CardioVascular and Interventional Radiology

Published Online: 6 May 2004

Cardiovasc Intervent Radiol (2004) 27:198–203
DOI: 10.1007/s00270-004-0029-1

Guidelines for Stenting in Infrainguinal Arterial Disease

Dimitrios Tsetis,[1] Anna-Maria Belli[2]

[1]Department of Radiology, University Hospital of Heraklion, Medical School of Crete, Heraklion, Greece
[2]Department of Radiology, St George's Hospital, Blackshaw Road, London SW19 6BG

Key words: Angioplasty—Stents—Femoropopliteal—Tibioperoneal—Artery—Restenosis

Background

The superficial femoral artery (SFA) is a common site of involvement of peripheral atherosclerotic disease [1]. The lesions are typically long, and clinical presentation is diverse. Invasive methods of treatment (percutaneous or surgical revascularization) should be reserved for patients with lifestyle disabling claudication, ischemic rest pain or nonhealing ischemic ulcers and gangrene [2] Patients with popliteal and below-knee occlusive disease often present with limb-threatening ischemia. They are usually elderly and have several comorbid conditions, such as diabetes and coronary artery disease, that increase the surgical risk.

Percutaneous tranluminal angioplasty (PTA) is the preferred initial treatment for patients with disabling claudication and femoropopliteal artery stenosis or occlusion as it has low mortality and morbidity and reduced hospital stay [3]. In the infrapopliteal territory, PTA is reserved for those with critical limb ischemia, although some recent reports of PTA of tibial arteries have also included patients with severe claudication [4–6]. Only 20–30% of patients with tibial disease have what traditionally has been considered optimal anatomy for percutaneous revascularization (i.e, a focal lesion with good run-off distally) [7, 8]. The majority of patients have severe, extensive three-vessel disease. Even in these cases percutaneous techniques are feasible and allow "straight line flow" to the foot to be established in at least one tibial vessel, which is sufficient for limb salvage in the majority of patients [9]. In favor of PTA as first line treatment is that failure rarely precludes surgical options. The surgical options of femorodistal and pedal bypasses are technically demanding and associated with 1.8–6% perioperative mortality [10, 11]. The Transatlantic Intersociety Consensus recommends that when two techniques give equivalent short- and long-term benefit, the technique with the least morbidity and mortality must be used first [12].

Although PTA is an effective treatment method in infrainguinal arterial occlusive disease, there is a subgroup of patients with nonconcentric, calcified and long-segment stenoses, and occlusions, in which results of PTA are poor and where stenting may have a role [13–17].

Lesion Classification and Treatment Options

The Transatlantic Intersociety Consensus (TASC) Document on Management of Peripheral Arterial Disease (PAD) [12] addresses the issue of choice between endovascular therapy and surgery for specific types of lesions in terms of complexity and length. This is based on the grounds that these parameters are important determinants of short- and long-term clinical outcome of the revascularization procedure. The lesions are classified into four groups (see Tables 1 and 2).

The endovascular approach is recommended for type A lesions, and bypass surgery is the treatment of choice in type D lesions. Between these two groups are types B and C lesions, which are considered amenable to either technique because there is insufficient evidence to make any firm recommendations. At present, endovascular treatment is more commonly used in type B lesions, and surgical treatment is more commonly used in type C lesions. Additionally, the presence of comorbid conditions and operator skills are added to the decision-making process in patients with types B and C lesions. Patients with femoropopliteal and / or infrapopliteal disease have the highest likelihood of coronary heart disease among all patients with symptomatic PAD [18–21]. As PTA is a low-risk procedure it could be proposed as the first invasive treatment option in all such patients as it does not preclude later bypass surgery, and at the same time preserves the saphenous vein for future coronary or lower extremity distal bypass surgery [1].

Correspondence to: Anna-Maria Belli; *email:* anna.belli@stgeorges.nhs.uk

Table 1. Morphologic stratification of femoropopliteal lesions

Type A	Single stenosis up to 3 cm long, not at the origin of SFA or distal popliteal artery
Type B	Single stenosis or occlusion up to 10 cm long not involving the distal popliteal artery
	Heavily calcified stenosis up to 3 cm long
	Multiple lesions each less than 3 cm long (stenoses and occlusions)
	Single or multiple lesions in the absence of continuous tibial run-off to improve inflow for distal surgical bypass
Type C	Single stenosis or occlusion >10 cm long
	Multiple stenoses or occlusions, each 3–5 cm, with or without heavy calcification
Type D	Complete common femoral artery and/or superficial femoral artery occlusion or complete popliteal and proximal trifurcation occlusion

