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Duplex-Guided Endovascular Repair of Popliteal Artery Aneurysms (PAAs): A New Approach to Avert the Use of Contrast Material and Radiation Exposure☆

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Abstract *Objective:* Our previously reported experience with balloon angioplasties and stenting for occlusive infra-inguinal arterial disease using duplex guidance encouraged us to expand the indication for this imaging modality to include endovascular repair of popliteal artery aneurysms (PAAs). The present study evaluated the feasibility of performing this procedure under duplex guidance alone.
Methods: Fifteen patients (14 males and one female) underwent duplex-guided placement of Viabahn® stented grafts (7—10 mm) for repair of PAAs over the last 50 months. The mean of patients' age was 80 ± 6 years (range: 66—92 years). Fifty-three percent of these patients had chronic renal failure. The mean PAA diameter was 22 ± 12 mm (range: 12—57 mm). Only two patients (13%) had no direct run-off to the foot. Pre-procedure mean PA volume flow (mPAVF) was 73 ± 39 ml/min. None of the patients received contrast material or radiation exposure.
Results: Fourteen endografts were placed percutaneously under local anaesthesia, and the remaining graft was placed during an open repair of an ipsilateral common femoral artery aneurysm under regional nerve block. Both the proximal and distal ends of the endograft were placed at least 2.5 cm into a non-dilated segment of the recipient artery. The post-procedure mPAVF was 137 ± 38 ml/min (range: 80—210 ml/min). There were no local complications. Three patients developed graft thrombosis at 2, 5 and 30 months post-procedure. The first two patients had no direct flow into the foot and had post-procedure mPAVF <100 ml/min. The remaining 12 endografts are patent from 1 month to 32 months (mean: 12 ± 13 months). These patients had post-procedure mPAFV >100 ml/min. Two patients (13%) died at 1 month (respiratory failure) and 3 months (intracranial haemorrhage) post-procedure.

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Conclusions: Endovascular repair of PAAs with Viabahn® stented grafts can be performed under duplex guidance alone. This imaging modality appears to be safe and reliable and it may be particularly beneficial in patients with renal failure. Poor run-off and low mPAVF (<100 ml/min) may be predictors of poor graft patency. To our knowledge, this is the first report of duplex-guided endovascular repair of PAAs.

Popliteal artery aneurysms (PAAs) remain the most common peripheral aneurysms encountered, accounting for up to 70–80% of all peripheral aneurysms.[1,2] While the aetiology of the disease is unclear, studies have shown that there is increased proteolytic activity found in the walls of PAAs, suggesting a pathogenesis similar to that found in abdominal aortic aneurysms.[3] The most significant complication is due to distal embolisation with associated acute limb ischaemia and limb loss rates being as high as 36% in patients with pedal pulses and increasing to 86% in patients without pedal pulses.[4] Our group has shown that small PAAs (<2 cm) with mural thrombus have an increased risk of developing acute limb ischaemia.[5] While there are differing opinions in the literature regarding the size at which an asymptomatic PAA should be repaired, there is general consensus that a symptomatic PAA should be repaired irrespective of size.

Surgical repair has been a generally accepted gold standard for treatment of PAA. The first reported endovascular repair of a PAA was by Marin et al. in 1994.[6] The endovascular approach offers advantages in an older population with associated multiple co-morbidities. Endovascular repair has been shown to have less blood loss, quicker recovery times with shorter hospital stays. Early results of endovascular repair of PAA have been comparable to results of open surgical repair of PAA, making it a more attractive option than open surgery.[2,7,8] Duplex guidance for endovascular procedures offers a significant advantage to traditional endovascular procedures by obviating the use of contrast dye and its associated complications, especially in patients with renal failure. It also offers the distinct benefit of visualising the detailed anatomic pathology within the vessel intended for treatment. Given our own previously reported experiences with duplex-guided infra-inguinal angioplasties, we expanded our indications to include endovascular repair of PAAs. In this case series, we report our experience with this treatment modality.

Patients and methods

Patient population

From March 2005 to May 2009, 15 patients presented to our institution with PAAs. This group included 14 males (93%) and 1 female (7%) with mean age of 80 ± 6 years (range: 66–92 years). Concomitant risk factors such as hypertension, diabetes, smoking and coronary artery disease were present in 10 (66%), 4 (27%), 6 (40%) and 7 (47%) patients, respectively. In addition, eight (53%) patients had elevated serum creatinine levels ($\geq$1.5 mg/dL).

Four PAAs (27%) were asymptomatic and the remaining 11 presented with various symptoms including claudication in nine cases (60%), ulcerations with rest pain in an additional case (7%) and acute ischaemia due to aneurysm thrombosis in the remaining case (7%).

