POPLITEAL ARTERY ANEURYSMS

Clinical relevance of dynamics and vulnerability

Rogier H.J. Kropman

Popliteal artery aneurysms. Clinical relevance of dynamics and vulnerability
Thesis, University Utrecht, Faculty of Medicine, with summary in Dutch
Proefschrift, Universiteit Utrecht, met een samenvatting in het Nederlands

ISBN:
Cover: Sandra Henken-Smits
Layout and Design: Wendy Schoneveld, www.wenzid.nl
Printed by: Gildeprint Drukkerijen Enschede

The printing of this thesis was financially supported by: Afdeling Heelkunde Universitair Medisch Centrum Utrecht, Angiocare B.V., Bard Benelux N.V., Endologix, Krijnen Medical Innovations, St Antonius ziekenhuis Nieuwegein Maatschap Heelkunde, St Antonius ziekenhuis Nieuwegein, Scovasc, WL Gore & Associates.

Financial support by the Dutch Heart Foundation for the publication of this thesis is gratefully acknowledged.

POPLITEAL ARTERY ANEURYSMS
Clinical relevance of dynamics and vulnerability

ARTERIA POPLITEA ANEURYSMA'S
Klinische relevantie van dynamiek en kwetsbaarheid

(met een samenvatting in het Nederlands)

PROEFSCHRIFT

ter verkrijging van de graad van doctor

aan de Universiteit Utrecht op gezag van de rector magnificus,

prof.dr. G.J. van der Zwaan, ingevolge het besluit van het college voor promoties

in het openbaar te verdedigen op vrijdag 28 juni 2013 des ochtends te 10.30 uur

door

Rogerius Henricus Johannes Kropman

Geboren op 3 november 1978 te Nijmegen

Promotor: Prof.dr. F.L. Moll

Co-promotor: Dr. J.P.P.M. de Vries

CONTENTS

CHAPTER 1

Introduction

EPIDEMIOLOGY AND PATHOPHYSIOLOGY

The occurrence of popliteal artery aneurysms (PAAs) was first documented by Antyllus in 200 BC with description of ligation of the aneurysm, followed by packing of the sac[1]. PAAs are characterized by a progressive arterial dilatation measured in absolute diameter (20 mm) or as a 50% enlargement compared with the adjacent normal artery and/or the contralateral popliteal artery when normal2. The normal diameter of the popliteal artery is 5 to 9 mm[2-5].

The popliteal artery is divided into the 3 segments, P1, P2, and P3. Between the adductor hiatus and the top of the kneecap, the popliteal artery is called segment P1. Segment P2 continues until the split of the knee articulation; thereafter, the popliteal artery is called segment P3 until the artery divides in the crural arteries. The bending point of the knee joint is between segment P1 and P2. The popliteal artery has two relatively fixed points, one proximal to the adductor canal and the other distal to the orifice of the anterior tibial artery[6]. In healthy volunteers, arterial flexions of the popliteal artery contribute to tortuosity during flexion and extension of the knee[7].

The overall PAA incidence in people aged older than 50 years is 0.1% to 2.8%[8-10]. Five to ten percent of patients with an abdominal aortic aneurysm (AAA) are also affected by a PAA[11-13]. PAAs most frequently affect elderly men. Detailed age- and gender-specific incidences of hospitalization for repair of elective and acute (thrombosed) PAAs are lacking. Arteriosclerosis is currently the most frequent cause of PAA formation and is involved with multiple cofactors. At the start of the last century, syphilis was the most frequent cause of PAAs but is seldom the cause now[14]. PAAs may rarely be associated with connective tissue diseases, such as Marfan syndrome or Ehlers-Danlos syndrome. The aorta is more frequently affected in those syndromes[15]. A congenital origin of PAA is also very rare. Other causes of nonatherosclerotic PAAs are popliteal artery entrapment syndromes and blunt or penetrating trauma[16].

TREATMENT

The primary goal of treatment of PAAs is to prevent (acute) thrombosis and, as a consequence, limb loss. Patients with symptomatic (mechanical complaints, acute ischemia, chronic ischemia) PAAs should undergo intervention because the risk of limb loss increases with the onset of symptomatic disease[17-20]. The treatment of asymptomatic PAAs remains controversial. Widespread consensus has been achieved to repair asymptomatic aneurysms $\geq$ 30 mm to prevent thromboembolic complications. No consensus has been reached for aneurysms between 20 and 30 mm[21-24]. Open surgical treatment with a venous bypass graft is currently the treatment of choice for most vascular surgeons. Patency rates of these reconstructions depend mainly on the quality and number of outflow arteries, the type of bypass material (venous or prosthetic), and whether the reconstruction is performed for acute ischemia or in an elective setting. During recent years, endovascular treatment (with a covered stent) has become a possible alternative for open surgery.

To improve early detection of PAAs and their concurrent treatment, risk stratification and knowledge of the anatomy of the aneurysm are important. Appropriate research is therefore essential to increase understanding of the treatment options and may prevent patients from becoming symptomatic. Further research is needed on (1) the optimum timing of intervention for asymptomatic PAAs, (2) finding other characteristics that will lead to acute thrombosis of the asymptomatic PAA besides diameter, and (3) the surgical treatment of choice in elective and acute settings.

OUTLINE OF THE THESIS

Knowledge of anatomic variations of the popliteal artery is essential for the management of peripheral vascular disease. It influences the success of femoropopliteal and crural reconstructions and may also be important in orthopedic surgery. Variations may increase the risk of bleeding, dissections, or ischemic complications. Therefore, this thesis will commence in **Chapter 2** by describing the variations in anatomy of the popliteal artery.

PAAs and AAAs frequently coincide. The frequency and nature of symptoms are different; however, most patients with a PAA will be symptomatic at the time of diagnosis, most frequently with thromboembolic complications, and less than 2% of patients present with a ruptured PAA. In contrast, patients with an AAA are mostly asymptomatic at the time of diagnosis, and when symptomatic, rupture is the most frequently observed symptom. In **Chapter 3**, the aneurysm wall composition of PAAs and AAAs is assessed.

Chapter 4 reports systematic reviews of short-term and long-term results of surgical and endovascular treatment of PAAs. Open surgical treatment with a venous graft is still the treatment of choice for most surgeons. During recent years, endovascular surgery has become an alternative to open surgery.

The most commonly performed surgical technique for PAA repair is the medial approach, with proximal and distal aneurysm ligation, followed by autologous vein or polytetrafluroethylene (PTFE) bypass grafting[25]. This technique does not exclude side branches with their origin in the PAA, which can be responsible for retrograde perfusion in the ligated aneurysm sac and eventually lead to aneurysm enlargement and worse, rupture[26-31]. An alternative technique is the posterior approach. This technique includes direct opening of the aneurysm sac, interrupting patent side branches of the genicular arteries, and autologous venous or PTFE interposition grafting. **Chapter 5** reports a head-to-head comparison of the medial and posterior approaches in the treatment of PAA.

In **Chapter 6**, a systematic review summarizes outcomes of acutely thrombosed PAAs treated with thrombolysis or thrombectomy, followed by a bypass. The primary end point in this study was limb salvage, and the secondary end points were mortality and patency of the bypasses.

It is not clear which characteristics of an asymptomatic PAA will lead to acute thrombosis; diameter alone might not be the only predicting factor. **Chapter 7** examines other possible features that may influence outcome such as the changes in lumen area and the degree of angulation directly proximal and distal of the PAA after flexion and extension of the knee joint.

The behavior of arterial disease is different in women and men in terms of anatomy, physiology, and clinical presentation. Combined results of studies focusing on the outcome of bypass surgery in the lower extremity do not show significant differences in primary patency rates, percentage of limb salvage, and survival between men and women[32-39]. **Chapter 8** investigates whether there is an association of gender on the outcome of PAA treatment.

Chapter 9 concludes this thesis, providing a general discussion and future perspectives. A summary in Dutch is presented in **Chapter 10**.

REFERENCES

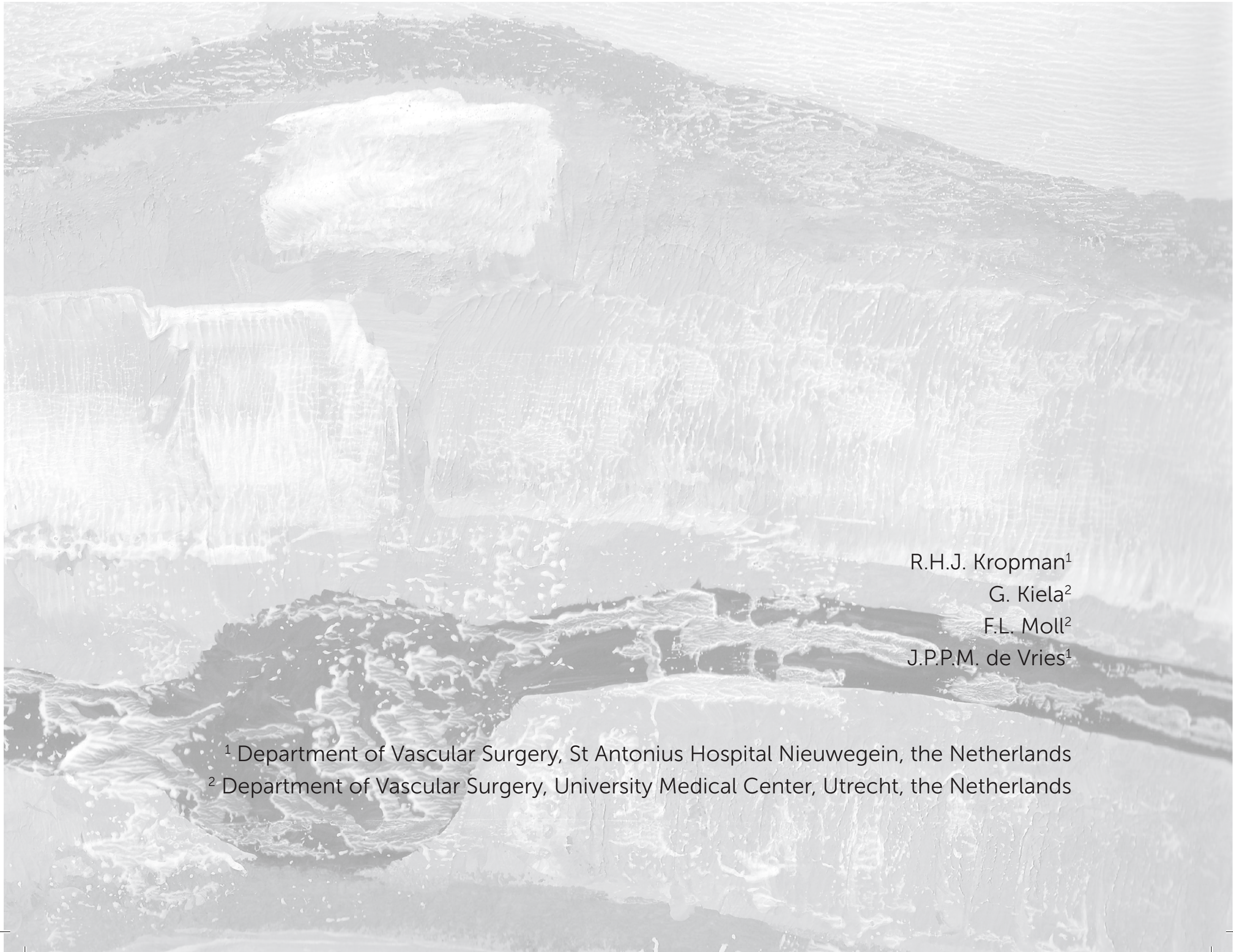
1. Friedman SG, Friedman MS. Matas, Antyllus and endoaneurysmorrhaphy. Surgery 1989;105:761-3.
2. Davis RP, Neiman HL, Yao JS, Bergan JJ. Ultrasound scan in diagnosis of peripheral aneurysms. Arch Surg 1977;112:55-8.
3. Johnston KW, Rutherford RB, Tilson MD, Shah DM, Hollier L, Stanley JC. Suggested standards for reporting on arterial aneurysms. Subcommittee on Reporting Standards for Arterial Aneurysms, Ad Hoc Committee on Reporting Standards, Society for Vascular Surgery and North American Chapter, International Society for Cardiovascular Surgery. J Vasc Surg 1991;13:452-8.
4. Wolf YG, Kobzantsev Z, Zelmanovich L. Size of normal and aneurysmal popliteal arteries: a duplex ultrasound study. J Vasc Surg 2006;43:488-92.
5. Zierler RE, Zierler BK. Duplex sonography of lower extremity arteries. In Zwiebel WJ, editor. Introduction to vascular ultrasonography. 3rd edition. Philadelphia: Saunders; 1983:237-51.
6. Avisse C, Marcus C, Ouedraogo T, Delattre JF, Menanteau B, Flament JB. Anatomo-radiological study of the popliteal artery during knee flexion. Surg Radiol Anat 1995;17:255-62.
7. Wensing PJ, Scholten FG, Buijs PC, Hartkamp MJ, Mali WP, Hillen B. Arterial tortuosity in the femoropopliteal region during knee flexion: a magnetic resonance angiographic study. J Anat 1995;186:133-9.
8. Duffy ST, Colgan MP, Sultan S, Moore DJ, Shanik GD. Popliteal aneurysms: a 10-year experience. Eur J Vasc Endovasc Surg 1998;16:218-22.
9. Hirsch AT, Haskal ZJ, Hertzer NR, Bakal CW, Creager MA, Halperin JL, et al. ACC/AHA 2005 Practice Guidelines for the management of patients with peripheral arterial disease (lower extremity, renal, mesenteric, and abdominal aortic): a collaborative report from the American Association for Vascular Surgery/Society for Vascular Surgery, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, Society of Interventional Radiology, and the ACC/AHA Task Force on Practice Guidelines (Writing Committee to Develop Guidelines for the Management of Patients With Peripheral Arterial Disease): endorsed by the American Association of Cardiovascular and Pulmonary Rehabilitation; National Heart, Lung, and Blood Institute; Society for Vascular Nursing; TransAtlantic Inter-Society Consensus; and Vascular Disease Foundation. Circulation 2006;113:e463-e654.
10. Pulli R, Dorigo W, Troisi N, Innocenti AA, Pratesi G, Azas L, et al. Surgical management of popliteal artery aneurysms: which factors affect outcomes? J Vasc Surg 2006;43:481-7.
11. MacSweeney ST, Skidmore C, Turner RJ, Sian M, Brown L, Henney AM, et al. Unravelling the familial tendency to aneurysmal disease: popliteal aneurysm, hypertension and fibrillin genotype. Eur J Vasc Endovasc Surg. 1996;12:162-6.
12. Sandgren T, Sonesson B, Ryden A, Lanne T. Arterial dimensions in the lower extremities of patients with abdominal aortic aneurysms--no indications of a generalized dilating diathesis. J Vasc Surg 2001;34:1079-84.
13. Diwan A, Sarkar R, Stanley JC, Zelenock GB, Wakefield TW. Incidence of femoral and popliteal artery aneurysms in patients with abdominal aortic aneurysms. J Vasc Surg 2000;31:863-9.
14. Spay G, Sarrat H, Magnin G, Sow I, Marchand P, Fayet I, et al. Syphilitic aneurysm with popliteal localization. J Surg (Paris) 1974;108:343-46.
15. Van der Heyde MN, Zwaveling A. Resection of an abdominal aortic aneurysm in a patient with Marfan's syndrome. J Cardiovasc Surg 1961;2:359-66.
16. Dawson I, Sie RB, van Bockel JH. Atherosclerotic popliteal aneurysm. Br J Surg 1997;84:293-9.
17. Carpenter JP, Barker CF, Roberts B, Berkowitz HD, Lusk EJ, Perloff LJ. Popliteal artery aneurysms: current management and outcome. J Vasc Surg 1994;19:65-72.
18. Gouny P, Bertrand P, Duedal V, Cheynel-Hocquet C, Lancelin C, Escourolle F, Nussaumeand O, Vayssairat M. Limb salvage and popliteal aneurysms: advantages of preventive surgery. Eur J Vasc Endovasc Surg 2000;19:496-500.
19. Roggo A, Brunner U, Ottinger LW, Largiader F. The continuing challenge of aneurysms of the popliteal artery. Surg Gynecol Obstet 1993;177:565-72.
20. Shortell CK, DeWeese JA, Ouriel K, Green RM. Popliteal artery aneurysms: a 25-year surgical experience. J Vasc Surg 1991;14:771-6.
21. Cross JE, Galland RB, Hingorani A, Ascher E. Nonoperative versus surgical management of small (less than 3 cm), asymptomatic popliteal artery aneurysms. J Vasc Surg 2011;53:1145-8.
22. Forbes TL, Ricco JB. Editors commentary. J Vasc Surg 2011;53;1145-48.
23. Cross JE, Galland RB. Part one: For the motion asymptomatic popliteal artery aneurysms (less than 3 cm) should be treated conservatively. Eur J Vasc Endovasc Surg 2011;41:448-9.
24. Hingorani A, Ascher E. Part two: Against the motion asymptomatic popliteal artery aneurysms (less than 3 cm) should be repaired. Eur J Vasc Endovasc Surg 2011;41:445-8; discussion 449.
25. Edwards WS. Exclusion and saphenous vein bypass of popliteal aneurysms. Surg Gynecol Obstet 1969;128:829-30.

26. Ebaugh JL, Morasch MD, Matsumura JS, Eskandari MK, Meadows WS, Pearce WH. Fate of excluded popliteal artery aneurysms. J Vasc Surg 2003;37:954-9.
27. Jones WT 3rd, Hagino RT, Chiou AC, Decaprio JD, Franklin KS, Kashyap VS. Graft patency is not only clinical predictor of success after exclusion and bypass of popliteal artery aneurysms. J Vasc Surg 2003;37:392-8.
28. Kirkpatrick UJ, McWilliams RG, Martin J, Brennan JA, Gilling-Smith GL, Harris PL. Late complications after ligation and bypass for popliteal aneurym. Br J Surg 2004;91:174-77.
29. Mehta M, Champagne B, Darling RC 3rd, Roddy SP, Kreienberg PB, Ozsvath KJ, et al. Outcome of popliteal artery aneurysms after exclusion and bypass: significance of residual patent branches mimicking type II endoleaks. J Vasc Surg 2004;40:886-90.
30. Van Santvoort HC, de Vries JPPM, Van de Mortel R, Wille J, Van de Pavoordt EDWM. Rupture of a popliteal artery aneurysm 10 years after surgical repair. Vascular 2006;14:227-30.
31. Wakassa TB, Matsunaga P, Da Silva ES, Pinto CA, Kauffman P, Aun R, et al. Follow-up of the aneurismal sac after exclusion and bypass of popliteal artery aneurysms. Clinics 2006;61:107-12.
32. Belkin M, Conte MS, Donaldson MC, Mannick JA, Whittemore AD. The impact of gender on the results of arterial bypass with in situ greater saphenous vein. Am J Surg 1995;170:97-102.
33. Frangos SG, Karimi S, Kerstein MD, Harpavat M, Sumpio B, Roberts AB, et al. Gender does not impact infrainguinal vein bypass graft outcome. Surgery 2000;127:679-86.
34. Harris EJ, Jr, Taylor LM, Jr., Moneta GL, Porter JM. Outcome of infrainguinal arterial reconstruction in women. J Vasc Surg 1993;18:627-34; discussion 34-6.
35. Kalman PG, Johnston KW. Predictors of long-term patient survival after in situ vein leg bypass. J Vasc Surg 1997;25:899-904.
36. Magnant JG, Cronenwett JL, Walsh DB, Schneider JR, Besso SR, Zwolak RM. Surgical treatment of infrainguinal arterial occlusive disease in women. J Vasc Surg 1993;17:67-76; discussion 8.
37. Mays BW, Towne JB, Fitzpatrick CM, Smart SC, Cambria RA, Seabrook GR, et al. Women have increased risk of perioperative myocardial infarction and higher long-term mortality rates after lower extremity arterial bypass grafting. J Vasc Surg 1999;29:807-12; discussion 12-3.
38. Roddy SP, Darling RC, 3rd, Maharaj D, Chang BB, Paty PS, Kreienberg PB, et al. Gender-related differences in outcome: an analysis of 5880 infrainguinal arterial reconstructions. J Vasc Surg 2003;37:399-402.
39. Henke PK, Proctor MC, Zajkowski PJ, Bedi A, Upchurch GR, Jr., Wakefield TW, et al. Tissue loss, early primary graft occlusion, female gender, and a prohibitive failure rate of secondary infrainguinal arterial reconstruction. J Vasc Surg 2002;35:902-9.

CHAPTER 2

Variations in anatomy of the popliteal artery and its sidebranches

Vasc Endovascular Surg 2011;45(6):536-540



R.H.J. Kropman[1]
G. Kiela[2]
F.L. Moll[2]
J.P.P.M. de Vries[1]

[1] Department of Vascular Surgery, St Antonius Hospital Nieuwegein, the Netherlands
[2] Department of Vascular Surgery, University Medical Center, Utrecht, the Netherlands

ABSTRACT

Knowledge of anatomic variations of the popliteal artery is essential for the management of peripheral vascular disease and in orthopedic surgery. The aim of this study was to perform an overview of the literature describing variations of the popliteal artery. To identify relevant literature, we performed a systematic search on Medline, Embase, and the Cochrane Database of Systematic Reviews. We included 4 studies of anatomic dissections and 11 radiologic retrospective series, comprising 7671 limbs, and a variation in popliteal branching was seen in almost 10%. The 3 most frequent variations in branching are a high origin of the anterior tibial artery, the trifurcation of the anterior tibial artery, peroneal artery, and posterior tibial artery, and a hypoplastic or aplastic posterior tibial artery. Awareness of the terminal branching pattern of the popliteal artery before intervention enhances the planning for successful operations and may reduce the incidence of serious, unexpected arterial injury.

INTRODUCTION

Knowledge of the normal anatomy and anatomic variations of the popliteal artery is essential for the successful management of peripheral vascular disease. It not only influences the success of femoropopliteal and tibial reconstructions, but in orthopedic surgery, including total knee replacement, proximal tibia osteotomy, or distal femur reconstructions, variations may increase the risk of bleeding, dissections, or ischemic complications. Traumatic injuries to the popliteal artery are uncommon. Most injuries are iatrogenic after knee replacement, with a reported incidence of 0.03% to 0.2%,[1-3] and have been associated with poor rates of limb salvage as well as high levels of morbidity. In both emergency and elective procedures, variations of the popliteal artery might have important clinical consequences. Iatrogenic injuries might be prevented if the popliteal artery anatomy and its possible anatomic variations are known in advance.

The popliteal artery normally crosses the popliteal fossa and gives rise to the anterior tibial artery (AT) and the tibial-peroneal trunk; thereafter, it further subdivides into the posterior tibial artery (PT) and peroneal artery (PR). Variations of the popliteal artery were explained by Senior et al4 in 1919 and are most often the consequence of persistence of embryonic vessels. The aim of this study was to perform an overview and compilation of the literature describing variations of the popliteal artery and its sidebranches.

METHODS

Literature Search

To identify relevant literature, we systematically searched Medline, Embase, and the Cochrane Database of Systematic Reviews, using various terms for “popliteal artery” and “lower limb artery” combined with terms for “variation,” “anatomy,” and “branching” (Table 1). Included were full original human studies from 1 January 1900 until 1 June 2009. Studies had to be written in the English, French, or German language. Studies were screened by title and abstract by two reviewers (R.K. and G.K.) independently to identify potentially relevant articles, using the inclusion and exclusion criteria. Figure 1 illustrates the search for relevant manuscripts. Reviews and case reports were excluded. Full texts of all included articles were retrieved for further analysis. The first description of variations in popliteal branching dates from the beginning of the 20th century. Medical databases do not cover articles from this period; therefore, a manual cross-check from the reference lists of all relevant articles was performed. This identified additional articles and books that were not found in the medical databases by our search terms.

Selection and appraisal

Studies were selected when all the inclusion criteria were met. First, the data of all studies had to be described or had to be able to be classified by the unified classification of Lippert and Pabst,[5] which was modified 4 years later by Kim et al[6] (Figure 2).

Table 1. Search-terms for Medline and Embase.

