SUMMARY AND PERSPECTIVE
To introduce the reader of this thesis with some background, in Chapter 1 a brief compilation of historical and current clinical aspects and possible solutions for the treatment of peripheral aneurysms was given. In this thesis, peripheral aneurysms are defined as aneurysms arising distally from the aortic bifurcation. Deliberately, aneurysms of the upper extremities are not discussed. They are very rare entities. An overview is given of aneurysmal disease in general and of peripheral aneurysms more specifically. Past and present treatment modalities are reviewed and an introduction to the endovascular repair is depicted.

The rationale of the thesis is outlined in Chapter 2. The thesis covers several aspects of the endovascular repair of iliac and popliteal artery aneurysms and these two different entities are the basis for a separation of this thesis in two sections. The iliac artery aneurysm is the subject in Section I and the popliteal artery aneurysm in Section II, respectively.

**Section I**

**Endovascular treatment of iliac artery aneurysms**

In Chapter 3 we report the mid-term results of a prospective cohort of iliac artery aneurysms treated with tubular stent-grafts. All iliac artery aneurysms referred to the University Medical Center Groningen between June 1998 and June 2005 were evaluated for endovascular repair. Criteria for repair were a diameter of ≥30 mm for anastomotic aneurysms and ≥35 mm for true aneurysms. Preferentially, tubular stent-grafts were used as compared to bifurcated aortoiliac devices. Follow-up included both radiographs of the abdomen and duplex ultrasound examination. In 35 patients, 40 iliac artery aneurysms were treated endovascularly with a tubular stent-graft. Elective repair was performed in 30 patients (86%) and emergent repair in five patients (14%). Aneurysms were false in 26 cases (65%) and true in 14 cases (35%). Local anesthesia was used in 74% of the cases. The stent-grafts that were used included the Excluder contralateral limb (n = 28, 70%), Passager (n = 9, 22.5%), Hemobahn (n = 2, 5%), and Wallgraft (n = 1, 2.5%). The mean operation time was 83 ± 28 min (range, 50 to 150 min). Mean hospital stay was 3.3 ± 2.3 days (range, 1 to 12 days). There was no 30-day mortality.

Patients were followed-up for a mean of 31.2 ± 20.7 months (range, 3 to 83 months). Complications occurred in two patients during follow-up, including migration with a proximal type I endoleak in one, and occlusion of the
stent-graft in the other. The internal iliac artery was intentionally sacrificed in 28 patients (70%), and this led to gluteal claudication in three patients. As a result of this study it was concluded that the endovascular repair of iliac artery aneurysms with flexible stent-grafts is a minimally invasive technique and is associated with low mortality and morbidity. Follow-up results up to 5 years suggested that the technique is durable. It should be regarded as a first choice treatment option for suitable aneurysms.

Chapter 4 concerns the report of the treatment algorithm and the early results with the use of an iliac branched device (IBD) to preserve the internal iliac artery in the treatment of aortoiliac and solitary common iliac artery aneurysms. From September 2004 on, all patients with aortoiliac aneurysms with a suitable proximal neck or with common iliac artery aneurysms were evaluated. Selection for treatment with an IBD was done based on activity level of the patient and anatomical criteria of the aneurysm. Absolute exclusion criteria included aneurysmal internal iliac artery, severe atherosclerosis of the internal iliac artery, and small residual common iliac artery lumen. Patients who were at risk of losing one of two patent internal iliac arteries were only considered for IBD if they were physically active. Follow-up was performed with computed tomography scanning at 6 weeks and 1 year, and yearly thereafter. Fifty-nine patients (39 aortoiliac, 20 common iliac artery) were evaluated for treatment with an IBD. Seven patients were not considered for IBD for low activity level. Twenty-five patients were not suitable because of adverse anatomy. In total, 27 patients (20 aortoiliac, 7 common iliac artery) were treated with 30 IBD. Technical success was achieved in 96.3% of patients. There was no 30-day mortality. Mean follow-up period was 16.0 ± 14.0 months. In three patients the internal iliac artery side branch occluded, resulting in buttock claudication in only one patient. No external iliac artery occlusion or device component disconnection was observed. This study illustrates that an IBD provides a totally endovascular option to preserve the internal iliac artery in selected aortoiliac and isolated common iliac artery aneurysms. Anatomical application rate for the use of an IBD was 52.5% in our series.

