Reconstruction of Stenotic or Occluded Iliofemoral Veins and Inferior Vena Cava Using Intravascular Stents: Re-establishing Access for Future Cardiac Catheterization and Cardiac Surgery

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OBJECTIVES
The study evaluated the safety and efficacy of stent reconstruction of stenotic/occluded iliofemoral veins (IFV) and inferior vena cava (IVC).

BACKGROUND
Patients with congenital heart defects and stenotic or occluded IFV/IVC may encounter femoral venous access problems during future cardiac surgeries or catheterizations.

METHODS
Twenty-four patients (median age 4.9 years) underwent implantation of 85 stents in 22 IFV and 6 IVC. Fifteen vessels were severely stenotic and 13 were completely occluded. Although guide wires were easily passed across the stenotic vessels, occluded vessels required puncture through the thrombosed sites using a stiff wire or transseptal needle. Once traversed, the occluded site was dilated serially prior to stent implantation.

RESULTS
Following stent placement, the mean vessel diameter increased from 0.9 ± 1.6 to 7.4 ± 2.6 mm (p < 0.05). Twenty-one of 28 vessels had long segment stenosis/occlusion requiring two to seven overlapping stents. Repeat catheterizations were performed in seven patients (9 stented vessels) at mean follow-up of 1.6 years. Seven vessels remained patent with mean diameter of 6.4 ± 2.0 mm. Two vessels were occluded, but they were easily recanalized and redilated. Echocardiographic follow-up in two patients with IVC stents demonstrated wide patency. In four additional patients, a stented vessel was utilized for vascular access during subsequent cardiac surgery (n = 3) and endomyocardial biopsy (n = 1). Therefore, 13 of 15 stented vessels (87%) remained patent at follow-up thus far.

CONCLUSIONS
Stenotic/obstructed IFV and IVC may be reconstructed using stents to re-establish venous access to the heart for future cardiac catheterization and/or surgeries. (J Am Coll Cardiol 2001;37:251–7) © 2001 by the American College of Cardiology

Repeated cardiac catheterization or indwelling femoral lines following cardiac surgery may result in severe stenosis or complete occlusion of the iliofemoral vein (IFV) and/or inferior vena cava (IVC). Vascular access from the iliofemoral venous system for future cardiac catheterization or surgery may be compromised. This limitation of vascular access is particularly problematic in infants and young children with congenital heart disease who may require multiple cardiac surgeries and/or diagnostic and interventional cardiac catheterizations. The purpose of this study was to assess the feasibility of treating IFV and IVC stenoses or occlusions with intravascular stents in order to maintain vascular patency for future cardiac catheterization and surgery. Immediate and limited intermediate-term results of the patency of the stented veins are reported.

METHODS
During cardiac catheterization from May 1992 to June 1999, patients with a stenotic or occluded IFV and/or IVC who will need future cardiac catheterization or surgery were identified. Only those vessels cannulated and stented were included in this study. Angiographic data of the stented vessels was analyzed. Both pre- and post-stent minimum vessel diameters were compared using a paired Student t-test. Pressure gradients were invariably absent because of adequate venous collateral flow in the presence of a low-pressure system and hence were not included in our evaluation. All patients were treated with aspirin empirically for at least six months following stent implant. Stent patency was evaluated at subsequent cardiac catheterization or surgery. In addition, IVC stents were evaluated with two-dimensional (2-D) and Doppler echocardiography at the time of clinic follow-up.