Preoperative evaluation

None of the patients described in this series had diagnostic contrast arteriography. Endovascular repair of the PAAs was offered to 14 patients based on results of preoperative duplex arteriography (DA) performed by experienced registered vascular technologists (RVTs). The remaining patient with acute arterial thrombosis had a combined procedure with duplex-guided suction thrombectomy preceding endograft placement. We routinely suggest to patients open or endovascular repair of PAAs $\geq$ 20 mm regardless of symptomatology and smaller PAAs (12–19 mm in diameter), which are symptomatic or have mural thrombus lining. The choice of endovascular versus open repair is usually based on patient's preference, co-morbidities and availability of autologous vein conduit.

Preoperative DA identified and evaluated the PAA's diameter, location and presence of mural thrombus (Fig. 1). The diameter of PAAs ranged from 12 mm to 57 mm (mean: 22 ± 12 mm). All eight (53%) small PAAs (<20 mm) were symptomatic and had mural thrombus (Fig. 2). Location and extent of the PAAs were described according to their position in relation to the knee joint: above the knee (AK), behind the knee (BH) or below the knee (BK).

Our DA protocol also included evaluation of nature and extent of occlusive disease in the femoral–popliteal arterial segment as well as infra-popliteal arteries.[9] All arterial segments were identified as patent or occluded. Occlusive

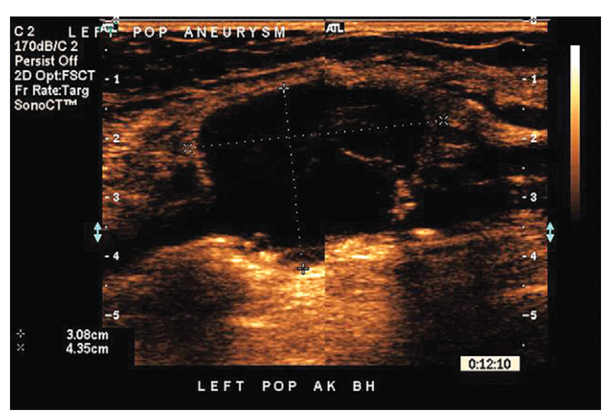

Figure 1 Intra-operative gray scale image of a large PAA located above and behind the knee with measured diameter of 3.08 cm and length of 4.35 cm.

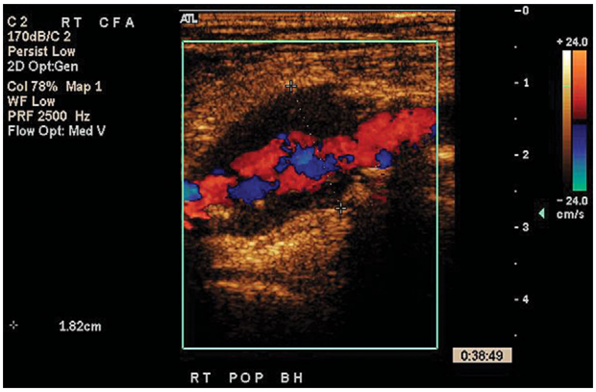

Figure 2 Intra-operative colour image of a 1.82 cm PAA with circumferential mural thrombus.

disease of patent arteries was classified as mild (<50% stenosis measured on B-mode or colour and peak systolic velocity (PSV) ratio <2); moderate (50–70% stenosis measured on B-mode or colour and PSV ratio 2–3) and severe (>70% stenosis measured on B-mode or colour and PSV ratio >3). There were five severe focal stenoses and one short (15 mm) occlusion identified in the ipsilateral superficial femoral artery.

There were four patients (27%) with all three patent disease-free infra-popliteal arteries, six patients (40%) with two patent arteries, three patients (20%) with one patent artery and two patients (13%) with no patent arteries, respectively. Duplex assessment of the aorto-iliac segment confirmed absence of significant aorto-iliac disease in all patients. Four patients (27%) had their abdominal aortic aneurysms (AAAs) repaired previously (three endovascular and one open repair), three additional patients (20%) had small asymptomatic AAAs and the remaining eight patients (53%) were AAA negative.