Chapter 5 is a technical note related to the introduction and deployment of an IBD. This technique always involves the use of two parallel guide wires, including the indwelling through-and-through wire and a wire to introduce
the bridging stent-graft. In this chapter we describe a technique that uses tromboned sheaths (i.e. a 7F ANL1 inside a 10F Balkin sheath) for increased crossover stability and avoids problems associated with the use of parallel wires inside one sheath. In addition, reduction of the gap between the IBD and the origin of the internal iliac artery may result in a more stable position of the device.

No prospective randomized trial has been performed to compare the results of open and endovascular repair of iliac artery aneurysms. A case-controlled study of 71 isolated iliac aneurysms (19 open and 52 endo) showed that endovascular repair was associated with a lower length of stay, lower requirement for peri-operative blood transfusion, and similar medium term outcomes compared to open repair. In addition, endovascular repair may be associated with lower 30-day mortality as compared to open repair. Despite the lack of clear evidence, endovascular repair is nowadays considered the preferred treatment for solitary iliac aneurysms. In cases where the aneurysm exerts compression on adjacent organs, however, open repair or at least open decompression of the aneurysm sac after endovascular exclusion, is recommended. The IBD has not yet been adopted by all vascular surgeons. First, there are still no clear guidelines regarding when to save one or both internal iliac arteries. Second, the endovascular technique with the IBD is still technically demanding and challenging to the vascular surgeon, it is time-consuming, and last but not least the device is expensive. No randomized controlled trial has been carried out to compare the results of the IBD to internal iliac artery occlusion. In addition, quality of life studies have not been performed. In a retrospective study, Verzini et al. compared the results of hypogastric revascularization by branch endografting with those of hypogastric occlusion in 74 patients (32 IBD and 42 hypogastric occlusions) who were treated for iliac or aortoiliac aneurysms. Technical failure was similar for IBD deployment (2/32) compared with hypogastric occlusion (2/42). Reintervention rates were similar (5/32 vs 4/42) at one year. Buttock claudication or erectile dysfunction were more frequent after hypogastric occlusion (8/42) compared to the IBD group (1/32) although the difference was statistically not significant.
Section II
Endovascular treatment of popliteal artery aneurysms

Popliteal artery aneurysms can be treated endovascularly with less peri-operative morbidity compared to open repair. To evaluate suitability of the endovascular technique and the clinical results of this treatment, we analyzed a prospective cohort of consecutive popliteal aneurysms. The results of this analysis are outlined in Chapter 6. All popliteal artery aneurysms between June 1998 and June 2004 that measured >20 mm in diameter were analyzed for endovascular repair. Anatomic suitability was based largely on quality of the proximal and distal landing zone as determined by angiography. Endovascular treatment was performed using a nitinol-supported expanded polytetrafluoroethylene (PTFE) lined stent-graft introduced through the common femoral artery. Sixty-seven aneurysms in 57 patients were analyzed. Ten aneurysms (15%) were excluded from endovascular repair or from any repair at all, for various reasons. The remaining 57 (85%) were treated endovascularly, of which five were treated emergently for acute ischemia. During a mean of 24 months follow-up, 12 stent-grafts (21%) occluded. Primary and secondary patency rates were 80% and 90% at 1 year, and 77% and 87% at 2 years of follow-up, respectively. Postoperative treatment with clopidogrel proved to be the only significant predictor for success. This study demonstrated that the endovascular repair of a popliteal artery aneurysm is feasible. Changes in the material used, and the addition of clopidogrel to the standard postoperative treatment with acetylsalicylic acid, may improve patency rates.

In the cohort of patients that were described in Chapter 6, complications occurred. The effect of the learning curve on the occurrence of complications was evaluated in a prospective cohort, as described in Chapter 7. Between June 1998 and February 2007, 73 popliteal aneurysms were treated by endovascular means. Primary outcome was stent-graft patency. Secondary outcome was a combined end-point of stent-graft related complications, including occlusion, migration, stent-graft fracture, and stenosis. To study the learning curve, the cohort of patients was divided into two groups (group A from 1 to 23; group B from 24 to 73). Cut-off point chosen was the introduction of the more aggressive postoperative anticoagulation protocol with clopidogrel. Eighteen (25%) stent-grafts occluded.
This resulted in a reintervention in 11 patients. Migration, fracture, and stenosis were diagnosed in 9, 3 (2 leading to occlusion), and 2 limbs, respectively. These 14 complications accounted for reinterventions in 8 additional patients. In total, 19 of the 73 limbs (26%) required 20 reinterventions. Overall 3-year and 5-year patency rates were 77% and 70% for primary patency, and 86% and 76% for secondary patency, respectively. There were more occlusions in group A (8/23, 35%) versus group B (10/50, 20%) (P = 0.22). With regard to the combined endpoint, there were more events in group A (14/23, 61%) than in group B (16/50, 32%) (P = 0.016). According to this study, the results of endovascular repair of popliteal artery aneurysms are improving and in range with those of open repair. One of the points of concern of endovascular treatment of popliteal artery aneurysms is that a stent-graft is positioned in an artery with hinge points. As a result, the stent-graft is exposed to repetitive flexion and extension movements and susceptible to material failure, especially of the nitinol skeleton.

