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The contemporary hybrid operative procedure for incapacitating post-thrombotic iliofemoral and vena caval obstruction improves procedural outcomes

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ABSTRACT

Objective: Chronic, post-thrombotic iliofemoral and inferior vena caval obstruction is associated with debilitating morbidity. Venoplasty and stenting are often successful; however, in the presence of a diseased or occluded common femoral vein (CFV), failure is common. A hybrid operative procedure of open surgical CFV endovenectomy and endoluminal recanalization or bypass of the obstructed iliofemoral and vena caval segments has been developed and modified. The purpose of this report was to assess the technical evolution of this procedure on operative complications.

Methods: Thirty-one patients undergoing CFV endovenectomy and proximal ipsilateral endoluminal reconstruction (iliac, inferior vena caval) or contralateral outflow were analyzed. The initial techniques of patient management were compared with the present contemporary techniques, evaluating procedural complications and failures. The contemporary procedure evolved to include routine axial imaging, preoperative venography through the popliteal vein, preoperative passage of a guidewire or catheter into the patent vena cava, placement of an ipsilateral popliteal vein sheath for intraoperative and postoperative anticoagulation, routine patch closure, routine arteriovenous fistulas, routine completion intravascular ultrasound, and long-term anticoagulation with warfarin to a target international normalized ratio of 3.0 to 4.0. Procedure-related complications were compared between the initial and contemporary techniques.

Results: Of 17 patients treated with the early techniques, 15 (88%) had major complications: 5 iliofemoral thromboses, 4 major wound bleeds, 4 wound infections, and 2 CFV stenoses requiring reintervention. One iliac vein rupture treated with a stent graft thrombosed. Of 14 patients treated with the contemporary techniques, 2 (14%; $P = .006$) had major complications: 1 bleed and 1 infected seroma. One intraoperative iliac vein rupture, treated with a second stent relining the first, remains patent.

Conclusions: Contemporary hybrid operative techniques for incapacitating post-thrombotic iliofemoral and vena caval obstruction increase procedural success and reduce complications compared with the initial approach. The contemporary techniques are recommended for patients undergoing hybrid operative management of post-thrombotic iliofemoral and vena caval occlusion involving the CFV. (J Vasc Surg: Venous and Lym Dis 2019;7:65-73.)

Keywords: Post-thrombotic iliofemoral venous obstruction; Post-thrombotic syndrome; Hybrid operative procedures; Endovenectomy; Iliofemoral venous stenting

Post-thrombotic obstruction of the iliofemoral venous system results in high venous pressures,[1] producing potentially severe lower extremity morbidity.[2,3] Venoplasty and stenting have been effective for relieving iliac vein and vena caval obstructions and occlusions.[4,5] However, these procedures fail if adequate inflow to the stents or outflow from the stents is not achieved. The common femoral vein (CFV) is the "gatekeeper" of the venous return from the leg as all of the main veins—femoral vein (FV), profunda femoris vein (PFV), and great saphenous vein (GSV)—drain into and through the CFV. Therefore, if obstruction of the CFV is not eliminated, compromised inflow to iliac veins or iliac vein stents remains.

The thrombus burden of iliofemoral deep venous thrombosis is large and frequently does not resolve when it is treated with anticoagulation alone. The acute thrombus evolves to a collagenous obstruction,[6] firmly adhering to the vein wall, obstructing the orifices of major vein branches draining into the CFV, and often obliterating its lumen. Once this stage is reached, percutaneous techniques inadequately restore luminal integrity or adequate inflow into the recanalized iliofemoral segment.

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We embarked on an interdisciplinary approach to recanalize the occluded iliofemoral venous system by addressing the inflow problem with surgical disobliteration of the entire CFV and the orifice of the PFV and endovascular recanalization of the occluded iliac veins and inferior vena cava (IVC) or bypass to the patent contralateral iliofemoral venous system if ipsilateral recanalization could not be achieved. Patients benefited from their restored venous drainage; however, significant and frequent procedural complications occurred with the early procedure. As our experience matured and the techniques were modified, notably fewer procedure-related complications were encountered. The aim of this report was to objectively assess the impact of the evolution of the contemporary hybrid techniques on procedure-related complications.

ARTICLE HIGHLIGHTS

- **Type of Research:** Single-center retrospective cohort study
- **Take Home Message:** Thirty-six venous reconstructions were performed in 31 patients with a hybrid technique of common femoral vein endovenectomy and iliofemoral and caval stenting (n = 30) or surgical bypass (n = 6). Preoperative imaging, arteriovenous fistula, regional, anticoagulation, and improved techniques resulted in a higher rate of procedural success in the last 14 patients, with a decrease in major complication rate from 88% (15/17) to 14% (2/14).
- **Recommendation:** The authors suggest using their contemporary hybrid operative technique for surgical treatment of incapacitating post-thrombotic iliofemoral and vena caval obstruction to increase procedural success and to reduce complications.

