Aortic Arch Reconstruction Using Nonvalved Femoral Vein Homograft in High-Risk Neonates

Kyle G. Mitchell, MD, MSc[1], Julija Dobrila, MD[1], Blaz Podgorsek, MD[1], Christopher Greenleaf, MD[1], Peter Chen, MD[1], Jorge D. Salazar, MD[1], and Damien J. LaPar, MD, MSc[1]

[1] Division of Pediatric and Congenital Heart Surgery, University of Texas McGovern Medical School, Houston, TX, USA

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Abstract

Aortic arch obstruction is often present with complex concomitant congenital heart defects (CHDs). The use of nonvalved femoral vein homograft (FVH) to reconstruct the aortic arch has distinct surgical advantages, including simplified reconstruction. We present an intraoperative video of a Yasui procedure utilizing FVH for aortic reconstruction in a 12-day-old (2.2 kg) neonate with right ventricular outflow tract obstruction, malalignment ventricular septal defect, aortic valve atresia, aortic arch hypoplasia, atrial septal defect, and ductal dependent systemic circulation. Further, we report outcomes for a series of three additional neonatal patients with complex CHD and aortic arch obstruction who underwent FVH arch reconstruction.

Introduction

Surgical repair of neonatal aortic arch obstruction is often complicated by the presence of complex concomitant congenital heart defects. Although traditional Norwood-style arch reconstruction with patch augmentation of the aorta remains a safe and well-established repair,[1] a more expeditious strategy may be desired in certain high-risk neonates who present with complex defects and anatomic challenges. We describe the use of nonvalved femoral vein homograft (nvFVH) as a conduit for arch reconstruction in a series of four consecutive neonates with arch obstruction and provide an intraoperative video demonstrating technical details of the use of FVH arch reconstruction in a patient undergoing a Yasui procedure.

Case Series

Patient 1

A 2.2 kg neonate presented with aortic valve atresia, hypoplastic ascending aorta/proximal arch, right ventricular outflow tract (RVOT) obstruction, malalignment ventricular septal defect (VSD), atrial septal defect (ASD), and patent ductus arteriosus (PDA) with ductal-dependent systemic circulation. The patient underwent a Yasui procedure (Figure 1, Video 1) on day of life (DOL) 12, using a 10 mm nvFVH as a conduit to reconstruct the aortic arch, a 10 mm valved FVH (vFVH) as the right ventricle to pulmonary artery conduit (RVPAC), and autologous pericardium to close the VSD and baffle to the Damus-Kaye-Stansel (DKS) anastomosis. Cardiopulmonary bypass (CPB), aortic cross clamp (AXC), and antegrade cerebral perfusion (ACP) times were 293, 186, and 36 minutes, respectively. The patient was extubated on postoperative day (POD) 3 and was discharged home on POD 50. Echocardiogram (seven months postoperatively) demonstrated a patent DKS anastomosis with unobstructed aortic arch, complete closure of the VSD, unobstructed RVOT and RVPAC, bidirectional ASD (3 mm fenestration), and good biventricular function. Catheterization demonstrated unobstructed flow through the neoaortic arch (Figure 2, Video 1).

Patient 2

A 3.2 kg neonate presented with interrupted aortic arch (IAA) type B, double inlet left ventricle, VSD, aortic valve hypoplasia, functional single ventricle, PDA, and tracheoesophageal fistula. We performed pulmonary artery banding on DOL 4 and definitive repair at DOL 15. The aortic root was augmented with a pericardial patch, a 9 mm nvFVH was used as a conduit from the aortic root to descending aorta, and the distal ascending aorta with arch branches was reimplanted into the neoaortic arch in an end-to-side fashion (CPB, AXC, and ACP times: 125, 82, and 28 minutes, respectively). At eight months follow-up, the patient has remained without evidence of obstruction of the reconstructed arch.

Patient 3

A 38-day-old, 2.4 kg neonate underwent repair of IAA-type A and truncus arteriosus (TA) with VSD closure and PDA division. nvFVH was used to reconstruct the aorta from the truncal valve to descending aorta, and a vFVH was used as an RVPAC (CPB, AXC, and ACP times: 178, 127, and 35 minutes, respectively). She was discharged home on POD 16. Echocardiogram (18 months postoperatively) demonstrated trace neoaortic valve regurgitation, good biventricular function, and an unobstructed reconstructed aortic arch.

