanding of such differences might help to identify candidates for bridge-to-recovery therapy.

Our patient had chronic anthracycline cardiomyopathy, which is generally thought to be irreversible.[24] However, several examples of reversed acute and chronic anthracycline cardiotoxicity have been published.[25-27] Although we were encouraged by our patient's seemingly complete recovery of systolic ventricular function and improved histologic results, the natural history of this disease and her initial histologic profile increase the risk of a future decline in cardiac function.

The most extreme method of VAD explantation involves device removal via sternotomy. Least extreme is simple ligation of the outflow graft, which functionally excludes the device from the circulation but leaves it in place.[28] Our removal of everything but the sewing ring obviated potential problems.

In current practice, the coring site can be plicated after removing the ring, but this deforms the LV geometry and makes VAD reinsertion far more technically demanding.[29] Another option is to create a felt plug and insert it into the ring. The felt plug obviates the need for LV plication, thus sparing further injury to the myocardium and distortion of the ventricular geometry. We have used the latter technique at our institution.[20]

The titanium plug's material properties and engineering design make it superior to the felt plug for inser-

tion into the sewing ring. The result is a perfect fit, a hermetically closed hole in the ventricle, and a surface that will not promote thrombus formation.[18] The German investigators who originally used the titanium plug found no visible thrombus 3 years after its placement.[30] To our knowledge, our report is the first and, so far, only description of the titanium plug's use in the U.S.