METHODS

From March 2008 through September 2016, there were 31 patients with incapacitating post-thrombotic iliofemoral obstruction involving the CFV who underwent hybrid operative procedures to restore unobstructed venous drainage from the involved leg to the patent vena cava. *Incapacitating* is defined as lower extremity pain and swelling with or without ulceration, causing disability and inability to maintain employment or to perform activities of daily life. The procedure-related complications were recorded and segmented by initial compared with contemporary techniques.

The initial technique is summarized in Table I. The modifications used in the contemporary procedure are summarized in Table II.

Initial technique. Bilateral venous duplex ultrasound examinations and air plethysmography were performed as part of the initial evaluation and routinely during follow-up, evaluating patency and reflux. Ascending phlebography, performed from the foot as part of the preoperative evaluation, occasionally provided additional detail. Magnetic resonance venography and computed tomography venography were not uniformly available and axial images were obtained selectively.

The majority of patients were taking warfarin, and the anticoagulation was discontinued 3 to 4 days preoperatively to allow the international normalized ratio (INR) to drift below 1.6. Direct oral anticoagulants were discontinued 24 hours preoperatively. Preoperative aspirin 81 mg/d and clopidogrel 75 mg/d were initiated 3 days preoperatively. Patients took chlorhexidine showers for 20 minutes twice daily beginning 3 days preoperatively, and a chlorhexidine skin preparation was used in all patients. All patients signed an informed consent.

All procedures were performed under general anesthesia. A cephalosporin antibiotic was infused at the time of skin incision. A longitudinal inguinal incision was performed to expose the entire CFV, 2 to 3 cm of the distal external iliac vein (EIV), and 2 to 3 cm of the PFV and FV.

A long venotomy of the entire CFV was performed, followed by an endovenectomy that requires sharp dissection to remove the firmly adherent and obstructing collagen.[6] Dissection was extended into the orifice of the PFV and GSV when indicated. Bovine pericardial patch closure was performed selectively.

A 10F sheath was brought into the inguinal wound through a separate stab wound in the upper thigh to permit a smooth, straight access to the iliofemoral venous system. The sheath was passed into the endovenectomized CFV, which was closed primarily or with a bovine pericardial patch, leaving the distal 3 mm of venotomy open, through which the sheath was inserted. The sheath was secured with a Dacron tape tourniquet placed around the CFV. A guidewire was then passed through the sheath and maneuvered through the obstructed iliac veins into the patent IVC. This often required an extended period of time.

Venoplasty and stenting were then performed from the EIV to the IVC. Attempts were made to avoid crossing the inguinal ligament with the stent. In patients with bilateral disease, the infrarenal IVC was invariably occluded. The occluded IVC was stented before the iliac veins using 20-mm balloon-expandable bare-metal stents. The iliac veins were dilated and stented from the distal EIV to the IVC. The EIV was stented with a 12- to 14-mm Wallstent (Boston Scientific, Marlborough, Mass) and the common iliac vein (CIV) with a 14- to 18-mm Wallstent. If rupture of the iliac vein occurred, it was treated by an appropriately sized stent graft (Viabahn; W. L. Gore & Associates, Flagstaff, Ariz). Completion venography was performed, followed by removal of the sheath and closure of the venotomy. Depending on the quality of the venous Doppler signal in the CFV, a decision was

