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## Endovascular repair of peripheral artery aneurysms

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# Chapter 1

## INTRODUCTION

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Arterial obstructive disease as a result of atherosclerosis and aneurysmal dilatation are the two main diseases that affect large and middle-sized arteries in the human body. Arterial aneurysmal dilatation often occurs in patients with atherosclerosis and both pathologic conditions share common risk factors. For this reason, aneurysms that do not have a specific aetiology, such as a connective tissue disorder, infection, or post-dissection dilatation, are often described as “atherosclerotic” aneurysms. The location of the disease in the vessel wall, however, is different for atherosclerosis as compared to aneurysmal degeneration. In atherosclerosis, lesions are concentrated in the intima, whereas aneurysmal degeneration is located in the media and the adventitia. In addition, the pathologic feature of atherosclerosis is foam-cell formation whereas aneurysmal degeneration is marked by intense oxidative stress, inflammatory infiltration, transmural matrix degradation, and apoptosis and depletion of smooth-muscle cells.<sup>1</sup> As a result of the differences in pathophysiology between atherosclerosis and aneurysmal degeneration, most aneurysms formerly called “atherosclerotic”, can therefore better be described as “nonspecific” or “degenerative” in origin.<sup>2</sup> As the incidence of aneurysmal degeneration is highest in the infrarenal abdominal aorta, this type of aneurysm has been investigated more intensively and serves as the basis of understanding of the pathophysiology of less common aneurysms occurring in other locations in which similar processes have been discovered.<sup>3</sup>

This thesis focuses on the endovascular repair of aneurysms which are localized distally from the aortoiliac bifurcation and are described as “peripheral aneurysms” throughout the text.

## **Peripheral aneurysms of the lower extremity**

Aneurysmal degeneration most commonly occurs in the infrarenal abdominal aorta with a prevalence of 3% to 10% in men >50 years old and varying with the prevalence of risk factors in the population.<sup>4</sup> More peripheral aneurysms, including solitary iliac, popliteal, and femoral aneurysms (in decreasing incidence) are less frequently occurring entities. Using the National 1990 Hospital Discharge Summary Data, which is a complex sample of non-federal short-stay hospitals in the United States, it was shown that the incidence of iliac and femoral/popliteal artery aneurysms in hospitalized American men was 6.58 and 7.39 per 100,000 respectively.<sup>5</sup>

In a Danish study that screened 4,176 abdominal aortic aneurysms, the prevalence of isolated common iliac artery aneurysms was 0.05% in men between 65 and 73 years old.<sup>6</sup> A large autopsy study on 26,251 patients who died in Malmö (Sweden) between 1971 and 1985, found a 0.03% prevalence of isolated iliac artery aneurysms.<sup>7</sup>

The relative incidence of common and internal iliac artery aneurysms has been documented as 80% and 20% respectively, with the external iliac artery almost never involved, for reasons not exactly known.<sup>8</sup> The relative distribution of femoral aneurysms is 80%, 15%, and 5%, for the common, superficial, and deep femoral artery, respectively.<sup>9</sup>

Peripheral lower extremity aneurysms can all exist as solitary aneurysms although they frequently will occur together with aneurysms in another location, especially the abdominal aortic aneurysm. In a series studied by Diwan et al. of 252 male abdominal aortic aneurysms, the incidence of femoral or popliteal aneurysms was 14%.<sup>10</sup> In another study by Graham et al. of 100 profunda femoris artery aneurysms, 85% were associated with an abdominal aortic aneurysm, and 44% with a popliteal artery aneurysm.<sup>11</sup>