Patient 4

A 2.5 kg neonate presented with IAA-type B, TA, RVOT obstruction, and PDA. On DOL 40, complete repair of IAA and TA with truncal valve repair was achieved using an 8 mm nvFVH to reconstruct the arch from the neoaortic root to descending aorta. vFVH was used as an RVPAC (CPB, AXC, and ACP times: 452, 338, and 57 minutes, respectively). Echocardiogram (POD 52) demonstrated good ventricular function without aortic arch obstruction. Patient was discharged home on POD 53.

Comment

Neonates with aortic arch obstruction may present with complex associated cardiac malformations; in some, a means of simplifying and expediting the repair may be desired. To illustrate the technical advantages of the

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Corresponding Author:
Damien J. LaPar, Division of Pediatric and Congenital Heart Surgery, University of Texas McGovern Medical School, 6414 Fannin Street, Houston, TX 77030, USA.
Email: damien.j.lapar@uth.tmc.edu

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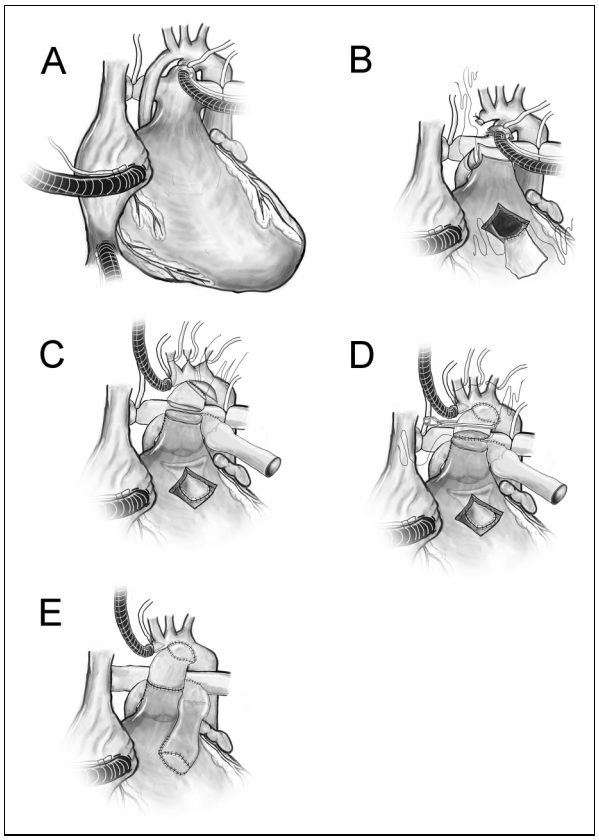

Figure 1. (A) Ductal and bicaval cannulation. (B) Hypoplastic ascending aorta was ligated. A side-to-side Damus-Kaye-Stansel (DKS) anastomosis was fashioned between ascending aorta and main pulmonary artery at right pulmonary sinus. The ventricular septal defect was closed with a pericardial patch and baffled to the DKS. (C) The distal anastomosis using nonvalved femoral vein homograft (FVH) from DKS to lesser curvature of arch (augmented with patch) and distal anastomosis for right ventricle to pulmonary artery conduit (valved FVH). (D) Anastomosis between the nonvalved FVH to the DKS. (E) Demonstration of completed repair. The fenestrated atrial septal defect closure is not shown. DKS, Damus-Kaye Stansel; FVH, femoral vein homograft; RVPAC, right ventricle to pulmonary artery conduit.

use of FVH as an aortic reconstructive conduit, we present as a representative example a video of a Yasui procedure demonstrating the use of nvFVH as a conduit from the aortopulmonary anastomosis to the aortic arch. The use of nvFVH as a conduit in the Yasui procedure has been described as a means to facilitate expeditious aortic reconstruction.[2] In select patients, its technical advantages (ease of use, reduced cerebral perfusion or circulatory arrest time, ready availability, and less complex anastomoses) are similarly advantageous in patients requiring concomitant repair of other associated defects (eg, TA [*Patients 3 and 4*]). Although in the case presented in the accompanying video we elected to include a patch at the distal aortic anastomosis and a proximal hood at the RV to PA conduit, the use of FVH as a reconstructive conduit may in some cases obviate the technical need for these steps (by allowing, eg, spatulation of the vein graft at anastomotic sites). In addition, the use of tissue from a single donor may limit antigenic exposure in complex patients for whom a subset may ultimately require transplantation.