Technique. Stents were implanted in the obstructed or occluded vessels using standard techniques (1–5). Modifications were made based on the specific vessel affected and whether severe stenosis or complete occlusion was found. Iliofemoral veins. If an IFV was severely stenotic but not occluded, an end hole catheter was advanced across the affected vessel and exchanged for a superstiff guide wire. Balloon dilation was performed initially to permit passage of a Mullins sheath (Cook, Bloomington, Indiana) for stent delivery and implantation.
If an IFV was completely occluded, the first indication was usually the inability to pass a wire into the IVC even though there was blood return through the percutaneous needle. A hand injection into the needle reveals venous collaterals draining into the paravertebral venous system. When this problem was encountered, careful review of the angiogram with emphasis on the very early phase of the injection in both the anteroposterior (AP) and lateral projections often revealed a small, tapering blind-end remnant of the superficial femoral vein (Fig. 1A). It is preferable to film the hand injection at 60 frames/s but no less than 30 frames/s to ensure recognition of this vessel remnant before the venous collaterals superimpose upon the occluded femoral vessel in the AP projection (Fig. 1B). This femoral vein remnant is easily missed because the remnant may be present in only one or two frames. The lateral projection is particularly useful because the femoral vein remnant takes an anterior course in contrast to the more posteriorly positioned paravertebral venous collaterals (Fig. 1C).

Once this vessel remnant was identified, an 0.018- or 0.025-in. (0.045- or 0.063-cm) stiff straight wire such as a Glidewire or the stiff end of a Teflon wire was advanced through the percutaneous needle as far into the vessel as possible. The percutaneous needle was exchanged for a 4–5F tapered dilator, which was also advanced as far as possible. The stiff dilator prevents buckling of the wire during its advancement. With the support of the stiff dilator, the wire was pushed into the occluded vessel in millimeter increments. A still-frame image from the angiogram was used as a roadmap to facilitate this procedure. Each time the wire was advanced further, the dilator was also advanced further over the wire. Keeping the dilator in place, the wire was removed and a small hand injection of contrast was performed into the dilator to assess for extravasation (Fig. 2). Often, contrast stains the surrounding thrombus defining the lumen of the occluded vessel. Multiple hand injections were performed until the wire traversed the occluded segment and contrast flowed freely in an unobstructed proximal segment of the vessel (Fig. 3). Once the dilator recanalized the occluded vessel, a stiff exchange length guide wire such as a Platinum Plus wire (Boston Scientific, Watertown, Massachusetts) was advanced through the dilator into the proximal IVC and the occluded vessel was serially dilated using dilators or balloons until the vessel lumen was large enough to accommodate a 7–9F Mullins sheath for stent delivery (Fig. 4). When a single stent was inadequate to cover the entire length of the stenotic segment, multiple overlapping stents were used (Fig. 5). To ensure the stents did not separate during expansion, at least a 2-mm portion was overlapped. A final injection of contrast into the stented vessel was performed to evaluate flow and residual venous collaterals (Fig. 6). Often, the diagnostic component of the cardiac catheterization was carried out through the long Mullins sheath before proceeding with stent implantation of the occluded vessel.

During stent implantation of the femoral veins, a clamp was positioned on the surface of the groin corresponding to the level of the inguinal ligament defining the caudal limit for stent implantation (Fig. 5). A percutaneous needle was also left on the surface of the groin, parallel to the course of the femoral vein, to determine the level at which the tip of the needle may enter the stent (Fig. 7). Often, the most caudal edge of the stent was positioned such that its inferior edge would permit entrance with a femoral percutaneous needle. This strategy was designed to allow recanalization with a needle should the stent become occluded in the future. Using the AP and lateral projections, one can advance a percutaneous needle into an occluded vessel as

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**Figure 1.** (A) This 5.3-kg infant with hypoplastic left heart syndrome s/p Norwood I operation underwent a pre-Glenn catheterization. Hand injection of contrast demonstrated complete occlusion of the left iliofemoral venous system, with contrast entering the paravertebral venous collateral circulation. (B) Careful evaluation of the early phase of the same injection demonstrated a tiny superficial femoral vein remnant (arrow) before filling by the superimposed paravertebral venous collaterals. (C) The same injection on the lateral projection showed the anterior position of the femoral vein remnant (arrow) compared to the posterior paravertebral collateral veins.
defined by the lumen of the stent. Further advancement with a wire within the stent will ensure no extravasation. On the lateral projection, the most caudally implanted stent was positioned such that it was not anterior to the bladder. The level of the most caudal edge of the stent was in the mid-portion of the bladder. At the end of the procedure, the hips were flexed to assess the stent position on the lateral projection (Fig. 8). This maneuver documented the absence of stent movement during hip flexion.