The nationwide Swedish vascular registry (Swedvasc) showed that 28.1% of unilateral popliteal artery aneurysms were associated with an abdominal aortic aneurysm, 8.4% with an iliac artery aneurysm and 9.4% with a femoral aneurysm.<sup>12</sup> As a result of the described associations, it is generally recommended to screen all patients with peripheral lower extremity aneurysms for the presence of an abdominal aortic aneurysm and other peripheral aneurysms, especially on the contralateral side, using duplex examination. In addition, it seems wise to screen all patients with an abdominal aortic aneurysm for the presence of peripheral artery aneurysms. The incidence of popliteal artery aneurysms in a population without abdominal aortic aneurysm is very low. As a result of a community-based abdominal aortic aneurysm screening programme, Claridge et al. found three popliteal artery aneurysms in a group of 112 patients with a small abdominal aortic aneurysm and no popliteal artery aneurysm in a group of 171 patients with a normal-sized aorta.<sup>13</sup>

A distinct entity is formed by the iatrogenic pseudoaneurysm in the groin. As a result of a puncture hole in the femoral artery (most often the common femoral artery) after an intraarterial catheterization, arterial blood flows in a virtual space which is the pseudoaneurysm. The wall of the pseudoaneurysm does not contain one single layer of the native artery but is formed

by fibrous tissue. The incidence of femoral postcatheterization pseudoaneurysms has been reported between 0.05% and 4% and increases with the use of larger sheaths.<sup>14</sup>

## Natural history and symptomatology

The natural history of peripheral aneurysms is associated with continuous enlargement. As with abdominal aneurysms, larger peripheral aneurysms seem to grow faster than smaller ones. The average expansion rate of a common iliac artery aneurysm has been calculated to be at least 2.9 mm per year in a series of 104 cases.<sup>15</sup> Others describe an average expansion rate of 0.5 to 1.5 mm per year for aneurysms <3 cm with an increase up to 2.8 mm per year for aneurysms  $\geq$ 3 cm.<sup>16</sup> In a series of 24 popliteal aneurysms described by Pittathankal and Galland et al., growth rates were 1.5 mm, 3.0 mm, and 3.7 mm per year for aneurysms of <20 mm, 20-30 mm, and >30 mm in diameter, respectively.<sup>17</sup> This is in concordance with the study of Stiegler et al. who also reported a doubling of the growth rate for popliteal aneurysms >20 mm in diameter as compared to smaller ones.<sup>18</sup> Unlike for abdominal artery aneurysms, where female sex, smoking, and a higher mean blood pressure were found to be independent risk factors for rupture<sup>19</sup>, no such association has been demonstrated for peripheral aneurysms.

Iliac aneurysms are particularly associated with rupture. Due to the anatomical location deep in the pelvis, iliac aneurysms are difficult to detect during clinical examination and will often stay asymptomatic until they rupture. Nevertheless, they can exert compression on adjacent pelvic structures, leading to ureteral obstruction, hematuria, iliac vein thrombosis, large bowel obstruction, and lower extremity neurological deficits. Femoral aneurysms will often be detected by the presence of a palpable mass in the groin or thigh region and eventually lead to pain.<sup>20</sup> Popliteal aneurysms more often will lead to distal ischemia as a result of thrombosis or embolization and rarely present with rupture. The annual complication rate associated with an asymptomatic popliteal artery aneurysm was found to be 14%, increasing to 68% after 5 years.<sup>20,21</sup> Femoral and popliteal aneurysms that are large enough to exert compression on adjacent structures can obviously lead to deep venous thrombosis or a neurological deficit.

Although no clear guidelines have been formulated, the recommended and generally accepted diameter thresholds for intervention in asymptomatic

