Percutaneous Transhepatic Venous Access for Catheter Ablation Procedures in Patients With Interruption of the Inferior Vena Cava

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Background—Catheter ablation of left-sided atrial arrhythmias generally is performed using a transfemoral venous approach through the inferior vena cava (IVC). In this report, we assessed the feasibility of a percutaneous transhepatic approach to ablation of left-sided atrial arrhythmias in 2 patients with interruption of the IVC.

Methods and Results—Patient 1 had atrial flutter in the setting of complex congenital heart disease and prior Fontan for univentricular physiology and a single atrium. Patient 2 had atrial fibrillation. Percutaneous hepatic vein access was obtained with ultrasound and fluoroscopic guidance. Transseptal catheterization was performed in patient 2. After the procedure, the hepatic tract in patient 1 was cauterized using a bipolar radiofrequency catheter, and an Amplatzer vascular plug was used in patient 2 to obtain hemostasis. Percutaneous hepatic vein access was achieved without complications. After electroanatomical mapping, a linear lesion was placed between the single atroventricular valve and the confluence of the hepatic veins in patient 1; this terminated the flutter, and bidirectional block was achieved. In patient 2, the pulmonary veins were electrically isolated using an extraostial approach, isolating the ipsilateral veins in pairs. Additionally, ablation of right-side atrial flutter was achieved by obtaining bidirectional block across a linear lesion between the tricuspid valve and confluence of the hepatic veins. Hemostasis of the transhepatic tract was attained in both patients.

Conclusions—In patients with interrupted IVCs, a percutaneous transhepatic approach is a feasible alternative for performing catheter ablation of complex left-sided arrhythmias. (Circ Arrhythm Electrophysiol. 2011;4:235-241.)

Key Words: congenital heart diseases ■ atrial flutter ■ atrial fibrillation ■ ablation ■ hepatic veins

The success of catheter ablation for the treatment of cardiac arrhythmias has expanded the patient population eligible to receive this therapy. Although catheter positioning typically is achieved through the femoral veins, there are patients in whom this approach is not possible because of venous occlusion or absence of the inferior vena cava (IVC) (Figure 1). In these rare situations, access to the heart may still be achieved with a superior approach, that is, with catheters descending from the superior vena cava (SVC) into the right side of the heart.1-9 Alternatively, left-sided heart arrhythmias may be accessed using a retrograde aortic approach.10 However, these approaches are less favorable due to diminished catheter control and stability.

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The percutaneous transhepatic approach is an alternative method of obtaining venous access when traditional means are not possible and can provide access to the heart from an inferior approach.11-19 This approach has been reported to be feasible, with a complication rate of <5%.20 Although this approach has most frequently been described in children undergoing invasive electrophysiology procedures,21-24 there are no such reports of its use in adults. In this article, we describe 2 patients with congenitally interrupted IVCs in whom the percutaneous transhepatic approach was successfully used to eliminate atrial arrhythmias.

Methods and Results

Percutaneous catheter ablation was performed in 2 patients with interruption of the IVC. The approach and considerations for obtaining hepatic venous access as well as for achieving hemostasis on completion of the procedure is described in detail for each patient.

Patient 1

A 36-year-old woman with a history of complex congenital heart disease and prior Fontan procedure had a 10-year history of symptomatic atrial flutter resistant to β-blockers, digoxin, sotalol, and amiodarone (Figure 2A). She was born with (1) a single ventricle, (2) a single atrium with pulmonary and hepatic veins but...
complete absence of the IVC, (3) a persistent left SVC, (4) a single atrioventricular (AV) valve, and (5) D-transposition of the great vessels. At the age of 3, the patient underwent a palliative subclavian-to-pulmonary artery anastomosis. And at the age of 28, she underwent (1) a Fontan procedure with a total cavopulmonary connection in Kawashima modification (pulmonary truck disconnection, anastomosis of the left-side SVC and azygous veins to the left pulmonary artery), (2) placement of a Carpentier AV ring, and (3) placement of an epicardial DDD permanent pacemaker.

The patient was brought to the electrophysiology laboratory to undergo catheter ablation of atrial flutter. Preprocedural CT imaging demonstrated the absence of an IVC and confirmed drainage of the hepatic veins directly into the single atrium (Figures 1B, 1C, and 2B). Initially, an attempt to access the single atrium using a retrograde aortic approach was unsuccessful likely because of the Carpentier AV ring. Accordingly, access to the single atrium was planned through a transhepatic approach.