Database	Syntax in Title or Abstract	Hits
EMBASE	(variation OR variations OR variant OR branch OR branch OR pattern OR patterns OR anatomic OR anatomy OR variability OR anomaly OR anomalies OR 'run off' OR 'take off') AND ('popliteal artery' OR 'popliteal arteries' OR 'lower limb artery' OR 'lower limb arteries' OR 'lower leg artery' OR 'lower leg arteries' OR 'lower extremity artery' OR 'lower extremity arteries')	1236828 7616 = 344 390 sept
MEDLINE	("popliteal artery" OR "popliteal arteries" OR "lower limb artery" OR "lower limb arteries" OR "lower leg artery" OR "lower leg arteries" OR "lower extremity artery" OR "lower extremity arteries") AND (variation OR variations OR variant OR branch OR branch OR pattern OR anatomic OR anatomy OR variability OR anomaly OR anomalies OR "run off" OR "take off" OR branches OR patterns)	3371 1192924 = 467 470 sept

Studies published before this classification was developed were ordered in the appropriate category based on the classification of Kim et al.[6] by two reviewers (R.K. and G.K.), independently. When the description was not clear, the article was excluded. The unified classification of Kim et al describes 3 types of popliteal branching variations and various subtypes (Figure 2):

I: Normal level of branching

Type IA, normal level of popliteal arterial branching, is described proximal to the lower border of the popliteus muscle, where the popliteal artery divides into the AT, the PT, and the PR. Type IB describes trifurcation when the origins of the 3 major branches do not differ more from each other then 0.5 mm. Type IC is when there is an anterior tibioperoneal trunk.

II: High division of the popliteal artery (at or above the knee joint)

In type IIA, the AT arises at or above the knee joint. In our study, type IIA1 and IIA2 have been added to estimate a total average of type IIA. When the PT arises at or above the knee joint, it is called type IIB. In type IIC, the PR arises at or above the knee joint.

III: Hypoplastic or aplastic branching with altered distal supply.

Type IIIA contains a hypoplastic/aplastic PT. Type IIIB describes a hypoplastic/aplastic AT. When the PT and the AT are hypoplastic/aplastic, it is called type IIIC.

Second, the study had to include at least 20 extremities. Third, the study had to be an original patient series. Studies that contained duplicate material were excluded, and those with the best-documented material were included for analysis.

Data extraction

The following data were documented: method of data collection, number of limbs examined, types, and incidences. Included articles were checked for differences in symmetry of the contralateral leg and sex.

RESULTS

The initial search identified 442 articles related to our search terms. After screening the titles and abstracts, 17 articles were found relevant. After assessment of those 17 full text publications, 7 articles were excluded. Four articles were excluded because it was not possible to classify the popliteal artery according to the classification of Kim et al.[6] In 1 article, data of a study we had already included were used. Two articles were in Russian and Italian, both lacking an abstract. Relevant references and related articles from the manual cross-check resulted in 5 more articles and 1 important book on arterial variations (Figure I). One of the first publications of the anatomy of the popliteal artery

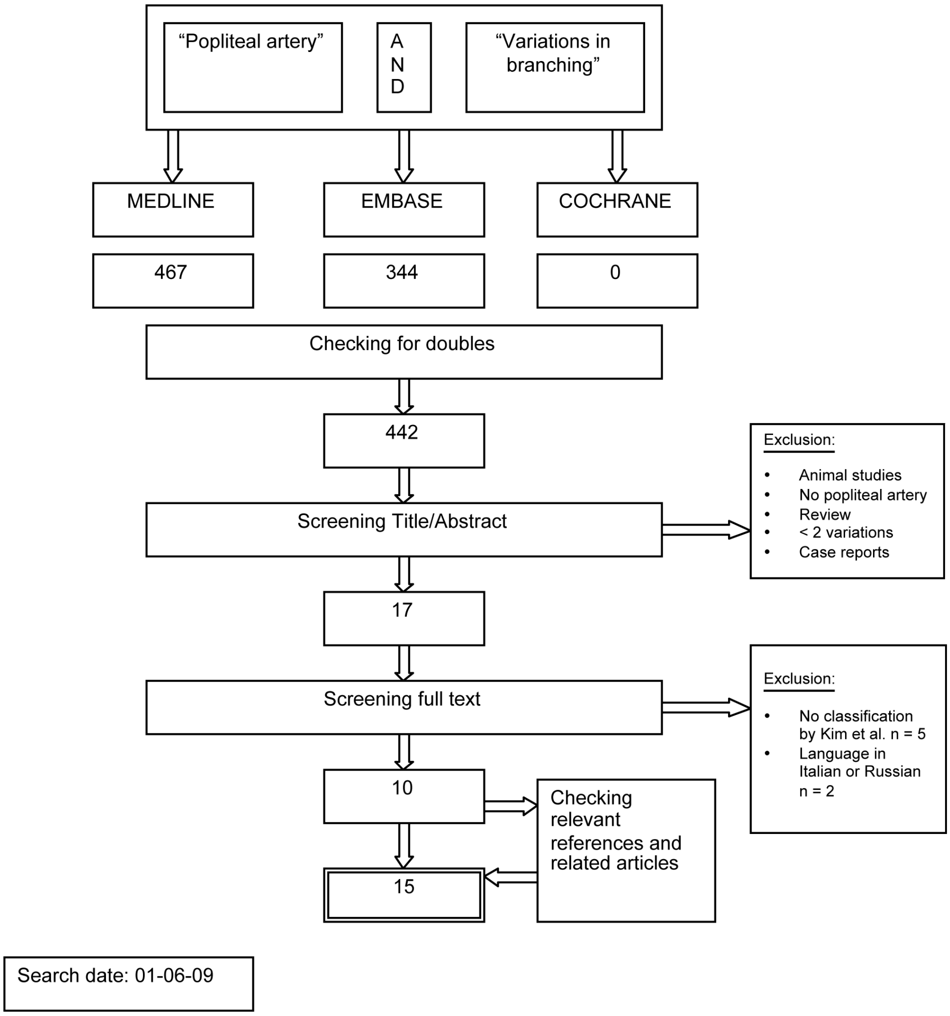


Figure 1. Flowchart showing selection of articles.

is part of Adachi's[7] "Das Arteriensystem der Japanner" which was published in 1928 as a result of more than 30 years of research. This book included no original studies and was not included in our review. Finally, 4 studies focusing on anatomic dissections[8-11] and 11 radiologic retrospective series,[6,12-21] for a total of 7671 limbs, were included in this review.

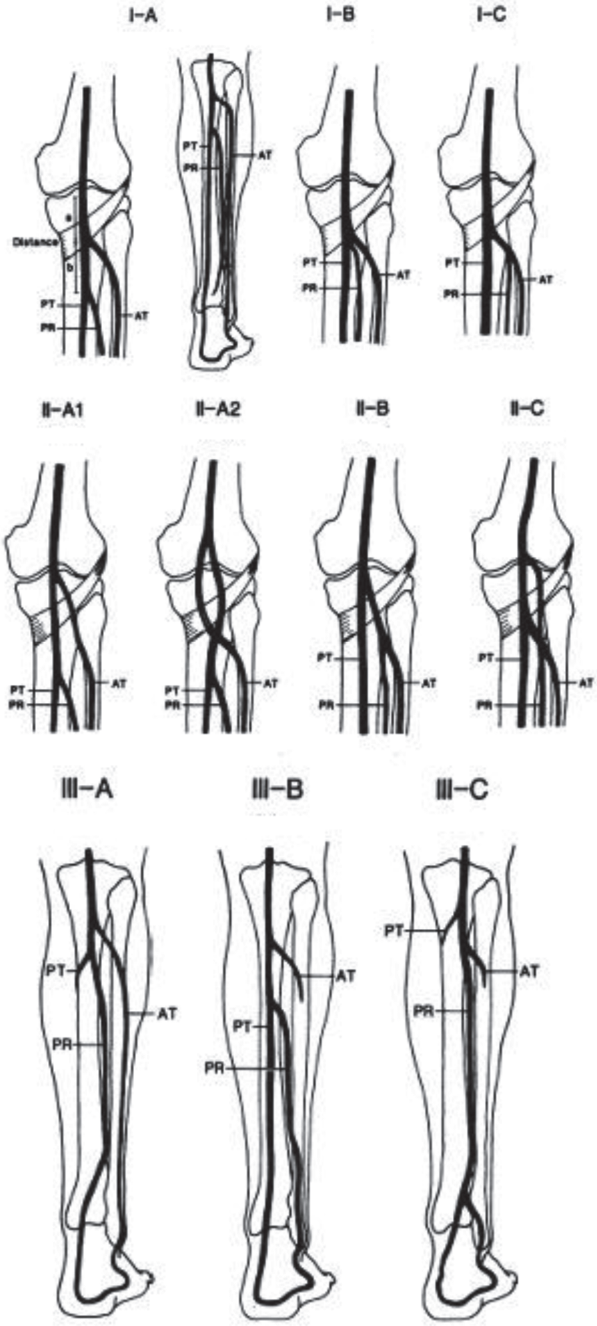


Figure 2. Classification of popliteal branching variations.
AT: anterior tibial artery, PT: posterior tibial artery, PR; peroneal artery
Reprinted with permission from Annals of Surgery (1989;210(6):776-781) and Kim et al.[6]

The incidence rate of the popliteal variation types are summarized in Table I.
Normal level of popliteal arterial branching (type IA) has been described in 6970 extremities (91%). Eight variations in branching have been diagnosed in the studies, of which 3 variations are relatively frequent: (1) an origin of the AT above the knee joint (type IIA), with an incidence of 2.9%; (2) type IIIA containing a hypoplastic or aplastic PT, with an incidence of 2.4%; and (3) the trifurcation of the AT, PR, and PT (type IB), with an incidence of 2.0%. The rarest reported variations are a high division of the PR (type IIC) and a hypoplastic/aplastic PT and AT (type IIIC), with both at an incidence of less than 0.2% (Table 2).
Only two studies described left-right predominance for variations in popliteal branching.8,12 A variation in branching was found in 20 left extremities (49%) compared with 21 right extremities (51%). If a variant is present in a patient, there is a probability of 19% to 33% that the other limb has an variation in popliteal branching as well.[8,12,15] No differences in the number of variations were seen between men and women.[11,12,23]

DISCUSSION

In 1919, Senior et al[4] was the first to describe the embryology of the vascular supply to the lower extremities. The popliteal and peroneal arteries are derived from the primitive middle and distal segments of the sciatic artery, which is an embryonic vessel that supplies the lower limbs. Variations in popliteal artery branches are the result of persisting embryonic vessels or may occur from abnormal fusions.[4,16,22]
Aging of the population has led to an increase in peripheral vascular disease. This results in higher demands on vascular reconstructive procedures. The popliteal artery is often involved in those procedures. In almost 10% of the population, a variation of the normal popliteal artery branching will be diagnosed. Ignorance of those vascular variations may result in serious complications.[6,23,24] Type II variations with high division of the popliteal artery can cause failure of performing the correct anastomosis in femoropopliteal bypass surgery, resulting in retrograde flow that can result in early occlusion of the bypass because of poor runoff. Vascular abnormalities can make surgery more difficult, not only in grafting procedures but also in reconstructions of traumatic injuries. For instance, type IIA popliteal branching will lead to an increased risk of injury of the AT in orthopedic operations because the AT is fixed against the posterior cortex of the tibia by the popliteus muscle.[1]
Anatomic knowledge is necessary for a correct surgical approach and positioning of the bypass. There is no literature on sensitivity or specificity of the different diagnostic tools for diagnosis of popliteal artery anatomy variations.
We believe this is the largest review of the literature about the variations of the popliteal artery. A variation of the popliteal branching was seen in 9% of the 15 studies that were included. Incidences of variant anatomy ranged from 6.4%[18] to 18.2%.[21] The three most common variations were a high origin of the AT (type IIA), a high origin of the trifurcation (type IB), and a hypoplastic-aplastic PT (type IIIA).

Table 2. Incidence of appearance (%) of the subtypes of the popliteal artery division.

Reference	Year	Extremities (n)	Method	IA (%)	IB (%)	IC (%)	IIA (%)	IIB (%)	IIC (%)	IIIA (%)	IIIB (%)	IIIC (%)
Ozgur *et al.*	2008	40	Dissection	90.0	0.0	2.5	5.0	2.5	0.0	0.0	0.0	0.0
Kil *et al.*	2008	1242	Angiography	89.2	1.5	0.1	1.2	0.4	0.0	5.1	1.7	0.8
Day *et al.*	2006	1037	Angiography	90.7	3.2	0.3	4.5	1.1	0.2	0.8	0.1	0.1
Szpinda *et al.*	2006	152	Angiography	87.5	2.6	2.0	2.0	5.9	-	-	-	-
Piral *et al.*	1996	40	Dissection	90.0	5.0	5.0	-	-	-	0.0	0.0	0.0
Voboril *et al.*	1990	253	Angiography	81.8	5.5	-	2.0	2.4	-	7.5	0.8	-
Prayer *et al.*	1990	414	Angiography	90.1	0.7	0.7	4.1	2.9	-	1.0	0.5	-
Davies *et al.*	1989	200	Angiography	88.0	6.0	-	2.0	1.5	-	2.5		-
Kim *et al.*	1989	605	Angiography	92.2	2.0	1.2	3.7	0.8	0.2	3.8	1.6	0.2
Mauro *et al.*	1988	343	Angiography	88.0	4.1	1.2	2.3	0.9	-	-	2.3	-
Bardsley *et al.*	1970	235	Angiography	92.8	0.4	-	4.2	1.7	-	0.9	-	-
Pirker *et al.*	1970	2000	Angiography	93.6	-	1.0	2.6	1.2	-	1.3	0.4	-
Keen *et al.*	1961	280	Dissection	90.7	4.3	0.4	4.0	1.1	-	2.5	5.0	-
Morris *et al.*	1960	246	Angiography	88.6	2.9	1.2	3.6	0.8	-	-	-	-
Trotter *et al.*	1940	584	Dissection	92.3	2.1	0.5	2.7	1.4	-	-	0.3	

CONCLUSION

A variation in popliteal branching can be seen in almost 10% of limbs. The 3 variations in branching with the highest incidence are a high origin of the AT above the knee joint, the trifurcation of the AT, PR, and PT, and a hypoplastic or aplastic PT. Awareness of the terminal branching pattern of the popliteal artery before intervention enhances the planning for operations and should reduce the incidence of serious, unexpected arterial injury during orthopedic, vascular surgery, and percutaneous procedures.

REFERENCES

1. Klecker RJ. The aberrant anterior tibial artery: magnetic resonance appearance, prevalence and surgical implications. Am J Sports Med. 2008;36(4):720-727.
2. Langkamer VG, Local vascular complications after knee replacement: a review with illustrative case reports. Knee. 2001;8:259-264
3. Stewart AH, Baird RN. The prevention and early recognition of arterial complications in total knee replacements: a vascular surgical perspective. Knee. 2001;8:265-267
4. Senior HD. Abnormal branching of the popliteal artery. Am J Anat. 1929;44:111-120.
5. Lippert H, Pabst R. Arterial variations in man: classification and frequency. Muchen: JF Bergman Verlag;1985
6. Kim D, Orron DE, Skillman JJ. Surgical Significance of Popliteal Arterial Variants. A Unified Angiographic Classification. Ann Surg. 1989;210:776-781.
7. Adachi B. Das arteriensystem der Japaner. Verlag der Kaiserlich-Japanischen Universität, Vol II, Kyoto: Maruzen 1928.
8. Keen JA. A study of the Arterial Variations in the Limbs, with special reference to symmetry of vascular patterns. Am J Anat. 1961;108;245-261.
9. Ozgur Z, Ucerler H, Aktan Ikiz ZA. Branching patterns of the popliteal artery and its clinical importance. Surg Radiol Anat. 2009;31(5):357-362.
10. Piral T, Germain M, Princ G. Absence of the posterior tibial artery: implications for free transplants of the fibula. Surg Radiol Anat. 1996;18:155-158.
11. Trotter M. The Level of termination of the popliteal artery in the white and the negro. Am J Anthrop. 1940;109-118.
12. Bardsley JL. Variations in branching of the popliteal artery. Radiology. 1970;94(3):581-587.
13. Davies BW, Husami TW, Lewis J, Retrum E. Developmental variations of the popliteal artery and its branches: a clinical correlation. Contemp Surg. 1989;34:28-32.
14. Day CP, Orme R. Popliteal artery branching patterns – an angiographic study. Clin Radiol. 2006;61:696-699
15. Kil SW, Jung GS. Anatomical variations of the popliteal artery and its tibial branches: analysis in 1242 extremities. Cardiovasc Intervent Radiol 2009;32(2):233-240.
16. Mauro MA. The popliteal artery and its branches: embryologic basis of normal and variant anatomy. AJR Am J Roentgenol. 1988;150:435-437.
17. Morris GC. Anatomical studies of the distal popliteal artery and its branches. Surg Forum.1960;10:498-502
18. Pirker E. Die Röntgenanatomie von arterienvarietäten an den unteren extremitäten und ihre häufigkeit. Fortschr Geb Rontgenstr Nuklearmed. 1970;112(6):731-745.
19. Prayer L, Karnel F, Schurawitzki H. Angiographische darstellung der aufzweigungen der arteria poplitea in die unterschenkelarterien- Variationen und Häufigkeitsverteilung. Röntgenpraxis. 1990;43:100-103.
20. Szpinda M. Digital-image analysis of the angiographic patterns of the popliteal artery in patients with aorto-illiac-occlusive disease (Leriche syndrome). Ann Anat. 2006;188(4):377-382.
21. Voboril R. Note on variability of the arteries of the lower extremities in man. Folia Morphol. 1990;38(3):265:72
22. Tindall AJ. Prevalence and surgical significance of a high-origin anterior tibial artery. J Ortop Surg. 2006;14(1):13-6.
23. Neville RF. Popliteal artery agenesis: A new anatomic variant. J Vasc Surg. 1990;12:573-576.
24. Sanders J. Variations and anomalies of the popliteal and tibial arteries. Am J Surg. 1986;152:531-534.

CHAPTER 3

Wall composition of popliteal artery aneurysms differs from abdominal aortic aneurysms

Submitted to Eur J Vasc Endovasc Surg

R. Hurks[a,b]
R.H.J. Kropman[c]
C.W.A. Pennekamp[a]
I.E. Hoefer[b]
J.P.P.M. de Vries[c]
G. Pasterkamp[b]
A. Vink[d]
F.L. Moll[a]

[a] Vascular Surgery, University Medical Center, Utrecht, the Netherlands
[b] Experimental Cardiology laboratory, University Medical Center, Utrecht, the Netherlands
[c] Vascular Surgery, St Antonius Hospital, Nieuwegein, the Netherlands
[d] Pathology, University Medical Center, Utrecht, the Netherlands

ABSTRACT

Objectives

Popliteal artery aneurysms (PAAs) and abdominal aortic aneurysms (AAAs) frequently coincide, however, symptomatology differs. We systematically assessed aneurysm wall composition to compare both anatomic locations.

Methods

Aneurysmal walls of 38 PAAs and 198 AAAs were harvested from patients undergoing elective open surgical repair. Elastin, collagen, smooth muscle cell, iron, and inflammatory cells were quantified by (immune-)histochemistry. In addition, protease and cytokine levels were measured.

Results

Aneurysmal degradation resulted in similarly degraded media. Location of inflammation differed: focus for T and B lymphocytes and plasma cells was the intima in PAAs (all $P<0.001$) and the adventitia for AAAs (all $P<0.001$). Iron was more often observed in PAAs than in AAAs (68% vs. 1%, $P<0.001$), indicating more previous intramural hemorrhages. MMP-2 activity was higher in PAAs than in AAAs (median[interquartile range] 0.363[0.174-0.556] vs. 0.187[0.100-0.391], $P=0.008$), whereas MMP-9 showed no difference. Walls of AAAs were richer in tested cytokine levels than walls of PAAs, with the exception of IL-6.

Conclusions

PAAs showed more signs of previous hemorrhages compared with AAAs. In addition, inflammation in PAAs is mainly located in the intima, whereas its focus in AAAs is the adventitia. These results suggest important differences in the pathophysiology of aneurysm formation between these locations and might explain the differences in presentation upon diagnosis.

INTRODUCTION

Despite different anatomic locations and different wall compositions, the elastic aortic artery and the muscular popliteal artery have comparable elastic artery-like mechanical properties in aged healthy individuals.[1] Both arteries can suffer from aneurysmal degradation; however, aneurysm formation is most commonly found in the abdominal aorta (AAA), with a prevalence of 5% to 10% in men aged 65 to 79 years.[2] Popliteal artery aneurysms (PAAs) form the second most frequently found aneurysm, with a prevalence of 1% in the same age category.[3] Both aneurysms frequently coincide: 5% to 10% of patients with an AAA may be affected with a PAA,[4-6] and about 40% of patients with a PAA also have an AAA.[7, 8] The frequency and nature of symptoms are different: approximately two-thirds of patients with a PAA will be symptomatic at the time of diagnosis, most frequently with thromboembolic complications, and less than 2% of patients present with a ruptured PAA.[7, 9] In contrast, patients with an AAA are mostly asymptomatic at the time of diagnosis, and when symptomatic rupture is the most frequently observed symptom, leaving only 5% of AAAs diagnosed by distal embolization.[10] AAAs and PAAs are often regarded as the result of similar processes.[11, 12] Given the differences in symptoms, complications, and anatomic location, we aimed at finding an explanation for the described similarities and differences by systematically assessing the aneurysm wall composition of PAAs and AAAs.

METHODS

Aneurysm-express biobank

The Aneurysm-express biobank is a prospective cohort study, and its design was described previously.[13] Briefly, all patients scheduled for open aneurysm repair in the University Medical Center Utrecht and St Antonius Hospital Nieuwegein were asked to participate in this study. Indication for open surgical repair was according to international standards and when endovascular treatment was not appropriate.[12] Patients with terminal malignancies were excluded. The medical ethics committees of both centers approved the study, and participants provided written informed consent. Baseline data were obtained from an extensive cardiovascular questionnaire, according to Rose,[14] and from clinical records, including cardiovascular risk factors and medication use. Aneurysm diameter was assessed by computed tomography angiogram or magnetic resonance angiography.

Aneurysm tissue processing

During surgery, a part of the aneurysm wall was collected next to the arteriotomy. The specimen was immediately transported to the laboratory and cut into 5-mm segments. The middle segment was fixated in 4% formaldehyde and embedded in paraffin for histology. A series of stainings was performed on consecutive slides: hematoxylin and eosin (HE) for overview, elastin van Gieson (EvG) for elastin, Sirius red for collagen, Perls

for iron, α-smooth muscle actin for smooth muscle cells (SMCs), CD68-macrophages, CD45-lymphocytes, CD3-T-lymphocytes, CD20-B-lymphocytes, and CD138-plasma cells. Extracellular matrix (elastin, collagen) components and iron were assessed on a scale from 0 to 3 (0 = no staining, 1 = minor, 2 = moderate, and 3 = heavy staining). In the media, the percentage of elastin fibers disruption was scored (the part of the media where no elastic fibers were present). The different inflammatory cells were also scored on a scale of 4 at 100× magnification per representative field: 0 (no), less than 50 positively stained cells; 1 (minor), 50 to 100 cells; 2 (moderate), 100 to 150 cells; and category 3 (heavy), more than 150 cells. Two independent observers (RH, CP), who were blinded from clinical data and laboratory results, scored all stainings separately in the intima, media, and adventitia.
The adjacent segment was used for protein extraction using Tris isolation (Roche, Basel, Switzerland) and subsequent protein concentration assessment with the BCA protein assay kit (Pierce Biotechnology, Rockford, IL, USA) according to the manufacturers' protocol. Matrix metalloproteinase (MMP) activities were determined with the Amersham MMP-2 and -9 Biotrak Activity Assay system (GE Healthcare Limited, Amersham, UK). Levels of interleukin (IL) -1β, -2, -4, -5, -6, -8, -10, -12p70, interferon (IFN)-γ, and tumor necrosis factor (TNF)-α and -β were quantified in the aneurysmal wall by fluorescent bead immunoassay (Bendermed Systems, Vienna, Austria).

