HANDS ON

How to perform transconduit and transbaffle puncture in patients who have previously undergone the Fontan or Mustard operation

Jae-Sun Uhm, MD, PhD,* Nam Kyun Kim, MD,† Tae-Hoon Kim, MD,* Boyoung Joung, MD, PhD,* Hui-Nam Pak, MD, PhD,* Moon-Hyoung Lee, MD, PhD*

From the *Department of Cardiology, Severance Cardiovascular Hospital, Yonsei University College of Medicine, Seoul, Korea, and †Department of Pediatric Cardiology, Severance Cardiovascular Hospital, Yonsei University College of Medicine, Seoul, Korea.

Introduction

The incidence of arrhythmia is high in patients who have undergone a surgical procedure for complex congenital heart disease.† Catheter ablation is a good therapeutic option to achieve a cure for tachyarrhythmia or a decrease in tachycardia burden. However, there are considerable limitations for a catheter approach to the heart in patients who have undergone a lateral tunnel or extracardiac conduit Fontan operation or an atrial switch operation (eg, Senning operation or Mustard operation).‡ In these patients, a transconduit or transbaffle puncture is needed for electrophysiological procedures.¶ A transconduit or transbaffle puncture is a challenging procedure because of the hardness of the conduit (or baffle) wall and unusual anatomy. We describe technical tips for transconduit and transbaffle puncture in patients who underwent lateral tunnel or extracardiac conduit Fontan operation or Mustard operation.

Fontan operation and atrial switch operation

The Fontan operation is performed for palliation in patients with a single functional ventricle.¶ In patients with Fontan circulation, the superior and inferior venae cavae (SVC and IVC) are connected to the pulmonary artery and the single functioning ventricle serves as a pump for systemic circulation. In the first-generation Fontan operation, the right atrial appendage is connected to the pulmonary artery (atriopulmonary connection Fontan operation). However, right atrial enlargement has often developed in patients with an atriopulmonary connection Fontan pathway. Circulation efficacy has been decreased and atrial arrhythmia has frequently developed because of an enlarged right atrium. In the second-generation Fontan operation, the IVC is connected to the pulmonary artery with the lateral tunnel in the atrium. The lateral tunnel is made of the atrial lateral wall and a graft in the atrium. However, right atrial enlargement and long suture lines have contributed to atrial arrhythmia in patients with a lateral tunnel Fontan pathway. In the third-generation Fontan operation, the IVC is connected to the pulmonary artery with an extracardiac conduit along the lateral wall of the right atrium. The lateral tunnel and extracardiac conduit are usually made of the pericardium or expanded polytetrafluoroethylene (ePTFE, Gore-Tex, W. L. Gore and Associates, Newark, DE). Since the 1990s, the extracardiac conduit Fontan operation has been a common procedure for a functional single ventricle.

The atrial switch operation has been performed in patients with complete transposition of the great arteries (TGA) or congenitally corrected TGA.§ The Senning operation and Mustard operation are typical procedures for atrial switch. In the Senning operation, venoatrial connection is switched using an autologous atrial flap. The Mustard operation was developed because of the technical complexity of the Senning operation. In the Mustard operation, the venoatrial connection is switched using an intra-atrial baffle made of autologous pericardium. In the 1980s, the atrial switch operation was replaced by the arterial switch operation (ie, Jatene operation) because of a high incidence of sinus node dysfunction and atrial tachyarrhythmia, and progressive right (systemic) ventricular failure in the atrial switch operation. Currently, the atrial switch operation is still performed as a part of double switch operation in patients with congenitally corrected TGA.

Before transconduit or transbaffle puncture

The patient’s prior surgical record should be meticulously reviewed before transconduit or transbaffle puncture is performed. It is more challenging and time-consuming to
puncture an ePTFE conduit than a pericardial conduit. A radiofrequency transseptal needle or an extrasteep Brockenbrough needle (XS series) and various sizes of angioplasty balloons need to be prepared before the procedure in patients with an ePTFE conduit. Preprocedural cardiac computed tomography (CT) should be performed in all patients with Fontan circulation and an intra-atrial baffle. Cardiac CT is very helpful for identification of the cardiac and vascular anatomy and 3-dimensional electroanatomic mapping (Figures 1A, 1B, and 1C). The appropriate conduit or baffle puncture site and direction can be estimated based on cardiac CT images. Transbaffle leak or fenestration should be meticulously sought on CT images (Figure 1C). Sternal suture wires are useful landmarks for determination of puncture site. The puncture level that has been determined on CT before procedure can be identified on real-time fluoroscopic imaging based on sternal suture wires. Intracardiac echocardiography (ICE) is essential for real-time guidance to the proper puncture site. Before the transconduit puncture, the inducibility of tachyarrhythmia should be confirmed. Conduit or baffle angiography is performed before the positioning of catheters. An electrophysiological catheter can be placed in the ventricle via a retrograde aortic approach. In patients with lateral tunnel Fontan circulation, atrial signal recording and atrial pacing can be performed with a catheter that is placed into the lateral tunnel via the femoral vein. In patients with extracardiac conduit Fontan circulation, the recording of atrial signals and sometimes atrial pacing can be performed with an esophageal catheter. Alternatively, a deflectable catheter can be inserted into the atrium through the femoral artery, aorta, ventricle, and atroventricular valve. In some patients with lateral tunnel Fontan circulation, the coronary sinus opens into the lateral tunnel. In these patients, a catheter can be placed into the coronary sinus through the IVC and lateral tunnel. In some cases, His bundle signals can be recorded from the aortic cusp with a deflectable catheter. After the inducibility of tachycardia is confirmed by a basic electrophysiological study, a transconduit or transbaffle puncture is performed.