The procedure was performed with conscious sedation. The international normalized ratio the morning of the procedure was 1.0. Femoral venous access was obtained, and a quadripolar catheter was placed in the azygous vein posterior to the single atrium; the far-field atrial electrogram served as a timing reference. The right upper abdomen was prepped and draped in a sterile fashion. Percutaneous transhepatic access was then obtained using a 22-gauge Chiba needle (EMcision Ltd; London, UK) placed below the right costal margin between the midclavicular and right anterior axillary line. The position and trajectory of the needle was guided by visualization of the hepatic vein with ultrasound (Figure 3A). The needle was advanced with intermittent aspiration and injection of contrast to document entry into the hepatic vein (Figures 3B, 3C, online-only Data Supplement Video 1). Once the vein was entered, a guidewire was placed into the single atrium and the needle exchanged for a standard 8-F vascular sheath (online-only Data Supplement Video 2). At this point, intravenous heparin was administered to achieve an activated clotting time of >300 seconds.

The procedure was performed using the Navistar RMT Thermo-cool catheter (Biosense Webster; Diamond Bar, CA) guided by the Niobe II magnetic navigation system (Stereotaxis; St Louis, MO). Initially, the 3D rendering of the cardiac anatomy was rapidly integrated with the electroanatomical mapping system (CARTO; Biosense Webster) by mapping the arch and descending aorta (Figure 2B, online-only Data Supplement Video 3). Using a combination of activation and entrainment mapping, the atrial flutter was identified to be a macro-reentrant circuit coursing around the AV annulus (Figure 2B, online-only Data Supplement Video 4). Importantly, the circuit was demonstrated to traverse through the isthmus between this single AV valve and the confluence of the hepatic veins as they enter the atrium. Accordingly, radiofrequency energy was delivered to create a linear lesion between the AV valve and the hepatic venous confluence (Figure 2B). Termination of the arrhythmia occurred during ablation, and the arrhythmia remained non-inducible. Additionally, isthmus block was demonstrated with differential pacing maneuvers using a duo-decapolar catheter placed within the single atrium (Figure 2C and 2D). The overall procedure time was 230 minutes and required 15 minutes of fluoroscopy.

At the end of the procedure, protamine was administered to reverse the heparin. The hepatic sheath was withdrawn from the lumen of the hepatic vein and positioned within the liver parenchyma just outside the site where the hepatic vein was entered (confirmed by contrast injection). A commercially available 5-F endovascular bipolar radiofrequency catheter commonly used for vascular occlusion (EMcision Ltd) was placed through this sheath into the hepatic tract (Figure 4A). Bipolar radiofrequency energy was applied (20 W) within the hepatic tract, thereby coagulating the adjacent hepatic tissue to achieve immediate hemostasis. No periprocedural complications occurred. Full anticoagulation with intravenous heparin and warfarin therapy was initiated 6 hours postprocedure. The patient had no recurrence of arrhythmias in the subsequent 18 months of follow-up.
Patient 2
A 58-year-old woman with a history of an aortic arch aneurysm with a Bentall procedure in 1976 had symptomatic drug-refractory paroxysmal atrial fibrillation. Because of severe depression of her left ventricular ejection fraction (28%), which was believed to be resulting from tachycardiomyopathy, she was scheduled to undergo a catheter ablation procedure. A preprocedure CT scan revealed the presence of a left-sided SVC and a dilated hemiazygous vein, the latter of which was highly suggestive of the absence of an IVC.

The international normalized ratio the morning of the procedure was 1.7. The procedure was performed under general anesthesia. Femoral venous access was obtained, and a decapolar catheter was used.