Table 2. Morphologic stratification of infrapopliteal lesions

Type A	Single stenoses shorter than 1 cm in the tibial or peroneal arteries
Type B	Muliple focal stenoses of the tibial or peroneal vessels, each less than 1 cm long
	One or two focal stenoses, each less than 1 cm long, at the tibial trifurcation
	Short tibial or peroneal stenosis in conjunction with femoropopliteal PTA
Type C	Stenoses 1–4 cm long
	Occlusions 1–2 cm long of the tibial or peroneal vessels
	Extensive stenoses of the tibial trifurcation
Type D	Tibial or peroneal occlusions longer than 2 cm
	Diffusely diseased tibial or peroneal vessels.

Technical Aspects of Stenting and Stent Selection

An ipsilateral antegrade approach for mid and distal femoropoliteal lesions and either a contralateral retrograde or ipsilateral retrograde transpopliteal artery approach for proximal SFA lesions may be used [22, 23]. A 6 or 7 Fr introducer sheath is typically required and long, curved sheaths can be used to place stents across the aortic bifurcation.

Current stent lengths are generally too short for extensive disease, so stents are placed across the site of residual stenosis after PTA or across the site of residual occlusion. Several stents may be placed sequentially until patency is achieved [22, 24]. Stent sizes are 1 ml larger than the reference vessel and either self-expanding or balloon-expandable stents may be used. Balloon-expandable stents should be avoided at sites where they may be compressed by external forces. Post-dilatation of the deployed stent to imbed the metal struts into the vessel wall is important for all stent designs.

Balloon-expandable stainless steel stents maintain their radial strength and shorten minimally with implantation, allowing for precise placement [2]. However, there is a risk of external compression at the adductor canal [25]. Balloon-expandable tantalum stents are more flexibile and possibly more resilient to compression [24, 26] but they shorten by about 10% on full expansion [2]. It is postulated that a balloon-expandable stent may cause less sustained stress to the vessel wall than a self-expandable stent [27].

Wallstent (Meditech, Boston Scientific, Boston, MA) was the first self-expanding stent used in the femoropopliteal region. It is made from a cobalt-based alloy and is highly flexibile and available in long lengths, allowing a single stent to cover long, diffuse disease [28–32]. Disadvantages include foreshortening during its deployment, making precise placement more difficult and suboptimal vessel wall apposition. Self-expanding nitinol stents have several favorable characteristics for use in the femoropopliteal artery. Radial expansion occurs with stent warming in the artery, and because of the 10- to 20-fold increase in "spring-like" behavior of nitinol compared to traditional stainless steel stents, the stent achieves its nominal diameter once deployed with no significant foreshortening [33]. Another important advantage of nitinol stents is their resistance to external deformation which allows for their placement in areas of flexion (i.e., distal SFA and popliteal artery). Finally, nitinol is more stable and less prone to corrosion than stainless steel. It is less prone to strain-related fatigue and does not cause the MRI susceptibility artifact of stainless steel.

The Problem of Stent Restenosis

Intimal hyperplasia (IH) is a major limitation of stenting. It contributes to a high rate of restenosis, especially in diffuse long-segment stenoses or occlusions or when multiple stents are implanted [2, 34]. Vascular injury after intraluminal dilatation causes a cascade of complex events which are not yet fully understood. The more pronounced IH after stent placement compared to PTA alone is most likely due to constant arterial wall pressure by the stent; it is known from previous studies that increasing degrees of IH are closely correlated with increased severity of vessel injury, especially if the endothelium and internal elastic lamina are violated [35, 36]. It is difficult to correlate geometric configuration of the stent with the degree of stent-induced arterial overexpansion. However, it seems that stent design and stent surface pattern play a significant role on thrombus adhesion, which affects the magnitude of IH [22, 37]. Animal studies have shown that slow flow in the stented area encourages deposition of larger amounts of thrombus followed by more IH [38, 39]. As this layer of surface thrombus tends to reduce the lumen more markedly in small arteries, Palmaz suggested that the metal surface in stents intended for use in smaller caliber arteries must be kept as small as possible by improvements in the mesh design [40]. Sapoval et al. [31] found that IH and restenosis was more prominent in stented human SFAs of less than 5 mm diameter than arteries 5 mm or greater [31]. Another study found that stent restenosis rises from 4% in the proximal SFA to 10% in its midsegment and to greater than 18% in the distal SFA [34].