**Stepwise approach to Fontan conduit puncture**

We highly recommend a stepwise approach to Fontan conduit puncture (Figure 2). An ICE catheter is placed into the Fontan pathway through the femoral vein. The angle between the Fontan conduit wall and the vertical line needs to be measured at the Fontan conduit angiography (Figure 3A). A stepwise approach includes 4 stages—needling, wiring, puncture dilation, and introducer insertion—and 9 steps. In the first step, the conduit puncture is performed using a Brockenbrough needle (BRK or BRK-1) and a Swartz introducer (SR-0 or SL-1). If the tip of the Swartz introducer slides along the conduit wall instead of into the puncture site, holding the dilator with a gooseneck or multisnare catheter is helpful in preventing the dilator from sliding along the conduit wall during conduit puncture as the second step (Figure 3B, 3C).

Holding the dilator by a snare is especially useful in patients with an angle <35° between the Fontan conduit wall and the vertical line. It is also useful in patients with levocardia and the left IVC because the Fontan conduit wall is not aligned with the IVC line. If the second step fails, an extrasteep Brockenbrough needle (XS series) is used as a third step. If an extrasteep Brockenbrough needle is not available in your electrophysiology laboratory, you can make an extrasteep needle with a regular Brockenbrough needle. The very distal tip of the stylet of the Brockenbrough needle should be cut with scissors so that the cut surface of the stylet tip becomes sharp. A hard conduit wall could be easily punctured with an assembly of the Brockenbrough needle and this cut stylet. If the third step fails, a radiofrequency transseptal needle is used as a fourth step. If the conduit wall seems to be too hard, a radiofrequency transseptal needle or an extrasteep Brockenbrough needle may be used for the first attempt. During the needling stage, ICE can visualize the needle position and the adjacent structures (Figure 3D). If contrast medium is injected through the Brockenbrough needle, the presence of puncture or not can be confirmed by not only fluoroscopic images but also observation of

![Figure 1](https://example.com/figure1.png) **Figure 1** Cardiac computed tomography of patients who underwent A: lateral tunnel (autologous pericardium), B: extracardiac conduit (expanded polytetrafluoroethylene) Fontan operation, and C: Mustard operation. A = atrium; B = baffle; F = Fontan conduit; LA = left atrium; LV = left ventricle; PVA = pulmonary venous atrium; RA = right atrium; RV = right ventricle; SVA = systemic venous atrium; V = ventricle.
bubbles with ICE. If the Swartz introducer can be inserted into the atrium at each step of the needling stage, the procedure has successfully achieved the end point of conduit puncture. If the puncture is too small for the introducer to be inserted into the atrium after conduit puncture, a 0.014-inch wire is inserted into the atrium via the Brockenbrough needle and the conduit puncture as a fifth step. The conduit puncture is dilated with angioplasty balloons (≥4.5 mm in diameter for a nonsteerable introducer and ≥6.0 mm in diameter for a steerable introducer) as a sixth step (Figure 3E). If the angioplasty balloon cannot pass through the conduit puncture, step-by-step dilation starting with a 2-mm angioplasty balloon is recommended. If the sixth step fails, the conduit puncture is dilated with noncompliant or cutting balloons as a seventh step. If the seventh step fails, the dilator for an Inoue balloon (Toray Corporation, Tokyo, Japan) is used for dilation of the puncture as the final attempt (Figure 3F). If the Swartz introducer can be inserted into the atrium at each step in the dilation stage, the procedure has successfully reached an end point of conduit puncture. When the Swartz introducer is inserted into the atrium through the conduit puncture as a ninth step, an electrophysiological procedure can be started.