Statistical analyses

Data are presented as median with interquartile range (IQR) or as number with percentage of total for discrete variables. Continuous variables were compared using the Mann-Whitney test or Spearman's nonparametric correlation, where appropriate, and discrete values were tested using the $\chi 2$ test. Probability values of less than 0.05 were considered significant. All analyses were performed with SPSS 15 software (SPSS Inc, Chicago, IL, USA).

RESULTS

Arterial tissue from 38 PAAs of 36 patients was collected and from 198 AAAs of 198 different patients. Baseline characteristics of the study groups are reported in Table 1. Most patients were men, which was even more pronounced in the PAA patients (82% vs 95%, respectively; $P = 0.040$). The patients with PAA were younger (median [IQR] 65.0 [60.0-73.0] vs 71.0 [64.7-76.0] years, $P = 0.010$) and had more previously diagnosed manifestations of aneurysms (53% and 12%, $P < 0.001$; Table 1).
Representative histology is shown in Figure 1. Histologic characteristics of the structural wall components for both aneurysm groups are reported in Table 2. The intima of AAAs showed cholesterol cores more frequently than PAAs (55% vs 16%, $p < 0.001$). The media layer was similarly degraded in PAAs and AAAs, not showing differences in elastin disruption (25 [IQR, 10-95] and 40 [IQR, 10-80], $P = 0.841$) or staining for SMCs (34% and 34%, $P = 0.988$).

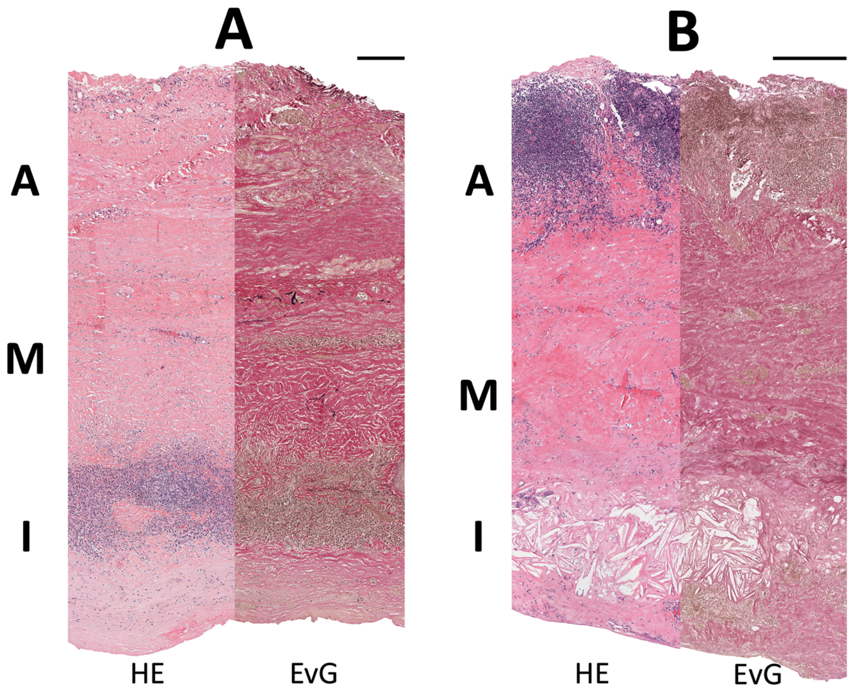


Figure 1. Representative histology for popliteal artery aneurysm (PAA) and abdominal aortic aneurysm (AAA). Photomicrographs show a composite of hematoxylin and eosin and elastic van Gieson stainings. Location of the different layers are marked: I, intima; M, media; A, adventitia. Note the location of the inflammatory infiltrate, the intima in PAA, and the adventitia in AAA. Scale bars represent 0.5 mm.

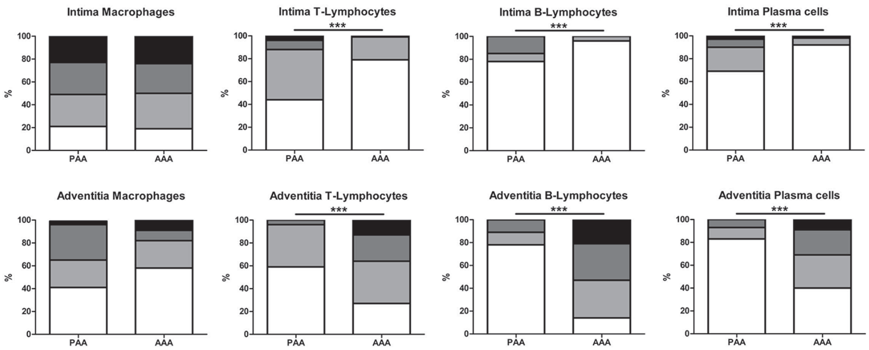


Figure 2. Comparison of inflammatory cell presence on histology in the two types of aneurysm. Per representative field: white color represents <50 cells, light grey represents 50 to 100 cells, dark grey represents 100 to 150 cells, and black represents >150 cells. PAA is popliteal artery aneurysm, AAA is abdominal aortic aneurysm. *** $P < 0.001$.

Table 1. Baseline characteristics.

Characteristics [a]	AAA (n=198)	PAA (n=38)	*P*-value
Age, y	71.0 [64.7-76.0]	65.0 [60.0-73.0]	0.010 *
Male sex	160 (82)	36 (95)	0.040 *
Current smoker	94 (48)	17 (45)	0.678
Diabetes type 2	31 (16)	6 (16)	0.984
Hypertension	141 (72)	26 (68)	0.661
Coronary artery disease	78 (40)	12 (32)	0.325
Chronic obstructive pulmonary disease	41 (21)	5 (13)	0.282
Body mass index, kg/m^2	25.6 [23.6-28.0]	27.1 [25.6-28.1]	0.118
Aneurysm diameter, mm	61 [56-71]	30 [21-46]	<0.001 *
Coinciding PAA	4 (2)		
Coinciding AAA		15 (39)	
Coinciding contralateral PAA		17 (45)	
History of any other aneurysm detected	23 (12)	20 (53)	<0.001 *
Statin use	119 (61)	21 (55)	0.396
Aspirin use	134 (69)	23 (61)	0.742
ACEI use	70 (36)	13 (34)	0.816
Angiotensin II receptor blocker use	35 (18)	7 (18)	0.884
Hospital stay, days	10.0 [8.0-14.0]	6.0 [4.0-9.0]	<0.001 *

[a] Data are presented as median [interquartile range] or as No. (%). **P* < 0.05. Abbreviations: AAA, abdominal aortic aneurysm; ACEI, angiotensin-converting enzyme inhibitor; PAA, popliteal artery aneurysm.

Table 2. Histologic characteristics of structural arterial wall components.

Aneurysm wall characteristics [a]	AAA (n=198)	PAA (n=38)	*P*-value
Intima			
Cholesterol core, presence, n (%)	108 (55)	6 (16)	<0.001 *
Collagen	67 (34)	22 (58)	0.010 *
SMC	45 (23)	14 (37)	0.076
Media			
Elastin disruption, median [IQR], %	40 [10-80]	25 [10-95]	0.841
SMC	68 (34)	13 (34)	0.988
Adventitia			
Collagen	148 (75)	18 (47)	0.003 *
SMC	75 (38)	5 (13)	0.011 *
Iron deposition, presence, n (%)	1 (1)	26 (68)	<0.001 *

[a] Data are presented as No. (%) of heavy staining vs minor staining unless otherwise indicated. **P* < 0.05. Abbreviations: AAA, abdominal aortic aneurysm; IQR, interquartile range; PAA, popliteal artery aneurysm; SMC, smooth muscle cells.

Focus of inflammation was the intima in PAAs and the adventitia in AAAs, as is shown for the different assessed inflammatory cells in Figure 2. Remarkably, PAAs had far more iron deposits in the adventitia (68% vs 1%, $P < 0.001$; Figure 3).
Cytokine levels showed a more pronounced inflammation in AAAs than in PAAs, with the exception of IL-6, which showed a weak opposite trend (Table 3). MMP-2 activity was higher in PAAs (0.187 [IQR, 0.100-0.391] vs 0.363 [IQR, 0.174-0.556] ng/mL, $P = 0.008$), whereas MMP-9 activity was similar in both aneurysms (0.203 [IQR, 0.032-0.767] vs 0.258 [IQR, 0.000-0.637] ng/mL, $P = 0.401$).

Table 3. Protease and cytokine levels.

Aneurysm wall characteristics [a]	**AAA (n=198)**	**PAA (n=38)**	***P*-value**
IL-1β	0.00 [0.00-0.45]	0.00 [0.00-0.00]	<0.001 *
IL-2	1.87 [0.78-3.96]	0.00 [0.00-0.81]	<0.001 *
IL-4	0.00 [0.00-0.81]	0.00 [0.00-0.00]	<0.001 *
IL-5	0.81 [0.09-2.42]	0.00 [0.00-0.00]	<0.001 *
IL-6	1.12 [0.26-6.97]	3.55 [1.11-8.29]	0.101
IL-8	22.85 [10.13-50.46]	9.47 [3.09-29.94]	0.024 *
IL-10	0.28 [0.00-1.11]	0.00 [0.00-0.33]	0.007 *
IL-12	0.35 [0.00-1.24]	0.00 [0.00-0.00]	<0.001 *
TNF-α	0.21 [0.00-0.73]	0.00 [0.00-0.06]	<0.001 *
TNF-β	0.40 [0.00-2.20]	0.00 [0.00-0.00]	<0.001 *
IFN-γ	0.68 [0.01-1.74]	0.00 [0.00-0.00]	<0.001 *
Active MMP-2	0.187 [0.100-0.391]	0.363 [0.174-0.556]	0.008 *
Active MMP-9	0.203 [0.032-0.767]	0.258 [0.000-0.637]	0.401

[a] Data are presented as median and [interquartile range]. $*P < 0.05$. Cytokines are in pg/mL, MMP activities in ng/mL. IL, interleukin; TNF, tumor necrosis factor; IFN, interferon; MMP, matrix metalloproteinase.

DISCUSSION

To our knowledge, this is the first study to systematically report histologic characteristics in the different layers of the PAA. Given the frequent association with AAA, the coincidence in patients, and the comparison in literature, these aneurysms were used as a reference, and marked differences were found.
As in other muscular arteries, the diameter of the popliteal artery increases with age, being affected by age and body size, and is larger in men than in women. With aging, the popliteal artery also suffers from a decreased distensibility, which is more pronounced in men than in women. These changes do not fit the characteristics of a true muscular artery, because, for example, this does not occur in the common femoral artery but is very similar to the pattern observed in a large elastic artery such as the aorta.[1, 15] Despite original differences in histologic composition between the aorta and the popliteal artery (elastic vs. muscular), aneurysm formation resulted in a similar degraded media in our study. Previous smaller studies suggested a common etiology for AAAs and peripheral

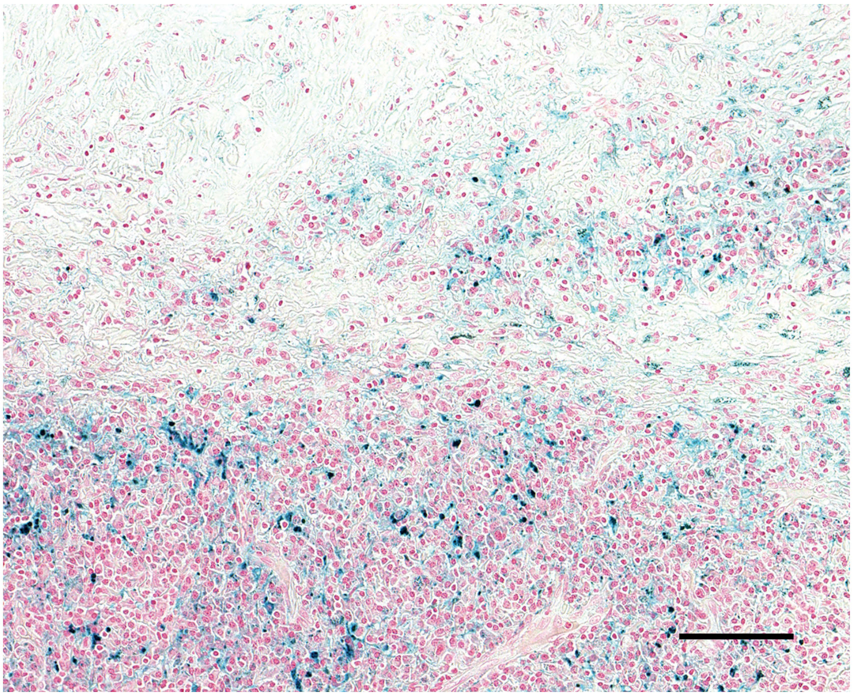


Figure 3. Representative Perls staining of a popliteal artery aneurysm. Blue staining shows the presence of iron. Scale bar indicates 0.1 mm.

aneurysms. A central role for SMC apoptosis was proposed, which was also observed in AAAs and other peripheral aneurysms.[16, 17] Another study reported a marked overlap in inflammation between AAA and PAA.[18] Unfortunately, in these studies differences in wall layers remained unreported and focus was the inflammatory infiltrate. The present study shows that compared with AAAs, the media in PAAs is similarly degraded.

The focus on different layers in the arterial wall also proves important in assessing the inflammatory infiltrate. Where previous smaller studies investigated the inflammatory infiltrate in general, we show that the focus of inflammation in the PAA lies in the intima rather than in the adventitia, as in the AAA. Our findings might explain the difference in symptoms between a PAA and an AAA: the intima is adjacent to the mural thrombus or lumen and is likely to influence processes such as thromboembolism or thrombosis as seen in PAAs, whereas the nature of AAAs is one of expansion and rupture.

In addition, the inflammatory reaction in AAAs is far more pronounced than in PAAs, given the higher cytokine levels in AAAs and the larger proportion of high categories histologic inflammation.

The frequent presence of iron depositions in PAAs with virtually no depositions in AAAs also marks an important difference. Iron remnants are long-term results from hemorrhages,[19] and this finding might point to a different etiology. Intramural bleeding can point to a healed dissection or repetitive smaller tears of the connective tissue, or both. This might be explained by structural factors, including turbulent blood flow in association with arterial branching points and wall fatigue secondary to repeated knee flexion.[11]

MMP-9 is the most abundantly present protease and the most frequently investigated MMP in AAAs.[20] Given the similar levels in AAAs and PAAs, MMP-9 appears to be a common factor and likely is vital for aneurysm formation in general. MMP-2 is more active in PAAs, despite lower numbers of inflammatory cells but it can also be produced by SMCs[21], pointing to a more important role in progression of the PAA or a role in a repair mechanism.

Our study design was hampered by not being able to assess temporal changes in the aneurysm walls, which holds true for all current aneurysm-related research on human material. Aneurysmal disease is characterized by a large proportion of men, which is often described for AAAs but is even more pronounced in PAAs, reaching 94.2% to 99.8%.[9, 22] This is also the case in our study. The lower age in the PAA group might be explained by the occurrence of symptoms leading to an earlier diagnosis and treatment. Both characteristics are not likely to have influenced our results, because the absolute differences are small and no influences on wall composition have been reported.

CONCLUSION

Inflammation in the PAA is mainly located in the intima, whereas the degree of inflammation in the AAA is more pronounced and its focus is the adventitia. In addition, PAAs show more iron compared with AAAs, which might be explained by more (repetitive) external trauma in the PAA through bending of the knee and turbulent flow resulting in tissue tears. Our results suggest differences in the mechanism of aneurysm formation between both localizations, and this might explain the difference in presenting symptoms.

ACKNOWLEDGEMENTS

We thank Marjolein Kerver, MSc, and Petra van der Kraak-Homoet for technical assistance. This work was supported by a grant from foundations Leatare and Concordia Trajectina.

REFERENCES

1. Debasso R, Astrand H, Bjarnegard N, Ryden Ahlgren A, Sandgren T, Lanne T. The popliteal artery, an unusual muscular artery with wall properties similar to the aorta: implications for susceptibility to aneurysm formation? J Vasc Surg. 2004;39:836-42.
2. Cosford PA, Leng GC. Screening for abdominal aortic aneurysm. Cochrane Database Syst Rev. 2007:CD002945.
3. Trickett JP, Scott RA, Tilney HS. Screening and management of asymptomatic popliteal aneurysms. J Med Screen. 2002;9:92-3.
4. MacSweeney ST, Skidmore C, Turner RJ, Sian M, Brown L, Henney AM, et al. Unravelling the familial tendency to aneurysmal disease: popliteal aneurysm, hypertension and fibrillin genotype. Eur J Vasc Endovasc Surg. 1996;12:162-6.
5. Sandgren T, Sonesson B, Ryden A, Lanne T. Arterial dimensions in the lower extremities of patients with abdominal aortic aneurysms--no indications of a generalized dilating diathesis. J Vasc Surg. 2001;34:1079-84.
6. Diwan A, Sarkar R, Stanley JC, Zelenock GB, Wakefield TW. Incidence of femoral and popliteal artery aneurysms in patients with abdominal aortic aneurysms. J Vasc Surg. 2000;31:863-9.
7. Kropman RH, De Vries JP, Moll FL. Surgical and endovascular treatment of atherosclerotic popliteal artery aneurysms. J Cardiovasc Surg (Torino). 2007;48:281-8.
8. Ravn H, Wanhainen A, Bjorck M. Risk of new aneurysms after surgery for popliteal artery aneurysm. Br J Surg. 2008;95:571-5.
9. Ravn H, Bergqvist D, Bjorck M. Nationwide study of the outcome of popliteal artery aneurysms treated surgically. Br J Surg. 2007;94:970-7.
10. Baxter BT, McGee GS, Flinn WR, McCarthy WJ, Pearce WH, Yao JS. Distal embolization as a presenting symptom of aortic aneurysms. Am J Surg. 1990;160:197-201.
11. Henke PK. Popliteal artery aneurysms: tried, true, and new approaches to therapy. Semin Vasc Surg. 2005;18:224-30.
12. Hirsch AT, Haskal ZJ, Hertzer NR, Bakal CW, Creager MA, Halperin JL, et al. ACC/AHA 2005 Practice Guidelines for the management of patients with peripheral arterial disease (lower extremity, renal, mesenteric, and abdominal aortic): a collaborative report from the American Association for Vascular Surgery/Society for Vascular Surgery, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, Society of Interventional Radiology, and the ACC/AHA Task Force on Practice Guidelines (Writing Committee to Develop Guidelines for the Management of Patients With Peripheral Arterial Disease): endorsed by the American Association of Cardiovascular and Pulmonary Rehabilitation; National Heart, Lung, and Blood Institute; Society for Vascular Nursing; TransAtlantic Inter-Society Consensus; and Vascular Disease Foundation. Circulation. 2006;113:e463-654.
13. Hurks R, Hoefer IE, Vink A, de Vries JP, Heijmen RH, Schoneveld AH, et al. Aneurysm-Express: Human Abdominal Aortic Aneurysm Wall Expression in Relation to Heterogeneity and Vascular Events - Rationale and Design. Eur Surg Res. 2010;45:34-40.
14. Rose GA, Blackburn H. Cardiovascular survey methods. Monogr Ser World Health Organ. 1968;56:1-188.
15. Sandgren T, Sonesson B, Ahlgren AR, Lanne T. Factors predicting the diameter of the popliteal artery in healthy humans. J Vasc Surg. 1998;28:284-9.
16. Jacob T, Ascher E, Hingorani A, Gunduz Y, Kallakuri S. Initial steps in the unifying theory of the pathogenesis of artery aneurysms. J Surg Res. 2001;101:37-43.
17. Jacob T, Schutzer R, Hingorani A, Ascher E. Differential expression of YAMA/CPP-32 by T lymphocytes in popliteal artery aneurysm. J Surg Res. 2003;112:111-6.
18. Abdul-Hussien H, Hanemaaijer R, Kleemann R, Verhaaren BF, van Bockel JH, Lindeman JH. The pathophysiology of abdominal aortic aneurysm growth: corresponding and discordant inflammatory and proteolytic processes in abdominal aortic and popliteal artery aneurysms. J Vasc Surg. 2010;51:1479-87.
19. Wartman WB, Laipply TC. The fate of blood injected into the arterial wall. Am J Pathol. 1949;25:383-95.
20. McMillan WD, Tamarina NA, Cipollone M, Johnson DA, Parker MA, Pearce WH. Size matters: the relationship between MMP-9 expression and aortic diameter. Circulation. 1997;96:2228-32.
21. McMillan WD, Patterson BK, Keen RR, Pearce WH. In situ localization and quantification of seventy-two-kilodalton type IV collagenase in aneurysmal, occlusive, and normal aorta. J Vasc Surg. 1995;22:295-305.
22. Johnson ON, 3rd, Slidell MB, Macsata RA, Faler BJ, Amdur RL, Sidawy AN. Outcomes of surgical management for popliteal artery aneurysms: an analysis of 583 cases. J Vasc Surg. 2008;48:845-51.

CHAPTER 4

Surgical and Endovascular Treatment of Atherosclerotic Popliteal Artery Aneurysms

J Cardiovasc Surg (Torino) 2007;48:281-8

R.H.J. Kropman[1]
J.P.P.M. de Vries[1]
F.L. Moll[2]

[1] Department of Vascular Surgery, St Antonius Hospital Nieuwegein, the Netherlands
[2] Department of Vascular Surgery, University Medical Center, Utrecht, the Netherlands

ABSTRACT

Background
Popliteal artery aneurysms are the most common peripheral aneurysms. Patients with unrecognized aneurysms may present with acute limb ischemia and considerable threat for limb loss due to thromboembolic complications. This article reviews short-term and long-term results of surgical and endovascular treatment for mainly elective repair of popliteal artery aneurysms.

Methods
A systemic review was conducted of data in the English literature from 1990.

Results
The review included 1 prospective randomized trial, 6 prospective studies, and 42 retrospective studies on the management of popliteal artery aneurysms. These studies contained 2197 patients with 2882 popliteal artery aneurysms. Short-term results are acceptable, with average 1-year patency rates of 90% for surgical treatment and 75% for endovascular treatment, and respective limb salvages rates of 95% and 100%. Endovascular treatment lacks long-term follow-up, whereas venous surgical repair has an average 5-year patency rate of up to 85% (prosthetic grafts, 40%-80%).

Conclusions
There is a need for randomized trials comparing long-term results of surgical versus endovascular treatment of popliteal artery aneurysms. So far, long-term results of elective surgical repair for popliteal artery aneurysms are acceptable if venous grafts are used. In any case, acute repair of popliteal artery aneurysms must be avoided.

INTRODUCTION

Popliteal artery aneurysm (PAA) appears to be relatively uncommon in the general population, with an incidence of 0.1% to 2.8%[1-3]. Popliteal artery aneurysm is considered to be the second most frequent location of arterial aneurysms, accounting for up to 70% of all peripheral aneurysms[4]. Popliteal aneurysms may cause serious ischemic complications, associated with thromboembolization, which often results in limb loss. Open surgical treatment with a venous bypass graft is still the treatment of choice for most surgeons. Patency rates of these reconstructions depend mainly on the quality and number of outflow arteries, the type of bypass material (venous or prosthetic), and whether the reconstruction is performed for acute ischemia or in an elective setting. During recent years, endovascular treatment has become a valid alternative for open surgery.

To identify relevant literature, we performed a search on PubMed using a wide spectrum of search terms that describe the terms popliteal artery aneurysm and surgical or endovascular treatment. For surgical treatment of PAA, we used the terms *surgical treatment, open repair, popliteal artery aneurysm*, and the combination of MeSH terms *Popliteal Artery* and *Aneurysm*. For endovascular treatment we used the terms *stenting, popliteal artery aneurysm stenting, endovascular treatment, percutaneous transluminal angioplasty*, and the combination of MeSH terms Stents and *Angioplasty*. The following limitations were inserted: humans, English language; published date: 1990-01-01 to 2006-12-31; and age: middle age and older. We selected all relevant articles. Results were collected from 49 series published in the English language literature containing clinical data from a total of 2197 patients with 2882 PAAs.

Anatomy

The popliteal artery is located behind the knee in the popliteal fossa and is a continuation of the superficial femoral artery after it passes the adductor hiatus canal. It is susceptible to simultaneous forces, such as flexion, extension, and rotation, and has to overcome unique mechanical stress. The popliteal artery is divided into the 3 segments P1, P2, and P3. Between the adductor hiatus and the top of the kneecap, the popliteal artery is called segment P1. Segment P2 continues until the split of the knee articulation; thereafter, the popliteal artery is called segment P3 until the artery divides in the crural arteries. The bending point of the knee joint is between segment P1 and P2.