**Inferior vena cava.** The technique of stent implantation of stenotic IVC was similar to stenotic IFVs with one additional caveat. Hand injections of contrast were used to evaluate stent position in relationship to the renal vein orifices so as to avoid overlap (Fig. 9). Fortunately, IVC obstructions usually occurred distal to the entrance of the renal veins and not at the interrenal vein segment.

If a completely occluded IVC was encountered, a sheath was inserted into the right internal jugular vein and a second catheter was advanced through the right atrium to the site of the IVC occlusion. With the catheter positioned in the distal IVC as a “target,” a transseptal needle, Mullins sheath, and a dilator (Cook, Bloomington, Indiana) were advanced from the femoral vein directed toward the “target” catheter superiorly under fluoroscopic guidance in both AP and lateral projections. Contrast was hand-injected into the dilator after the wire was removed, demonstrating no extravasation. Note the length of the occluded segment, which extended from the left superficial femoral vein to the midportion of the IVC just below the renal veins (arrows).

Through a 4F dilator, a stiff 0.018-in. (0.0457-cm) wire was carefully pushed into the occluded vessel in millimeter increments followed by advancement of the dilator. The wire and dilator should follow the expected course of the IFVs in both AP and lateral projections. Contrast was hand-injected into the dilator after the wire was removed, demonstrating no extravasation. Note the length of the occluded segment, which extended from the left superficial femoral vein to the midportion of the IVC just below the renal veins (arrows).

The wire and dilator were advanced beyond the occluded segment. Contrast flowed freely into the patent IVC and the renal veins (arrow).

An exchange guide wire was passed across the recanalized vessel, and balloon dilation of the entire occluded segment was carried out initially.

Seven overlapping stents were implanted. A clamp was placed on the surface of the groin corresponding to the level of the inguinal ligament (dashed line), which defined the caudal limit for stent implant. The three most inferior overlapping stents are shown here.
lateral projections. To evaluate for extravasation, small increments of needle advancement were followed by small hand injections of contrast into the needle. Once contrast was seen to flow freely within the IVC beyond the occluded segment, the long sheath and dilator were advanced cephalad across the occluded segment. The needle was removed and an exchange guide wire was inserted into the dilator and used for balloon dilation and stent implantation.

RESULTS

Patient profile. Twenty-four patients were included in our study. The median age was 4.9 years (range 0.2 to 12 years) and weight was 15.9 kg (range 5.3 to 41.6 kg). Bilateral IFV occlusion or obstruction was found in 10 patients. A unilaterally affected iliofemoral venous system was seen in 11 patients. The IVC occlusion or obstruction was identified in six patients, three of whom had combined IFV and IVC obstruction.

Indications for stent implantations included the need for additional cardiac catheterizations (12 patients) and future cardiac surgery (11 patients). One patient who developed acute renal failure and hepatic dysfunction two days following cardiac surgery required a stent to open an acute proximal IVC occlusion.
Stent data. Eighty-five Palmaz stents (Johnson & Johnson Interventional Systems, Warren, New Jersey) were implanted in 28 vessels in 24 patients. Severe stenosis was present in 15 vessels, while complete occlusion was encountered in 13 vessels. Eighteen right IFVs received 65 stents and four left IFVs received 12 stents. In the IVC, seven stents were implanted in six vessels (4 occluded, 2 severely stenotic). Stents used included the Palmaz P-154, P-204, P-294, P-394, and P-308. No complications were encountered during the stent procedures in 23 patients. In one patient, mild extravasation of contrast was noted during passage of the wire across an occluded left IFV. However, the vessel was successfully traversed and stented without subsequent problems.