The polymer cover of stent-grafts can potentially reduce tissue in-growth at the treatment site and thereby improve patency. Pore size of the graft material affects the healing

process: a pore size of 60–90 μm was claimed to be optimal for promotion of graft healing [41]. The role of Dacron and PTFE-covered stent-grafts has been explored in the femoropopliteal artery [42–50].

Inhibition of IH by local pharmacological interventions is also a concept under investigation. Use of stents as drug carrier systems potentially achieves high local drug concentrations over a longer period of time without systemic toxicity. A self-expanding nitinol stent (SMART Nitinol Self-expanding Stent, Cordis) coated with a polymer impregnated with Sirolimus (rapamycin)—a natural macrocyclic, lipophilic lactone with immunosuppressive antibiotic activity—is the first drug-eluting stent to be studied in femoral arterial occlusive disease [51].

Endovascular brachytherapy (EB) is another technology being investigated to reduce restenosis. Adventitial labeling and immunostaining have suggested inhibition of smooth muscle cell proliferation in the adventitia and favorable effects on vessel remodeling as mechanisms by which radiation reduces arterial lumen restenosis [52]. The radiation may either be gamma radiation, which has to be delivered by a high dose remote afterloader or beta radiation by the use of radioactive stents. Radioactive 32P-stents have so far only been studied in the coronary arteries; restenosis at the edges of the stent without visible intraluminal stenosis (the candy-wrapper phenomenon) represents a significant drawback of these devices and it is attributed to balloon injury and the lower radiation dose at the edge of the stent [53, 54].

Results of Femoropopliteal Stenting Compared with PTA

There are several factors determining long-term outcome of femoropopliteal PTA. A Cox stepwise multiple regression model in three of the studies [14–16] showed the following variables to be associated with a favorable outcome: claudication, non-diabetic patients, proximally located short lesions, stenoses, good distal run-off, lack of residual stenoses on the post-PTA angiogram, and improvement in the ABI by >0.1. The most consistent and important determinant of long-term clinical success among studies for femoropoliteal PTA is the status of the runoff circulation below the knee. Recurrent stenosis after prior femoropopliteal balloon angioplasty seems to be an independent risk factor for restenosis [55].

The primary patency rates for femoropopliteal PTA range from 47–86% at 1 year, 42–60% at 3 years, and 41–58% at 5 years [13–17, 56–58]. The primary patency rates for femoropopliteal stenting range from 22–86% at 1 year, and 18–76% at 3 years (2, 24, 25, 28–32, 34, 59–62). The results are wider ranging but otherwise similar to those of PTA. Lammer [22] assessed the weighted average of published long-term patency rates after stenting of femoropoliteal artery stenoses and occlusions in 585 patients (600 limbs, 80% claudicants) and found this to be 67% and 58% at 1 and 3 years, respectively.

There are relatively few randomized studies comparing PTA with stenting in the femoropopliteal artery. Cejna et al. [63] randomized 154 occlusions up to 5 cm in length to PTA ($n = 77$) or PTA plus Palmaz stenting ($n = 77$). The initial technical success was better with stenting (84% for PTA vs 99% for stenting), but long-term results showed no significant difference compared with PTA (cumulative primary patency rates at 12 and 24 months were 64% and 53%, respectively for PTA vs 63% and 58%, respectively for stenting). Another two, small randomized studies [64, 65] showed no significant difference in primary or secondary patency rates between PTA and stenting using the Palmaz stent. Do et al. [30] performed a comparative, non-randomized study of PTA and Wallstent and found that primary 1-year patency rates based on clinical status and ABI were not significantly different between PTA and stenting (65% vs 59%, respectively). However, in patients with recurrent femoropoliteal lesions elective stenting performs better than repeated PTA according to a recent prospective nonrandomized study with a large sample size, which reported a 12-month patency of 52% after stenting versus 33% after PTA of recurrent lesions [55]. No difference in stent-related restenosis or occlusion among the current, commercially available bare stents has been demonstrated.

Stent-graft patency is at least partially dependent on the type of graft material used and device design. Dacron-covered stent-grafts implanted in the femoropopliteal artery are associated with fever and local pain, known as the "postimplantation syndrome." The patency rates of Dacron-covered stent grafts are as low as 23% at 1 year due to high rates of early thrombosis and high early and late rates of restenosis at the edge of the device, thus making this type of stent-graft unsuitable for the treatment of femoropopliteal arterial occlusive disease [42].