Intra-atrial baffle puncture in patients who have undergone a Mustard operation
In the most cases, baffle puncture in patients who underwent a Mustard operation is not as challenging as an ePTFE extracardiac Fontan conduit puncture, because the most baffles are made of the pericardium. At first, baffle angiography needs to be performed (Figure 4A). If a transbaffle leak is present, the wire and the Swartz (or Mullins) introducer can be inserted via the transbaffle leak (Figure 4B). If transbaffle leak is absent, the baffle puncture needs to be performed with a Brockenbrough needle and Swartz introducer under fluoroscopic and ICE guidance. The angle of the Brockenbrough needle tip needs to be adjusted to 10°–30°, according to the angle between the IVC and the baffle wall. When the Swartz introducer is inserted into the pulmonary venous atrium through the baffle puncture, atrioatrial and an electrophysiological procedure are started.

Figure 2  A stepwise approach to Fontan conduit puncture: 4 stages and 9 steps. BRK = Brockenbrough; EP = electrophysiological; NC = noncompliant; RF = radiofrequency.
Figure 3  A Fontan conduit puncture in a patient with extracardiac conduit Fontan circulation made of expanded polytetrafluoroethylene. A: Fontan conduit angiography. B: Fluoroscopic image obtained while performing conduit puncture with a Brockenbrough needle and holding the dilator tip with a snare. C: The Brockenbrough needle and a Swartz introducer with the dilator tip held with a snare to prevent its sliding along the conduit wall. D: Intracardiac echocardiography of the conduit puncture. E: Conduit puncture dilation with an angioplasty balloon. F: Conduit puncture dilation with an Inoue balloon dilator. A = atrium; F = Fontan conduit; ICE = intracardiac echocardiography; LPA = left pulmonary artery; V = ventricle; θ = angle between the Fontan conduit wall and vertical line.
Anticoagulation during and after an electrophysiological procedure

During the procedure, the activated clotting time is maintained between 300 and 350 seconds by heparin infusion for prevention of thromboembolism. After the procedure, oral anticoagulation therapy needs to be maintained for ≥3 months for preventing blood clots from entering the systemic circulation through the conduit puncture. However, the optimal duration of oral anticoagulation therapy has not been determined, because the time for natural closure of transconduit or transbaffle punctures is not known.

Our experiences

We tried to puncture Fontan conduits and intra-atrial baffles in 15 cases and succeeded in 14 cases using the stepwise approach, from December 2013 to April 2017. The level of difficulty of conduit puncture is mainly dependent on the material of the conduit. ePTFE conduit puncture is more difficult and time-consuming than pericardial conduit or baffle puncture because the ePTFE conduit wall is harder than the pericardial conduit wall. The median and interquartile ranges of procedure times for pericardial and ePTFE conduit punctures were 11.5 minutes (10.0–14.8 minutes) and 81.0 minutes (52.3–117.5 minutes), respectively. In the failed case, we could not access to the Fontan conduit, because of the interruption of both femoral veins. Fontan conduit puncture through a region of overlap between the IVC and atrium beneath the ePTFE conduit was possible in some patients. However, the cavoatrial overlap area was insufficient in patients who had undergone an extracardiac conduit Fontan operation in adulthood. We have experienced no complications related to the procedure. Hemopericardium is possible but very rare, because the pericardium is usually adhesive due to prior cardiac surgery. Stroke or systemic thromboembolic events are also possible complications, because the

Figure 4  Baffle puncture in a patient who underwent a Mustard operation for transposition of the great arteries. A: Baffle angiography. B: Insertion of a Swartz introducer through the baffle leak. C: Intracardiac echocardiography of the atrium and baffle. D: Atriography. B = baffle; IVC = inferior vena cava; LPV = left pulmonary vein; PVA = pulmonary venous atrium; RV = right ventricle; SVA = systemic venous atrium; SVC = superior vena cava.
catheters are inserted into the systemic circulation. The intravenous administration of heparin and monitoring of activated clotting time are important.

An alternative to transconduit or transbaffle puncture
If a remote magnetic navigation system is available, the system may be used to place a mapping catheter and move it in the atrium through the femoral artery, aorta, and ventricle without conduit or baffle puncture. With the magnetic navigation, both procedure time and radiation exposure can be reduced.10

Conclusion
A stepwise approach can be safely applied to Fontan conduit puncture in patients with a lateral tunnel or an extracardiac conduit. Transbaffle puncture can be safely performed under fluoroscopic and ICE guidance in patients who underwent a Mustard operation.

Acknowledgments
The authors thank Yun Hee Chang, MD, a former cardiac surgeon from the Department of Thoracic and Cardiovascular Surgery, Seoul St. Mary’s Hospital, Catholic University of Korea, and Yu Rim Shin, MD, a cardiac surgeon from the Division of Cardiovascular Surgery, Severance Cardiovascular Hospital, Yonsei University College of Medicine, Seoul, Korea, for their counsel, supervision, and critical revision on descriptions of Fontan operations and atrial switch operations.

References