good-risk and surgically fit patients are the following: 3.5 cm for a common iliac artery aneurysm, although most iliac aneurysms do not rupture until they have reached a diameter of 4 or 5 cm<sup>15</sup>; 3.0 cm for an internal iliac artery aneurysm<sup>22</sup>; 2.5 cm for a common femoral artery aneurysm; 2.5 cm for a superficial femoral artery aneurysm<sup>20</sup>; 2.0 cm for a profunda femoris artery aneurysm<sup>21</sup>; and 2.0 cm for a popliteal artery aneurysm.<sup>18,25-28</sup> With regard to the popliteal artery, a lot of controversy still exists about the exact diameter cut-off point for treatment, with a gray zone between 2 and 3 cm. Galland et al. have advocated using a combination of aneurysm size and distortion of the popliteal artery as a guideline to treat asymptomatic popliteal aneurysms. The highest predictive value for symptomatology would be a diameter of  $\geq 3$  cm and a distortion of  $>45^\circ$ , measured as the angle of the most proximal curve in the popliteal artery.<sup>21</sup> The impact of thrombus in the wall of the aneurysm on the occurrence of symptoms is unclear, although it is reasonable to believe that thrombus may dislodge and cause peripheral embolization. In the Swedvasc registry, 96.6% of the popliteal artery aneurysms had  $>2$  mm of thrombus in the wall of the popliteal artery.<sup>12</sup>

## Diagnosis and follow-up

Asymptomatic peripheral aneurysms are nowadays often diagnosed on a computed tomography (CT) scan that was performed for another indication. A clinical suspicion of a peripheral aneurysm can be confirmed by duplex ultrasound examination or by CT or magnetic resonance (MR) angiography. Follow-up of a peripheral aneurysm can best be performed with a duplex ultrasound scan to measure the maximal diameter in a plane perpendicular to the axis of the vessel. In addition, with a duplex scan, the presence of thrombus in the wall of the aneurysm can be visualised. The quality of the inflow and outflow tract can be assessed and ankle/brachial pressure indices measured. Follow-up intervals should be dictated by the expected growth rate of the aneurysm. The exact growth rate of the different types of aneurysms, however, is difficult to predict, is often characterized by a staccato pattern<sup>29</sup>, and may be subject to factors as smoking<sup>15</sup> and hypertension.<sup>17</sup> To give recommendations on the ideal follow-up interval for the different aneurysms based on diameter and threshold for intervention is difficult. It should rather be dictated by the individual patient's risk factors, including

contralateral disease, aneurysmal disease elsewhere, smoking and hypertension.<sup>29</sup>

## Treatment

### Historical perspective

Operative treatment of peripheral aneurysms started in the 18<sup>th</sup> century. The indication for treatment in the early days of surgical practice for peripheral aneurysms was actually to induce thrombosis. Patients presented with pain, swelling of the leg due to venous compression, and rupture of the aneurysm. Thrombosis was induced either by compression or ligation. Different techniques have been described and were dictated by the anatomical location of the aneurysm, either deep in the pelvis (iliac vessels) or located more superficially (femoral or popliteal vessels).

The “Hunterian ligation”, performed by John Hunter (St George’s Hospital, London) in 1785 on a 45-year-old coachman with a popliteal artery aneurysm was said to be a legendary intervention in those days. It proved to be successful after 15 months when the patient died of other causes and the aneurysm proved to be still thrombosed. In 1817, Sir Astley Paston Cooper (Guy’s Hospital, London), who was an apprentice of Hunter, performed the first operation for an iliac artery aneurysm in a 37-year-old man with a traumatic aneurysm of the external iliac artery that was eroding through the skin. He ligated the aorta above the aneurysm. The patient survived the operation but died 40 hours later.<sup>30</sup> Valentine Mott (New York) who had been trained by Cooper in London, performed the first successful operation for a common iliac artery aneurysm in a 33-year-old farmer in 1827. He ligated the proximal iliac artery.<sup>27</sup> Until the 1950’s, ligation was the only treatment option for iliac artery aneurysms.<sup>31</sup>

In the 20<sup>th</sup> century, for popliteal artery aneurysm repair, a reconstruction through a posterior approach with a vein graft interposition was first introduced by Erich Lexer (University of Jena, Germany) in 1912, next by Hogarth Pringle (Glasgow Royal Infirmary) and Bertram Bernheim (Union Protestant Infirmary, Baltimore) in 1915. In 1969, Edwards described for the first time the technique of proximal and distal ligation and reversed saphenous vein bypass grafting through a medial approach.<sup>28</sup>