On the other hand, ePTFE covered stent-grafts have shown more promising patency rates. A variety of studies in long (>10 cm) femoro-popliteal disease have reported 1 year primary and secondary patency rates ranging from 40–79% and 83–93%, respectively [43–49]. In one of the latest prospective studies, Jathke et al. [43] reported that reocclusion with this type of stent-graft was associated with plaque progression and IH formation in the native artery immediately adjacent to the stent-graft, and IH inside the stent graft was not detected in any of the cases. The Hemobahn ePTFE endoprosthesis is also the only device to be compared with PTA alone in a pospective randomized study in relatively long (mean length 7 cm) femoropopliteal arterial disease. Despite the small number of patients enrolled in this study, at 6-month follow-up with duplex, a 93% primary patency was reported for the group treated with stent-grafts versus 42% for the angioplasty group; at 2-years the difference was even more striking: 87% versus 25%, respectively [50].

The trials of drug-eluting stents in the femoropopliteal artery are still in their early stages. Preliminary reports suggested an advantage of the slow Sirolimus (rapamycin)

eluting stent (SES) group at 18 months [66], however, this trend disappeared at 24-month follow-up and there was no difference in restenosis rate in the two types of drug-eluting stents and bare-stent groups.

The role of brachytherapy and radioactive stents is being more extensively investigated in the coronary circulation than the peripheral arterial system and very few large trials have been reported. The Vienna 04 Trial [67] evaluated brachytherapy with an Iridium-192 source delivered by a high-dose remote afterloader after peripheral stenting in 33 patients with long-segment (mean length 17 cm) obstructive lesions. Only 12% of arteries had in-stent restenosis caused by IH but there was a high incidence (21%) of thrombotic occlusions occurring between 3.5 and 6 months after the intervention that required treatment by thrombolysis. This may be avoidable with administration of antiplatelet agents such as clopidogrel.

Results of Infrapopliteal Stenting Compared with PTA

Infrapopliteal PTA is currently reserved for patients suffering from critical limb ischemia. Most of these are elderly with multiple comorbidities, and clinical success is more important than long-term angiographic patency because once healing has occurred, collateral flow may be sufficient to preserve tissue integrity if there is no further injury [68].

Primary patency rates for PTA in crural vessels range between 40% and 81% at one year [69–71] and can be up to 78% at 2 years [72]. However, the limb salvage rate is higher at between 77% and 89% at one year [69–73]. Predictive factors that lower the limb salvage rate are the presence of diabetes and renal failure [69, 74].

The only published data regarding infrapopliteal stenting comes from Rand et al. [75] who commenced a prospective, randomized, multicenter trial to compare the Carbofilm-coated stents (Carbostent, coronary stent system, Sorin) with PTA in 32 patients with high-grade infrapopliteal artery stenoses up to 3 cm in length. The 6-month patency rate for the PTA group was 51.2% versus 81.2% for the Carbostent group. The 12-month patency rate for the stented group was unchanged at 81.2%.

Complications of Infrainguinal Stenting

Major complications are those resulting in unplanned increase in the level of care, prolonged hospitalization, permanent sequelae or death. The weighted average of major complications for femoropopliteal stenting versus PTA are 7.3% (0–17%) versus 4.3% (2.4–6.3%) [3, 13–17, 24, 28–32, 34, 56, 57, 60–62, 76]. These are most commonly due to puncture site problems, i.e., hematomas and pseudoaneurysms and thromboembolic occlusions.

Full-dose anticoagulation for patients with infrainguinal stents and stent-grafts is recommended to prevent acute thrombosis of the stented segment which can occur in up to 25% of cases within the first month of treatment [28, 42, 77]. Heparin in a dose of 3000–5000 units is usually given intraarterially once the introducer sheath has been placed. Evidence from coronary circulation supports the application of an anticoagulation regime of low-molecular-weight heparin for 2–14 days, and a combination of acetylsalicyclic acid (50–350 mg daily) with clopidogrel (300 mg starting dose followed by 75 mg daily) [78–81]. However, the more frequent use of anticoagulation and anti-platelet regimes during and after stent placement in the infrainguinal vessels will predispose to more puncture site complications [12]. White et al. [61] have shown that for short lesion stenting, long-term anticoagulation may not be necessary.

Postimplantation syndrome with fever and local pain complicates PTFE-covered stent-grafts in up to 5.8% [43] and Dacron-covered stent grafts in up to 40% of patients [42]. Stent-related infection is a rare but serious complication of endovascular procedures [82–84]. Predisposing factors include prolonged (>24 hours) or repeated catheterization [85–87]. Use of a sterile technique is mandatory but there is no consensus or evidence to advise routine use of prophylactic antibiotics.