The mean minimum diameter of the vessels before the stent procedure was 0.9 ± 1.6 mm increasing to 7.4 ± 2.6 mm after stent placement (p = 0.0001). Long segment stenoses or obstructions were found in 21 of 28 vessels (75%), which required two to seven overlapping stents.

Follow-up. To date, follow-up data was available on 15 of 28 stents (12 of 24 patients). Cardiac catheterization was performed in nine stented vessels (7 patients) at median follow-up of 0.92 years (range 0.44 to 2.17 years). These vessels included right IFV (4 patients), left IFV (2 patients), and IVC (3 patients). Seven stented vessels were widely patent and lined with a neo-intimal layer measuring 0.5 to 2.8 mm in thickness (mean 1.3 mm). Two stented vessels were completely occluded, one of which was a stented IVC with a large venous collateral bypassing the stented segment. Interestingly, this patient also had a stented left femoral vein that remained widely patent. The second occluded vessel at follow-up was a stented left IFV. This particular patient originally had an occlusion in the left IFV that extended into the distal IVC and who received several overlapping stents. Fortunately, the distal IVC stent remained patent with venous collaterals entering into the stented segment of the IVC. In both patients, the occluded stents were recanalized using a stiff wire and redilated using additional stents.

Three patients underwent cardiac surgery between one week and 12 months following the stent procedure. At the time of surgery, the stented vessels were cannulated and used for central access. In addition, a stented vessel in a post–cardiac transplant patient was utilized for repeated endomyocardial biopsies. Although no angiograms were performed to confirm patency of these stented vessels, the fact that they were successfully cannulated would imply patency.

In two patients with IVC stents, echocardiographic follow-up was obtained at 25.2 and 51 months after implant. Both stents were in good position, and IVCs remained widely patent as demonstrated by 2-D and Doppler imaging. Therefore, 13 of 15 stented vessels (87%) were found to be patent at follow-up. Two occluded vessels were successfully recanalized and redilated. Recanalization was facilitated by presence of the stent within the vascular lumen.

DISCUSSION
Obstructed IFV and IVC: Causes, symptoms, and incidence. In children with congenital heart defects, iliofemoral venous stenosis or occlusion may result from prolonged indwelling catheters following cardiac surgery or repeated use for cardiac catheterization. In cases where catheter-based interventions are performed, often larger sheaths are necessary. When these procedures are performed in infants and young children, the iliofemoral venous system is highly susceptible to the development of stenosis or occlusion. Occasionally, the distal IVC also becomes stenotic or occluded, as seen in our cohort. Except for an occasional dilated superficial vein noted in the lower abdomen and pelvic region, a stenotic or occluded IFV is usually not accompanied by any clinical signs or symptoms. The deep femoral veins remain patent and venous collaterals will drain blood from the affected leg via the paravertebral venous system to the proximal IVC, often at the level of the renal veins. Therefore, true incidence of iliofemoral vein obstruction is not known. Although no data indicate that leg growth and development are compromised by a stenotic or occluded IFV, access to the heart from the superficial femoral vein may become limited if not impossible. In contrast to children with congenital heart disease, IVC obstruction presenting in adults is primarily due to abdominal and pelvic malignancies, and results in IVC syndrome (leg pain, edema, venous ulceration) (6). Surgical recanalization is often ineffective, and angioplasty alone exhibits a high restenosis rate (7–10).