## Current treatment modalities

Since the era of John Hunter and Sir Astley Cooper, not only operative techniques, but also the indications for treatment have evolved. In the early days, symptoms of compression and rupture including pain, obstruction of adjacent structures, and swelling of the limb were indications for treatment. In present times, peripheral aneurysms are primarily treated to prevent all complications mentioned above. Operative techniques have evolved from simple compression and ligation to induce thrombosis to revascularization using a bypass or interposition graft. For this purpose, techniques using autologous material such as the saphenous vein were developed first. Prosthetic graft material was introduced in the 1950's. Stanley Crawford reported in 1958 the use of Dacron as bypass material to treat popliteal artery aneurysms.<sup>32</sup>

In the last decade of the 20<sup>th</sup> century, the rapid evolution towards endovascular techniques using covered stents, which are introduced through the common femoral artery, has changed the surgical landscape of peripheral aneurysm repair significantly.

## Treatment of iliac artery aneurysms

### Open surgical repair

Open surgical treatment of iliac artery aneurysms is still a challenge for the 21<sup>st</sup> century vascular surgeon. Often, the location of the iliac artery is deep in the pelvis, complicated by adjacent structures as deep veins, the ureter, and on the left side by the overlying sigmoid colon. These anatomical configurations make an intervention in this area difficult and prone to complications. In case of an aortoiliac aneurysm, reconstruction through a midline laparotomy is still preferred, although some do advocate a retroperitoneal approach, especially for high-risk patients.<sup>33</sup> An aortobiliac bypass graft is constructed, preferably by landing on the iliac bifurcation. In case of an aneurysmatic iliac bifurcation or internal iliac artery, the distal anastomosis is constructed on the external iliac artery or, in case of severe atherosclerosis, even on the common femoral artery through a separate groin incision. For solitary unilateral aneurysms of the common or internal iliac artery, a retroperitoneal approach through an incision in the lower flank is preferred.<sup>30,34</sup>



The aneurysm is opened and an interposition graft is constructed. When a large internal iliac artery aneurysm is present, the distal branches of the internal iliac artery are ligated from the outside or over sewn from the inside after opening the aneurysm, followed by an interposition graft between common and external iliac artery.

## Endovascular repair

For endovascular repair of iliac artery aneurysms there are basically two options. An endovascular aortobiliac bifurcation graft (or aortouniliac stent-graft with crossover bypass graft) is used to treat aortoiliac aneurysms and solitary iliac aneurysms with a too short or absent proximal landing zone to be treated with a single stent-graft in the iliac artery. For solitary common and/or internal iliac artery aneurysms with a proximal neck suitable as proximal landing zone, a stent-graft is positioned in the iliac artery, starting at the aortic bifurcation and landing distally in the distal common iliac artery, provided there is a suitable landing zone, or else in the external iliac artery. In 1998, and still at the beginning of the endovascular era, Krupski et al. wrote that 'endovascular repair may be less durable and effective than direct surgical repair'.<sup>30</sup> Since then, however, endovascular techniques have flourished, also for the treatment of iliac artery aneurysms and some aspects of this evolution are illustrated in this thesis.

## The internal iliac artery

The fate of the internal iliac artery is an important issue in iliac aneurysm repair. Occlusion of the internal iliac artery can result in pelvic ischemic complications with both buttock claudication and erectile dysfunction being most prevalent. Bladder dysfunction, sacral decubitus ulceration, colonic ischemia, spinal cord ischemia, and scrotal skin sloughing also can occur. The debate as regards the incidence and clinical significance of internal iliac artery occlusion is still ongoing. Especially the difference in outcome between unilateral and bilateral occlusion and between embolization versus simple overstenting of the internal iliac artery is still not clear.<sup>35</sup> Lin et al. recently reviewed the literature regarding the treatment of solitary iliac aneurysms from 2000 to 2008 and found that buttock claudication appeared with an incidence of 28% (198/706) for unilateral and of 42% (43/102) for