Recommendations for Infra-Inguinal Stenting

1. There is currently insufficient evidence to recommend stenting in the femoropopliteal or tibial arteries as a primary approach to the treatment of symptoms of peripheral vascular disease in the infra-inguinal circulation.
2. There is insufficient evidence to support the use of stents in post-PTA restenosis.
3. Stents are indicated when there is a suboptimal result following PTA due to elastic recoil of the artery or hemodynamically significant dissections that fail to respond to prolonged balloon inflation (2–5 min) and threaten to cause arterial occlusion.
4. The choice of stent may depend on the site and length of disease but otherwise there is no evidence to support the use of a particular stent design and as yet there is insufficient evidence to justify routine use of covered or coated stents.
5. There is no consensus and insufficient evidence to provide advice on the routine use of prophylactic antibiotics.

References

1. Isner JM, Rosenfield K (1993) Redefining the treatment of peripheral arterial disease. Role of percutaneous revascularization. Circulation 88:1534–1557
2. Gray BH, Olin JW (1997) Limitations of percutaneous transluminal angioplasty wth stenting for femoropopliteal arterial occlusive disease. Semin Vasc Surg 10:8–16
3. Hunink MGM, Wong JB, Donaldson MC, et al. (1995) Revascularization for femoropopliteal disease: A decision and cost-effectiveness analysis. JAMA 274:165–171
4. Flueckiger F, Lammer J, Klein GE, et al. (1992) Percutaneous transluminal angioplasty of crural arteries. Acta Radiol 33:152–155