Table I. Initial technique

Preoperative evaluation and preparation
1. Bilateral noninvasive evaluation with venous duplex ultrasound and air plethysmography
2. Selective axial imaging (computed tomography scan, magnetic resonance venography)
3. Ascending phlebograms of diseased leg: foot access
4. Chlorhexidine showers, 20 minutes two times daily × 3 days preoperatively
5. Discontinue warfarin 3 days preoperatively.
6. Discontinue direct-acting oral anticoagulants 24 hours preoperatively.
7. Aspirin 81 mg/d and clopidogrel 75 mg/d × 3 days preoperatively
8. Cilostazol 100 mg/day × 3 days preoperatively if prosthetic bypass is anticipated
Operative technique
1. Complete exposure of CFV, distal EIV, cephalad 2 to 3 cm of FV and PFV.
2. Control all side branches.
3. Systemic anticoagulation with UFH
4. "Test venotomy" of CFV after all clamps applied (to confirm that all venous inflow to CFV is controlled)
5. Extend the venotomy from the FV to the EIV.
6. Perform complete endovenectomy from FV to EIV.
7. Selective patch closure with GSV or bovine pericardium
8. Place large sheath into CFV through separate skin puncture distal to wound to ensure smooth, straight access for proximal recanalization.
9. Pass guidewire from CFV into patent IVC, balloon dilate, and stent.
10. Use 12- to 14-mm stents for EIV, 14- to 18-mm stents for CIV.
11. Stent from EIV to IVC. Stenting under the inguinal ligament was avoided.
12. If iliac vein rupture occurs, repair with covered stent.
13. Ensure that CIV stent extends into the patent IVC, completely treating the CIV obstruction but minimally compromising the orifice of the contralateral CIV.
14. If a guidewire cannot pass from the CFV into the patent IVC, construct a cross-pubic bypass.
15. If cross-pubic bypass is performed, use contralateral GSV if adequate or 10-mm externally supported PTFE graft to contralateral EIV.
16. Perform completion phlebography.
17. Selective small (3.5-4.0 mm) AVF from SFA to distal CFV
18. Measure CFV pressures before and after AVF is opened to be sure venous pressure does not increase with fistula flow.
19. Band autogenous AVF to 3.5 to 4 mm to ensure it does not enlarge over time.
20. Use 4-mm PTFE graft for prosthetic AVF, if necessary.
21. Spray wound with recombinant thrombin to improve hemostasis.
22. Place closed suction drainage catheter in base of wound.
23. Close wound with running absorbable suture to ensure hemostatic and lymphostatic wound closure. Avoid tape closure of skin.
Postoperative care
1. Wrap leg with cotton gauze and elastic bandage from base of toes to upper thigh.
2. Systemic anticoagulation with UFH through arm vein or foot vein
3. Oral anticoagulation with warfarin, first dose the evening of procedure; INR target of 2.0 to 3.0
4. Intermittent pneumatic compression bilaterally when patient is not ambulating
5. Continue aspirin 81 mg/d and clopidogrel 75 mg/d × 8 weeks, then discontinue clopidogrel, continue aspirin
6. Continue cilostazol 100 mg twice per day if prosthetic graft was used.
7. Predischarge venous duplex ultrasound to evaluate reconstruction. If abnormality or thrombus is found, intervene and correct.
8. Elastic compression stockings of 30 to 40 mm Hg ankle gradient to be worn daily
9. Postdischarge follow-up at 1 month, 3 months, 6 months, 9 months, and 12 months or as needed for new signs or symptoms

AVF, Arteriovenous fistula; *CFV,* common femoral vein; *CIV,* common iliac vein; *EIV,* external iliac vein; *FV,* femoral vein; *GSV,* great saphenous vein; *INR,* international normalized ratio; *IVC,* inferior vena cava; *PFV,* profunda femoris vein; *PTFE,* polytetrafluoroethylene; *SFA,* superficial femoral artery; *UFH,* unfractionated heparin.

made as to whether a small (3.5-4 mm) arteriovenous fistula (AVF) would be constructed from the superficial femoral artery (SFA) to the distal CFV. When an AVF was constructed, a 3.5-mm arterial punch was used to produce the arteriotomy and venotomy. A 2- to 3-cm segment of autogenous vein was used, usually harvesting a branch of the GSV to construct a two-anastomosis AVF. Bovine pericardium was wrapped around the AVF to prevent dilation. If autogenous vein was not available, a small piece of 4-mm polytetrafluoroethylene (PTFE) graft was used for the AVF.

On completion of the procedure, the wound was sprayed with recombinant thrombin. A 7 F closed suction drain was placed in the base of the wound. Wounds were closed in multiple layers with running absorbable sutures to achieve a hemostatic and lymphostatic closure. The skin was closed with 4-0 nylon or skin staples.

Standard intravenous anticoagulation was continued throughout the operation and postoperative period. Unfractionated heparin (UFH) was converted to warfarin to a target INR of 2 to 3 and continued indefinitely. Combined platelet inhibition was continued for 8 weeks, at which time clopidogrel was discontinued. Low-dose aspirin was continued.

If ipsilateral iliac vein recanalization could not be accomplished, a cross-pubic venous bypass was performed. A Palma procedure using the contralateral GSV