Procedure technique and results

Technique

All endovascular repairs of the PAA procedures were performed in the operating room. An HDI 5000 scanner with SonoCT® feature (Philips Medical Systems, Bothell, WA, USA) was used routinely. A linear 7–4-MHz probe inserted in sterile plastic cover with coupling gel was used for insonation of the arteries that were ≤4-cm deep while a curved 5–2-MHz transducer was needed for visualisation of deeper arterial segments including the distal superficial femoral artery (SFA) and the above-the-knee PA. After sterile prepping and draping of the ipsilateral lower extremity, we reconfirmed preoperative duplex findings, measured PAA diameter and length and diameter and length of the adjacent normal arterial segments to be used as graft landing zones. Additionally, we acquired the mean PA volume flow (mPAVF) using duplex colour image and spectral analysis behind the knee three times and recorded a mean value.

A similar sample of mean PA volume flow (mPAVF) was also obtained three times immediately after completion of the procedure.

All procedures were carried out via an ipsilateral common femoral artery (CFA) access. Fourteen cases were performed under local anaesthesia of the puncture site and light sedation and the remaining case under regional nerve block for concomitant open CFA aneurysm repair. Viabahn® diameter and length were chosen based on precise intra-operative arterial measurements. The short-sheath diameter varied from 8 Fr to 11 Fr to accommodate the selected Viabahn® size. Graft diameters were at least 1 mm larger than the lumen of the adjacent proximal artery. Both the proximal and distal ends of the endografts were placed at least 2.5 cm into a non-dilated segment of the recipient artery. Five cases (33%) required two separate endograft modules placed telescopically into each other (with smaller diameter distally) to ensure entire long PAA lining. The locations of the distal Viabahn® end was at the AK PA in 3 cases (20%), BH PA in 6 cases (40%) and BK PA in the remaining 6 cases (40%). After deployment, endografts were ironed by Ultrathin® balloons with diameters matching the lumen of the respective covered arteries.

Four of the six ipsilateral SFA stenoses required placement of self-expanding nitinol stents for plaque recoil. The two remaining stenoses were located close to the proximal aneurysm end and were covered by the stented Viabahn® grafts. Overall technical success was 100% (all cases). None of the patients received contrast material or were exposed to radiation. Total procedure time from beginning of intra-operative confirmatory duplex scan to sheath removal ranged from 19 to 55 min (mean: 35 ± 10 min).

Haemodynamic information

The pre-procedure mPAVF was 73 ± 39 ml/min (range: 24–140 ml/min). The post-procedure mPAVF was 142 ± 42 ml/min (range: 80–210 ml/min).

Follow-up and patency

None of the grafts developed any evidence of kinking, deformity or stenosis during follow-up. Three patients developed graft thrombosis at 2, 5 and 30 months post-procedure. The first two patients had no direct run-off to the foot and were the only two cases with post-procedure mPAVF <100 ml/min ($p < 0.03$). The remaining 12 endografts are patent from 1 month to 32 months (mean: 11 ± 12 months). These patients had post-procedure mPAFV >100 ml/min. The 6-, 12- and 30-month patency rates were 82%, 82% and 53%, respectively.

Morbidity and mortality

There were no local intra-operative complications. We routinely assessed all newly placed Viabahn endografts with completion colour duplex scan in at least three planes (posterior sagittal, medial or lateral sagittal and posterior transverse). This thorough examination allowed us to visualise the entire excluded aneurysmal sac and confirm absence of endoleaks by absence of colour flow outside the endograft (Fig. 3). All infra-popliteal arteries were evaluated to identify possible embolisation or thrombosis during

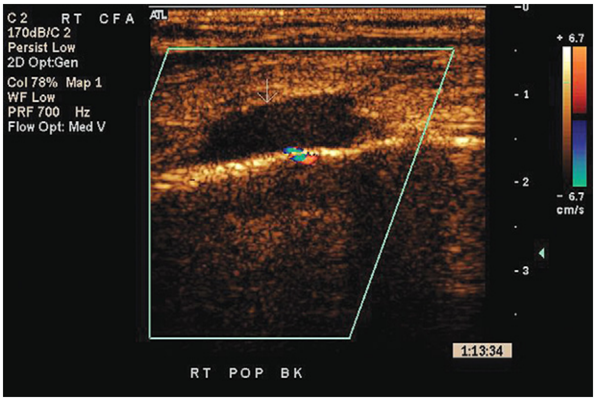

Figure 3 Intra-operative colour image of the newly placed Viabahn® graft. Please note absence of flow in the excluded PAA.

graft and balloon manipulations prior to removing the guidewire and sheath. No postoperative pseudoaneurysms of the sheath insertion site were noted.

Two patients died (13%) at 1 month (respiratory failure) and 3 months (intracranial haemorrhage) post-procedure.