Figure 2. Electroanatomical map for patient 1. A, A 12-lead ECG demonstrates the clinical arrhythmia for patient 1—atrial flutter with 2:1 atrioventricular (AV) conduction. B, Integration of the 3D CT rendering of the single atrium for patient 1 with a CARTO electroanatomic map created using the Niobe II magnetic navigation system (also see online-only Data Supplement Video 3). Using a timing reference placed in the azygous vein, an activation map of the clinical arrhythmia was created and is displayed here. Regions with early activation are shown in red, whereas regions with late activation are shown in purple. The activation sequence was consistent with a macro-reentrant arrhythmia coursing around the AV valve. Areas with a good postpacing interval during entrainment are indicated by the green dots, whereas areas with poor postpacing intervals during entrainment are indicated by the blue dots. Ablation was performed in the isthmus between the single AV valve and confluence of hepatic veins entering the atrium. C, Demonstration of isthmus block with differential pacing. A duo-decapolar catheter is placed within the single atrium. The conduction time when pacing from electrode pair 9 to 10 (blue dot) to the electrode pair 5 to 6 (red circle) was 206 ms. D, Demonstration of isthmus block with differential pacing. A duo-decapolar catheter is placed within the single atrium. The conduction time when pacing from electrode pair 11 to 12 (blue dot) to the electrode pair 5 to 6 (red circle) was 186 ms. The presence of a conduction time when pacing from electrode pair 11 to 12 compared to 9 to 10 was consistent with block across the isthmus.

Figure 3. Ultrasound-guided approach for obtaining percutaneous hepatic vein access. A, A transcutaneous ultrasound probe with sterile covering is used to visualize a hepatic vein. The angulation of the percutaneous needle is oriented in a similar fashion to the imaging probe to facilitate access to the hepatic vein. B, Visualization of a hepatic vein with the transcutaneous ultrasound probe. C, The percutaneous needle tip (arrow) can be visualized with the ultrasound probe as it enters the hepatic vein. D, Confirmation of entrance into the hepatic vein can be achieved by injecting contrast through the percutaneous needle (arrow). If hepatic vein access is successful, then echocardiographic contrast can be visualized in the hepatic vein (see also online-only Data Supplement Video 1).
advanced through the right femoral vein. The catheter coursed to the left of the spinal column through an azygous vein, and then entered the right atrium (RA) through the persistent left-side SVC and coronary sinus (Figure 5A, online-only Data Supplement Video 5); the IVC was confirmed to be absent. Right internal jugular venous access was then obtained, and a second decapolar catheter was placed through the RA into a hepatic vein (Figure 5A, online-only Data Supplement Video 5).

Percutaneous hepatic venous access was obtained using a 7-in 22-gauge spinal needle (BD Medical; Franklin Lakes, NJ) under fluoroscopic and ultrasound guidance. Entry was obtained below the right costal margin between the midclavicular and right anterior
axillary line. The trajectory of the needle was similar to the angle required for the ultrasound transducer probe to visualize a hepatic vein. Additionally, a transesophageal echocardiogram probe was placed in the stomach, which also allowed for visualization of the needle and the hepatic vein. The decapolar catheter in the hepatic vein also served as a fluoroscopic guide to help direct the needle in the appropriate direction (Figure 5A, 5B, online-only Data Supplement Video 5). The needle was advanced with intermittent aspiration and contrast injection to determine when the vein was entered (Figure 5A, 5B, online-only Data Supplement Video 5).

After the vein was entered, an angioplasty guidewire was inserted through the needle and advanced into the RA (Figure 5B, online-only Data Supplement Video 5). The needle was then exchanged and serial dilation performed with a 6- and 8-F dilator. Then, the angioplasty guidewire was exchanged for a 0.035-in guidewire (Figure 5C, online-only Data Supplement Video 5) and an SL1 sheath subsequently placed in the RA. A 10 000-U heparin bolus was administered before performing transseptal puncture, and a heparin infusion was initiated to maintain an activated clotting time of >300 seconds. To minimize periprocedural complications, a single transseptal puncture was performed using fluoroscopic and transesophageal echocardiogram guidance. Because of difficulty crossing the interatrial septum, radiofrequency energy (20 W) was delivered to the hub of the transseptal needle to facilitate perforation. Once the SL1 was placed within the left atrium (LA), it was exchanged over a guidewire for a deflectable sheath (Agilis; St Jude Medical, Inc; Minneapolis, MN) (Figure 5, online-only Data Supplement Video 5).

An electroanatomical mapping system (NavX; St Jude Medical, Inc) and a multispline catheter (Pentarray; Biosense Webster) were used to create 3D geometric renderings of the various chambers of the heart (LA-pulmonary veins [PVs], RA, coronary sinus, and left-sided SVC) (Figure 6A, 6B, online-only Data Supplement Video 6). The multispline catheter was used because in addition to its ability to rapidly created geometry and collect electric information, its ability to conform to anatomy was particularly relevant in this patient whose anteroposterior LA dimension was particularly small. As shown in Figure 6A, 6B, and online-only Data Supplement Video 6, this patient has a quite flattened LA anatomy, and based on our experience with other patients with this anomalous atrial geometry, we believed that the multispline catheter would be easier to use than a standard circular mapping catheter.