Table II. Contemporary technique: Modifications to initial technique

Preoperative evaluation and preparation of the patient
1. Axial imaging for all patients
2. Bilateral ascending phlebography through popliteal veins
3. Preoperative placement of sheath in popliteal vein (surgical side) for intraoperative and postoperative anticoagulation
4. Preoperative passage of guidewire and catheter through occluded veins into patent IVC
Operative technique
1. Patch closure of all veins using bovine pericardium
2. Transect catheter in CFV intraoperatively and pass guidewire into IVC to be used for iliocaval recanalization.
3. Extend stent into the patent or patched CFV above the SFJ.
4. Completion intravascular ultrasound in all
5. If cross-pubic bypass with 10-mm externally supported PTFE is required, transect CFV on donor limb and perform end-to-end anastomosis. Perform end-to-end anastomosis to stump of GSV at SFJ on recipient limb.
6. If cross-pubic bypass is constructed using the contralateral GSV, perform venography after vein is tunneled but before anastomoses.
7. Perform small (3.5-4.0) permanent AVF in all patients. Wrap autogenous AVF with bovine pericardium
Postoperative care
1. Postoperative anticoagulation with UFH at 600 to 700 IU/h through ipsilateral popliteal vein sheath × 4 or 5 days (patient ambulatory)
2. Long-term anticoagulation with warfarin; INR target of 3 to 4. After 6 to 12 months, INR target is reduced to 2 to 3. Consider converting to oral direct Xa inhibitor after 6 to 12 months.

AVF, Arteriovenous fistula; *CFV,* common femoral vein; *GSV,* great saphenous vein; *INR,* international normalized ratio; *IVC,* inferior vena cava; *PTFE,* polytetrafluoroethylene; *SFJ,* saphenofemoral junction; *UFH,* unfractionated heparin.

was the preferred technique. If the GSV was inadequate (<4 mm) or not available, a 10-mm externally supported PTFE graft was used, constructing the standard end-to-side anastomoses on donor and recipient veins. The recipient vein was often the EIV exposed through a suprainguinal incision for the graft to be positioned in a “lazy S” configuration.

Contemporary technique. Modifications of the contemporary technique began with preoperative axial imaging and a full noninvasive evaluation of all patients. All patients undergo bilateral ascending venography through the popliteal veins as part of the initial diagnostic evaluation to more clearly define the obstructive pattern of their proximal disease and the contralateral venous outflow (Fig 1). This often provided additional detail, such as better visualization of the PFV branches and partial recanalization of the proximal FV, CFV, or EIV not available from other studies, to assist in planning of the procedure.

In addition to combined platelet inhibition, in patients in whom a prosthetic bypass is anticipated, cilostazol 100 mg orally twice a day is initiated preoperatively and continued postoperatively to reduce the risk of neointimal fibroplasia.[7,8]

The day before the operative procedure, the patient has an ipsilateral popliteal vein sheath inserted with a guidewire passed through the iliofemoral occlusions and into the patent IVC. A 5-mm balloon dilation is performed to produce a channel through which a small catheter is passed from the popliteal vein into the IVC (Fig 2). Four of the five patients with vena caval occlusion had one guidewire passed from the right jugular vein through the iliocaval occlusion into one of the CFVs. This guidewire expedites intraoperative venoplasty and stenting and substantially reduces operating room time. Intraoperative anticoagulation is achieved by infusing UFH through the popliteal vein sheath, thereby obtaining maximal anticoagulant concentration in the target vein.

During the endovenectomy, the catheter in the CFV is exposed (Fig 3). After completion of the endovenectomy, the catheter is transected and a guidewire is passed into the IVC. The distal end of the guidewire is then passed into and through the 10F sheath that was brought into the wound through a separate stab incision in the thigh. The 10 F sheath is then guided into the iliofemoral segment as described before. Clamps on vein side branches remain in place. Stenting is performed as described previously; however, the distal margin of the stent is now extended beneath the inguinal ligament landing just above the saphenofemoral junction (SFJ) in the endovenectomized and patched CFV, ensuring that there is no residual obstruction in the CFV. If iliac vein rupture occurs, the venous stent is relined with a bare-metal stent after the proximal obstruction is eliminated (Fig 4). Intravascular ultrasound is now routine, ensuring that unobstructed drainage from the CFV into the IVC has been achieved.

All patients have a small, permanent AVF constructed from the SFA to the distal CFV. Postoperative anticoagulation with UFH infusion is continued through the ipsilateral popliteal sheath at 700 IU/h (or bilateral popliteal sheaths for bilateral procedures). Warfarin is initiated the night of the operation with a target INR of 3 to 4 for the first 6 to 12 months, after which the target INR is reduced to 2 to 3 or the patient is converted to an oral direct Xa inhibitor.