At the popliteal fossa the popliteal artery divides into different branches: the lateral superior genicular artery, the medial superior genicular artery, the medial inferior genicular artery, and the lateral inferior genicular artery. Below the knee joint, the popliteal artery divides into anterior tibial artery and the tibioperoneal trunk, which divides into the peroneal artery and the posterior tibial artery (Figure 1). The total length of the popliteal artery is 12 to 18 cm, of which 5 to 7 cm is distal of the knee joint split.

The normal diameter of the popliteal artery is 5 to 9 mm[5-8]. The popliteal artery is considered to be aneurysmal if its external diameter exceeds 20 mm or measures more than 1.5 times the diameter of the normal proximal popliteal artery.

Etiology

Aneurysms can generally be categorized as either true or false. True aneurysms occur when all layers of the arterial wall are abnormally dilated. False aneurysms are due to a defect in the arterial wall related to trauma or mycotic infections. The pathogenesis of true PAAs has not been definitively established.

At the start of this century, syphilis was the most frequent cause of PAAs but is seldom the cause now[9]. Popliteal aneurysms may rarely be associated with connective tissue diseases such as Marfan syndrome or Ehlers-Danlos syndrome; the aorta is more frequent affected in those syndromes[10]. A congenital origin of PAA is also very rare. Other causes of nonatherosclerotic PAAs are popliteal artery entrapment syndromes and blunt or penetrating trauma[11].

Arteriosclerosis is currently the most frequent cause of PAA formation and is involved with multiple cofactors. The predominance of PAAs in men suggests a genetic factor, as in the case for abdominal aortic aneurysms[12]. A deficit of collagen may be a precipitating cause of aneurysm formation and expansion, as has already published for abdominal aortic aneurysm[13].

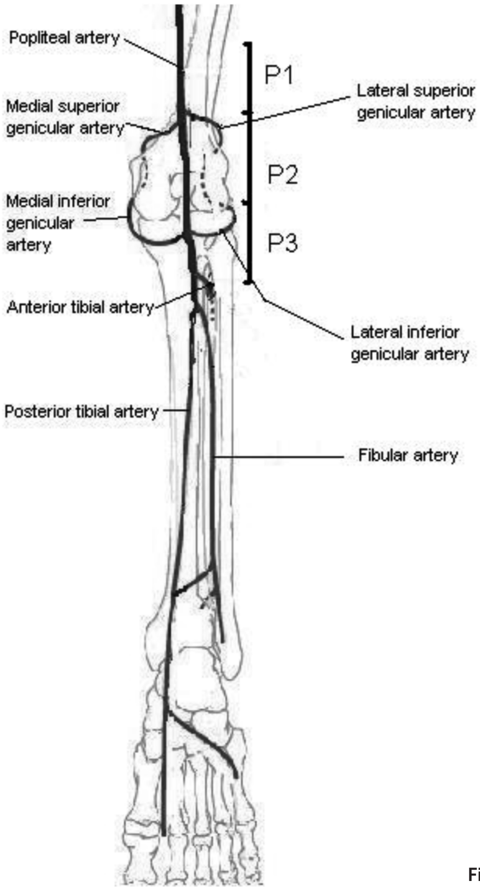


Figure 1. The arteries of the lower extremity.

One of the factors proposed as a possible contributor of aneurysm formation is turbulent flow beyond a relative stenosis. In these individuals, the tendinous hiatus adductorius, the heads of the gastrocnemius muscle, and popliteal ligaments may compress the artery. Another cause of turbulent flow leading to aneurysm formation is sstemic stress of hypertension, which is present in many patients. Alterations in the arterial wall caused by vibration and turbulence proximal to a major side branch or from stress and kinking during knee joint flexion might contribute to aneurysm formation as well.

Clinical manifestations

The clinical manifestations of PAAs span the spectrum from an asymptomatic pulsatile mass to severe lower extremity ischemia. Approximately 42% of patients are asymptomatic at the time of diagnosis (Figure 2)[1,3,14-60]. Symptomatic patients present with lower extremity ischemia, which can be manifested as claudication, rest pain, or tissue loss associated with thrombosis or embolization and, rarely, with rupture. Local symptoms, including awareness of a popliteal mass, local pain, and leg swelling due to popliteal vein compression, account for the remainder of symptoms (Figure 2)[1,3,14-60].

The main complications of PAA include thrombosis, distal embolization, and rupture. Thrombosis may result from multiple embolic events that occlude the crural arteries and precipitate thrombosis of the PAA, with severe ischemia as the usual result.

In some patients, this process may progress slowly and allows the development of collateral circulation. When thrombosis occurs in these patients ischemia might not be limb threatening. Rates of acute limb ischemia due to PAA thrombosis are 7% to 68%, depending on the extent of thrombosis[1, 3,14-60]. Acute limb ischemia requires immediate treatment to prevent limb loss. Rarely, patients may present with a ruptured PAA (4%), which also requires emergency repair (Figure 2)[1, 3,14-60]. Popliteal artery aneurysms are usually diagnosed in the sixth and seventh decades of life (Figure 3) and have a strong male predilection, with a male/female ratio of 20:1 (Table 1)[1,3,14-60].

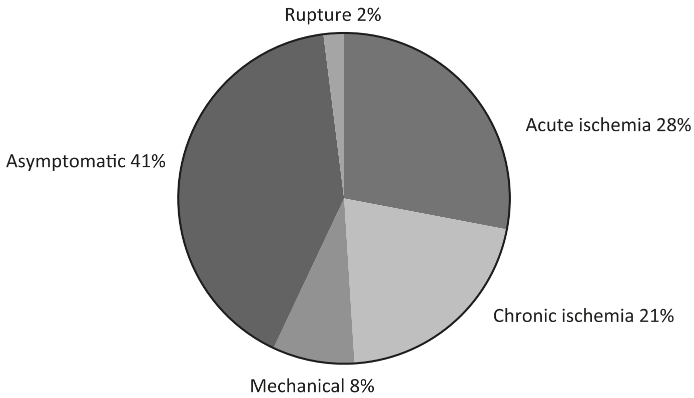


Figure 2. Presenting symptoms associated with 2882 popliteal artery aneurysms. Values are means. Data are derived from series published between January 1990 and December 2006(1,3,14-60).

CHAPTER 4

Popliteal artery aneurysms are associated with aneurysms at other locations. An abdominal aorta aneurysm is present in 39% of patients with a PAA. Risk factors for atherosclerosis are common in these patients, 56% have a history of smoking, 49% have hypertension, and approximately 13% have diabetes. As expected, the incidence of other cardiovascular diseases is high. More than 30% of patients have evidence of significant cardiac disease, and 12% manifest cerebrovascular disease (Table 1)[1,3,14-60].

Diagnosis

It is very important to diagnose PAA before limb-threatening thrombotic complications occur[3, 61]. Physical examination remains difficult[62], however, and once the diagnosis is suspected, it must be confirmed by duplex ultrasonography, computed tomography (CT) angiography, or magnetic resonance arteriography (MRA). In general, ultrasonography is the most commonly used diagnostic tool to confirm a PAA. Duplex ultrasonography can help to determine the presence of an aneurysm and whether it contains thrombus. Angiography cannot determine the size of the aneurysm, but MRA or angiography are essential before surgery because they will provide secure information about the patency of arterial segments proximal and distal to the aneurysm.

Indications for treatment

Patients with symptomatic PAAs should undergo intervention because of the risk of limb loss due to thromboembolic complications increases with the onset of symptomatic disease[14-17]. Several authors, however, have also reported a high incidence of complications in patients with asymptomatic lesions, varying from 28% to 100%, with amputation rates up to 20%[16,18-22]. Dawson et al.[19] described cumulative complication rate of untreated asymptomatic PAAs (mean aneurysm size, 31 mm) during follow-up as high as 24% at 1 year, increasing to 68% at 5 years after diagnosis.

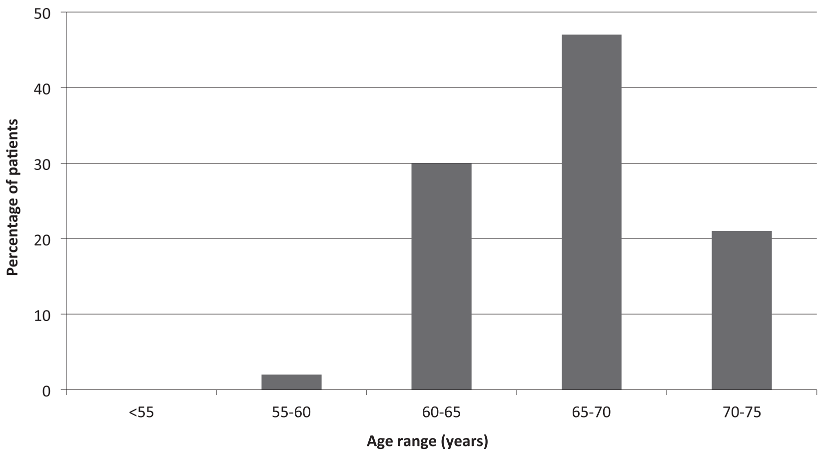


Figure 3. Distribution of mean age at presentation in 2197 patients with popliteal artery aneurysms. Data are derived from series published between January 1990 and December 2006(1,3,14-60).

Table 1. Preoperative characteristics.

	n	Incidence (%)*
Men	2197	94.9(5.6) (76.5-100)
Bilateral aneurysm	1750	44.3(20.0) (13-86)
Cerebrovascular accident	533	11.9(6.8) (3-22)
Acute myocardial infarction	1149	30.9(11.8) (8-52)
Aortic aneurysm	1342	39.2(15.1) (7-80)
Diabetes mellitus	1248	13.0(8.3) (1-41)
Hypertension	1502	49.0(15.1) (9-88)
Hypercholesterolaemia	590	31.4(11.8) (11-61)
Tobacco history	978	56.2(23.7) (20-92)

* Values are means (standard deviation) (range). Data are derived from series published between January 1980 and December 2006[1,3,14-60.]

The treatment of asymptomatic aneurysms is still controversial. Many authors recommend elective surgical intervention in patients with low surgical risk who have asymptomatic aneurysms larger than 20 mm with mural thrombosis[19,21,23-26]. Elective surgery for asymptomatic popliteal aneurysms has a very low associated risk of limb loss or death[6,17,18,25]. Lowell et al.[21] reported aneurysm diameter exceeding 2 cm, presence of thrombus, and poor runoff as risk factors for ischemic complications in a group of 67 aneurysms treated conservatively. Davidovic et al.[24], Duffy et al.[1], Vermilion et al.[63], and Whitehouse et al.[64] found that untreated aneurysms smaller than 2 cm in diameter were associated with a much lower incidence of complications compared with PAAs larger than 20 mm. In contrast, Inahara and Toledo[65] found no significant correlation between aneurysm sac diameter and risk for complications.

In the analysis of early-term (<30 days) and long-term results of endovascular and surgical repair of PAAs, studies reporting data merely on acutely treated PAAs were excluded. The included articles primarily describe elective PAA repair, however, numerous articles also include a few symptomatic PAAs. Unfortunately, these patients could not be excluded from this review because only a combined patency rate and limb salvage rate was given.

Surgical repair

Medial approach

The most common performed surgical technique for PAA repair is the medial approach, which consists of a combined supragenicular and infragenicular incision at the medial side of the leg. The popliteal artery is exposed and ligated distally and proximally from the PAA, after which end-to-end or end-to-side autologous venous or polytetrafluoroethylene (PTFE) bypass grafting is performed66. This approach is preferred by surgeons because of its technical ease and the accessibility of the great saphenous vein through the medial incision. In case of a more proximal or distal PAA, this approach remains applicable.

Posterior approach
This approach includes a lazy S-shaped incision in the posterior aspect of the knee, with dissection in between the medial and lateral head of the gastrocnemius muscle, taking care not to injure the tibial nerves and popliteal vein. The popliteal artery is clamped superior and inferior of the PAA, after which the aneurysm sac is opened with a longitudinal arteriotomy, and mural thrombosis is evacuated. Patent side branches of the genicular arteries are interrupted, and autologous venous or PTFE interposition grafting is performed with end-to-end anastomoses[28,29].

Early (<30 days) complications
No studies to date have compared the medial and the posterior approach so differences in early complications have not been reported. Our analysis, which included both surgical approaches, found 1711 PAAs treated by open repair. In-hospital mortality was 2.0% (range, 0%3.6%), but all deaths were not directly related to the PAA. Amputations occurred in 3.2% of the patients (range, 0%-14.5%). In 3.9% (range, 0%-10%), early graft thrombosis occurred and necessitated a reintervention during the same hospital stay. Other complications, such as wound infection, foot drop, deep venous thrombosis and hematoma, are summarized in Table 2[1,3,14,15,17,21-30,32,36-39,41,44,46,49,51,53-55,58-60].

Endovascular repair
Endovascular procedure
The advent of endovascular technology and its application in the treatment of aortic aneurysms has led to increased adaptation of these techniques for the treatment of PAAs. This intervention is mostly performed under local anesthesia. The approach is from an ipsilateral antegrade common femoral artery puncture with an 8F to 14F sheath or, seldom, through an open exposure of the femoral artery. The selection of the appropriate stent graft is determined by measurements of landing zone diameters and lengths[29,30]. In most studies a self-expanding nitinol-supported stent graft is used, for example the

Table 2. Thirty-day complication rates in open versus endovascular repair of PAAs.

	OR	**ER**
Mortality	2.0 (0-3.6)	1.3 (0-11)
Amputation	3.2 (0-15)	0
Occlusion	3.9 (0-10)	3.6 (0-22)
Wound infection	4.7 (0-20)	0
Foot drop	1.3 (0-5)	0
DVT	1.6 (0-9)	0
Haematoma	3.4 (0-7)	0.5 (0-4)
Endoleak	x	4.5 (0-14)

*Values are presented in percentage of and are means (range). Data are derived from series published between January 1980 and December 2006 associated with 1711 PAA open repaired and 176 PAAs endovascular repaired[(1,3,14,15,17,21-30,32,36-39,41,44,46,49,51,53-55,58-60)]. *OR*: open repair, ER: endovascular repair, DVT: deep venous thrombosis

Hemobahn and Viabahn stent grafts (W.L. Gore & Associates, Inc, Flagstaff, Ariz). Endovascular graft repair has the advantage of being minimally invasive.

Early (<30 days) complications

Of 176 PAAs repaired endovascularly, 8 were treated for acute ischemia and 4 because of rupture. The 8 PAAs leading to acute ischemia were treated with thrombolysis and subsequent stent grafting. Only 1 patient (0.5%) died after endovascular treatment due to an unrelated cause. No amputations were necessary in any study. In 3.6% (range, 0% to 22%), an occlusion of the stent graft was reported that needed reintervention. Only 1 patient was converted from an endovascular PAA repair to an open repair. During the 30-day period, 4.5% (range 0-14) experienced an endoleak[29,30,44,47,49,51,54,60] (Table 2).

Late results of intervention

Surgical repair

The reported overall 5-year primary patency rates for surgical repair of PAA are 66% to 86%, with mean 5-year limb salvage rates of 93% (range, 86% to 99%) (Table 3)[1,3,14,16-18,21-23,27-29,32,34,36-38,41,46,53,55]. Operative results are closely related to the presence of symptoms, the status of distal outflow, and the type of graft material. Results for prosthetic grafts are inferior to vein grafts: 5-year primary patency rates are 81% to 94% for venous grafts and 40% to 81% for prosthetic grafts[16,18,21,38,46,55]. Outcomes for patients undergoing elective repair of their PAA are favorable for acute repair, especially when asymptomatic and distal vessel runoff is preserved[3,17,21,40,55,59].

A disadvantage of the medial approach is that it does not exclude side branches with their origin in the PAA. These can be responsible for persistent retrograde perfusion in the ligated aneurysm sac and eventually lead to persistent aneurysm enlargement and, worse, rupture[31-35,67]. A disadvantage of the posterior approach is that it is technically more challenging compared with the medial approach because the tibial nerve and popliteal vein are often densely adherent to large aneurysms.

Endovascular repair

Published results show 47% to 89% 1-year primary patency rates for endoluminal repair of PAA, with 100% 1-year limb salvages rates in all studies. With our PubMed search, we only found 2 studies with 3-year primary patency rates, which were 72% and 75% (Table 4).

Data are derived from series published between January 1980 and December 2006.

Potential advantages of endovascular repair of PAA include eliminating the need for open surgery in high-risk patients and morbidity of wound complications, and it is cost-efficient due to reduced intervention time and hospital stay[29]. However, unique complications are seen after PAA endovascular intervention in up to 14% of patients, including graft migration and endoleak[29,30,44,47,49,51,54,60].

In the only prospective randomized trial, Antonello et al.[29] described no significant difference in early mortality, morbidity, and patency between surgical repair and endovascular repair. This study reported 2-year primary patency rates of 100% for open

Table 3. Reported primary patency, secondary patency, and limb salvages after surgical repair of popliteal artery aneurysm.

Reference	Year	Primary patency 1 year	Primary patency 3 years	Primary patency 5 years	Secondary patency 1 year	Secondary patency 3 years	Secondary patency 5 years	Limb salvage 1 year	Limb salvage 3 years	Limb salvage 5 years
Dawson *et al.*[18]	1991	85	85	75	—	—	—	95	95	95
Shortell *et al.*[17]	1991	90	78	72	—	—	—	94	94	94
Roggo *et al.*[16]	1993	—	—	69	—	—	—	—	—	94
Carpenter *et al.*[14]	1994	93	80	71	—	—	—	93	90	90
Hagino *et al.*[46]	1994	95	95	—	—	—	—	100	100	—
Lowell *et al.*[21]	1994	—	—	—	—	—	—	96	96	94
Varga *et al.*[22]	1994	—	—	—	—	—	—	100	—	—
Sarcina *et al.*[55]	1997	95	82	78	—	—	—	97	88	86
Duffy *et al.*[1]	1998	85	71	—	92	85	—	96	96	—
Reix *et al.*[53]	2000	91	—	—	—	—	—	100	—	—
Galland *et al.*[41]	2002	90	72	—	—	—	—	—	—	—
Ascher *et al.*[36]	2003	72	—	—	—	—	—	94	—	—
Jones *et al.*[32]	2003	—	—	86	—	—	—	—	—	—
Mahmood *et al.*[28]	2003	77	69	69	96	87	87	—	—	87
Aulivola *et al.*[23]	2004	96	88	85	100	75	97	98	—	98
Blanco et al.[37]	2004	89	—	79	91	—	79	99	99	99
Mehta *et al.*[34]	2004	—	81	75	—	94	94	—	—	96
Antonello *et al.*[29]	2005	100	91	—	100	91	—	100	100	—
Bourriez-PTFE *et al.*[38*]	2005	83	51	—	95	88	—	100	100	—
Bourriez-venous *et al.*[38†]	2005	96	94	—	99	99	—	99	99	—
Beseth *et al.*[27]	2006	92	—	—	96	—	—	100	—	—
Pulli *et al.*[3]	2006	80	74	66	—	—	84	94	90	87

Data are derived from series published between January 1980 and December 2006. * PTFE, † venous

Table 4. Reported primary patency, secondary patency and limb salvages after endovascular treatment of popliteal artery aneurysm.

Reference	Year	Primary patency 1 year	Primary patency 3 years	Primary patency 5 years	Secondary patency 1 year	Secondary patency 3 years	Secondary patency 5 years	Limb salvage 1 year	Limb salvage 3 years	Limb salvage 5 years
Henry *et al.*[47]	2000	78	—	—	86	—	—	—	—	—
Rosenthal *et al.*[54]	2000	89	—	—	—	—	—	100	—	—
Howell *et al.*[49]	2002	69	—	—	93	—	—	100	—	—
Tielliu *et al.*[60]	2003	74	—	—	—	—	—	—	—	—
Gerasimidis *et al.*[44]	2003	47	—	—	75	—	—	100	—	—
Antonello *et al.*[29]	2005	87	—	—	100	100	—	100	100	—
Tielliu *et al.*[30]	2005	80	72	72	90	77	77	100	100	100
Mohan *et al.*[51]	2006	80	75	—	89	83	—	100	—	—

repair and 80% for endovascular repair. At 3 years, the secondary patency rate was 90.9% for the surgical treatment and 100% for the endovascular treatment [29].
To know the exact indication of endovascular treatment in the repair of PAAs, more and larger trials have to be performed to investigate the early-term and long-term patency and the different selection criteria's.

CONCLUSION

Popliteal artery aneurysms are relatively rare, with an incidence of 0.1% to 2.8%. A patient with a PAA must be screened to see if it is a contralateral PAA and if an aortic aneurysm is also present. The cutoff point for elective treatment of a PAA seems to be a diameter of 20 mm. Currently, only 1 randomized trial comparing short-term results of open and endovascular repair of PAAs has been published, and no significant difference was found between the treatments. Both intervention modalities have acceptable early results, 1-year patency rates, and limb salvage rates. Endovascular treatment lacks long-term follow-up, whereas venous surgical repair has an average 5-year patency rate of as high as 85%, which is better than prosthetic repair. More randomized trials comparing both intervention modalities are needed. In any case, acute repair of PAAs must be avoided.