The durability of this repair strategy has not been established. In this series, no patient required reintervention on the reconstructed aortic arch

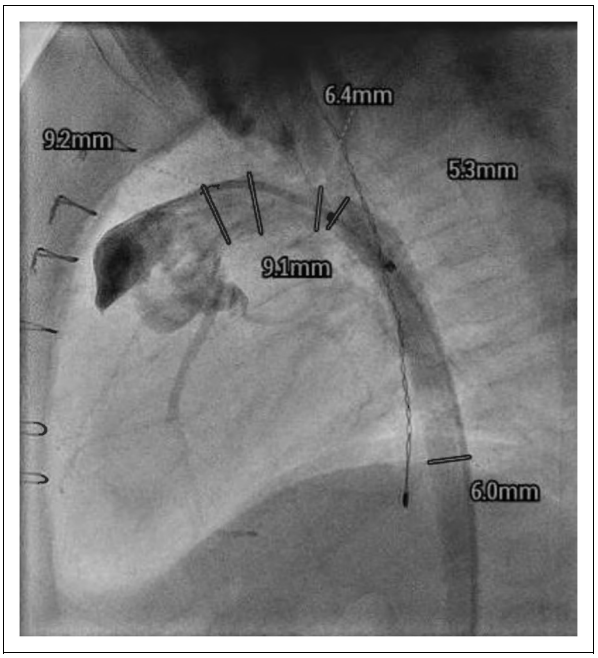

Figure 2. Catheterization (Patient 1, seven months postoperatively) demonstrating unobstructed neoaortic arch.

at the time of the last follow-up; however, this is limited by the lack of long-term outcome data. On the other hand, the use of FVH as a neoaortic conduit has been described in a large series of patients with hypoplastic left heart syndrome who underwent Norwood reconstruction, with results suggesting an acceptable growth profile and rates of stenosis.[3] Therefore, it is reasonable to expect that FVH aortic arch reconstruction could be a feasible strategy in highly selected neonates with high-risk arches. However, the ultimate long-term fate of the FVH conduit is unknown, and several possibilities of conduit growth in relation to patient somatic growth exist (FVH stenosis, aneurysmal dilation, proportional growth, and absence of conduit growth with subsequent size mismatch). As such, it must be emphasized that additional long-term data are needed to characterize long-term outcomes and potential size mismatch or dilation of the FVH conduit as patients grow.

In summary, nvFVH may be used successfully as a reconstructive aortic conduit in neonates with aortic arch obstruction who are undergoing complex biventricular repairs. We feel that FVH reconstruction may be most advantageous in the following groups of patients: (1) patients with a history of prematurity; (2) neonates at high risk for neurologic complications who require minimized ACP times; (3) prostaglandin-dependent neonates requiring arch reconstruction in the setting of other high-risk features; (4) those with compromised ventricular function, coronary anomalies, or moderate or more severe atrioventricular valve dysfunction; and (5) those with highly abnormal aortic arch and head vessel anatomy. The use of nvFVH provides an important alternative to conventional arch reconstruction and may permit simplification and expediting of repair in selected patients with complex cardiac malformations.

Authors' Statement

This report was approved by the Institutional Review Board (protocol HSC-MS-21-0563). Permission was granted by the patients' families to publish the case report.