Using an externally irrigated radiofrequency ablation catheter (Celsius Thermocool; Biosense Webster), lesions were placed in the periosteal region to electrically isolate the PVs in ipsilateral pairs (Figure 6A and 6B). PV isolation was confirmed with the multispline catheter. In addition, there was complete absence of pace capture (10 mV, 2 ms) on the ablation line.25 Additionally, in the RA, a linear lesion was placed in the isthmus region between the tricuspid annulus and confluence of the hepatic veins into the RA (Figure 6A and 6B). Bidirectional block was confirmed by differential pacing from the ostium of the coronary sinus and measuring the conduction time to 2 locations on the lateral RA and vice versa. Finally, ablation lesions were placed at the left-sided SVC. The overall procedure time was 330 minutes, and required ~35 minutes of fluoroscopy.

At the end of the procedure, protamine was given to reverse the heparin. The transseptal sheath was exchanged for a short, 8-F vascular sheath whose tip was positioned within the hepatic vein (Figure 4B, online-only Data Supplement Video 5). The vascular sheath was then withdrawn such that the tip was situated just outside of the hepatic vein lumen. An Amplatzer Vascular Plug (AGA Medical; Plymouth, MN) was placed within the lumen of the hepatic tract to achieve hemostasis (Figure 4C, 4D, online-only Data Supplement Video 5). In addition, Gelfoam sponge (Pfizer; New York, NY) was placed though the vascular sheath into the tract. No periprocedural complications occurred, and warfarin therapy was maintained throughout the periprocedural period. No arrhythmias were detected during the follow-up period (4 months), and the repeat left ventricular ejection fraction at 3 months postprocedure had improved to a near-normal level (45%).

**Discussion**

Congenital abnormalities of the venous system are rare but well described, with interruption or congenital stenosis of the IVC occurring in ~0.15% of the general population.26 In the most common variant of IVC interruption, the segment of the IVC between the hepatic and renal veins is absent, with blood from the liver typically draining directly into the RA through hepatic veins and that from the lower extremities draining into the RA through the ayzygous system (Figure 1A). Knowledge of this anatomic variation is vital because it allows invasive electrophysiologists to thoughtfully plan a percutaneous approach.

Alternative approaches of entry to the atria are possible when the IVC is not available. A superior approach through the SVC has been well described for invasive electrophysiology procedures, including atrial flutter and fibrillation procedures.1–9 However, this approach may be suboptimal for both of the procedures described herein. Variation in respiration may prevent optimal tissue-catheter contact during RA isthmus ablation.1 Transseptal access also may be challenging with a superior approach because of the lack of sheath support when positioning and puncturing through the fossa ovalis. Additionally, the lack of support from the lower rim of the fossa ovalis may increase the difficulty of performing ablation adjacent to the left inferior PV,8 and the tight curve required to ablate the right-side PVs also increases the difficulty of ablation in the antrum of the right-side PVs.9 In rare circumstances with IVC interruption, suprarenal branching may be present, with an IVC remnant draining into the hepatic veins, which subsequently drain into the RA.27 In this situation, one may access the RA with an inferior approach,
passing the long transseptal sheath through this anomalous venous system. However, this situation is exceptionally rare.

Another alternative is the retrograde aortic approach. However, this approach was not used in either of our patients because of the technical difficulty in placing the catheter across the Carpentier AV ring in patient 1 and the technical difficulty of placing continuous linear lesions to permanently isolate the PVs in patient 2. Of note, the LA-PV geometry was particularly challenging in patient 2 because of the minimal anteroposterior left atrial dimension (Figure 6A, 6B).

Percutaneous hepatic access has been used for achieving long-term vascular access in patients requiring hemodialysis, total parenteral nutrition, and chemotherapy. Additionally, the use of this approach for cardiac catheterization procedures has been well described in the pediatric literature. The large caliber of hepatic veins makes them well suited to accommodate sheaths used for percutaneous catheter ablation procedures. Additionally, the inferior approach increases catheter stability and is optimal for procedures such as RA isthmus ablation and transseptal catheterization and PV isolation.