REFERENCES

1. Duffy ST, Colgan MP, Sultan S, Moore DJ, Shanik GD. Popliteal aneurysms: a 10-year experience. Eur J Vasc Endovasc Surg 1998;16:218-22.
2. Hirsch AT, Haskal ZJ, Hertzer NR, Bakal CW, Creager MA, Halperin JL, et al. ACC/AHA 2005 Practice Guidelines for the management of patients with peripheral arterial disease (lower extremity, renal, mesenteric, and abdominal aortic): a collaborative report from the American Association for Vascular Surgery/Society for Vascular Surgery, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, Society of Interventional Radiology, and the ACC/AHA Task Force on Practice Guidelines (Writing Committee to Develop Guidelines for the Management of Patients With Peripheral Arterial Disease): endorsed by the American Association of Cardiovascular and Pulmonary Rehabilitation; National Heart, Lung, and Blood Institute; Society for Vascular Nursing; TransAtlantic Inter-Society Consensus; and Vascular Disease Foundation. Circulation 2006;113:e463-e654.
3. Pulli R, Dorigo W, Troisi N, Innocenti AA, Pratesi G, Azas L, et al. Surgical management of popliteal artery aneurysms: which factors affect outcomes? J Vasc Surg 2006;43:481-7.
4. Dent TL, Lindenauer SM, Ernst CB, Fry WJ. Multiple arteriosclerotic arterial aneurysms. Arch Surg 1972;105:338-44.
5. Davis RP, Neiman HL, Yao JS, Bergan JJ. Ultrasound scan in diagnosis of peripheral aneurysms. Arch Surg 1977;112:55-8.
6. Johnston KW, Rutherford RB, Tilson MD, Shah DM, Hollier L, Stanley JC. Suggested standards for reporting on arterial aneurysms. Subcommittee on Reporting Standards for Arterial Aneurysms, Ad Hoc Committee on Reporting Standards, Society for Vascular Surgery and North American Chapter, International Society for Cardiovascular Surgery. J Vasc Surg 1991;13:452-8.
7. Wolf YG, Kobzantsev Z, Zelmanovich L. Size of normal and aneurysmal popliteal arteries: a duplex ultrasound study. J Vasc Surg 2006;43:488-92.
8. Zierler RE, Zierler BK. Duplex sonography of lower extremity arteries. In Introduction to vascular ultrasonography. III edition. Philadelphia: Zwiebel WJ Edit; 1983.p237-51.
9. Spay G, Sarrat H, Magnin G, Sow I, Marchand P, Fayet I, et al. Syphilitic aneurysm with popliteal localization. J Surg (Paris) 1974;108:343-46.
10. Van der Heyde MN, Zwaveling A. Resection of an abdominal aortic aneurysm in a patient with Marfan's syndrome. J Cardiovasc Surg 1961;2:359-66.
11. Dawson I, Sie RB, van Bockel JH. Atherosclerotic popliteal aneurysm. Br J Surg 1997;84:293-9.
12. Kuivaniemi H, Shibamura H, Arthur C, Berguer R, Cole CW, Juvonen T, et al. Familial abdominal aortic aneurysms: collection of 233 multiplex families. J Vasc Surg 2003;37:340-5.
13. Busuttil RW, Abou-Zamzam AM, Machleder HI. Collagenase activity of the human aorta. A comparison of patients with and without abdominal aortic aneurysms. Arch Surg 1980;115:1373-8.
14. Carpenter JP, Barker CF, Roberts B, Berkowitz HD, Lusk EJ, Perloff LJ. Popliteal artery aneurysms: current management and outcome. J Vasc Surg 1994;19:65-72.
15. Gouny P, Bertrand P, Duedal V, Cheynel-Hocquet C, Lancelin C, Escourolle F, Nussaumeand O, Vayssairat M. Limb salvage and popliteal aneurysms: advantages of preventive surgery. Eur J Vasc Endovasc Surg 2000;19:496-500.
16. Roggo A, Brunner U, Ottinger LW, Largiader F. The continuing challenge of aneurysms of the popliteal artery. Surg Gynecol Obstet 1993;177:565-72.
17. Shortell CK, DeWeese JA, Ouriel K, Green RM. Popliteal artery aneurysms: a 25-year surgical experience. J Vasc Surg 1991;14:771-6.
18. Dawson I, van Bockel JH, Brand R, Terpstra JL. Popliteal artery aneurysms. Long-term follow-up of aneurysmal disease and results of surgical treatment. J Vasc Surg 1991;13:398-407.
19. Dawson I, Sie R, van Baalen JM, van Bockel JH. Asymptomatic popliteal aneurysm: elective operation versus conservative follow-up. Br J Surg 1994;81:1504-7.
20. Hands LJ, Collin J. Infra-inguinal aneurysms: outcome for patient and limb. Br J Surg 1991;78:996-8.
21. Lowell RC, Gloviczki P, Hallett JW, Jr., Naessens JM, Maus TP, Cherry KJ, Jr., Bower TC, Pairolero PC. Popliteal artery aneurysms: the risk of nonoperative management. Ann Vasc Surg 1994;8:14-23.
22. Varga ZA, Locke-Edmunds JC, Baird RN. A multicenter study of popliteal aneurysms. Joint Vascular Research Group. J Vasc Surg 1994;20:171-7.
23. Aulivola B, Hamdan AD, Hile CN, Sheahan MG, Skillman JJ, Campbell DR, Scovell SD, LoGerfo FW, Pomposelli FB, Jr. Popliteal artery aneurysms: a comparison of outcomes in elective versus emergent repair. J Vasc Surg 2004;39:1171-7.
24. Davidovic LB, Lotina SI, Kostic DM, Cinara IS, Cvetkovic SD, Markovic DM, Vojnovic BR. Popliteal artery aneurysms. World J Surg 1998;22:812-7.
25. Halliday AW, Taylor PR, Wolfe JH, Mansfield AO. The management of popliteal aneurysm: the importance of early surgical repair. Ann R Coll Surg Engl 1991;73:253-7.

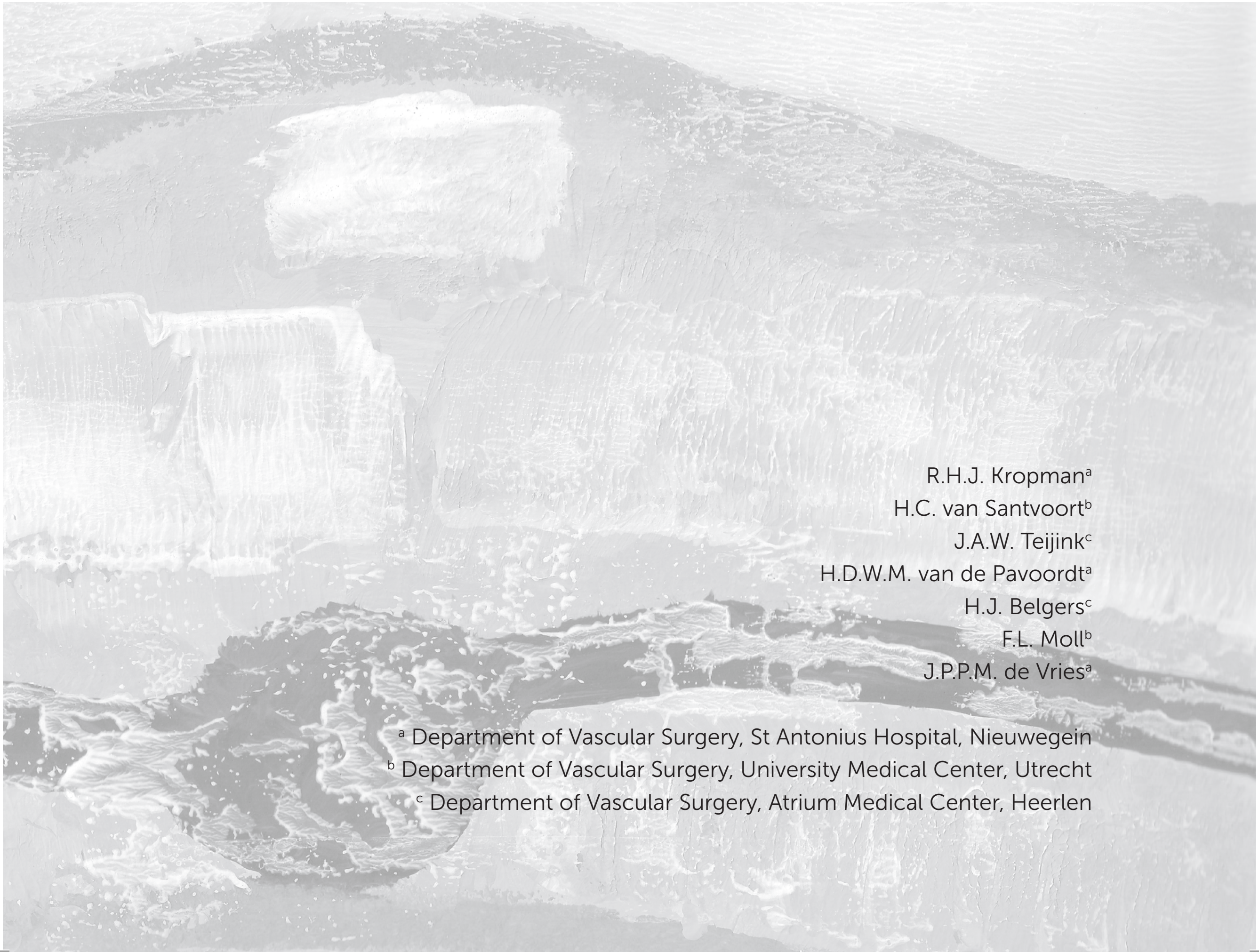
26. Ramesh S, Michaels JA, Galland RB. Popliteal aneurysm: morphology and management. Br J Surg 1993;80:1531-3.
27. Beseth BD, Moore WS. The posterior approach for repair of popliteal artery aneurysms. J Vasc Surg 2006;43:940-4.
28. Mahmood A, Salaman R, Sintler M, Smith SR, Simms MH, Vohra RK. Surgery of popliteal artery aneurysms: a 12-year experience. J Vasc Surg 2003;37:586-93.
29. Antonello M, Frigatti P, Battocchio P, Lepidi S, Cognolato D, Dall'Antonia A, Stramana R, Deriu GP, Grego F. Open repair versus endovascular treatment for asymptomatic popliteal artery aneurysm: results of a prospective randomized study. J Vasc Surg 2005;42:185-93.
30. Tielliu IF, Verhoeven EL, Zeebregts CJ, Prins TR, Span MM, van den Dungen JJ. Endovascular treatment of popliteal artery aneurysms: results of a prospective cohort study. J Vasc Surg 2005;41:561-567.
31. Ebaugh JL, Morasch MD, Matsumura JS, Eskandari MK, Meadows WS, Pearce WH. Fate of excluded popliteal artery aneurysms. J Vasc Surg 2003;37:954-9.
32. Jones WT, III, Hagino RT, Chiou AC, Decaprio JD, Franklin KS, Kashyap VS. Graft patency is not the only clinical predictor of success after exclusion and bypass of popliteal artery aneurysms. J Vasc Surg 2003;37:392-8.
33. Kirkpatrick UJ, McWilliams RG, Martin J, Brennan JA, Gilling-Smith GL, Harris PL. Late complications after ligation and bypass for popliteal aneurysm. Br J Surg 2004;91:174-7.
34. Mehta M, Champagne B, Darling RC, III, Roddy SP, Kreienberg PB, Ozsvath KJ, Paty PS, Chang BB, Shah DM. Outcome of popliteal artery aneurysms after exclusion and bypass: significance of residual patent branches mimicking type II endoleaks. J Vasc Surg 2004;40:886-90.
35. Wakassa TB, Matsunaga P, da Silva ES, Pinto CA, Kauffman P, Aun R, Puech-Leao P. Follow-up of the aneurysmal sac after exclusion and bypass of popliteal artery aneurysms. Clinics 2006;61:107-12.
36. Ascher E, Markevich N, Schutzer RW, Kallakuri S, Jacob T, Hingorani AP. Small popliteal artery aneurysms: are they clinically significant? J Vasc Surg 2003;37:755-60.
37. Blanco E, Serrano-Hernando FJ, Monux G, Vega M, Martin A, Rial R, Reina T, Sanchez-Hervas L. Operative repair of popliteal aneurysms: effect of factors related to the bypass procedure on outcome. Ann Vasc Surg 2004;18:86-92.
38. Bourriez A, Melliere D, Desgranges P, D'Audiffret A, Allaire E, Becquemin JP. Elective popliteal aneurysms: does venous availability has an impact on indications? J Cardiovasc Surg (Torino) 2005;46:171-5.
39. Bowrey DJ, Osman H, Gibbons CP, Blackett RL. Atherosclerotic popliteal aneurysms: management and outcome in forty-six patients. Eur J Vasc Endovasc Surg 2003;25:79-81.
40. Dorigo W, Pulli R, Turini F, Pratesi G, Credi G, Innocenti AA, Pratesi C. Acute leg ischaemia from thrombosed popliteal artery aneurysms: role of preoperative thrombolysis. Eur J Vasc Endovasc Surg 2002;23:251-4.
41. Galland RB, Magee TR. Management of popliteal aneurysm. Br J Surg 2002;89:1382-5.
42. Galland RB, Magee TR. Popliteal aneurysms: distortion and size related to symptoms. Eur J Vasc Endovasc Surg 2005;30:534-8.
43. Gawenda M, Sorgatz S, Muller U, Walter M, Erasmi H. The thrombosed popliteal aneurysm with distal arterial occlusion--successful therapy by interdisciplinary management. Thorac Cardiovasc Surg 1995;43:112-6.
44. Gerasimidis T, Sfyroeras G, Papazoglou K, Trellopoulos G, Ntinas A, Karamanos D. Endovascular treatment of popliteal artery aneurysms. Eur J Vasc Endovasc Surg 2003;26:506-11.
45. Greenberg R, Wellander E, Nyman U, Uher P, Lindh M, Lindblad B, Ivancev K. Aggressive treatment of acute limb ischemia due to thrombosed popliteal aneurysms. Eur J Radiol 1998;28:211-8.
46. Hagino RT, Fujitani RM, Dawson DL, Cull DL, Buehrer JL, Taylor SM, Mills JL. Does infrapopliteal arterial runoff predict success for popliteal artery aneurysmorrhaphy? Am J Surg 1994;168:652-6.
47. Henry M, Amor M, Henry I, Klonaris C, Tzvetanov K, Buniet JM, Amicabile C, Drawin T. Percutaneous endovascular treatment of peripheral aneurysms. J Cardiovasc Surg (Torino) 2000;41:871-83.
48. Hoelting T, Paetz B, Richter GM, Allenberg JR. The value of preoperative lytic therapy in limb-threatening acute ischemia from popliteal artery aneurysm. Am J Surg 1994;168:227-31.
49. Howell M, Krajcer Z, Diethrich EB, Motarjeme A, Bacharach M, Dolmatch B, Walker C. Waligraft endoprosthesis for the percutaneous treatment of femoral and popliteal artery aneurysms. J Endovasc Ther 2002;9:76-81.
50. Marty B, Wicky S, Ris HB, Mueller X, Fischer A, Hayoz D, von Segesser LK. Success of thrombolysis as a predictor of outcome in acute thrombosis of popliteal aneurysms. J Vasc Surg 2002;35:487-93.
51. Mohan IV, Bray PJ, Harris JP, May J, Stephen MS, Bray AE, White GH. Endovascular popliteal aneurysm repair: are the results comparable to open surgery? Eur J Vasc Endovasc Surg 2006;32:149-54.
52. Pittathankal AA, Dattani R, Magee TR, Galland RB. Expansion rates of asymptomatic popliteal artery aneurysms. Eur J Vasc Endovasc Surg 2004;27:382-4.
53. Reix T, Rudelli-Szychta P, Mery B, Sevestre-Pietri MA, Pietri J. Treatment of popliteal arterial aneurysm using a superficial femoral artery autograft. Ann Vasc Surg 2000;14:594-601.
54. Rosenthal D, Matsuura JH, Clark MD, Kirby LB, Knoepp LF. Popliteal artery aneurysms: is endovascular reconstruction durable? J Endovasc Ther 2000;7:394-8.

55. Sarcina A, Bellosta R, Luzzani L, Agrifoglio G. Surgical treatment of popliteal artery aneurysm. A 20 year experience. J Cardiovasc Surg (Torino) 1997;38:347-54.
56. Sie RB, Dawson I, van Baalen JM, Schultze Kool LJ, van Bockel JH. Ruptured popliteal artery aneurysm. An insidious complication. Eur J Vasc Endovasc Surg 1997;13:432-8.
57. Steinmetz E, Bouchot O, Faroy F, Charmasson L, Terriat B, Becker F, Cercueil JP, Krause D, Brenot R, David M. Preoperative intraarterial thrombolysis before surgical revascularization for popliteal artery aneurysm with acute ischemia. Ann Vasc Surg 2000;14:360-4.
58. Stone PA, Armstrong PA, Bandyk DF, Keeling WB, Flaherty SK, Shames ML, Johnson BL, Back MR. The value of duplex surveillance after open and endovascular popliteal aneurysm repair. J Vasc Surg 2005;41:936-41.
59. Taurino M, Calisti A, Grossi R, Maggiore C, Speziale F, Fiorani P. Outcome after early treatment of popliteal artery aneurysms. Int Angiol 1998;17:28-33.
60. Tielliu IF, Verhoeven EL, Prins TR, Post WJ, Hulsebos RG, van den Dungen JJ. Treatment of popliteal artery aneurysms with the Hemobahn stent-graft. J Endovasc Ther 2003;10:111-6.
61. Ouriel K, Shortell CK. Popliteal and femoral aneurysms. In Vascular Surgery, IV edition. Philadelphia: Rutherford Edit; 1995.p1103-12.
62. Downing R, Grimley RP, Ashton F, Slaney G. Problems in diagnosis of popliteal aneurysms. J R Soc Med 1985;78:440-4.
63. Vermilion BD, Kimmins SA, Pace WG, Evans WE. A review of one hundred forty-seven popliteal aneurysms with long-term follow-up. Surgery 1981;90:1009-14.
64. Whitehouse WM, Jr., Wakefield TW, Graham LM, Kazmers A, Zelenock GB, Cronenwett JL, Dent TL, Lindenauer SM, Stanley JC. Limb-threatening potential of arteriosclerotic popliteal artery aneurysms. Surgery 1983;93:694-9.
65. Inahara T, Toledo AC. Complications and treatment of popliteal aneurysms. Surgery 1978;84:775-83.
66. Edwards WS. Exclusion and saphenous vein bypass of popliteal aneurysms. Surg Gynecol Obstet 1969;128:829-30.
67. van Santvoort HC, de Vries JP, van de MR, Wille J, van de Pavoordt ED. Rupture of a popliteal artery aneurysm 10 years after surgical repair. Vascular 2006;14:227-30.

CHAPTER 5

The medial versus the posterior approach in the repair of popliteal artery aneurysms: A multicenter case-matched study

J Vasc Surg 2007;46:24-30



R.H.J. Kropman[a]
H.C. van Santvoort[b]
J.A.W. Teijink[c]
H.D.W.M. van de Pavoordt[a]
H.J. Belgers[c]
F.L. Moll[b]
J.P.P.M. de Vries[a]

[a] Department of Vascular Surgery, St Antonius Hospital, Nieuwegein
[b] Department of Vascular Surgery, University Medical Center, Utrecht
[c] Department of Vascular Surgery, Atrium Medical Center, Heerlen

ABSTRACT

Objectives

This study was conducted to compare the early and mid-term results of the medial and posterior approaches in the surgical treatment of popliteal artery aneurysms (PAAs).

Methods

From 1992 to 2006 in three hospitals, 110 popliteal aneurysms needed surgical repair by either a posterior or a medial approach. Thirty three out of thirty six aneurysms repaired by the posterior approach could be case-matched to a medial excluded PAA according to the criteria of (1) patient age, (2) cardiovascular comorbidity, (3) indication for PAA repair, (4) diameter of PAA at time of surgical repair, (5) number of distal outflow vessels at time of surgical repair, and (6) type of bypass or interposition graft (venous or polytetrafluoroethylene).

Results

During the 30-day postoperative period, seven complications (21%) occurred in each group, no patients died, and no amputations were necessary. Two patients in the posterior group versus none in the medial group ($P < .05$) needed thrombectomy because of occlusion of the reconstruction. The mean follow-up was 47 months (range, 2 to 176). In this period, 13 deaths occurred, but none were related to the previous interventions. The primary patency rates at 6 months and at 1, 3, and 4 years were 84%, 79%, 66%, and 66% in the posterior group and 96% (P<0.05), 93% (P<0.05), 76% (P=NS), and 69 % (P=NS) for the medial group, respectively. The secondary patency rates at 6 months, and at 1, 3, and 4 years were 100%, 100%, 100%, and 90% in the posterior group and 96%, 96%, 96%, and 90% in the medial group, respectively (P = NS). Limb salvage rates were 97% for the posterior and 100% for the medial group (P = NS). No neurologic complications or venous damage was seen in either group. Irrespective of approach, venous reconstructions resulted in significantly higher patency rates compared to prosthetic reconstructions at 3-year follow-up (84% versus 67%, P< .01). During follow-up, including duplex scanning, two patients in the medial group needed renewed surgical intervention and posterior exclusion because of persistent flow and growth of the native aneurysm.

Conclusion

Early (< 1 year) primary patency rates of the medial approach were significantly better than the posterior approach, maybe due to the limited posterior exposure. However, in the absence of a significant difference in long-term primary and secondary patency rates between the posterior and medial approach, and considering the substantial risk of aneurysm growth after medial approach (up to 22%), the posterior approach might be the surgical method of preference for PAA repair on the long run.

INTRODUCTION

Even though popliteal artery aneurysm (PAA) is uncommon, with an incidence of 0.1% to 2.8%, it is the second most frequent location of arterial aneurysms.[1-4] An untreated PAA will lead to complications within a 5-year interval in 68% to 74% of patients.[1,3,5,6] The main complications of PAA include distal embolization, thrombosis, and rupture. Thromboembolic complications carry a high risk of major amputation (20% to 59%) and even mortality (up to 11%).[7,8] In contrast, elective repair can be performed with minimal chance of limb loss on the long term (<10%).[1,3] PAAs >2 cm in diameter in patients with a low surgical risk are generally considered an indication for elective surgical intervention.[2,5]

The most common performed surgical technique for PAA repair is the medial approach with proximal and distal aneurysm ligation, followed by autologous vein or polytetrafluoethylene (PTFE) bypass grafting. The 5-year primary patency rates for this technique are 50% to 86%.[1,7-12] This technique does not, however, exclude side branches with their origin in the PAA, which can be responsible for retrograde perfusion in the ligated aneurysm sac and eventually lead to aneurysm enlargement and worse, rupture.[13-18] Direct exclusion from an extended medial incision is technically possible, with transection of the sartorius, gracilis, semimembranosus, and semitendinosus tendons. The only structure in the way is the medial head of the gastrocnemic muscle which might be rather easily to work around. Through such an extended medial incision the entire popliteal artery can be exposed then.

An alternative technique is the posterior approach. This technique includes a curved incision in the fossa poplitea, followed by direct opening of the aneurysm sac, interrupting patent side branches of the genicular arteries, and autologous venous or PTFE interposition grafting. Hereafter, retrograde perfusion of the aneurysm sac can no longer occur. The disadvantages of the posterior approach might be more dissection-related complications compared with the medial approach. So far, little is known about the results of this posterior technique. In a recent, noncontrolled case series that reported on early and mid-term outcomes of PAA repair with the posterior approach, the 2-year primary patency rate was 92.2%.[19]

The aim of this study was to perform the first head-to-head comparison of both the medial and posterior approach in the treatment of PAA. To minimize selection bias and confounding, a case-matched study was conducted.

METHODS

All patients admitted for a PAA from January 1992 to July 2006 at St. Antonius Hospital, Nieuwegein; University Medical Center, Utrecht; and Atrium Medical Center, Heerlen, The Netherlands, were identified by a computer database search using the International Classification of Diseases code for PAA. The operation records of all patients were reviewed. Only patients with a posterior approach or medial approach for repair of PAA were included in this study. In all three hospitals a dorsal approach is only performed if the popliteal aneurysm doesn't extent to the proximal boundary of the P1 segment of the popliteal artery. Both approaches had to be able to be performed in the selected patients, which excluded aneurysms passing above the Hunter canal (n = 31). This substantial amount of aneurysms could not be operated through a posterior approach and were operated through a medial approach. All computerized medical reports and patient characteristics of the two groups were reviewed to collect variables for case-matching. The registry review identified 110 PAAs, of which 74 were repaired through the medial approach and 36 were treated by the posterior approach.

Case-matching

Because of the smaller number of posterior treated popliteal aneurysms each of these 36 aneurysms was tried to match with an aneurysm that underwent medial exclusion by ligation just proximally and distally of the popliteal aneurysm, for the following formerly defined prognostic criteria[3,8]:

1. patient age $\pm$ 12 years,
2. cardiovascular comorbidity—coronary artery disease, yes or no,
3. indication for PAA repair—symptomatic acute, symptomatic chronic, or asymptomatic and growth,
4. diameter of PAA $\pm$ 9 mm at time of surgical repair,
5. number of distal outflow vessels at time of first surgical repair—none, one, two, or three (as measured with duplex ultrasound imaging, digital subtraction angiography or magnetic resonance arteriography [MRA]), and
6. type of bypass or interposition graft (autologous vein or PTFE).

In three aneurysms treated by the posterior approach, case-matching was not possible because the PAA diameter was >70 mm (n = 2) and the patient was 90 years old (n = 1). These patients were excluded from further analysis.

Surgical technique

The posterior approach includes a lazy S-shaped incision in the posterior aspect of the knee, with dissection in between the medial and lateral head of the gastrocnemic muscle, taking care not to injure the tibial nerves and popliteal vein. The popliteal artery is clamped superior and inferior of the PAA, after which the aneurysm sac is opened with a longitudinal arteriotomy and mural thrombosis is evacuated. Patent side branches of the genicular arteries are interrupted, and autologous venous or PTFE interposition grafting is performed with end-to-end anastomoses.[8,19,20]

The medial approach consists of a combined supra and infra genicular incision at the medial side of the leg. The popliteal artery is exposed and ligated distally and proximally from the PAA, after which an end-to-end or end-to-side autologous venous or PTFE bypass grafting is performed.[21]

All patients received 5000 IU of heparin before cross-clamping the popliteal artery and 80 mg acetylsalicytic acid (ASA) daily for at least 3 months postoperative.

Data collection

The following additional preoperative variables were collected for the 66 matched aneurysms: gender, presence of bilateral PAA, presence of abdominal aortic aneurysm, symptoms (acute, chronic, or asymptomatic), diameter of the PAA, vascular risk factors, type of preoperative imaging, and the use of preoperative urokinase treatment. Perioperative variables collected were type of bypass/interposition graft (great saphenous vein, PTFE) and 30-day complications. Follow-up variables were hemodynamic stenosis or occlusion of the bypass/interposition graft, renewed symptoms, endovascular or surgical reinterventions, absence or existence of flow in the PAA, major amputation of the ipsilateral leg, and mortality.