At the completion of the procedure, the patient’s leg is wrapped from the base of the toes to the upper thigh, allowing the intravenous tubing connected to the popliteal vein sheath to exit between the layers of the wrap. The patient begins to ambulate on postoperative day 1, with the popliteal sheath in place. UFH is continued for

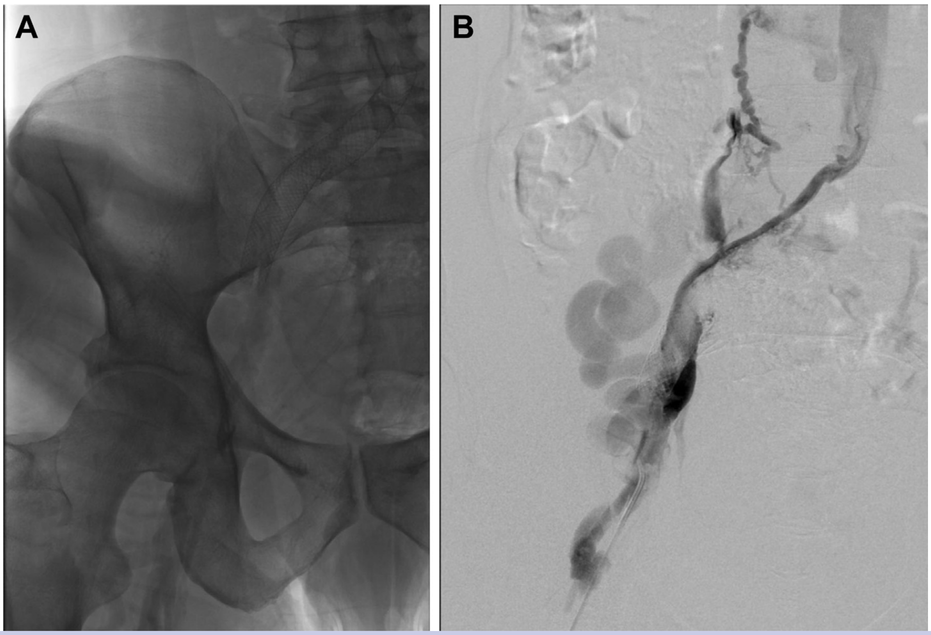

Fig 1. Preoperative venography comparing foot access **(A)** and popliteal vein access **(B)** in the same patient. Note improved detail using popliteal vein access.

5 days and the INR is in the therapeutic range, at which time the sheath is removed.

If preoperative passage through the occluded iliac veins was not successful (most commonly because of previously failed iliofemoral venous stenting), an endovenectomy, patch closure, and cross-pubic bypass with an AVF is planned, without intraoperative attempts at ipsilateral recanalization. If a cross-pubic bypass is required and a good-quality saphenous vein is available, it is mobilized, transected distally, and tunneled. A venogram is obtained before any anastomosis to ensure proper position, with no redundancy or kinking. The GSV to CFV anastomosis is performed as a 1-cm side-to-side anastomosis with the end of the GSV extending distally and anastomosed to the side of the SFA, thereby constructing an inline AVF. The AVF segment between the SFA and the CFV anastomoses is wrapped with a bovine pericardial patch to prevent enlargement of the AVF beyond its 3.5- to 4-mm initial size.

If a GSV is not available, a 10-mm PTFE graft is used. However, the CFV is transected after the endovenectomy is performed. The distal segment of CFV is patched, and an end-to-end anastomosis to the 10-mm PTFE graft is performed after the graft is tunneled (Fig 5). On the recipient leg, the GSV is transected at an angle near the SFJ, and an end-to-end anastomosis to the 10-mm graft is performed. This generally is a good size match and minimizes flow pattern disturbance as it is an end-to-end anastomosis. A small SFA to CFV AVF is constructed.

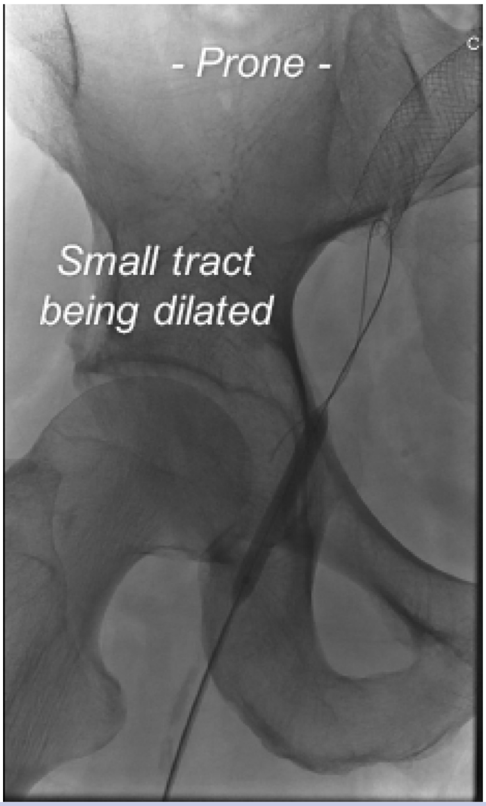

Fig 2. Placement of a guidewire and catheter 1 day preoperatively from the ipsilateral popliteal vein to the inferior vena cava (IVC). The small tract is being dilated with a 5-mm balloon, preparing the channel for catheter passage.