bilateral internal iliac artery occlusion. New onset erectile dysfunction emerged in 19% (29/152) for unilateral and in 24% (17/70) for bilateral internal iliac artery occlusion. The incidence of colonic ischemia after endovascular abdominal aneurysm repair (EVAR) and internal iliac artery occlusion was increased with an overall incidence of 3.4%. After solitary iliac aneurysm repair, this incidence must be lower because the inferior mesenteric artery is not compromised. The risk of spinal cord ischemia after internal iliac artery occlusion is <0.1%.<sup>35</sup>

When trying to predict the occurrence of adverse effects of internal iliac artery occlusion, it is important to understand that the circumflex branches of the common femoral artery and branches of the profunda femoris artery provide greater collateral circulation than the contralateral internal iliac artery.<sup>35,36</sup> In addition, risk factors for complications after internal iliac artery occlusion are younger age and bad left ventricular function.<sup>37</sup> Other risk factors predictive for symptoms of ischemia after internal iliac artery occlusion were found to be >70% stenosis of the contralateral internal iliac artery, absence of filling of three or more named hypogastric branches, and diseased or absent ascending branches of the ipsilateral femoral artery.<sup>38</sup> Also, patency of the inferior mesenteric artery, the subclavian artery, and previous history of abdominal or thoracic aneurysm repair, either open or endovascular, must be considered before the decision is taken to occlude one or both internal iliac arteries.<sup>39</sup>

Occlusion of the internal iliac artery can be established by embolization or by simply overstenting the origin of the artery. Embolization can be performed with coils or with a plug (e.g. Amplatzer vascular plug, AGA Medical Co., Plymouth, Minn, USA), both preferably positioned in the proximal part of the internal iliac artery so as not to overstent and occlude the origin of the branches and thereby compromising collateral flow.<sup>40</sup> Overstenting alone may be performed when there is circumferential apposition of the stent-graft to the wall of the artery at the level of the origin of the internal iliac artery. A type II endoleak, which may result from back bleeding from the internal iliac artery, can at that point in time, however, not be solved in an endovascular way.

In endovascular abdominal aneurysm repair (EVAR), no benefit has been shown of sequential as compared to simultaneous (i.e. at the time of aneurysm exclusion) internal iliac artery embolization.<sup>40</sup>

For the preservation of the internal iliac artery in iliac aneurysm repair,

different techniques have been developed. With the hypogastric artery bypass, an endograft is introduced from the ipsilateral common femoral artery and positioned from the external to the internal iliac artery, combined with a contralateral aortouniiliac endograft and a surgical crossover bypass.<sup>41,42</sup> Antegrade hypogastric stent-grafting combined with a surgical crossover bypass<sup>20</sup> and relocation of the iliac bifurcation are other solutions.<sup>43</sup> Finally, the iliac branched device (IBD) which constitutes of a bifurcated endograft for the common iliac artery with an incorporated branch for the internal iliac artery, is the only totally endovascular option to spare the internal iliac artery. This technique will be discussed in detail in this thesis.

## **Treatment of femoral artery aneurysms**

Common femoral artery aneurysms are in general treated by open surgery with an interposition graft from the distal external iliac artery or proximal common femoral artery to the superficial femoral and/or profunda femoris artery. The main reason for which the common femoral artery aneurysm is generally not treated with a stent-graft is that the femoral bifurcation is often involved in the aneurysm and therefore either profunda femoris or superficial femoral artery would be sacrificed.