Follow-up

The surveillance program consisted of postoperative clinical and ultrasonographic or MRA examinations at 1, 6, and 12 months, and yearly thereafter. Graft patency was assessed, including the native artery proximal and distal of the anastomoses. In addition, flow in the eliminated aneurysm sac was examined using duplex ultrasound imaging.

Definitions

Primary patency was defined as uninterrupted flow (<50% stenosis) in the bypass/interposition graft with neither an additional procedure performed nor an intervention to solve disease progression in the adjacent native vessel. If a minor procedure such as percutaneous transluminal angioplasty was necessary to protect patency, and the bypass was not occluded, the designation assisted primary patency was used. Secondary patency was defined as restoration of graft patency by percutaneous or surgical intervention because of occlusion or technical problems with the graft or the anastomoses.[22] Acute limb ischemia was classified according to the acute limb ischemia classification by Rutherford et al.[22]

Statistical analysis

Standard descriptive statistics were used. PAAs that were repaired by the posterior approach were compared with matched PAAs treated by the medial approach with primary, primary assisted, and secondary patency rates after 6 months and 1, 3, and 5 years. Patency rates were computed using the Kaplan-Meier method and compared with the log-rank test. Values were compared by the Student *t* test, X^2 test, and the Fisher exact test, as appropriate. A two-tailed $P < .05$ was considered statistically significant. The analysis was performed using SAS 8.2 software (SAS Inc, Cary, NC).

RESULTS

Preoperative characteristics

Table I shows the preoperative characteristics of both the medial and posterior group. Adequate matching was obtained for all matching criteria. In addition, there were no differences between groups for incidence of cerebrovascular accidents, hypertension, hyperlipidemia, diabetes mellitus, smoking, or concomitant abdominal aortic aneurysm. Only the incidence of contralateral PAA differed significantly between both groups (posterior, 48% vs medial, 85%, *P* = .002).

The patients of the 66 case matched PAAs had a mean age of 72 years (range, 56 to 85 years), and 94% were men. Forty-four patients (67%) of the whole cohort had bilateral PAAs, of which 32 popliteal aneurysms had not to be treated because of asymptomatic aneurysms < 20mm. The remaining contralateral PAAs were treated surgically (n = 11) and endovascularly (n = 1). Thirty-three (50%) had a concomitant abdominal aortic aneurysm. All PAAs were of atherosclerotic origin. The mean diameter of the PAAs at the time of intervention was 32 $\pm$ 10 mm (range, 17 to 58 mm) confirmed by duplex ultrasonography, Computed Tomography angiography, or Magnetic Resonance Arteriography. These modalities were also used to rule out significant thrombus at the planned proximal and distal anastomosis.

The PAAs were asymptomatic in 25 (38%) of the 66 cases, and indication for surgical intervention in these patients was yearly growth of >10%, with an absolute mean diameter of 31 $\pm$ 8 mm. Another 15 patients (23%) presented with disabling intermittent claudication (8 in the posterior group, 7 in the medial group; *P* = NS), and 13 patients (20%) presented with local compression symptoms caused by the aneurysm (6 in the posterior group, 7 in the medial group; *P* = NS).

Thirteen patients (20%) had acute symptomatic PAAs (7 posterior, 6 medial, *P* = NS), 12 patients (7 posterior, 5 medial) presented with critical ischemia owing to thromboembolic complications, and one patient presented with a ruptured PAA.

A digital substraction angiography was performed in the 12 patients with acute ischemia. Before undergoing surgical repair, four patients had thrombolytic therapy with urokinase (90,000 IU/h intraarterial) for a maximum of 72 hours. Thrombolysis was successful in three patients. One patient showed no clinical or angiographic improvement after 24 hours of thrombolysis and underwent a thrombectomy and an interposition graft.

The other eight patients (4 in the posterior group, 4 in the medial group) with acute ischemia underwent urgent operation because of immediately threatening acute limb ischemia that precluded thrombolytic pretreatment. Before bypass or interposition grafting, thrombectomy of the crural arteries was performed and outflow from at least one crural artery was achieved.

Operative details

Autologous vein was the preferred graft material, with the ipsilateral reversed great saphenous vein most commonly used in 36 patients. The lesser saphenous vein was used in 12 patients, and a prosthetic graft was implanted in the remaining 18 (27%). The medial group had 24 great saphenous vein reconstructions (73%) and 9 prosthetic reconstructions (27%). In the posterior group 12 greater saphenous vein reconstructions (37%), 12 lesser saphenous vein reconstructions (36%), and also 9 (27%) prosthetic reconstructions were performed. The number of patent crural arteries was one in 15%, two in 36%, three in 42% of the patients, and was unknown in 4 patients (Table 1).

Perioperative (30 days) results

The 30-day postoperative mortality rate was 0% in both groups, and no amputation was necessary. Postoperative complications are summarized in Table 2. Seven complications (21%) occurred in both groups. In the posterior group, there were two occluded venous interposition grafts (successful thrombectomy in both patients) in the first 24 hours post-operative, one compartment syndrome (dermato fasciotomy), one deep wound infection (surgical drainage), and three superficial wound infections (intravenous antibiotics). In the medial group, there were two patients with a compartment syndrome (dermato fasciotomy), one patient each with saphenus nerve neuralgia, an infected seroma (surgical drainage), and postoperative bleeding (re-exploration), and two superficial wound infections (intravenous antibiotics).

The perioperative 30-day primary patency rate for the posterior approach was 94% versus 100% in the medial group ($P < .05$), secondary patency rates for both groups were 100%.

Table 1. Preoperative characteristics.

	Posterior Group n (%)	**Medial Group n (%)**
Patient total	33	33
Age (years)	65 $\pm$ 9	65 $\pm$ 10
Abdominal aortic aneurysm	16 (48%)	17(51%)
Contralateral PAA	16 (48%)	28 (85%)*
Vascular risk factors		
Coronary heart disease	10 (30%)	9 (27%)
Cerebrovascular accident	2 (6%)	3 (9%)
Hypertension	15 (45%)	16 (48%)
Hyperlipidemia	10 (30%)	8 (24%)
Diabetes mellitus	4 (12%)	3 (9%)
Smoking	17 (52%)	13(39%)
Symptoms/indication for intervention		
Symptomatic, acute	7 (21%)	6 (18%)
Symptomatic, chronic	14 (42%)	14 (42%)
Asymptomatic	12 (36%)	13 (39%)
Diameter PAA (mm)	32$\pm$10	32$\pm$10
Operative details		
Runoff status (vessels)		
0	0 (0%)	0 (0%)
1	5 (15%)	5 (15%)
2	12 (36%)	12 (36%)
3	14 (42%)	14 (42%)
n.a.	2 (6%)	2 (6%)
Venous bypass graft	24 (73%)	24 (73%)
PTFE bypass graft	9 (27%)	9 (27%)

PAA, Popliteal artery aneurysm; PTFE, polytetrafluoroethylene. * $P = .002$

Table 2. Thirty-day postoperative complications.

	Posterior Group n, (%)	Medial Group n, (%)
Patients	33	33
No complication	26 (79%)	26 (79%)*
Wound infection	3 (9%)	2 (6%)*
Wound infection deep	1 (3%)	0 (0%)*
Bleeding	0 (0%)	1 (3%)*
Occlusion	2 (6%)	0 (0%)†
Fasciotomy	1 (3%)	2 (6%)*
Amputation	0 (0%)	0 (0%)*
Others	0 (0%)	2 (6%)*

* *P* = not significant. † *P* = <.05

Long-term results

Mean follow-up was 47 months (range, 2 to 176 months), and no patient was lost to follow-up. Although 13 deaths (10 in the medial group, 3 in the posterior group) occurred during follow-up, none was related to previous interventions.

Posterior group

One patient (3%) underwent a successful percutaneous transluminal angioplasty (PTA) because of a >75% symptomatic stensosis of the interposition venous graft. Two patients underwent a percutaneous endovascular intervention because of an occlusion of the graft. Both attempted interventions failed, but because of mild clinical complaints, no surgical intervention was indicated. One patient required a renewed interposition graft because of an infected PTFE interposition graft. Owing to occlusion and restenosis of the interposition graft, and despite of two endovascular attempts, a transtibial amputation was necessary. A symptomatic proximal anastomotic aneurysm developed in another patient and was repaired with an interposition graft.

Medial group

A successful PTA was performed because of a >75% symptomatic stenosis of the bypass. Four endovascular interventions were necessary because of occlusion of the bypasses, and all interventions were initially successful. During follow-up of those four patients, surgical revision of the bypass was necessary in two patients because of reocclusion, another endovascular reintervention was needed owing restenosis with severe clinical complaints, and one patient with mild complaints did not need a reintervention. A symptomatic proximal anastomotic aneurysm was treated with an interposition graft.

Two patients in the medial group showed growth of the aneurysm during follow-up (after 80 and 120 months) despite proximal and distal aneurysm ligation. Both PAAs became symptomatic again; in one patient the PAA ruptured, and the other presented with local compression symptoms. Both were successfully treated with a posterior approach, opening of the PAA, and interrupting of the side branches.

Kapler-Meier life table analyses of primary and secondary patency of the medial and posterior groups are shown in Figure 1 and Figure 2. The primary patency rates at 6 months, and 1, 3, and 4 years were, respectively, 84%, 79%, 66%, and 66% in the posterior group and 96% (*P* < .05), 93% (*P* < .05), 76% (*P* = NS), and 69% (*P* = NS) for the medial group. At 6 months and 1 year, the respective assisted primary patency rates were 84% and 80% for the posterior group and 100% and 96% for the medial group (*P* = .04). The respective assisted primary patency rates at 3 and 4 years were 80% and 80% for the posterior group and 85% and 78% for the medial group (*P* = NS). The secondary patency rates at 6 months, and 1, 3, and 4 years were, respectively, 100%, 100%, 100%, and 90% in the posterior group and 96%, 96%, 96%, and 90% in the medial group (*P* = NS). Limb salvage rates were 97% in the posterior group and 100% in the medial group (*P* = NS). Long-term (4 year) primary and secondary patency rates of the 44 PAAs which were excluded from this case-matched study were 68% and 91% respectively, and were not significantly different compared to the included PAAs.

The primary patency of autologous venous bypasses and PTFE grafts is shown in Figure 3. At the 3-year follow-up, the primary patency rate of the venous bypasses was significantly better compared with prosthetic grafts (84% vs 67%, *P* < .01). This was irrespective of approach (medial group 86% vs 68% and dorsal group 84% vs 65%).

No neurologic complications or problems related to the deep venous system occurred in either group.

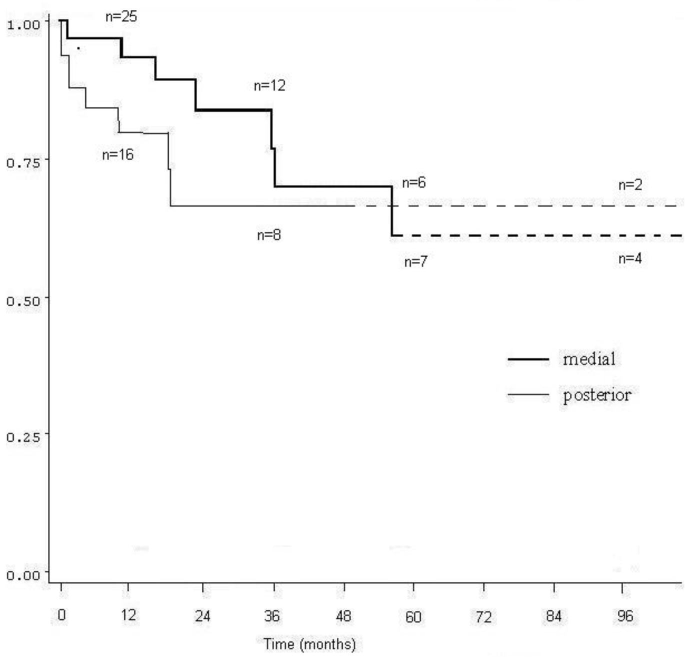


Figure 1. Kaplan-Meier life table analysis of primary patency after surgical repair of popliteal artery aneurysm through a medial or posterior approach (log-rank, *P* = .4187).

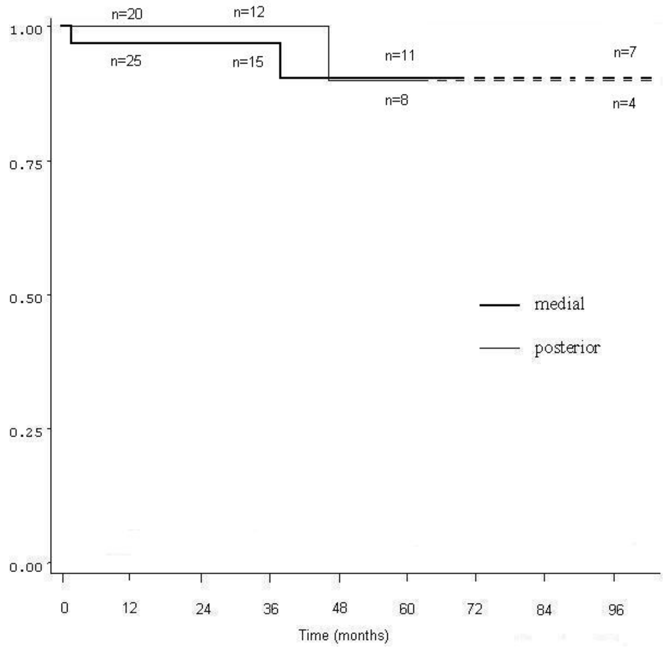


Figure 2. Kaplan-Meier life table analysis of secondary patency after surgical repair of popliteal artery aneurysm through a medial or posterior approach (log-rank, *P* = .9720).

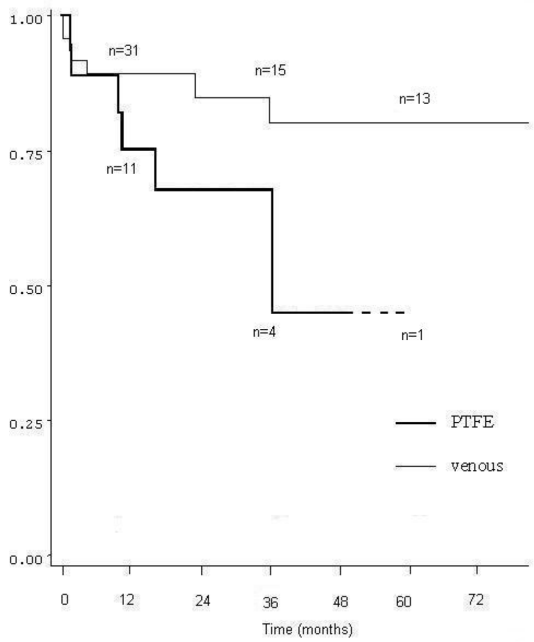


Figure 3. Kaplan-Meier life table analysis of primary patency after surgical repair of popliteal artery aneurysm PAA through a medial or posterior approach with either an autologous venous or polytetrafluoethylene (PTFE) bypass graft (log-rank, *P* = .0196).

DISCUSSION

This study is the first head-to-head comparison of the initial and mid-term outcomes of both the medial and posterior approach in the treatment of PAAs. According to evidence-based medicine guidelines, a retrospective case-matched study will yield the highest level of evidence in the absence of a prospective, randomized trial.[23] Furthermore, the entire medial group was a mixture of subgroups with varying exclusion techniques: some medial approached patients had their proximal ligation not just proximal of the aneurysm, but at the origo of the superficial femoral artery in the groin. Some patients had only proximal ligation and no distal ligation of the PAA, and some patients were treated by an extended medial approach with direct exclusion of the PAA. By mutual agreement with our statisticians we decided to case match popliteal aneurysms treated by a posterior approach and aneurysms repaired by a medial approach with ligation just proximally and distally from the PAA.

The medial approach with proximal and distal aneurysm ligation is by far the most commonly used surgical technique for PAA repair.[24] It might be preferred by surgeons because of its technical ease, safety, and the accessibility of the great saphenous vein through the medial incision. However, several recent publications have pointed out that after the medial approach, late aneurysm growth owing to retrograde flow through remaining side-braches of genicular arteries still can occur. This might lead to mechanical complications and sometimes even rupture.[13-18] To overcome this problems, the extended medial approach is used by some surgeons. Working around the medial head of the gastrocnemic muscle direct exclusion of the PAA will be possible. In our medial group <15 patients were treated by use of this technique.

One of the main advantages of the posterior approach is the definitive exclusion of the PAA, which has been proposed by several authors.[8,19] This method seems to be technically more challenging compared with the medial approach because the tibial nerve and popliteal vein are often densely adherent to large aneurysms by which exposure might be limited. Harvesting the great saphenous vein is often challenging through one posterior incision, which makes diversion to a separate medial incision or to harvest the lesser saphenous vein sometimes necessary. Popliteal aneurysms which extend above the Hunter canal are basically excluded to expose through a posterior approach.

The present study found no significant differences in long-term outcomes between the posterior and medial group in repair of PAAs not passing above the Hunter canal, in other words, not passing the proximal boundary of the P1 segment. Postoperative complications and primary, assisted primary, and secondary patency, and limb salvage rates were similar between the groups.

However, in the posterior group, two early (<24 hours) occlusions occurred. This lead to a significant difference in primary and assisted primary patency rates between the two groups perioperative, at 6 months and after 1 year of follow-up. Patients of the posterior and medial group reaching 6 months without a stenosis or occlusion, had no significant difference in 1 year primary patency ($P = 0.80$). Therefore, the significant difference in

CHAPTER 5

1 year primary patency between both groups is likely to be caused by the two early occlusions in the posterior group. Maybe the limited exposure was detrimental and cause of this early thrombotic complications. On the other hand, no anastomotic related failure could be found in both patients and no anastomotic revisions had to be performed. No significant kinking of the grafts were found during re-exploration on additional angiographies with the knee joint > 90 degrees flected. After thrombectomy, both grafts remained patent during long-term follow-up without renewed intervention.

No neurologic complications or problems related to the deep venous system were seen in the posterior or the medial groups.

In two retrospective studies, Mahmood et al.[8] and Martelli et al.[25] performed an univariate analysis to identify risk factors for graft failure after PAA repair using either the posterior or the medial approach. As in the present study, no significant differences for primary patency and the limb salvage between the posterior and medial approach were observed. Beseth et al.[19] reported a 2-year primary patency of 92.2% and a 2-year secondary patency of 95.8% for repair of PAA through the posterior approach. In our series, primary patency at 2 years was 66% and secondary patency was 100%. The low primary patency rate in our posterior group could partly be explained by the two early technical failures. The 4-year primary patency rate of 69% after the medial approach in this study is comparable with patency reported in literature of 50% to 86%.[1,7-12]

According to many authors, the graft material seems to influence the initial and mid-term results.[1,3,7,24,26,27] In our series, the graft material also influenced the primary patency at 1, 2, and 3 years. At 3 years, primary patency in the group treated with autologous venous graft was 84% vs 67% for the PTFE group ($P < .01$). This was irrespective of the kind of approach. So, in contrary to some studies in literature, venous posterior reconstructions proved to be better compared to prosthetic reconstructions. However, the small amounts of patients (9 prosthetic reconstructions in each group) and the retrospective character of this study have to be taken into account.

As mentioned earlier, a major disadvantage of the medial approach is the risk of remaining patent side branches of the aneurysm sac. In the present series, two patients in the medial group showed postoperative flow and aneurysm growth that required immediate reintervention. The reported incidence of postoperative aneurysm growth after the medial approach is 22% to 33%, and approximately 50% is associated with complications.[12-18] This seems to justify a regular yearly follow-up with duplex ultrasound imaging. Notably, loss of patency after the posterior approach in the present study occurred ≤2 years of follow-up in all cases. This suggests that a follow-up period of 2 years after repair of a PAA with a posterior approach might be sufficient.

Thrombolytic therapy has been widely advocated for occluded PAAs with acute ischemia before surgical revascularization; however, the limb must be capable of withstanding an additional period of ischemia. Therefore, thrombolytic pretreatment is discouraged in patients with level IIb acute limb ischemia or irreversible major tissue changes.[22,28,29] In only four studied patients (33%) with acute ischemia caused by thromboembolic complications did the level of ischemia allow preoperative thrombolysis.

If a PAA is passing above the Hunter canal, repair with a medial approach should primarily be performed, as is the case with PAAs combined with obstructions in the femoral superfical artery.

The present study has some limitations. Although the number of patients presented is in line with many published reports, the sample size is small. It was chosen not to simply compare the medial group with patients undergoing a posterior approach, because the aim was to minimize selection bias and confounding. Consequently, the two groups were highly comparable. Of course, owing to the retrospective character of this study, selection bias cannot be completely ruled out.

CONCLUSION

Early (< 1 year) primary patency rates of the medial approach are better compared to the posterior approach. Maybe the limited exposure is detrimental and cause of some early thrombotic complications in the posterior group which require reintervention. Venous reconstructions will led to significantly higher patency rates compared to prosthetic reconstructions irrespective of the manner of approach. On the long run, no significant differences in patency rates between the posterior and medial approach could be found. Considering the risk of persistent popliteal aneurysm growth (up to 22%) after distal and proximal ligation, the posterior approach might be the preferred surgical method of PAA repair at the end.

ACKNOWLEDGEMENTS

We would like to thank Dr Johannes C Kelder, St Antonius Hospital Nieuwegein, for the statistical assistance.