5. Bull PG, Mendel H, Hold M, et al. (1992) Distal popliteal and tibioperoneal transluminal angioplasty: Long-term follow-up. JVIR 3:45–53
6. Wagner HJ, Starck EE, McDermott JC (1993) Infrapopliteal percutaneous transluminal revascularization: Results of a prospective study on 148 patients. J Intervent Radiol 8:81–90
7. Schwarten DE, Cutcliff WB (1998) Arterial occlusive disease below the knee: Treatment with percutaneous transluminal angioplasty performed with low-profile catheters and steerable guide wires. Radiology 169: 71–74
8. Bakal CW, Cynamon J, Sprayregen S (1996) Infrapopliteal percutaneous transluminal angioplasty: What we know. Radiology 200:36–43
9. Bakal CW, Sprayregen S, Scheinbaum K, et al. (1990) Percutaneous transluminal angioplasty of the infrapopliteal arteries: Results in 53 patients. AJR 154:171–174
10. Pomposelli FB, Marcaccio EJ, Gibbons GW, et al. (1995) Dorsalis pedis arterial bypass: Durable limb salvage for foot ischemia in patients with diabetes mellitus. J Vasc Surg 21:375–384
11. Nehler MR, Moneta GL, Edwards JM, et al. (1993) Surgery for chronic lower extremity ischemia in patients eighty or more years of age: Operative results and assessment of postoperative independence. J Vasc Surg 18:18–26
12. TASC (2000) Transatlantic Intersociety Consensus (TASC) document on management of peripheral arterial disease. J Vasc Surg 31:S1–S296
13. Jeans WD, Amstrong S, Cole SEA, et al. (1990) Fate of patients undergoing transluminal angioplasty for lower-limb ischemia. Radiology 177:559–564
14. Capek P, McLean GK, Berkowitz HD (1991) Femoropopliteal angioplasty: Factors influencing long-term success. Circulation 83 (suppl 2):I70–I80
15. Johnston KW (1992) Femoral and popliteal arteries: Reanalysis of results of balloon angioplasty. Radiology 183:767–771
16. Matsi PJ, Manninen HI, Vanninen RL, et al. (1994) Femoropopliteal angioplasty in patients with claudication: Primary and secondary patency in 140 limbs with 1–3 years follow-up. Radiology 191:727–733
17. Murray JG, Apthorp LA, Wilkins RA (1995) Long-segment (>10 cm) femoropopliteal angioplasty: Improved technical success and long-term patency. Radiology 195:158–162
18. Smith GD, Shipley MJ, Rose G (1990) Intermittent claudication, heart disease risk factors, and mortality: The Whitehall study. Circulation 82:1925–1931
19. Criqui MH, Langer RD, Fronek A, et al. (1992) Mortality over a period of 10 years in patients with peripheral arterial disease. N Engl J Med 326:381–386
20. Newman AB, Sutton-Tyrrell K, Vogt MT, et al. (1993) Morbidity and mortality in hypertensive adults with a low ankle/arm blood pressure index. JAMA 270:487–489
21. Applegate WB (1993) Ankle/arm blood pressure index: A useful test for clinical practice. JAMA 270:497–498
22. Lammer J (2001) Femoropopliteal artery obstructions: From the balloon to the stent-graft. Cardiovasc Intervent Radiol 24:73–83
23. Yilmaz S, Sindel T, Ceken K, et al. (2001) Subintimal recanalization of long superficial femoral artery occlusions through the retrograde popliteal approach. Cardiovasc Interv Radiol 24:154–160
24. Strecker EPS, Boos IBL, Gottmann D (1997) Femoropopliteal artery stent-placement: Evaluation of long-term success. Radiology 205:375–383
25. Rosenfield K, Schainfeld R, Pieczek A, et al. (1997) Restenosis of endovascular stents from stent compression. J Am Coll Cardiol 29: 328–338
26. Strecker EPK, Boos IBL, Gottmann D, et al. (2001) Popliteal artery stenting using flexible tantalum stents. Cardiovasc Interv Radiol 24: 168–175
27. Shapiro MJ, Levin DC (1993) Percutaneous femoropopliteal graft placement: Is this the next step. Radiology 187:618–619
28. Rousseau HP, Raillat CR, Joffre FG, et al. (1989) Treatment of femoropopliteal stenoses by means of self-expandable endoprostheses: Midterm results. Radiology 172:961–964
29. Zollikofer CL, Antonucci F, Pfyffer M, et al. (1991) Arterial stent placement with use of the Wallstent: Midterm results of clinical experience. Radiology 179:449–456
30. Do-Dai-Do, Triller J, Walpoth BH, et al. (1992) A comparison study of self-expandable stents vs balloon angioplasty alone in femoropopliteal artery occlusions. Cardiovasc Intervent Radiol 15:306–312