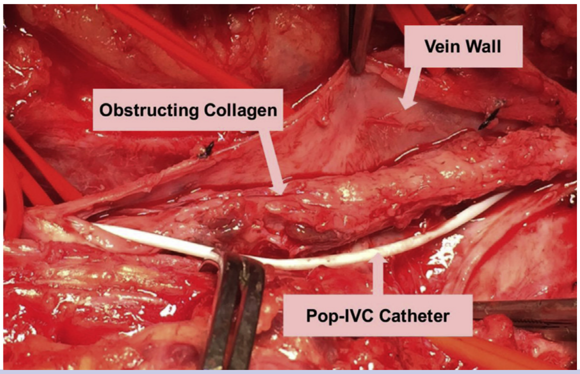

Fig 3. Intraoperative exposure of popliteal to inferior vena cava (*Pop-IVC*) catheter in the common femoral vein (CFV). Also visible is the core of obstructing collagen dissected from vein wall.

When a prosthetic is used, cilostazol is continued postoperatively. If a prosthetic is not used, cilostazol is discontinued in 8 weeks.

RESULTS

Thirty-six limbs in 31 patients underwent the hybrid operative technique of endovenectomy of the CFV with restoration of central venous drainage. All but two patients were C4 to C6 (clinical class of Clinical, Etiology, Anatomy, and Pathophysiology classification). Two patients had mild edema but incapacitating venous claudication. The mean time from acute deep venous thrombosis to the operative procedure was 6.7 years (range, 7 months-25 years).

Five patients had simultaneous bilateral procedures requiring recanalization of an occluded IVC. Thirty limbs had transluminal iliofemoral and vena caval recanalization, and six limbs required a cross-pubic bypass. One patient required a saphenopopliteal venous bypass in addition to a cross-pubic bypass to permit adequate venous drainage. Two cross-pubic bypass patients required the distal anastomosis (prosthetic graft) to be performed to the popliteal vein with construction of a popliteal AVF. Both remain patent at 1.5 and 7.5 years postoperatively.

The mean age was 46 years (16-69 years); 58% of patients were female (Table III). A procedure-related complication occurred in 61% of patients (Table IV), with 55% considered major. The distribution of procedure-related complications is summarized in Table V. The majority of all complications (83%) and major complications (87%) occurred in patients having the initial technique. Overall complications dropped from 94% (16/17) to 21% (3/14; $P < .001$) and major complications from 88% (15/17) to 14% (2/14; $P = .001$) when the contemporary modifications were used (Table V).

The specific major complications by procedure are listed in Table VI. Acute postoperative thrombosis was eliminated and wound bleeding and wound infection were markedly reduced as the contemporary modifications were adopted.