REFERENCES

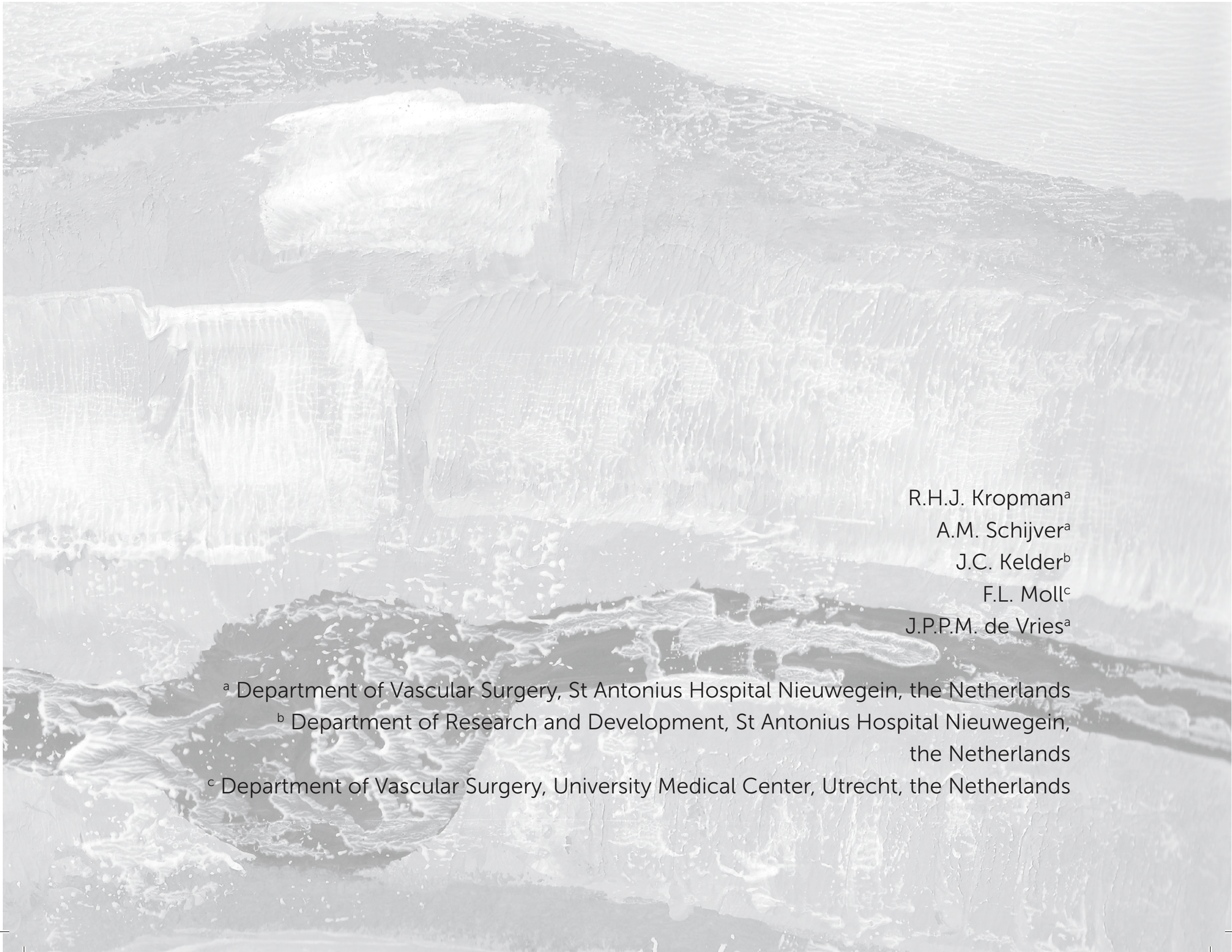
1. Dawson I, Sie RB, Van Bockel JH. Atherosclerotic popliteal aneurysm. Br J Surg 1997;84:293-99.
2. Duffy ST, Colgan MP, Sultan S, Moore DJ and Shanik GD. Popliteal aneurysms: a 10-year experience. Eur J Vasc Endovasc Surg 1998;16:218-22.
3. Pulli R, Dorigo W, Troisi N, Innocenti AA, Pratesi G, Azas L, et al. Surgical management of popliteal artery aneurysms: which factors affect outcomes? J Vasc Surg 2006;43:481-7.
4. Hirsch AT, Haskal ZJ, Hertzer NR, Bakal CW, Creager MA, Halperin JL, et al. ACC/AHA Guidelines for the Management of Patients with Peripheral Arterial Disease (Lower Extremity, Renal, Mesenteric, and Abdominal Aortic): A Collaborative Report from the American Associations for Vascular Surgery/Society for Vascular Surgery, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, Society of Interventional Radiology, and the ACC/AHA Task Force on Practice Guidelines (Writing Committee to Develop Guidelines for the Management of Patients with Peripheral Arterial Disease). Summary of recommendations. Circulation 2006;113:463-654.
5. Galland RB, Magee TR. Management of popliteal aneurysm. Br J Surg 2002;89:1382-85.
6. Roggo A, Brunner U, Ottinger LW, Largiader F. The continuing challenge of aneurysms of the popliteal artery. Surg Gynecol Obstet 1993;177:565-72.
7. Aulivola B, Hamdan AD, Hile CN, Sheahan MG, Skillman JJ, Campbell DR, et al. Popliteal artery aneurysms: A comparison of outcomes in elective versus emergent repair. J Vasc Surg 2004;39:1171-7.
8. Mahmood A, Salaman R, Sintler M, Smith SRG, Simms MH, Vohra RK. Surgery of popliteal artery aneurysms: a 12 year expeience. J Vasc Surg 2003;37:586-93.
9. Carpenter JP, Barker CF, Roberts B, Berkowitz HD, Lusk EJ, Perloff LJ. Popliteal artery aneurysms: current management and outcome. J Vasc Surg 1994;19:65-73.
10. Davidovic LB, Lotina SI, Kostic DM, Cinara IS, Cvetkovic SD, Markovic DM, et al. Popliteal artery aneurysms. World J Surg 1998;22:812-7.
11. Lowell RC, Gloviczki P, Hallett JW Jr, Naessens JM, Maus TP, Cherry KJ Jr, et al. Popliteal artery aneurysms: the risk of nonoperative management. Ann Vasc Surg 1994;8:14-23.
12. Mamode N, Scott RN. Graft type for femoro-popliteal bypass surgery. Cochrane Database Syst Rev 2000;CD001487.
13. Ebaugh JL, Morasch MD, Matsumura JS, Eskandari MK, Meadows WS, Pearce WH. Fate of excluded popliteal artery aneurysms. J Vasc Surg 2003;37:954-9.
14. Jones WT 3rd, Hagino RT, Chiou AC, Decaprio JD, Franklin KS, Kashyap VS. Graft patency is not only clinical predictor of success after exclusion and bypass of popliteal artery aneurysms. J Vasc Surg 2003;37:392-8.
15. Kirkpatrick UJ, McWilliams RG, Martin J, Brennan JA, Gilling-Smith GL, Harris PL. Late complications after ligation and bypass for popliteal aneurym. Br J Surg 2004;91:174-77.
16. Mehta M, Champagne B, Darling RC 3rd, Roddy SP, Kreienberg PB, Ozsvath KJ, et al. Outcome of popliteal artery aneurysms after exclusion and bypass: Significance of residual patent branches mimicking type II endoleaks. J Vasc Surg 2004;40:886-90.
17. Van Santvoort HC, de Vries JPPM, Van de Mortel R, Wille J, Van de Pavoordt EDWM. Rupture of a popliteal artery aneurysm 10 years after surgical repair. Vascular 2006;14:227-30.
18. Wakassa TB, Matsunaga P, Da Silva ES, Pinto CA, Kauffman P, Aun R, et al. Follow-up of the aneurismal sac after exclusion and bypass of popliteal artery aneurysms. Clinics 2006;61:107-12.
19. Beseth BD, Moore WS. The posterior approach for repair of popliteal artery aneurysms. J Vasc Surg 2006;43:940-5.
20. Graham L. Femoral and popliteal aneurysms. In: Rutherford RB, editor. Vascular surgery. 5th ed. Philadelphia, PA: Saunders; 2000. p. 1345-55.
21. Edwards WS. Exclusion and saphenous vein bypass of popliteal aneurysms. Surg Gynecol Obstet 1969;128:829-30.
22. Rutherford RB, Baker JD, Ernst C, Johnston KW, Porter JM, Ahn S, et al. Recommended standards for reports dealing with lower extremity ischemia. J Vasc Surg 1997;26:517-38.
23. Phillips B, Ball C, Sackett D, Badenoch D, Straus S, Haynes B, et al. Levels of evidence and grades of recommendations. Oxford Centre for Evidence-Based Medicine. Available at: www.cebm.net/levels_of_evidence.asp. Last accessed Nov 1, 2006
24. Blanco E, Serrano-Hernando FJ, Monux G, Vega M, Martin A, Rial R, et al. Operative repair of popliteal aneurysms: effect of factors related to the bypass procedure on outcome. Ann Vasc Surg 2004;18:86-92.
25. Martelli E, Ippoliti A, Ventoruzzo G, De Vivo G, Ascoli Marchetti A, Pistolese GR. Popliteal artery aneurysm. Factors associated with thromboembolism and graft failure. Int Angiol 2004;23:54-65.
26. Bourriez A, Melliere D, Desgranges P, D'Audiffret A, Allaire E, Becquemin JP. Elective popliteal aneurysms: does venous availability has an impact on indications? J Cardiovasc Surg (Torino) 2005;46:171-5.
27. Varga ZA, Locke-Edmunds JC, Baird RN. A multicenter study of popliteal aneurysms. Joint Vascular Research Group. J Vasc Surg 2004;20:171-7.

28. Marty B, Wicky S, Ris HB, Mueller X, Fischer A, Hayoz D, et al. Success of thrombolysis as a predictor of outcome in acute thrombosis of popliteal aneurysms. J Vasc Surg 2002;35:487-93.
29. Dorigo W, Pulli R, Turini F, Pratesi G, Credi G, Innocenti AA, et al. Acute leg ischaemia from thrombosed popliteal artery aneurysms: role of preoperative thrombolysis. Eur J Vasc Endovasc Surg 2002;23:251-4.

CHAPTER 6

Clinical outcome of acute leg ischemia due to thrombosed popliteal artery aneurysm: Systematic review of 895 cases

Eur J Vasc Endovasc Surg 2010;39:452-457



R.H.J. Kropman[a]
A.M. Schijver[a]
J.C. Kelder[b]
F.L. Moll[c]
J.P.P.M. de Vries[a]

[a] Department of Vascular Surgery, St Antonius Hospital Nieuwegein, the Netherlands
[b] Department of Research and Development, St Antonius Hospital Nieuwegein, the Netherlands
[c] Department of Vascular Surgery, University Medical Center, Utrecht, the Netherlands

ABSTRACT

Objectives

A systematic review was performed to summarize outcomes of acute thrombosed popliteal artery aneurysms (PAAs) treated with thrombolysis or thrombectomy followed by bypass.

Methods

A systematic review was conducted of data on acute thrombosed PAAs dated January 1, 1990, through June 30, 2008, using the Cochrane Library, MEDLINE and EMBASE databases. Primary endpoint was limb salvage, secondary endpoints were mortality and patency of the bypasses.

Results

No randomized trials, eight prospective studies, and 25 retrospective studies with 895 patients presenting with acute ischemia were included. The mortality rate after surgical repair was 3.2 per cent [95 % confidence interval (c.i.) 1.8 to 4.6]. The amputation rate was 14.1 per cent [95 % c.i. 11.8 to 16.4]. Thrombolysis before surgery did not result in a significant reduction of the number of amputations, compared with surgery (thrombectomy and bypass) alone. The mean primary patency rates of the bypasses at 1, 3, and 5 years were, respectively, 79, 77 and 74 % in the "thrombolysis" group and 71 ($P = 0.026$), 54 ($P = 0.164$), and 45 % ($P = 0.249$) in the "thrombectomy"group. Because of lack of sufficient data no distinction could be made concerning secondary patency rate and limb salvage rate between both groups.

Conclusions

Preoperative and intraoperative thrombolysis result in a significant improvement in 1 year primary graft patency rates, but does not result in a significant reduction for amputations compared with surgery alone.

INTRODUCTION

Popliteal artery aneurysms (PAAs) are the most frequently encountered peripheral arterial aneurysms, with an incidence of 0.1 to 2.8 %[1-3]. Many authors recommend elective surgical intervention in patients with asymptomatic aneurysms larger than 20 mm with mural thrombus because of the increased risk of thromboembolic complications[4-9]. Other authors suggest a diameter of 3 cm should be the cutoff point[10,11]. There is hardly any need to exclude PAAs to prevent rupture; in contrast with abdominal aortic aneurysms, PAA rupture is rare[4,8]. The consequences of acute thrombosis of a PAA are both limb- and life-threatening. Because of thromboembolization of the runoff arteries, an important risk of major amputation exists despite emergency interventions. Historically, surgical thrombectomy of the crural arteries and additional femoropopliteal or femorocrural bypass grafting was the treatment of choice. In the 1980s, however, intra-arterial catheter-directed thrombolysis was successfully attempted to improve arterial runoff before surgical revascularization to increase patency rates of peripheral bypass surgery[12]. During recent years, complete endovascular treatment (thrombolysis and stentgrafting) has become an alternative to open surgery.

The goal of this paper is to conduct a systematic review of patients presenting with acute thrombosed popliteal artery aneurysms with ischemia and to compare different strategies of treatment; preoperative thrombolysis followed by exclusion of the PAA with bypass surgery (group A) and surgery alone (crural thrombectomy and bypass surgery, group B), using as primary outcome limb loss and as secondary outcomes mortality rate and primary patency of the bypasses.

METHODS

Literature search

To identify relevant literature, a systematic search was performed in the medical databases of Medline (January 1990 through Jun 2008), Embase (January 1990 through Jun 2008), and Cochrane Library, comprising the Database of Systematic Reviews (January 1990 through Jun 2008). The keywords “acute ischemia,” OR “leg ischemia,” OR “acute thrombosis,” AND “popliteal artery aneurysm,” OR “thrombosed popliteal artery aneurysm,” were used along with synonyms. For endovascular or surgical treatment, we used the terms “thrombolysis,” OR “thrombosuction,” OR “endovascular treatment,”OR “surgical treatment,” OR “open repair,” OR “bypass,” OR “peripheral bypass”. There was no language restriction.

Criteria for inclusion

Titles and abstracts were screened by two reviewers (R.K. and J.V.) independently to identify potentially relevant articles, using the inclusion and exclusion criteria. Discrepancies in judgment were resolved after discussion and, when necessary, after mediation of a third reviewer (F.M.). First, patients had to be treated for an acute thrombosed popliteal artery aneurysm with either thrombolysis followed by bypass surgery, including intraoperative thrombolysis (group A) or surgery alone (crural thrombectomy followed by bypass, group B). In some articles, patients with acute thrombosed PAAs were not the main subject of the manuscript, but a subpopulation, and no detailed information was given of this subgroup. Data was included in this review only if there was a separate description of the acute PAAs in the article. Second, at least one of the outcome parameters--i.e. limb salvages, mortality and primary graft patency--had to be reported. Third, the study should include a minimum of 5 patients. Fourth, it should be an original patient series (studies containing duplicate material were excluded and the ones with the best documented material were included for analysis).

Data extraction

The following data were recorded per study: method of data collection (prospective or retrospective), selection of patients for the study (consecutive or selected and, if selected, inclusion and exclusion criteria). Furthermore, patient characteristics (number of patients, sex, age, grade of acute ischemia), relevant risk factors, (i.e., diabetes, smoking, hypertension, renal failure) and characteristics of the arterial tree (diameter PAA, number of outflow arteries) were recorded. Finally, data about the procedure were collected such as technique (medial/dorsal approach, venous/PTFE bypass, endovascular repair), and follow-up data. The following outcomes were recorded and analyzed: technical success, primary patency, limb salvage, complications, and survival. Technical success was defined as restored outflow through at least one patent crural artery in continuation with the pedal arch. Primary patency was defined as uninterrupted flow (< 50 % stenosis) in the bypass with neither an additional procedure performed nor an intervention to solve disease progression in the adjacent native vessel.
Data extraction was done by two reviewers (R.K. and J.V.) independently. Discrepancies in judgment were resolved after discussion and, when necessary, after mediation of a third reviewer (F.M.). Full text of these articles was retrieved for further analysis.

Data Analysis

Continuous values will be described as means $\pm$ standard deviation. Trial heterogeneity was estimated using the Cochrane Q statistic. The I^2 statistic, which is the proportion of total variation among studies that is likely to be explained by between-study heterogeneity rather than chance, is reported. Substantial heterogeneity exists when I^2 exceeds 50 %. Data were pooled using a fixed-effect model if heterogeneity was limited; a random-effect model was used when there was significant heterogeneity among the studies. The conventional 0.05 level of significance was employed.

Thrombolytic treatment

In 28 per cent of patients, a PAA was diagnosed due to acute symptoms of thrombosis[8]. Patients with acute limb ischemia usually present with limb-threatening ischemia with minimal or no sensory loss, which, in the the absence of paralysis is defined as grade IIa or, in the presence of sensory loss extending beyond the toes, grade IIb, according to

Rutherford acute limb ischemia classification[14]. Rutherford grade III limb ischemia presents with muscle paralysis extending above the foot, profound sensory loss, and inaudible arterial and venous Doppler signals[14]. This classification of acute ischemia is very important, because it determines the urgency of the treatment. Thrombolysis, with or without additional surgery, has been advised for the treatment of acute ischemia Rutherford class I to IIa[14]. When sensory loss or motor deficit is present (class IIb to III), there is no time for thrombolysis and surgery has to be performed immediately.
In recent years, a combination of thrombolysis followed by surgery, or sole endovascular treatment consisting of thrombolysis of the PAA and crural arteries and additional exclusion of the PAA with use of a covered stent, has been proposed for treatment of acute thrombosed PAA. Lysis can clear the thrombosed PAA itself and the runoff arteries effectively and might improve inflow and outflow and, therefore, relieve persistent ischemia. However, thrombolysis-related complications might occur, the limb must be capable of withstanding an additional period of ischemia, and the patient must tolerate the administration of a fibrinolytic agent. In the included studies no patients were treated with intravenous thrombolysis. Of the 313 patients treated with intra-arterial thrombolysis, 255 were treated with pre-operative thrombolysis, the remaining 58 were treated with intra-operative thrombolysis. Of note is that only 4 out of 22 studies used intra-operative thrombolysis.

RESULTS

The initial search yielded 135 articles. After screening of titles and abstract, 101 articles were excluded. The most frequent reasons for exclusion were study design (review, case report with <5 patients), location of aneurysms and no acute trombosed PAAs. One study was excluded after reading the full text.
Results were collected from 33 series containing data from 895 acute thrombosed PAAs[3-5,7,9-11,13,18-20,23,25-45]. Of those 895 patients, intra-arterial thrombolysis was used in 313 (35%)[3,4,7,10,11,18-20,23,27-29,32-34,36-39,4,44,45] (Figure 1). In 223 of 313 PAAs the thrombolytic treatment was successful, defined as restored outflow through at least one patent crural artery in continuation with the pedal arch, resulting in 71 % success. In 52 (17 %) patients the thrombolytic treatment was unsuccessful; all of those patients were treated with thrombectomy followed by bypass surgery and were included in the preoperative thrombolysis group. In 38 patients results of the thrombolytic therapy were not recorded. Only in 142 of the 313 acute thrombosed PAAs treated with thrombolysis details were published of complications during thrombolytic treatment (Table 1). Minor bleeding occurred in 14 patients (9.9 %), but none required surgical intervention. No major bleedings or cerebral vascular accidents were recorded. Most of the retrieved articles lacked detailed information concerning Rutherford grade of ischemia, time, total dose of thrombolytic treatment, and the number of patent crural arteries.
Of the 895 patients whose data were collected, the acute ischemia classification was only noted in 122 patients (17 %). Of these 122 patients 101 (83 %) presented with

marginally threatened limb ischemia grade IIa, 18 (15 %) patients presented with grade IIb, and 3 (3 %) presented with irreversible limb ischemia grade III. Only in the minority of these 122 patients, a description per individual patient of the method of treatment was provided.

Surgical vascular repair was performed in 846/895 patients (95 %). In 31 patients a primary amputation was necessary. Thrombolysis was followed by surgical repair in 295 of 313 patients. After thrombolysis, 18 patients did not undergo surgery, nine (3 %) were not fit for any surgery, and nine (3 %) received an endograft.

Data on the surgical approach was available for 372 of the 846 patients (44 %). A medial approach was used in 312 PAAs (84 %) and the posterior approach in 60 (16 %). In only

Table 1. Complications due to thrombolysis in 142 PAA[3,4,7,10,11,15,16,17,20,24,26,29,30,34-36,38,41,42].

	%	SD (%)
Haematoma	2.8	16,5
Minor bleeding	9.9	29,8
Major bleeding	0.0	
Acute leg detoriation	3.5	18,4
Foot drop	2.1	14,4
Pneumonia	0.7	8,4
Mortality	0.0	

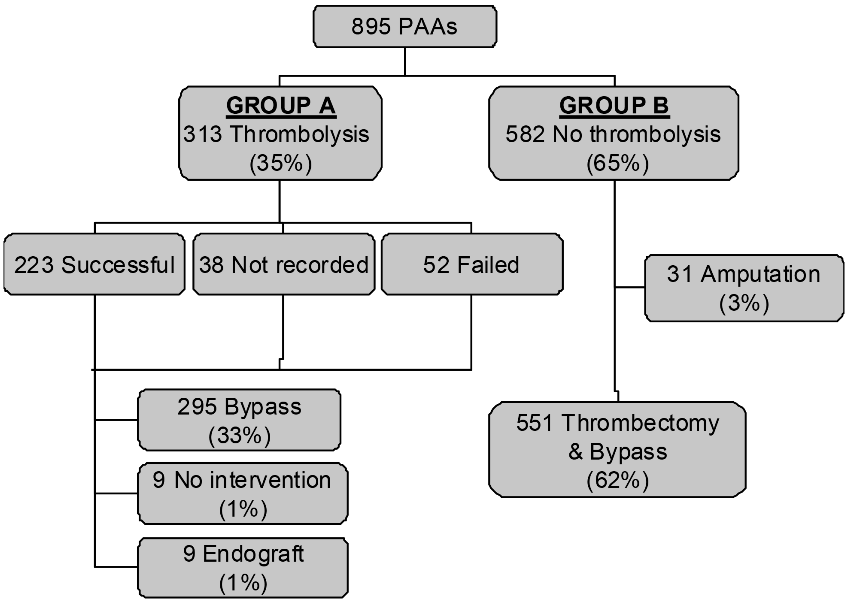


Figure 1. Flow chart of the treatment modalities of patient group A and B.

402 patients was the type of conduit recorded, comprising a vein graft in 318 patients (79 %) and a prosthetic graft in 84 (21 %). No detailed information was given concerning the type of prosthetic material used.

Early outcome (< 30 days) of acute thrombosed PAA

A 30-day fixed effect pooled mortality rate of 3.2 % [95 % confidence interval (c.i.) 1.8 to 4.6] was determined in 564 of 895 patients. Data concerning the mortality rates between both groups is too limited. The major amputation rate within 30 days was 14.1 % [95 % c.i. 11.8 to 16.4] (I^2 = 27 %) of the 895 acute thrombosed PAAs because of irreversible ischemia. Of these amputations, 31 (20 %) were performed without previous thrombolysis or bypass surgery. Thrombolysis before surgery resulted in a non-significant 2.3 per cent [95 % c.i. -12.7 to 8.2; *P* = 0.688] absolute reduction of the number of amputations compared with thrombectomy followed by bypass (Figure 2).

Long-term results of acute thrombosed PAAs

The mean primary patency rates at 1, 3, and 5 years after the bypass of the acute thrombosed PAAs were, respectively, 79 % ± 19.0 (n = 57) , 77 % ± 6.3 (n = 36), and 74 % ± 6.3 (n = 7) in group A and 71 % ± 12.8 (n = 88) (*P* = 0.026) , 54 % ± 26.0 (n = 37) (*P* = 0.164), and 45 % ± 28.4 (n = 16) (*P* = 0.249) in group B (Table 2).

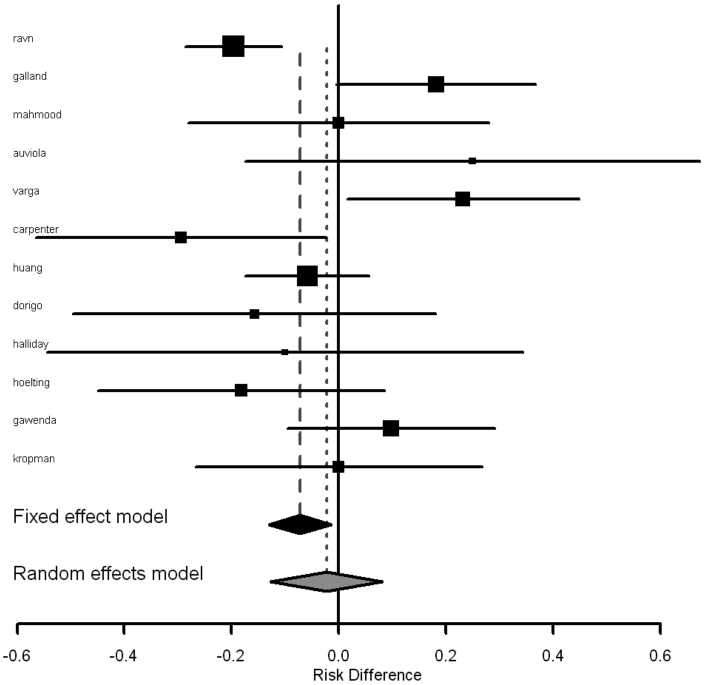


Figure 2. Amputation rate with or without preoperative thrombolysis in acute thrombosed popliteal artery aneurysms. Q-test: *P* = 0.0009, I2 = 65% [95 per cent c.i. 35.3 to 81.1]

Table 2. Primary patency rate for surgical repair of acute thrombosed PAA. [a] with thrombolytic therapy, [b] without thrombolytic therapy

Shortell *et al.*	1991	22[b]	69[b]	60[b]	39[b]	39[b]	39[b]
Carpenter *et al.*	1994	7[a] 17[b]	100[a] 66[b]	78[a] 48[b]	78[a] 38[b]	78[a] 38[b]	78[a] 38[b]
Hoelting *et al.*	1994	9[a] 11[b]	100[a] 66[b]	—	—	—	—
Sarcina *et al.*	1997	17[b]	88[b]	82[b]	76[b]	67[b]	67[b]
Steinmetz *et al.*	2000	15[a]	80[a]	80[a]	80[a]	—	—
Dorigo *et al.*	2002	14[a] 10[b]	74[a] 56[b]	—	—	—	—
Galland *et al.*	2002	22[a] 14[b]	—	—	76[a] 67[b]	—	—
Marty *et al.*	2002	11[a]	46[a]	—	—	—	—
Aulivola *et al.*	2004	4[a] 9[b]	67[a] 85[b]	67[a] 85[b]	67[a] 85[b]	67[a] 85[b]	67[a] 85[b]
Huang *et al.*	2007	24[a] 50[b]	84[a] 62[b]	—	—	—	—

Because of the small group size no distinction between the different approaches and the different types of conduit could be made.
Because of lack of data in the included studies no distinction between group A and group B could be made concerning mean secondary patency rates and mean limb salvage rates. The mean secondary patency rates and mean limb salvages rates at 1 year were, 82% ± 24.6 (n = 74) and 85% ± 10.4 (n = 94), respectively and at 5 years, 80% ± 14.0 (n = 26) and 76% ± 13.1 (n = 41), respectively.