Discussion

The growing body of literature suggests that endovascular repair of PAA has become a valid alternative to open repair for PAA in high-risk patients with good arterial run-off. As the technology and technique for endovascular repair of PAA has developed over the past 15 years, the results of this procedure have improved. Tielliu et al. reported on their experience of treatment of PAA from June 1998 to February 2007 with endografts.[10] Graft thrombosis remained the most frequent complication after endovascular repair. The authors of this study concluded that their findings suggested that outcomes for endovascular repair would continue to improve as the technology develops and technical experience increases.[10] Currently, there remain no standard guidelines for the placement of endografts in the PAA. Investigators are using variable-length landing zones of at least 1–2 cm, oversizing by 10–15% and avoiding overlap at the flexion points in the PAA.[8,10,11] It is generally agreed that avoidance of endovascular repair should be considered in patients with small PAs, poor distal run-off and distal neck of <1 cm.[8,10,11]

Patients undergoing endovascular repair of PAA have a shorter mean hospital stay, and shorter mean operative time as compared with patients undergoing open repair.[2,12] On the other hand, graft thrombosis has been noted to occur more frequently with endovascular repair as compared to open repair.[12] In our present series, two patients with poor distal run-off developed graft thrombosis. Similarly, the literature analysing open PAA-repair shows worse graft patency in patients with poor distal run-off.

From our own experience collected over the last 6 years, we have established the efficacy of use of duplex as the sole modality for performing infra-inguinal re-vascularisations.[9,13,14] The use of ultrasonography obviates the need for the patient and the practitioner to be exposed to radiation. It also avoids the use of contrast media and its associated complications, most significant of which is contrast nephropathy. This approach is especially beneficial in patients with chronic renal failure or significant dye allergies. The high-resolution images offered by duplex scanning show the anatomy of the PAA in great detail, allowing precise measurement of diameter and length of the proximal and distal landing zones imperative for appropriate selection of endoprosthesis. This precision helps reduce the risk of inherent endograft shortcomings, such as infolding and possible collapse.[15]

By preparing the entire lower limb into a sterile field, the sonographer has full access to perform any needed limb manipulations to obtain the appropriate images of the entire PA in multiple planes (posterior, medial and lateral, both sagittal and transverse). In our experience, these require relatively simple movements, such as slight flexion of the knee combined with lateral or medial hip rotation, to adequately assess PA as well as crural arteries. While providing excellent visualisation, these manipulations do not compromise position of various catheters and wires.

Another significant advantage of duplex-assisted repair is that it can show the amount and location of mural thrombus, allowing the operator to precisely navigate endovascular tools through the aneurysm and decrease the prospect of distal embolisation during the procedure.

Low PAVF (<100 ml/min) can serve as a powerful predictor of both early (30 days) and mid-term (6 months) patency after sub-intimal dissection and balloon angioplasty of the femoral–popliteal arterial segment.[16] Similarly, we obtained and analysed mean PAVFs in the duplex-guided endovascular PAA repair cohort of patients. In the current series, both patients that had endograft thrombosis had mean PAVFs <100 ml/min. One of the drawbacks of duplex ultrasonography after deployment of a polytetrafluoroethylene (PTFE)-lined endograft is that it is porous and does not allow lumen insonation during initial 24–48 h to assess for technical success. We can overcome these limitations by visualising the walls of the endoprosthesis after balloon angioplasty in two views coupled with haemodynamic parameters – arterial volume flows, peak systolic velocities and waveform analysis – of the distal vessels. These data can illustrate technical issues such as in-stent stenosis, kinking or inflow lesions that may compromise endograft patency.

When necessary, we deployed two endografts to provide adequate landing zones and fully cover longer aneurysms. In five such cases (33%) we developed the following algorithm: (1) deployed the distal endograft, (2) brought the distal end of the second device to match up with the proximal end of the deployed graft, (3) measured and marked a point on the mounting catheter 2–3 cm away from the groin sheath valve, (4) advanced the second graft into the lumen of the deployed graft while firmly holding the groin sheath, (5) confirmed an adequate proximal landing zone of the second proximal graft and (6) deployed the proximal graft. During post-deployment graft "ironing" the straightening of the PTFE contour signalled full balloon inflation and adequate graft wall apposition. While not performed in our current series, it is also feasible to perform knee-flexion maneuvers after graft deployment to determine any anatomical kinking that may occur while sitting, walking or exercising.

In conclusion, the use of duplex guidance to perform endovascular repair provides distinct advantages by eliminating the need for contrast and radiation and their possible complications. Technical advantages include being able to precisely maneuver through the PAA sac filled with mural thrombus to prevent distal embolisation and select the proper size endoprosthesis to lessen the chance of infolding and graft collapse.

Conflict of Interest/Funding

None declared.

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