Stent use of congenital heart disease. The use of intra-vascular stents for a variety of vascular stenoses in congenital heart disease is well established (1–5,11–20). Mullins et al. and others have reported the safe and effective use of the Palmaz stent to treat stenoses in branch pulmonary arteries and large systemic and pulmonary veins (1–5,11–15). Stent implantation to maintain patency of the ductus arteriosus and stent dilation of renal artery stenosis, coarctation of the aorta and various surgically created baffles have also been reported (16–20). Though there is literature on stent dilation of stenotic IVC (21,22), there are only scant reports documenting the use of stents to treat obstructed IFVs in adults (6), and to our knowledge there are no reports of recanalization and stent implantation for a completely occluded IVC or IFV. This is particularly important in patients with congenital heart disease who require femoral venous access for future cardiac surgeries and/or cardiac catheterizations. Furthermore, many of the interventional catheterizations performed in this group of patients require more than one venous access.

Alternative vascular access. When obstructed IFVs are encountered during a cardiac catheterization, alternative vascular access is available. Access to the heart from the internal jugular vein can be easily performed, but manipulation of catheters from the neck is more difficult, and the patient’s airway may be compromised during the procedure.
Larger sheaths required for interventional procedures and additional radiation to the operator render the internal jugular vein route less desirable. Others have reported alternative access to the heart, including the transhepatic and translumbar route (23–27). Direct transthoracic puncture to the heart has also been reported (28–30). All of these techniques have higher risks and potential complications. Therefore, recanalizing and maintaining femoral vein patency using stents would be highly desirable in patients who will require additional cardiac surgeries or catheterizations.

**Anticipation and preparation for obstructed femoral venous access.** Due to the lack of symptoms in obstructed IFVs, the physician performing cardiac catheterizations is often unprepared to treat this vascular problem. Typically, one encounters this complication at the time of a routine cardiac catheterization, when, during venous access attempts, the needle “draws” blood, but the guide wire cannot be advanced. The diagnosis of femoral venous stenosis or occlusion is confirmed only by a hand injection of contrast into the needle under fluoroscopy. When the paravertebral collateral venous flow is noted, further attempts to gain access from the affected leg are abandoned and the contralateral leg or another venous route is used. For routine diagnostic catheterization, single femoral venous access is adequate. However, this can be problematic when more than one venous access site is necessary for certain interventional procedures or when the contralateral IFV is also compromised. Hence, anticipation and preparation for repair of this type of vascular stenosis is important, especially in patients in whom cardiac surgeries and/or catheterizations were carried out at a young age.

Whenever a remnant of an occluded superficial femoral vein is encountered (prior to superimposition by the contrast in the paravertebral veins), our experience has indicated successful recanalization in all cases. Even when no remnant is found, recanalization using the previously described technique is still possible, but not in all cases. Because this was a retrospective study, the success rate in recanalization of an occluded femoral vein without a remnant vessel remains undetermined. Based on our experience, we estimate an approximate 60% success rate. In the “nonsuccessful” group, we simply could not traverse the occluded segment and proceed with an alternative route of access to the heart. No complications were encountered in the attempts at recanalization.

**Follow-up and future concerns.** Long-term patency of these stented vessels has not been determined at this time. However, the most caudally implanted stent is positioned such that a percutaneous needle can reach the most inferior edge of the stent. In the event the stent becomes completely occluded, under biplane fluoroscopic guidance, a needle can recanalize an occluded intravascular stent without risk of extravasation. This was demonstrated in two patients in whom stent occlusion was found at routine follow-up cardiac catheterization. Both stents were recanalized and redilated successfully, and access to the heart was achieved for cardiac catheterization.

Another concern is the potential for further dilation after stent implantation as the child grows. Although we do not have data on further dilation of stents in the IFVs and the IVC, further dilation of implanted stents in the other vessels has been reported in both animal and clinical studies (30–32).

**Conclusions.** In summary, a stenotic or occluded IFV or IVC can be traversed with a wire and dilated with a stent safely and effectively. The stented vessels can provide venous access for future cardiac catheterization or surgery. The majority of IFV and IVC stents (87%) have remained patent at intermediate-term follow-up. Those stents that have become occluded can be easily recanalized and redilated to re-establish venous access to the heart.

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### REFERENCES