References

1. Cabrera AG, Sundareswaran KS, Samayoa AX, Jeewa A, McKenzie ED, Rossano JW, et al. Outcomes of pediatric patients supported by the HeartMate II left ventricular assist device in the United States. J Heart Lung Transplant 2013;32 (11):1107-13.
2. Maybaum S, Mancini D, Xydas S, Starling RC, Aaronson K, Pagani FD, et al. Cardiac improvement during mechanical circulatory support: a prospective multicenter study of the LVAD Working Group. Circulation 2007;115(19):2497-505.
3. Dandel M, Weng Y, Siniawski H, Stepanenko A, Krabatsch T, Potapov E, et al. Heart failure reversal by ventricular unloading in patients with chronic cardiomyopathy: criteria for weaning from ventricular assist devices. Eur Heart J 2011;32 (9):1148-60.
4. Birks EJ, George RS, Hedger M, Bahrami T, Wilton P, Bowles CT, et al. Reversal of severe heart failure with a continuous-flow left ventricular assist device and pharmacological therapy: a prospective study. Circulation 2011;123(4):381-90.
5. Drakos SG, Terrovitis JV, Anastasiou-Nana MI, Nanas JN. Reverse remodeling during long-term mechanical unloading of the left ventricle. J Mol Cell Cardiol 2007;43(3):231-42.
6. Liden H, Karason K, Bergh CH, Nilsson F, Koul B, Wiklund L. The feasibility of left ventricular mechanical support as a bridge to cardiac recovery. Eur J Heart Fail 2007;9(5):525-30.
7. Gorcsan J 3rd, Severyn D, Murali S, Kormos RL. Non-invasive assessment of myocardial recovery on chronic left ventricular assist device: results associated with successful device removal. J Heart Lung Transplant 2003;22(12):1304-13.
8. Simon MA, Primack BA, Teuteberg J, Kormos RL, Bermudez C, Toyoda Y, et al. Left ventricular remodeling and myocardial recovery on mechanical circulatory support. J Card Fail 2010;16(2):99-105.
9. Morales DL, Almond CS, Jaquiss RD, Rosenthal DN, Naftel DC, Massicotte MP, et al. Bridging children of all sizes to cardiac transplantation: the initial multicenter North American experience with the Berlin Heart EXCOR ventricular assist device. J Heart Lung Transplant 2011;30(1):1-8.
10. Reinhartz O, Keith FM, El-Banayosy A, McBride LR, Robbins RC, Copeland JG, Farrar DJ. Multicenter experience with the Thoratec ventricular assist device in children and adolescents. J Heart Lung Transplant 2001;20(4):439-48.
11. Blume ED, Naftel DC, Bastardi HJ, Duncan BW, Kirklin JK, Webber SA; Pediatric Heart Transplant Study Investigators. Outcomes of children bridged to heart transplantation with ventricular assist devices: a multi-institutional study. Circulation 2006;113(19):2313-9.
12. Hetzer R, Potapov EV, Stiller B, Weng Y, Hubler M, Lemmer J, et al. Improvement in survival after mechanical circulatory support with pneumatic pulsatile ventricular assist devices in pediatric patients. Ann Thorac Surg 2006;82(3):917-25.
13. Imamura M, Dossey AM, Prodhan P, Schmitz M, Frazier E, Dyamenahalli U, et al. Bridge to cardiac transplant in children: Berlin Heart versus extracorporeal membrane oxygenation. Ann Thorac Surg 2009;87(6):1894-901.
14. Zimmerman H, Covington D, Smith R, Ihnat C, Barber B, Copeland J. Recovery of dilated cardiomyopathies in infants and children using left ventricular assist devices. ASAIO J 2010;56(4):364-8.
15. Ihnat CL, Zimmerman H, Copeland JG, Meaney FJ, Sobonya RE, Larsen BT, et al. Left ventricular assist device support as a bridge to recovery in young children. Congenit Heart Dis 2011;6(3):234-40.
16. Fan Y, Weng YG, Xiao YB, Huebler M, Franz N, Potapov E, Hetzer R. Outcomes of ventricular assist device support in young patients with small body surface area. Eur J Cardiothorac Surg 2011;39(5):699-704.
17. Valeske K, Thul J, Muller M, Bauer J, Hijjeh N, Schranz D, Akinturk H. Mechanical circulatory support in pediatric patients - a review of 15 years [abstract]. Thorac Cardiovasc Surg 2012;60:PP46. Available from: https://www.thieme-connect.com/products/ejournals/abstract/10.1055/s-0031-1297693.
18. Potapov EV, Stepanenko A, Hennig E, Hetzer R, Krabatsch T. A titanium plug simplifies left ventricular assist device removal after myocardial recovery. J Heart Lung Transplant 2010;29(11):1316-7.
19. Adachi I, Guzman-Pruneda FA, Jeewa A, Fraser CD Jr, Dean McKenzie E. A modified implantation technique of the HeartWare ventricular assist device for pediatric patients. J Heart Lung Transplant 2015;34(1):134-6.
20. Lowry AW, Adachi I, Gregoric ID, Jeewa A, Morales DL. The potential to avoid heart transplantation in children: outpatient bridge to recovery with an intracorporeal continuous-flow left ventricular assist device in a 14-year-old. Congenit Heart Dis 2012;7(6):E91-6.
21. Rossano JW, Lorts A, VanderPluym CJ, Jeewa A, Guleserian KJ, Bleiweis MS, et al. Outcomes of pediatric patients supported with continuous-flow ventricular assist devices: a report from the Pediatric Interagency Registry for Mechanical Circulatory Support (PediMACS). J Heart Lung Transplant 2016;35(5):585-90.
22. Schulze PC, Kitada S, Clerkin K, Jin Z, Mancini DM. Regional differences in recipient waitlist time and pre- and post-transplant mortality after the 2006 United Network for Organ Sharing policy changes in the donor heart allocation algorithm. JACC Heart Fail 2014;2(2):166-77.
23. Weia BC, Adachi I, Jacot JG. Clinical and molecular comparison of pediatric and adult reverse remodeling with ventricular assist devices. Artif Organs 2015;39(8):691-700.
24. Chatterjee K, Zhang J, Honbo N, Karliner JS. Doxorubicin cardiomyopathy. Cardiology 2010;115(2):155-62.
25. Castells E, Roca J, Miralles A, Manito N, Ortiz D, Gonzalez J, et al. Recovery of ventricular function with a left ventricular axial pump in a patient with end-stage toxic cardiomyopathy not a candidate for heart transplantation: first experience in Spain. Transplant Proc 2009;41(6):2237-9.
26. Freilich M, Stub D, Esmore D, Negri J, Salamonsen R, Bergin P, et al. Recovery from anthracycline cardiomyopathy after long-term support with a continuous flow left ventricular assist device. J Heart Lung Transplant 2009;28(1):101-3.
27. Khan N, Husain SA, Husain SI, Khalaf N, George J, Raissi F, et al. Remission of chronic anthracycline-induced heart failure with support from a continuous-flow left ventricular assist device. Tex Heart Inst J 2012;39(4):554-6.
28. Cohn WE, Mallidi HR, Frazier OH. Safe, effective off-pump sternal sparing approach for HeartMate II exchange. Ann Thorac Surg 2013;96(6):2259-61.
29. Cohn WE, Gregoric ID, Radovancevic B, Frazier OH. A felt plug simplifies left ventricular assist device removal after successful bridge to recovery. J Heart Lung Transplant 2007;26 (11):1209-11.

30. Potapov EV, Huebler M, Morawietz L, Hetzer R. Connective tissue overgrowth on a titanium plug inserted to facilitate left ventricular assist device explantation. J Heart Lung Transplant 2011;30(2):235-6.