Declaration of Conflicting Interests

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Supplemental Material

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Hybrid Norwood for Hypoplastic Left Heart Syndrome With Rare Aortic Arch Anatomy

W. Hampton Gray, MD[1], Robert A. Sorabella, MD[1], C. Mason Berry, MS[1], Luz A. Padilla, MD, MSPH[1], Mark A. Law, MD[2], and Robert J. Dabal, MD[1]

[1] Division of Cardiothoracic Surgery, Department of Surgery, University of Alabama at Birmingham; Birmingham, AL, USA
[2] Division of Pediatric Cardiology, Department of Pediatrics, University of Alabama at Birmingham; Birmingham, AL, USA

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Abstract

We describe the hybrid Norwood as first-stage palliation for a patient with hypoplastic left heart syndrome, right aortic arch, right descending aorta, bilateral ductus arteriosus, and left innominate artery arising from the left ductus.

Introduction

Hypoplastic left heart syndrome (HLHS) with a right aortic arch (RAA) and right descending aorta (RDA) is a rare association. Traditional Norwood reconstruction for HLHS is prohibitive with an RAA and RDA because the aortopulmonary amalgamation (APA) lies on the opposite side of the rightward reconstructed aortic arch, precluding typical reconstruction. There are few reports regarding alternative surgical techniques in this rare subset of patients.[1–8] However, to our knowledge, no reports of a hybrid approach for this anatomic substrate in patients with HLHS exist. We describe a patient with HLHS and unusual aortic arch anatomy who underwent a hybrid procedure as first-stage palliation.

Case Description

A full-term newborn with a prenatal diagnosis of HLHS weighed 2.9 kg at birth. Postnatally, the child was found to have HLHS, mitral and aortic atresia, RAA, RDA, bilateral ductus arteriosus, left innominate artery originating from the left ductus arteriosus, and a small, diminutive ascending aorta less than 2 mm. Given the anatomical complexity, a computed tomography angiogram (CTA) was performed, which confirmed the above anatomy (Figure 1). We discussed this child at our multidisciplinary conference and due to several complicating factors (extremely small ascending aorta <2 mm, RAA with RDA, left innominate artery off the left ductus arteriosus, moderate tricuspid regurgitation [TR]), we elected a hybrid Norwood as first-stage palliation.

On day 10 of life, the child underwent surgery, following a median sternotomy, the pericardium was opened, and the anatomy was confirmed. The right and left pulmonary arteries (PAs) were dissected free, and a small portion of a 3.5 mm GORE-TEX® shunt was trimmed, opened, and passed around each PA distal to the takeoff of each respective ductus. These were tailored to the appropriate size and secured to each PA to prevent future migration. Next, a purse string suture was placed in the main PA, and an appropriate-sized sheath was placed by our interventional cardiologist for antegrade ductal stent placement. First, a 10 mm × 20 mm Protégé™ self-expanding stent was implanted into the right ductus arteriosus, followed by a 5 mm × 18 mm Resolute Onyx™ coronary drug-eluting stent into the left ductus arteriosus. Both stents were confirmed to be in a good position on post-angiogram assessment. The chest was left open and delayed sternal closure occurred on postoperative day 2. Echocardiogram demonstrated good right ventricular function, unobstructed bilateral ductal stents, unobstructed atrial septum, and moderate tricuspid insufficiency. CTA performed postoperatively is shown in Figure 2. There was one episode of necrotizing enterocolitis postoperatively. The patient recovered without issue and was extubated, and tolerated enteral nutrition with adequate weight gain. Balloon atrial septostomy was performed two weeks following the hybrid for evidence of restrictive atrial septum (the gradient went from 10 to 1 mm Hg in the cath lab). The patient was discharged home in stable condition and remains on a dual pathway (listed as 1B vs a potential comprehensive stage II pending favorable pre-Glenn cath data) given the moderate degree of TR. At last follow-up, the child continues to gain weight (currently 5.6 kg) with saturations in the low 80s and echocardiogram demonstrating good ventricular function, moderate TR, unrestrictive atrial level shunt, and bilateral PA band gradients around 4 m/s. Both parents provided permission to publish this case report.

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Corresponding Author:
W. Hampton Gray, Division of Cardiothoracic Surgery, Department of Surgery, 1700 6th Avenue South, WIC 9100, Birmingham, AL 35223, USA.
Email: whgray@uabmc.edu