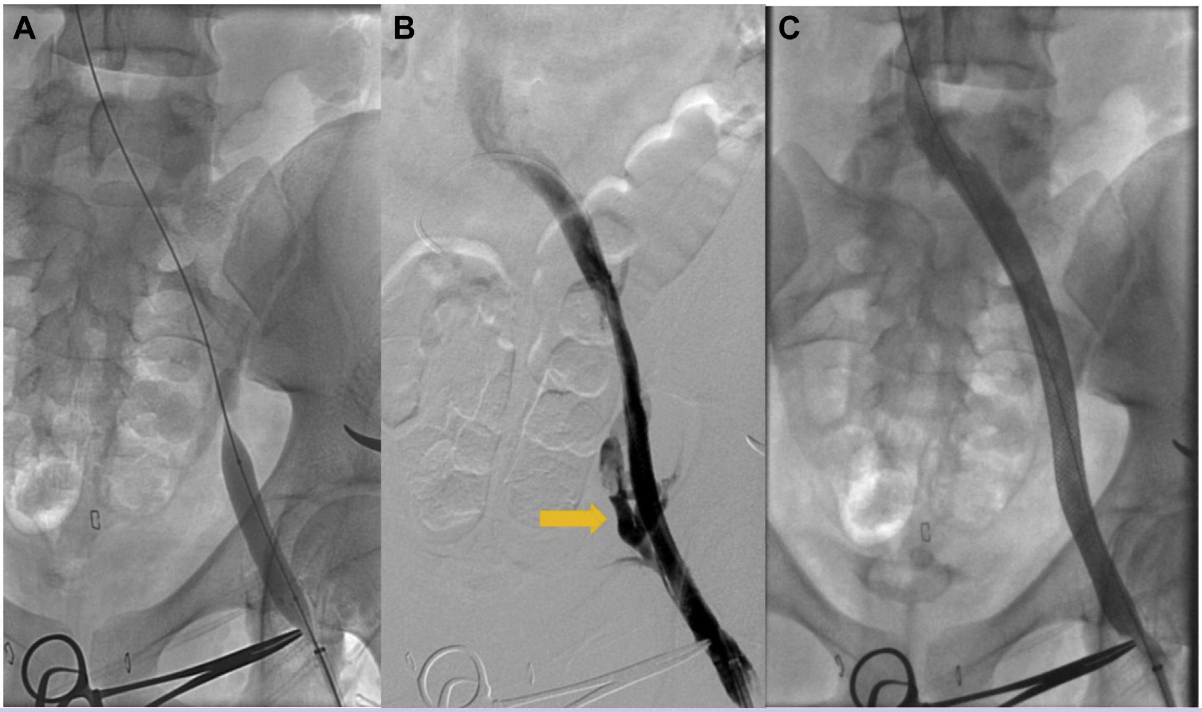

Fig 4. Intraoperative balloon dilation of distal external iliac vein (EIV; **A**) resulting in vein wall rupture (*arrow*) **(B)**. **C,** Vein segment with a bare-metal stent after correction of common iliac vein (CIV) stenosis. Figs 1 to 4 are from the same patient.

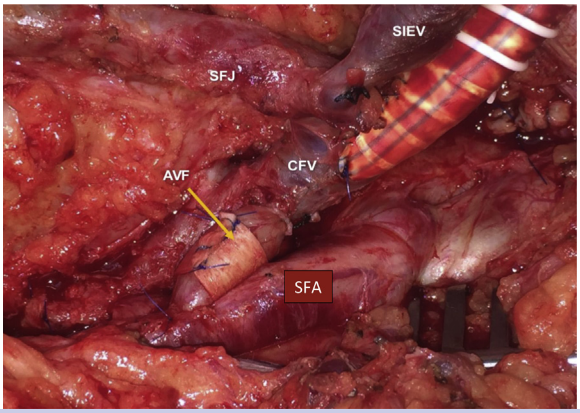

Fig 5. Intraoperative completion image following endovenectomy and cross-pubic bypass with 10-mm externally supported polytetrafluoroethylene (PTFE) graft. End-to-end PTFE to common femoral vein (*CFV*) anastomosis just cephalad to saphenofemoral junction (*SFJ*). SFA to distal CFV arteriovenous fistula (*AVF*) is wrapped with bovine pericardium to prevent enlargement and vessel dilation. *SFA,* Superficial femoral artery; *SIEV,* superficial inferior epigastric vein.

DISCUSSION

The CFV is the common channel through which venous blood returns from the lower extremity. Its contribution to success or failure of venous decompression is often underappreciated. Our observations indicate that fully restoring unobstructed venous drainage from the PFV to the patent IVC results in a meaningful clinical improvement in patients with chronic post-thrombotic iliofemoral obstruction. Stenting of a diseased distal CFV is likely to result in failure because of persistently inadequate inflow into the iliofemoral segment, as drainage from the PFV will be obliterated and the FV is often diseased.

However, the early procedure-related complications of the initial technique were disappointingly frequent and severe, such that they were becoming a disincentive to recommending the procedure to deserving patients. We began an evaluation of each step of the procedure to determine whether modifications could be implemented to reduce the frequency of major complications.

Table III. Patients and procedures

No. of patients	31
No. of limbs	36
Age, years, mean	46
Deep venous thrombosis procedure[a]	6.7 years
Male/female	13/18
Procedures	
Unilateral	26
Bilateral	5

[a]Time from acute deep venous thrombosis to procedure (mean).

Table IV. Overall procedural complications

All	61%	(19/31)
Major[a]	55%	(17/31)
Minor	6%	(2/31)

[a]Acute thrombosis, wound hematoma requiring evacuation, major wound infection reintervention for stenosis.

It became apparent that good axial imaging early in the course of evaluation of the patient often assisted with properly designing corrective procedures.

Operating time can be reduced by 2 hours or more by successful passage of a guidewire and a catheter through the occluded iliofemoral venous segment the day before the procedure. This is most commonly achieved using the popliteal vein approach, although access from the right jugular vein can be helpful, especially in patients with an occluded vena cava. In some patients with bilateral disease, both the popliteal vein and jugular vein approaches were used.

The entire CFV is exposed and completely disobliterated with the endovenectomy. Patch closure of all patients is now performed because each of those requiring early reintervention for stenosis were closed primarily.

Completion venography was performed in all patients. However, we found that untreated disease appearing acceptable on completion venograms was responsible for early postoperative thrombosis, which led to the routine use of completion intravascular ultrasound. We avoided passing the stent under the inguinal ligament in our initial procedure as a carryover of principles of treating arterial occlusive disease. It became evident that landing the stent into the CFV above the SFJ provided better inflow and durability of the reconstruction.