For a profunda femoris artery aneurysm, a femoral interposition graft is the preferred treatment above ligation alone, in view of the frequent preexistent superficial femoral artery occlusion in these cases.<sup>24</sup> Endovascular repair is anecdotal but feasible in selected cases with proximal and distal landing zones, away from the femoral artery bifurcation.<sup>44,45</sup>

For a superficial femoral artery aneurysm, an interposition graft or bypass with proximal and distal ligation can be constructed. Endovascular therapy is feasible and seven cases treated with a Wallgraft (Boston Scientific, Natick, Mass, USA) have been reported with a 100% patency after 1 year.<sup>46</sup>

For postcatheterization false aneurysms of the groin, open repair was the gold standard up till 1991. At that time, ultrasound scan-guided compression was introduced. This technique was a painful exercise for both patient and laboratory technician, and it was time consuming. Ultrasound scan-guided thrombin injection was introduced in 1986 by Cope and Zeit but became popular only years later. With ultrasound scan guidance and as an outpatient procedure, a concentrated solution of thrombin is injected in the pseudoaneurysm, after which thrombosis of the aneurysm and sealing

of the puncture hole immediately follow. Antiplatelet therapy or oral anti-coagulation is not a contraindication and does not limit clot formation. It is an almost painless and relatively costeffective and durable procedure. It has become the new gold standard for treatment of femoral postcatheterization pseudoaneurysms.<sup>47</sup>

## Treatment of popliteal artery aneurysms

### Open surgical repair

In contrast to the concept in the era of John Hunter, popliteal artery aneurysms are nowadays treated to prevent both the effects of chronic silent embolization and acute embolization or thrombosis. Both situations will eventually lead to some degree of limb ischemia, such as claudication or critical ischemia. All popliteal aneurysms contain thrombus to a certain degree, which depends on the size of the aneurysm.<sup>12,48,49</sup> It is reasonable to think that thrombus in the wall of the aneurysm will be the source of the emboli. Evidence that only aneurysms with a proven thrombus in the wall are at a high risk for embolization or thrombosis, however, is scarce.<sup>49</sup>

### *Type of approach and type of conduit*

Open repair is still considered the gold standard. The different surgical techniques for exclusion of a popliteal artery aneurysm can be divided into two groups. One is construction of a bypass via a medial approach after proximal and distal ligation of the popliteal artery. The other is an interposition graft after aneurysmectomy via a posterior approach.

With the standard medial approach, the popliteal artery is ligated proximally and distally to the aneurysm, and a bypass is constructed through a medial above-knee and below-knee incision. Bypasses start preferably from the above-knee superficial femoral artery to keep the bypass as short as possible. In cases where the superficial femoral artery is degenerated with aneurysmal dilatation or stenosis, a long bypass originating from the common femoral artery can be constructed. The distal anastomosis is usually performed onto the distal popliteal artery. When aneurysmal dilatation extends onto the tibioperoneal trunk or stenosis is present at that level, the distal anastomosis is made onto the peroneal or one of the tibial vessels.

With the medial approach, side branches cannot always be controlled unless a large incision over the knee joint is made with transection of the tendons of the pes anserinus and the semimembranosus muscle.

The posterior approach is used less frequently than the medial one. In a large Swedish registry, only 8.7% (60/717) of popliteal artery aneurysms were treated via a posterior approach.<sup>12</sup> With the patient in a prone position, and usually through an S-shaped incision with the upper limb of the incision on the medial side and the lower limb in between the two heads of the gastrocnemius muscles, the popliteal artery is dissected free with care of the tibial and peroneal nerves and the popliteal veins. Arterial and nerve branches to the medial head of the gastrocnemius muscle that cross the popliteal space from lateral to medial often have to be transected. The arteries above and below the popliteal artery aneurysm are clamped and the aneurysm is opened, side branches are oversewn from within the aneurysm, and an interposition graft is constructed with end-to-end anastomoses. Good results have also been reported using a straight incision instead of an S-shaped curvilinear incision.<sup>50</sup> The posterior approach provides a limited proximal access only up to the level of the adductor hiatus and is therefore not indicated for large aneurysms that extend beyond the hiatus. Distally, the trifurcation vessels can be exposed by dissection between the medial and lateral heads of the gastrocnemius muscle, although a medial approach with venous bypass is to be preferred when the distal anastomosis is on the tibial or peroneal vessels.