31. Sapoval MR, Long AL, Raynaud AC, et al. (1992) Femoropopliteal stent placement: Long-term results. Radiology 184:833–839
32. Martin FC, Katzen BT, Benetati JF, et al. (1995) Multicener trial of the Wallstent in the iliac and femoral arteries. J Vasc Intervent Radiol 6:843–849
33. Stainken B (2001) Peripheral vascular stents and covered stents: Trials and new approvals. J Vasc Intervent Radiol 12 (suppl):77–78
34. Henry M, Amor M, Ethevenot G, et al. (1995) Palmaz stent placement in iliac and femoropopliteal arteries: Primary and secondary patency in 310 patients with 2–4-year follow-up. Radiology 197:167–174
35. Sullivan TM, Ainsworth SD, Lana EM, et al. (2002) Effect of endovascular stent study geometry on vascular injury, myoinimal hyperplasia and restenosis. J Vasc Surg 36:143–149
36. Schwartz RS, Huber KC, Murphy JG, et al. (1992) Restenosis and the proportional neointimal response to coronary artery injury: Results in a porcine model. J Am Coll Cardiol 19:267–274
37. Duda SH, Bosiers M, Pusich B, et al. (2002) Endovascular treatment of peripheral artery disease with expanded PTFE-covered nitinol stents: Interim analysis from a prospective controlled study. Cardiovasc Intervent Radiol 25:413–418
38. Kauffmann GW (1991) Four years' experience with a balloon-expandable endoprosthesis: Experimental and clinical application. Radiologe 31:202–209
39. Richter GM, Palmaz JC, Noeldge G, et al. (1999) Relationship between blood flow, thrombus, and neointima in stents. J Vasc Interv Radiol 10:598–604
40. Palmaz JC (1988) Balloon expandable intravascular stent. Am J Roentgenol 150:1263–1269
41. Golden MA, Hanson SR, Kirkman TR, et al. (1990) Healing of polytetrafluoroethylene arterial grafts is influenced by graft porosity. J Vasc Surg 11:838–845
42. Ahmadi R, Schillinger M, Maca T, et al. (2002) Femoropopliteal arteries: Immediate and long-term results with a Dacron-covered stent-graft. Radiology 223:345–350
43. Jahnke T, Andersen R, Muller-Hulsbeck S, et al. (2003) Hemobahn stent-grafts for treatment of femoropoliteal arterial obstructions: Mid-term results of a prospective trial. J Vasc Interv Radiol 14:41–51
44. Lammer J, Dake MD, Bleyn J, et al. (2000) Peripheral arterial obstruction: Prospective study of treatment with a transluminally placed self-expanding stent-graft. Radiology 217:95–104
45. Dietrich EB, Papazoglou KI (1995) Endoluminal grafting for aneuysmal and occlusive disease in the superficial femoral artery: Early experience. J Endovasc Surg 2:225–239
46. Bray PJ, Robson WJ, Bray AE (2003) Percutaneous treatment of long superficial femoral artery occlusive disease: Efficacy of the Hemobahn stent-graft. J Endovasc Ther 10:619–628
47. Bauermeister G (2001) Endovascular stent-grafting in the treatment of superficial femoral artery occlusive disease. J Endovasc Ther 8:315–320
48. Deutschmann HA, Schedlbauer P, Berczi V, Portugaller H, Tauss J, Hausegger KA (2001) Placement of Hemobahn stent-grafts in femoropopliteal arteries: Early experience and mid-term results in 18 patients. J Vasc Interv Radiol 12:943–950
49. Fischer M, Sakriss U, Stalke J, Schulte KL (2001) Hemobahn endoprosthesis: Experience with percutaneous placing in the arteria femoralis superficialis. Zentralbl Chir 126:138–143
50. Saxon RR, Coffman JM, Gooding JM, Natuzzi E, Ponec JD (2003) Long-term results of ePTFE stent-graft versus angioplasty in the femoropopliteal artery: Single center experience from a prospective, randomized trial. J Vasc Interv Radiol 14:303–311
51. Duda SH, Pusich B, Richter G, et al. (2002) Sirolimus-eluting stents for the treatment of obstructive superficial femoral artery disease. Circulation 106:1505–1509
52. Waksman R (1996) Local catheter-based intracoronary radiation therapy for restenosis. Am J Cardiol 14:78(3A):23–28
53. Hehrlein C, Stintz M, Kinscherf R, et al. (1996) Pure b-particle-emitting stents inhibit neointima formation in rabbits. Circulation 93: 641–645
54. Albiero R, Mario C, van der Giessen WJ, et al. (1998) Procedural results and 30-day clinical outcome after implantation of b-particle emmiting radioactive stents in human coronary arteries. Eur Heart J 19:457
55. Schillinger M, Mlekusch W, Haumer M, Sabeti S, Ahmadi R, Minar E (2003) Angioplasty and elective stenting of de novo versus recurrent