From a safety perspective, a low complication rate has been reported for common noncardiac procedures (eg, portal venous catheterization and percutaneous transhepatic cholangiography) that use percutaneous hepatic venous access. Additionally, Shim and colleagues reported a complication rate of <5% when transhepatic venous access was obtained for invasive cardiac procedures in a pediatric population. However, this procedure must be performed with care to avoid complications. Specifically, transaminitis, hemorrhage, cholangitis, liver abscess, sepsis, hepatic vein thrombosis, gallbladder perforation, and pneumothorax may occur. Appropriate landmarking and use of imaging (eg, ultrasound and fluoroscopy) may minimize complications associated with this procedure.

In both of cases presented here, ultrasound guidance (transcutaneous and transesophageal) was useful to visualize the hepatic veins. In addition to minimizing radiation exposure, ultrasound is advantageous because (1) it allows for real-time visualization of the hepatic vein, thereby permitting the operator to select a suitable site to obtain percutaneous access; (2) it allows the operator to visualize the relationship between the needle and the vein to help orient the trajectory of the needle; and (3) it allows the operator to monitor for complications, such as a subcapsular hematoma. Such detailed soft tissue visualization is not possible with use of fluoroscopy alone. This approach also may minimize the number of punctures necessary to achieve access.

Varying approaches have been used to achieve hemostasis of the tract created in the liver parenchyma. Although some operators have simply used manual pressure or placed patients in the right lateral decubitus position, others routinely achieve hemostasis with the placement of intrahepatic coils or Gelfoam. In patient 1 of the present study, a novel method of achieving hemostasis was used, that is, bipolar radiofrequency energy to cauterize/coagulate the adjacent liver parenchymal tissue. This approach may be advantageous compared with the placement of coils or Gelfoam because it may avoid the potential complication of embolization of the coil or Gelfoam. A vascular plug was placed in the hepatic tract in patient 2. Care was taken to ensure that the plug was not placed within the hepatic vein itself where it could act as a nidus for thrombus, resulting in hepatic vein thrombosis. Regardless of the method used to achieve hemostasis, one must be vigilant for ongoing hemorrhage. CT and ultrasonography are useful diagnostic modalities to identify the presence of hemoperitoneum. Should this occur, a decision regarding the need for conservative management or surgical exploration is necessary. In both cases, our patients were monitored in an intensive care setting postprocedure because both had received anticoagulants.

In conclusion, percutaneous transeptal catheterization is a feasible alternative to performing invasive electrophysiology procedures when venous access is limited. The judicious use of preprocedural and intraprocedural imaging may facilitate the ease and safety of performing these procedures.

Disclosures
None.

References

**CLINICAL PERSPECTIVE**

Access to the cardiac chambers for cardiac electrophysiological procedures typically is achieved through the femoral venous approach. However, this approach may not be possible in patients with venous occlusion or congenital interruption of the inferior vena cava. In these situations, the percutaneous transhepatic approach may be used to access the cardiac chambers. In this study, 2 patients with congenital interruption of the IVC were successfully treated with the transhepatic approach to eliminate atypical atrial flutter and atrial fibrillation, respectively. The approach to obtaining access and methods for achieving hemostasis on completion of the procedure are described. The percutaneous transhepatic access is a feasible alternative to performing invasive electrophysiology procedures when venous access is limited. The judicious use of preprocedural and intraprocedural imaging facilitates the ease and safety of performing these procedures.
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SUPPLEMENTAL MATERIAL

Supplemental Online Video 1: Confirmation of entrance into the hepatic vein using ultrasound guidance.

Supplemental Online Video 2: Fluoroscopic images during percutaneous access in patient #1.

Supplemental Online Video 3: Aortic registration to facilitate integration of a pre-acquired CT scan of single atrium in patient #1.

Supplemental Online Video 4: Activation / propagation map demonstrating a macro-reentrant atrial arrhythmia around the single AV valve in patient #1.

Supplemental Online Video 5: Fluoroscopic approach to obtaining percutaneous trans-hepatic access to the left atrium and achieving hemostasis with deployment of a vascular plug in patient #2.

Supplemental Online Video 6: Fusion of a pre-acquired CT scan of the left atrium, right atrium, coronary sinus and left superior vena cava with an electroanatomic map created with the NavX system.