For both types of reconstruction, via the medial or the posterior approach, autologous venous grafts and prosthetic grafts are used. Harvesting the long saphenous vein is, however, easier through a medial approach. Venous reconstruction with the posterior approach using the long saphenous vein necessitates either two separate incisions and turning the patient's position during the operation, or the use of the short saphenous vein.

Beseth and Moore have described a series where only the posterior approach was used for repair of 30 popliteal artery aneurysms with a prosthetic graft (6 mm Dacron or 6 to 8 mm polytetrafluoroethylene (PTFE)).<sup>50</sup> Primary patency after 2 years was 92%. The authors state that they only used a medial approach with a venous graft when the aneurysm extended beyond the hiatus and when the distal anastomosis was onto the trifurcation vessels. One explanation for the good results in this series could be the relatively short length of the bypass.<sup>51</sup> In a multicenter case-matched study

comparing the medial and posterior approaches (33 posterior versus 33 medial), Kropman et al. found that primary patency at 1 and 4 years was 79% and 66% for the posterior approach and 93% ( $P < 0.05$ ) and 69% ( $P = \text{NS}$ ) for the medial approach after a mean follow-up of 47 months.<sup>48</sup> In addition, irrespective of approach, venous reconstructions resulted in significantly higher primary patency rates compared with prosthetic reconstructions at 3-year follow-up (84% versus 67%;  $P < 0.01$ ).<sup>52</sup> The Swedvasc registry demonstrated a primary patency rate at 1 year with venous and prosthetic bypass grafts of 90% and 72% respectively ( $P < 0.001$ ).<sup>12</sup> This can be explained by the fact that longer bypasses give better results with vein than with prosthetic grafts.<sup>51</sup>

### *Results after elective surgical repair*

The elective repair of an asymptomatic popliteal artery aneurysm is often mentioned as being associated with excellent results.<sup>53</sup> For asymptomatic cases only, 5-year patency rates vary between 78% and 86%.<sup>54-56</sup> Most series, however, report combined results for symptomatic and asymptomatic cases, with 5-year primary patency rates of between 60% and 86%.<sup>14,51-55,57-60</sup> Limb salvage rates for elective cases vary between 93% and 100%, indicating that surgical popliteal artery aneurysm repair is not without risk.<sup>54-56</sup> Primary patency rates at 10 years also vary considerably between studies and have been reported as low as 66% for elective cases.<sup>53</sup> In the various reports on open repair of popliteal artery aneurysms, only limited data are available on complications including saphenous nerve injuries for medial approaches, tibial and peroneal nerve injuries for posterior approaches, excessive blood loss due to injuries to the deep veins during dissection, postoperative deep venous thrombosis, lymph leakage, and wound healing problems. Morbidity as a result of these complications has to be taken into account when comparing open and endovascular treatment. In a series by Kropman et al. early (30 day) complications occurred in 21% of the cases, for both the medial and posterior approach ( $n = 33$  in both groups).<sup>52</sup> Risk factors for amputation after open repair are poor run off, urgent treatment, age above 70 years, and the use of a prosthetic graft.<sup>12</sup>