femoropopliteal lesions: 1 year follow-up. J Endovasc Ther 10:288–297
56. Gallino A, Mahler F, Probst P, et al. (1984) Percutaneous transluminal angioplasty of the arteries of the lower limbs: A 5-year follow-up. Circulation 70:619–623
57. Krepel VM, van Andel GJ, van Erp, et al. (1985) Percutaneous transluminal angioplasty of the femoropopliteal artery: Initial and long-term results. Radiology 156:325–328
58. Hunink MG, Donaldson MC, Meyerovitz MF, et al. (1993) Risks and benefits of femoropopliteal percutaneous balloon angioplasty. J Vasc Surg 17:183–192
59. Jahnke T, Voshage G, Muller-Hulsbeck, Grimm J, et al. (2002) Endovascular placement of self-expanding nitinol coil stents for the treatment of femoropoliteal obstructive disease. J Vasc Interv Radiol 13: 257–266
60. Liermann D, Strecker EP, Peters J (1992) The Strecker stent: Indications and results in iliac and femoropopliteal arteries. Cardiovasc Intervent Radiol 15:298–305
61. White GH, Liew SC, Waugh RC, et al. (1995) Early outcome and intermediate follow-up of vascular stents in the femoral and popliteal arteries without long-term anticoagulation. J Vasc Surg 21:270–279
62. Bray AE, Liu WG, Lewis WA, et al. (1995) Strecker stents in the femoropopliteal arteries: Value of Duplex ultrasonography in restenosis assessment. J Endovasc Surg 2:150–160
63. Cejna M, Illiasch H, Waldenberg P, et al. (1998) PTA vs Palmaz stent in femoropopliteal obstructions: A prospective randomized trial—long-term results. (abstract) Radiology 209:492
64. Grimm J, Muller-Hulsbeck S, Jahnke T, et al. (2001) Randomized study to compare PTA alone versus PTA with Palmaz stent placement for femoropopliteal lesions. J Vasc Interv Radiol 12:935–942
65. Vroegindeweij D, Vos LD, Tielbeek AV, et al. (1997) Balloon angioplasty combined with primary stenting versus balloon angioplasty alone in femoropopliteal obstructions: A comparative randomized study. Cardiovasc Intervent Radiol 20:420–425
66. Duda SH, Wiesinger B, Richter GM (2003) Sirolimus-eluting stents in SFA obstructions: Long-term SIROCCO trial results. CIRSE 2003 Annual Meeting and Postgraduate Course. Main Programme and Abstracts: abstr 35.3.2, p 157
67. Wolfram RM, Pokrajac B, Ahmadi R, et al. (2001) Endovascular brachytherapy for prophylaxis against restenosis after long-segment femoropopliteal placement of stents: Initial results. Radiology 220: 724–729
68. Gray BH, Laird JR, Ansel GM, et al. (2003) Complex endovascular treatment for critical limb ischemia in poor surgical candidates: A pilot study. J Endovasc Ther 9:599–604
69. Soder HK, Manninen HI, Jaakkola P, et al. (2000) Prospective trial of infrapopliteal artery balloon angioplasty for critical limb ischemia. J Vasc Intervent Radiol 11:1021–1031
70. Lofberg AM, Karacagil S, Ljungman (2001) Percutaneous transluminal angioplasty of the femoropopliteal arteries in limbs with chronic critical limb ischemia. J Vasc Surg 34:114–121
71. Boyer L, Therre T, Garcier JM, et al. (2000) Infra-popliteal percutaneous transluminal angioplasty limb salvage. Acta Radiol 41:73–77
72. London NJ, Varty K, Sayers RD, et al. (1996) Percutaneous transluminal angioplasty for lower-limb critical ischemia. Br J Surg 83:1232–1235
73. Varty K, Nydahi S, Butterworth P, et al. (1996) Changes in the management of critical limb ischemia. Br J Surg 83:953–957
74. Vainio E, Salenius JP, Lepantalo M, et al. (2001) Endovascular surgery for chronic lower limb ischemia. Factors predicting immediate outcome on the basis of a nationwide vascular registry. Ann Chir Gynaecol 90:86–91
75. Rand T, Funovics M, Schoder M, et al. (2002) Stent versus PTA for the treatment of infrapopliteal lesions. Work in progress. Cardiovasc Intervent Radiol 25 (Suppl 2):S247
76. Gray B, Sullivan TM, Childs MB, et al. (1997) High incidence of restenosis /reocclusion of stents in the percutaneous treatment of long-segment superficial femoral artery disease after suboptimal angioplasty. J Vasc Surg 25:74–83
77. Henry M, Amor M, Cragg A, et al. (1996) Occlusive and aneurysmal peripheral arterial disease: Assessment of a stent-graft system. Radiology 201:717–724
78. Herbert JM, Dol F, Bernat (1998) The anti-aggregating and antithrombotic activity of clopidogrel is potentiated by aspirin in several experimental models in the rabbit. Thromb Haemost 80:512–518
79. Leon MN, Baim DS, Popma JJ, et al. (1998) A clinical trial comparing three antithrombotic drug regimens after coronary artery stenting: Stent Anticoagulation Restenosis Study Investigators. N Engl J Med 339: 1665–1675
80. Rupprecht HJ, Darius H, Borkowski U, et al. (1998) Comparison of antiplatelet effects of aspirin, ticlopidine, or their combination after stent implantation. Circulation 97:1046–1052
81. Moussa I, Oetgen M, Roubin G, et al. (1999) Effectiveness of clopidogrel and aspirin versus ticlopidin and aspirin in preventing stent thrombosis after coronary stent implantation. Circulation 99:2364–2366
82. Therasse E, Soulez G, Cartier P, et al. (1994) Infection with fatal outcome after endovascular metallic stent placement. Radiology 192: 363–365
83. Depairine MK, Ballard JL, Taylor FC, et al. (1996) Endovascular stent infection. J Vasc Surg 23:529–533
84. Leroy O, Martin E, Prat A, et al. (1996) Fatal infection of coronary stent implantation. Cathet Cardiovasc Diagn 39:168–170
85. McCready RA, Siderys H, Pittman JN, et al. (1991) Septic complications after cardiac catheterization and percutaneous transluminal coronary angioplasty. J Vasc Surg 14:170–174
86. Giannoukas AD, Tsetis DK, Touloupakis E, et al. (1999) Suppurative bacterial endarteritis after percutaneous transluminal angioplasty, stenting and thrombolysis for femoropopliteal arterial occlusive disease. Eur J Vasc Endovasc Surg 18:455–457
87. Dosluoglu HH, Curl R, Doerr RJ, et al. (2001) Stent-related iliac artery and iliac vein infections: Two unreported presentations and review of the literature. J Endovasc Ther 8:202–209