In Chapter 8, the incidence and origin of stent-graft fractures after endovascular repair, its impact on patency, and strategies to prevent fractures, are analyzed. For that purpose, data of 78 atherosclerotic PAA in 64 patients were gathered in a prospectively-held database from 1998 to 2009. All radiographs were reviewed to detect stent fractures. Only circumferential fractures were included for analysis; localized strut fractures were excluded. Clinical endpoints were circumferential stent fracture, occlusion, and clinical status of the patient. Mean follow-up time was 50 months (range, 1 to 127 months). Fifteen circumferential stent fractures occurred in 13 (16.7%) patients. The majority of stent fractures (93.3%) were associated with the use of multiple stent-grafts. At univariate analysis, younger age was identified as the only significant predictor for stent fracture (P = 0.007). The cumulative stent fracture-free survival was estimated at 78% and 73% at 5 and 10 years follow-up, respectively. The cumulative primary patency rate, defined as time to occlusion, was not different for the fracture group compared with the non-fracture group (P = 0.284). The conclusion could be drawn that the incidence of stent fractures after endovascular popliteal aneurysm repair is probably underreported in the literature. Stent-graft fractures mainly occur at overlap zones and are associated with younger age of the patient. Fracture of the stent did not significantly influence patency of the stent-graft.
Up till now, scepticism remains regarding the endovascular repair of popliteal artery aneurysms, the basis of which is mainly the hinge point in the popliteal artery. Concerns about stenosis at the edges of the stent-graft also exist. Therefore, most vascular surgeons still favour open surgical treatment. Only three studies comparing open and endovascular repair for the treatment of popliteal artery aneurysms have been published. They comprise in total 141 patients (37 endovascular and 104 open) that have been entered in a small meta-analysis.\textsuperscript{6} Thirty-day graft thrombosis and reintervention rate were more likely for endovascular repair. The postoperative length of stay was shorter in the endovascular group ($P < 0.001$). There was no significant difference in long-term primary patency.

Summarizing, endovascular techniques have gradually become in the last two decades a valuable alternative for standard open surgical repair of both iliac and popliteal artery aneurysms.

For iliac artery aneurysms, the endovascular repair with a stent-graft is now regarded the treatment of choice whenever the anatomy is favourable. A flexible and funnel-shaped device that adapts to the often tortuous anatomy of the iliac vessels is an advantage for successful outcome with regards to exclusion of the aneurysm and the prevention of postoperative occlusion of the stent-graft. The internal iliac artery is often sacrificed in treating iliac aneurysms, with significant risk for gluteal claudication or other symptoms of pelvic ischemia. To try to spare the internal iliac artery with endovascular techniques only, the iliac branched device has been developed. Benefit and complication rates on the long term of this device, however, are not clearly defined. In addition, effectiveness and quality of life studies have not been performed yet, especially to compare the results with the outcome of occlusion of the internal iliac artery.

For popliteal artery aneurysms, open surgical repair is still widely considered the standard treatment. Adoption of endovascular repair for this specific indication is increasing only very slowly. Refrains to apply this minimally invasive technique are mainly based on the dogma that stents should preferentially not be positioned crossing the hinge point of an artery. Although the literature comparing open and endovascular repair is scarce, results with regards to patency and limb salvage rates seem to be comparable. The big advantage is the reduction in morbidity as compared with open repair and it warrants further development of this technique.
Further refinement of stent-graft design, including availability of longer lengths, contoured edges, funnel-shaped devices, increased flexibility, and low thrombogenicity will eventually establish endovascular repair as the treatment of choice for popliteal artery aneurysms in the near future.

References