Early in our experience, the Doppler signal in the CFV was used to assess the need for an adjunctive AVF from the SFA to the distal CFV. It appears that the early Doppler signals do not always reflect longer term venous return. Several patients who thrombosed in the early postoperative period were returned to the operating room for thrombectomy, patch closure, and an adjunctive AVF, with subsequent durable patency. These observations led to routine patch closures and routine construction of a 3.5- to 4-mm AVF. The purpose of the AVF is to increase blood flow velocity and to diminish risk of thrombosis in these prothrombotic veins. The

Table V. Distribution of procedure-related complications

Complications	Initial technique (n = 17), % (n/N)	Contemporary technique (n = 14), % (n/N)	*P* value
Overall	94 (16/17)	21 (3/14)	<.001
Major	88 (15/17)	14 (2/14)	.006
Minor	6 (1/17)	7 (1/14)	.92

Table VI. Specific major complications according to procedure

Complication	Initial technique (n = 17), % (n/N)	Contemporary technique (n = 14), % (n/N)
Acute thrombosis	29 (5/17)	0
Wound bleed	24 (4/17)	7 (1/14)[a]
Wound infection	18 (3/17)	0
Infected seroma[b]	6 (1/17)	7 (1/14)
Reintervention for CFV stenosis[c]	12 (2/17)	0

CFV, Common femoral vein.
[a]CFV rupture after balloon dilation early postoperatively required ligation of arteriovenous fistula (AVF). Reconstruction remains patent.
[b]Following percutaneous attempts to drain seroma.
[c]Both patients had primary closure of the CFV.

AVF is intentionally small so as not to increase venous pressure or result in arterial or venous dilation over time. These small AVFs are considered permanent. No patient has yet to experience a complication of the small, permanent AVF. Prior experience has shown a 13% rate of venous thrombosis when temporary AVFs constructed after venous thrombectomy were closed electively.[9]

Verma and Tripahti[10] recently reported their technique of CFV endovenectomy and iliac vein stenting for post-thrombotic iliofemoral obstruction. They closed the CFV primarily and did not construct a supplemental AVF. Unfortunately, there were no procedural results or complications reported either to support or to challenge their technique.

de Wolf et al[11] reported the largest series of endovenectomy and AVF with iliac and vena cava stenting. They had a strikingly similar major complication rate of 74% compared with our 88% in patients in whom the initial technique was performed. However, they made no mention of altering their technique over time to reduce complications; 47% of their patients had primary closure of the CFV venotomy. They found that 60% of primary failures were due to CFV stenosis, which appears to support the concept of routine patch closure. They constructed large AVFs (6 mm) that were electively closed in most patients within 82 days (median). There was no indication of whether there were any thrombotic events after closure of the AVF.

Stenting of post-thrombotic iliac veins and the long endovenectomy of the CFV produce a highly prothrombotic venous conduit, promoting platelet activation and intravascular coagulation. Preoperative combined platelet inhibition is started in all patients, which is continued postoperatively. Initially, intraoperative anticoagulation was not reversed, and it was continued at a therapeutic level postoperatively through a systemic dose of heparin. Wound hematomas were common, requiring operative evacuation, with some resulting in wound infection. When postoperative therapeutic anticoagulation was not given early in our experience, some developed postoperative thrombosis, necessitating reintervention. These major problems appear to have been solved by placing a sheath in the ipsilateral popliteal vein preoperatively, using the sheath to infuse intraoperative and postoperative UFH. Postoperatively, heparin is infused at 600 to 700 IU/h. The concept is to eliminate systemic anticoagulation with its attendant risks of hemorrhage while delivering a supratherapeutic dose of heparin to the prothrombotic venous segment that was operated on and stented. UFH infusion is continued through the popliteal sheath for 5 days, until the INR is in the therapeutic range with the patient taking warfarin. Our target INR is now 3.0 to 4.0 and is adjusted to 2.0 to 3.0 after 6 to 12 months. Since adopting this method of postoperative anticoagulation, no patient has experienced a major wound hematoma or early postoperative thrombosis. We do not use direct-acting oral anticoagulants as there is no dose adjustment if higher levels of anticoagulation are desired. Their anticoagulant activity diminishes during the dosing cycle, which can reach low levels toward the end of the cycle. Furthermore, if a dose is missed, the patient will be unprotected and at high risk of thrombosis.

CONCLUSIONS

The contemporary technique of operative CFV endovenectomy and reconstruction of central venous drainage can be achieved with significantly improved safety and patency. Each element that was altered from the initial procedure to the contemporary procedure appears additive, contributing to progressively better patient outcomes. We are certain that the procedure will continue to be refined as more clinicians perform these techniques and critically examine their outcomes.

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AUTHOR CONTRIBUTIONS

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