### *Continuous aneurysmal sac flow and growth*

The exclusion of a popliteal artery aneurysm through a medial approach carries a risk for continuous collateral flow and growth of the aneurysm through backflow from genicular side branches originating from the aneurysm. Ravn et al. reported a 33% (57/174) incidence of continuous aneurysm perfusion after repair via a medial approach, with 88% of the cases becoming symptomatic and 14% requiring reoperation.<sup>12</sup> The authors noted that, especially after a long bypass originating from the common femoral artery, proximal ligation was often not performed. In contrast, with the posterior approach, 8.3% (2/24) of the aneurysms had expanded at re-examination and there were no reoperations for expansion.<sup>12</sup> Kirkpatrick et al. reported continuous aneurysm flow in 30% (12/36) of the cases, with growth in 50% after a 48-month follow-up.<sup>61</sup> Mehta et al. reported 38% (10/26) of cases showing flow in the aneurysmal sac after a follow-up of 38 months, with 23% demonstrating growth of the aneurysm and 12% ruptures.<sup>58</sup> Some authors therefore concluded that double ligation of the artery both proximally and distally has to be performed as close as possible to the popliteal artery aneurysm in order to achieve complete exclusion of the aneurysm.<sup>12,58,59,61,62</sup> Even then, collaterals originating from the aneurysm itself can be the source of continuous sac flow. Especially with the medial approach these collaterals are difficult to ligate.

### Endovascular repair

The endovascular repair of a popliteal artery aneurysm was first mentioned in 1994. Marin et al. used a polytetrafluoroethylene (PTFE) bypass with a stent attached on both ends to secure the graft in the popliteal artery above and below the aneurysm.<sup>63</sup> Numerous commercial stent-grafts have been developed since then and used to treat popliteal artery aneurysms. To place a stent-graft in the popliteal artery that is subject to repetitive flexion-extension movements requires radial force for apposition of the graft to the wall of the artery and to prevent migration. Flexibility to prevent kinking, and a specific design to prevent fracture of the stent material are other features of the ideal stent-graft. Description of the endovascular repair of popliteal artery aneurysms with the Hemobahn/Viabahn stent-graft, results and outcome of the procedure, and a review of the literature, are described in this thesis in detail.

## Emergency repair

Emergency repair is a predictor of worse outcome after surgical popliteal aneurysm repair compared with elective repair, with 5-year primary patency rates of between 49% and 65% and limb salvage rates no higher than 64%.<sup>54-56</sup> In the Swedvasc registry, 235 patients (33%) treated for acute ischemia between 1987 and 2002 had a higher risk for amputation than the patients who were treated electively.<sup>12</sup> The amputation rate at 1 year had decreased gradually since 1987 and was 5.4% for the period 1998 to 2002. This may reflect the increased use of pre-operative thrombolysis over the years.<sup>12</sup>

Intra-arterial thrombolysis is recommended as preoperative adjunct to recanalize the tibial vessels in case of an acutely thrombosed popliteal artery aneurysm. The choice between preoperative thrombolysis followed by a semiacute reconstruction, and intraoperative thrombolysis, however, is still controversial. Galland et al. demonstrated that preoperative intra-arterial thrombolysis was associated with an increased risk for embolization of thrombus and acute ischemic deterioration in up to 13% of the cases compared with intraoperative lysis.<sup>64</sup> The authors favour infusing the lytic agent during construction of the proximal anastomosis. In contrast, Ravn et al. found that the risk of amputation was lower in patients treated with preoperative thrombolysis than in those who received immediate surgical repair with adjunctive intraoperative thrombolysis.<sup>12</sup> Some have successfully experimented with intraoperative isolated perfusion of lytic agents.<sup>65</sup>

Despite thrombolysis, however, in some cases fragments will have embolized that cannot be lysed or removed during the subsequent intervention. In these cases, permanent loss of sensory or motory function will ensue or it will lead to amputation of the limb.<sup>28</sup>

## Conclusion

Peripheral artery aneurysms, defined in this thesis as aneurysms located distally from the aortic bifurcation, are rare entities. When they become symptomatic and lead to thrombosis, embolization or rupture, however, they can lead to severe morbidity and mortality. Therefore, patients with peripheral aneurysms nowadays ought to be treated before symptoms will occur. In the different paragraphs of this introduction, an overview was given



which concerns past and presence of open surgical repair. In the following chapters of this thesis, a number of different aspects of the endovascular repair of peripheral aneurysms will be described in detail.

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