DISCUSSION

Thrombolysis before surgery results in a significant improvement in 1 year primary graft patency rates compared with surgery alone. There is no effect concerning reduction in amputation rate.
No level 1 evidence can be obtained concerning this limb and life threatening subject. Remarkably, most published studies are conducted with retrospective data, and almost every study lacks important characteristics (grade of ischemia, type of graft material, outflow crural arteries, conduction of dermatofasciotomy, surgical approach), or long follow-up.
The reported overall 5-year primary patency rates for elective surgical repair of non-acute symptomatic PAA are 66 to 86 per cent[8]. In this review primary patency rates for acute symptomatic PAAs were 74 % in group A and 45 % in group B (P = 0.249) at 5 years. As in elective femoro-popliteal occlusions, the additional value of thrombolysis prior to bypass surgery remains to be proven[46-48].
The major amputation rate was 14 per cent because of irreversible ischemia. Thrombolysis before surgery resulted in a small absolute reduction of the number of amputations compared with surgery alone; however, this effect is not significant because of the high heterogenicity between the different studies, and the small numbers of the subgroups.
Endovascular stenting has been successfully used in the management of aortic

aneurysms; however, its utility in the treatment of PAAs remains questionable. Unfortunately, endovascular treatment of PAAs lacks long-term follow-up. Conversely, endovascular graft repair has the advantage of being minimally invasive, which is important in the treatment of unfit patients. Disadvantage of an all endovascular treatment of PAA thrombosis could be the fact that the restored flow is often in one crural artery, and the flow is unlikely to be sufficient to sustain a prosthetic stent. However, it is remarkable that after successful thrombolysis, with at least one patent crural artery, only nine patients received an endograft in this systematic analysis.

Operative results concerning repair of PAA are closely related to the status of the distal outflow and the type of graft material8. Unfortunately, only a few studies reported the status of the distal outflow and the grade of ischemia. Therefore, the patencies between both groups can not be statistically compared without taking notice of bias.

In any case, acute repair of PAAs must be avoided.

CONCLUSION

Preoperative and intraoperative thrombolysis do not result in a significant reduction for amputations. One year primary patency rates of surgical interventions after thrombolysis are significantly different compared with surgery alone, 3 and 5 years primary patency are not significantly different. No distinction could be made between both groups concerning secondary patency rate and limb salvage rate. Data on complete endovascular approach of thrombosed PAAs are scarce.

REFERENCES

1. Duffy ST, Colgan MP, Sultan S, Moore DJ, Shanik GD. Popliteal aneurysms: a 10-year experience. Eur J Vasc Endovasc Surg 1998;16:218-22.
2. Hirsch AT, Haskal ZJ, Hertzer NR, Bakal CW, Creager MA, Halperin JL, et al. ACC/AHA 2005 Practice Guidelines for the management of patients with peripheral arterial disease (lower extremity, renal, mesenteric, and abdominal aortic): a collaborative report from the American Association for Vascular Surgery/Society for Vascular Surgery, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, Society of Interventional Radiology, and the ACC/AHA Task Force on Practice Guidelines (Writing Committee to Develop Guidelines for the Management of Patients With Peripheral Arterial Disease): endorsed by the American Association of Cardiovascular and Pulmonary Rehabilitation; National Heart, Lung, and Blood Institute; Society for Vascular Nursing; TransAtlantic Inter-Society Consensus; and Vascular Disease Foundation. Circulation 2006;113:e463-e654.
3. Pulli R, Dorigo W, Troisi N, Innocenti AA, Pratesi G, Azas L, et al. Surgical management of popliteal artery aneurysms: which factors affect outcomes? J Vasc Surg 2006;43:481-7.
4. Aulivola B, Hamdan AD, Hile CN, Sheahan MG, Skillman JJ, Campbell DR, et al. Popliteal artery aneurysms: a comparison of outcomes in elective versus emergent repair. J Vasc Surg 2004;39:1171-7.
5. Davidovic LB, Lotina SI, Kostic DM, Cinara IS, Cvetkovic SD, Markovic DM, et al. Popliteal artery aneurysms. World J Surg 1998;22:812-7.
6. Dawson I, van Bockel JH, Brand R, Terpstra JL. Popliteal artery aneurysms. Long-term follow-up of aneurysmal disease and results of surgical treatment. J Vasc Surg 1991;13:398-407.
7. Halliday AW, Taylor PR, Wolfe JH, Mansfield AO. The management of popliteal aneurysm: the importance of early surgical repair. Ann R Coll Surg Engl 1991;73:253-7.
8. Kropman RHJ, De Vries JPPM, Moll FL. Surgical and endovascular treatment of atherosclerotic popliteal artery aneurysms. J Cardiovasc Surg 2007;48:281-8.
9. Lowell RC, Gloviczki P, Hallett JW, Jr., Naessens JM, Maus TP, Cherry KJ, Jr., et al. Popliteal artery aneurysms: the risk of nonoperative management. Ann Vasc Surg 1994;8:14-23.
10. Galland RB, Magee TR. Management of popliteal aneurysm. Br J Surg 2002;89:1382-5.
11. Ramesh S, Michaels JA, Galland RB. Popliteal aneurysm: morphology and management. Br J Surg 1993;80:1531-3.
12. Schwarz W, Berkowitz H, Taormina V, Gatti J. The preoperative use of intraarteial thrombolysis for a thrombosed popliteal artey aneurysm. J Cardiovasc Surg 1984;25:465-8.
13. Davis RP, Neiman HL, Yao JS, Bergan JJ. Ultrasound scan in diagnosis of peripheral aneurysms. Arch Surg 1977;112:55-8.
14. Rutherford RB, Baker JD, Ernst C, Johnston KW, Porter JM, Ahn S, et al. Recommended standards for reports dealing with lower extremity ischemia: Revised version. J Vasc Surg 1997;26:517-38.
15. McNamara TO, Fischer JR. Thrombolysis of peripheral arterial and graft occlusions: improved results using high dose urokinase. AJR 1985;144:769-75
16. Dube M, Soulez G, Therasse E, Cartier P, Blair JF, Roy P et al. Comparison of streptokinase and urokinase in local thrombolysis of peripheral arterial occlusions for lower limb salvage. J Vasc Interv Radiol 1996;7:587-93

27. Van Breda A, Katzen BT, Deutsch AS. Urokinase versus streptokinase in local thrombolysis. Radiology 1987;165:109-11

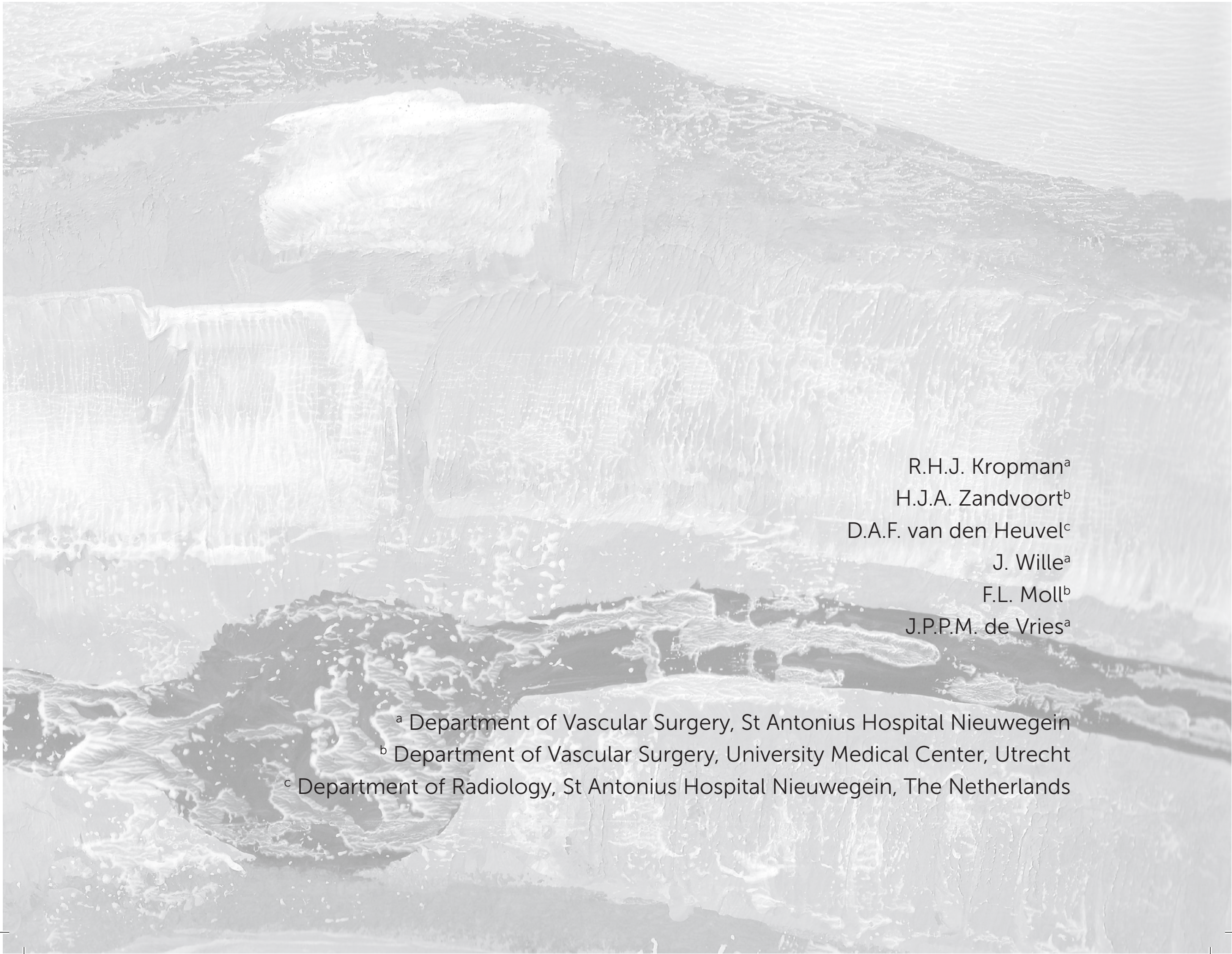
18. Dorigo W, Pulli R, Turini F, Pratesi G, Credi G, Innocenti AA, et al. Acute leg ischaemia from thrombosed popliteal artery aneurysms: role of preoperative thrombolysis. Eur J Vasc Endovasc Surg 2002;23:251-4
19. Marty B, Wicky S, Ris HB, Mueller X, Fischer A, Hayoz D, et al. Success of thrombolysis as a predictor of outcome in acute thrombosis of popliteal aneurysms. J Vasc Surg 2002;35:487-93.
20. Steinmetz E, Bouchot O, Faroy F, Charmasson L, Terriat B, Becker F, et al. Preoperative intraarterial thrombolysis before surgical revascularization for popliteal artery aneurysm with acute ischemia. Ann Vasc Surg 2000;14:360-4.
21. Edwards WS. Exclusion and saphenous vein bypass of popliteal aneurysms. Surg Gynecol Obstet 1969;128:829-30
22. Antonello M, Frigatti P, Battocchio P, Lepidi S, Cognolato D, Dall'Antonia A et al. Open repair versus endovascular treatment for asymptomatic popliteal artery aneurysm: results of a prospective randomized study. J Vasc Surg 2005;42:185-93
23. Mahmood A, Salaman R, Sintler M, Smith SR, Simms MH, Vohra RK. Surgery of popliteal artery aneurysms: a 12-year experience. J Vasc Surg 2003;37:586-93.
24. Bourriez A, Melliere D, Desgranges P, D'Audiffret, Allaire E, Becquemin JP. Elective popliteal aneurysms: does venous availability has an impact on indications? J Cardiovasc Surg (Torino) 2005;46:171-5
25. Hagino RT, Fujitani RM, Dawson DL, Cull DL, Buehrer JL, Taylor SM, et al. Does infrapopliteal arterial runoff predict success for popliteal artery aneurysmorrhaphy? Am J Surg 1994;168:652-6

26. Sarcina A, Bellosta R, Luzzani L, Agrifoglio G. Surgical treatment of popliteal artery aneurysm. A 20 year experience. J Cardiovasc Surg (Torino) 1997;38:347-54
37. Huang Y, Gloviczki P, Noel AA, Sullivan TM, Kalra M, Gullerud RE, et al. Early complications and long-term outcome after open surgical treatment of popliteal artery aneurysms: Is exclusion with saphenous vein bypass still the gold standard? J Vasc Surg 2007;45:706-15
28. Kropman RH, van Santvoort HC, Teijink J, van de Pavoordt HD, Belgers HJ, Moll FL, et al. The medial versus the posterior approach in the repair of popliteal artery aneurysms: A multicenter case-matched study. J Vasc Surg 2007;46:24-30.
29. Martelli E, Ippoliti A, Ventoruzzo G, de Vivo G, Ascolli Marchetti A, Pistolese GR. Popliteal artery aneurysms. Factors associated with thomboembolism and graft failure. Int Angiol 2004;23:54-65.
30. Ascher E, Markevich N, Schutzer RW, Kallakuri S, Jacob T, Hingorani AP. Small popliteal artery aneurysms: are they clinically significant? J Vasc Surg 2003;37:755-60.
31. Blanco E, Serrano-Hernando FJ, Monux G, Vega M, Martin A, Rial R, et al. Operative repair of popliteal aneurysms: effect of factors related to the bypass procedure on outcome. Ann Vasc Surg 2004;18:86-92.
32. Bowrey DJ, Osman H, Gibbons CP, Blackett RL. Atherosclerotic popliteal aneurysms: management and outcome in forty-six patients. Eur J Vasc Endovasc Surg 2003;25:79-81.
33. Carpenter JP, Barker CF, Roberts B, Berkowitz HD, Lusk EJ, Perloff LJ. Popliteal artery aneurysms: current management and outcome. J Vasc Surg 1994;19:65-72.
34. van Damme H, Trotteur G, Kerzmann A, Limet R. Intra-arterial thrombolysis of thrombosed popliteal artery aneurysm. A series of six cases. Acta Chir Belg 2006;106(6):679-83.
35. Galland RB, Magee TR. Popliteal aneurysms: distortion and size related to symptoms. Eur J Vasc Endovasc Surg 2005;30:534-8.
36. Gawenda M, Sorgatz S, Müller U, Walter M, Erasmi H. The thrombosed popliteal aneurysm with distal arterial occlusion – Succesful therapy by interdisciplinary management. Thorac Cardiovasc Surg 1995;43:112-6.
37. Gouny P, Bertrand P, Duedal V, Cheynel-Hocquet C, Lancelin C, Escourolle F, et al. Limb salvage and popliteal aneurysms: advantages of preventive surgery. Eur J Vasc Endovasc Surg 2000;19:496-500.
38. Greenberg R, Wellander E, Nyman U, Uher P, Lindh M, Lindblad B, et al. Aggressive treatment of acute limb ischemia due to thrombosed popliteal aneurysms. Eur J Radiol 1998;28:211-8.
39. Hoelting T, Paetz B, Richter GM, Allenberg JR. The value of preoperative lytic therapy in limb-threatening acute ischemia from popliteal artery aneurysm. Am J Surg 1994;168:227-31.
40. Lichtenfels E, Frankini AD, Bonamigo TP, Cardozo MA, Schulte AA. Popliteal artery aneurysm surgery: The role of emergency setting. Vasc Endovascular Surg 2008;42:159-64.
41. Ravn H, Björck M. Popliteal artery aneurysm with acute ischemia in 229 patients. Outcome after thrombolytic and surgical therapy. Eur J Vasc Endovasc Surg 2007;33:690-5.
42. Shortell CK, DeWeese JA, Ouriel K, Green RM. Popliteal artery aneurysms: a 25-year surgical experience. J Vasc Surg 1991;14:771-6.
43. Stone PA, Armstrong PA, Bandyk DF, Keeling WB, Flaherty SK, Shames ML, et al. The value of duplex surveillance after open and endovascular popliteal aneurysm repair. J Vasc Surg 2005;41:936-41.
44. Taurino M, Calisti A, Grossi R, Maggiore C, Speziale F, Fiorani P. Outcome after early treatment of politeal artery aneurysms. Int Angiol 1998;17:28-33.
45. Varga ZA, Locke-Edmunds JC, Baird RN. A multicenter study of popliteal aneurysms. Joint Vascular Research Group. J Vasc Surg 1994;20:171-7.
46. Ouriel K, Shortell CK, DeWeese JA, Green RM, Franscis CW, Azodo MV, et al. A comparison of thrombolytic therapy with operative revascularization in the treatment of acute peripheral arterial ischemia. J Vasc Surg 1994;19(6):1021-30.
47. Ouriel K, Veith FJ, Sasahara AA. A comparison of recombinant urokinase with vascular surgery as initial treatment for acute arterial occlusion of the legs. N Engl J Med 1998:338(16):1105-11.
48. No authors listed. Results of a prospective randomized trial evaluating surgery versus thrombolysis for ischemia of the lower extremity. Ann Surg 1994;220(3):251-66.

CHAPTER 7

CT angiography to evaluate hemodynamic changes in popliteal artery aneurysms during flexion and extension of the knee joint

Submitted to J Vasc Surg



R.H.J. Kropman[a]
H.J.A. Zandvoort[b]
D.A.F. van den Heuvel[c]
J. Wille[a]
F.L. Moll[b]
J.P.P.M. de Vries[a]

[a] Department of Vascular Surgery, St Antonius Hospital Nieuwegein
[b] Department of Vascular Surgery, University Medical Center, Utrecht
[c] Department of Radiology, St Antonius Hospital Nieuwegein, The Netherlands

ABSTRACT

Objective

It is not clear which characteristics of an asymptomatic popliteal artery aneurysm (PAA) will increase the risk for acute thrombosis. Besides PAA diameter, hemodynamic changes in the popliteal artery (including the aneurismal segment) during knee movement may play a role. This study examined changes in popliteal artery lumen area as well as changes in angles proximal and distal of the PAA during flexion and extension of the knee joint.

Methods

This was a single-center prospective study of consecutive patients with PAAs presenting from January 2010 to April 2012. Computed tomography angiography was used to perform measurements of the PAA during 0° extension and 90° flexion of the knee in a specially prepared brace. After semi-automated segmentation of the popliteal lumen, a center lumen line (CLL) was automatically constructed by placement of a start point 5 cm proximal to the PAA and an end point 5 cm distal to the aneurismal segment. PAA diameter and length, lumen area, and the degree of angulation were measured.

Results

The study included 13 men with 16 asymptomatic PAAs. Mean PAA diameter was 29 ± 11 mm, median PAA volume was 19 mL (interquartile range [IQR], 10-68 mL), and median PAA length was 63 mm (IQR, 51-112 mm). Median lumen area of the nondiseased popliteal artery directly proximal of the PAA was 57 mm^2 (IQR, 44-87 mm^2) in extension vs 51 mm^2 (IQR, 38-73 mm^2) during 90° flexion (P = .007). Median lumen area of the nondiseased popliteal artery directly distal of the PAA was 46 mm^2 (IQR, 32-66 mm^2) in extension vs 38 mm^2 (IQR, 30-62 mm^2) with 90° flexion of the knee (P = .03). The median of the greatest decrease in lumen area (direct proximal or distal from the aneurysm) after flexion and extension of the knee was 36 mm (IQR, 28-48 mm) in PAAs ≥30 mm compared with 11 mm (IQR, 4-18 mm) in PAAs <30 mm (P < .05). The proximal angulation between the axis of the lumen of the aneurysm and the axis of the lumen of the popliteal artery was a median of 48° in extension (IQR, 27º-61º) and 75° during flexion (IQR, 46º-99º; P = .02). Distal angulation was a median of 31° (IQR, 21º-42º) after extension vs 62° (IQR, 33º-81º) during flexion (P = .03). No significant differences were found between proximal and distal angulation in extension compared with flexion among small and large aneurysms (P = .87).

Conclusions

Knee bending in patients with PAAs will lead to a significant reduction in the lumen area proximal and distal of the PAA and produce a significant change in the degree of angulation at the proximal and distal part of the PAA, which may be a cause for increased thromboemboli. A significant decrease in lumen area was seen in PAAs ≥30 mm compared with PAAs <30 mm after flexion of the knee.

INTRODUCTION

Popliteal artery aneurysms (PAAs) are considered to be the second most frequent location of arterial aneurysms.[1-3] Approximately 40% of patients with a PAA are asymptomatic at time of diagnosis.[4,5] However, PAAs may cause serious ischemic complications, associated with thromboemboli, which may lead to limb loss.[6] Many authors recommend elective surgical intervention in patients with asymptomatic aneurysms >20 mm with mural thrombus because of the increased risk of thromboembolic complications.[7-11] Other authors suggest a cutoff point for intervention at a diameter of 30 mm.[12,13]

It is not clear which characteristics of an asymptomatic PAA will lead to acute thrombosis. Diameter alone might not be the only predicting factor. The popliteal artery has two relatively fixed points, one proximal to the adductor canal and the other distal to the orifice of the anterior tibial artery.[14] In healthy volunteers, arterial flexions of the popliteal artery contribute to tortuosity during flexion and extension of the knee, as described by Wensing et al.[15] Tortuosity is also seen in PAAs during flexion and extension of the knee joint, which might result in undesired and unexpected reduction in lumen area.[16] This reduction in lumen area might induce critical flow changes in the popliteal artery, which can lead to low-flow status, turbulent blood flow, and thromboembolization. This study examined changes in the lumen area and the degree of angulation directly proximal and distal of the PAA after flexion and extension of the knee joint and their association with the diameter of the PAA.

METHODS

This prospective single-center (St. Antonius Hospital Nieuwegein) study included all consecutive patients with an asymptomatic PAA from January 2010 to April 2012. PAAs were diagnosed by duplex ultrasound imaging. A preoperative computed tomography angiography (CTA) in flexion and extension was performed in PAAs >2 cm PAAs are defined as a localized dilatation of the popliteal artery >150% of the nondiseased ipsilateral popliteal artery. The medical ethical committee approved the study.

The following clinical characteristics of included patients were obtained: sex, presence of bilateral PAA, presence of abdominal aortic aneurysm, cardiovascular risk factors, type of preoperative imaging, and preoperative ankle-brachial index.

Imaging

CTA was performed on a 256-slice CT scanner (Philips Medical Systems, Best, The Netherlands). The femoropopliteal segment was scanned in 0° extension and in 90° flexion of the knee in a specially prepared brace. The extension and flexion scans were performed with 70-mL flow of 4.0 mL/s of iodinated contrast (Guerbet 300 mg iodine/mL), followed by a 40-mL 3.0 mL/s saline flush. Scanning parameters were 100 kV, 160 mAs, slice thickness, 1.5; increment, 0.75, pitch, 0.664, and a collimation of 128 × 0.625. All acquired CTA scans were transferred to a 3mensio Vascular 5.1 workstation (3mensio

Medical Imaging BV, Bilthoven, The Netherlands). After semi-automated segmentation of the popliteal lumen, a center lumen line (CLL) was automatically constructed by placement of a start point 5 cm proximal to the PAA and an end point 5 cm distal to the aneurysmal segment. Popliteal CLL spline points were manually checked and corrected, if necessary. Multiplanar reconstructions were made perpendicular to the popliteal CLL to perform measurements at two levels: just proximal and just distal to the PAA. Diameter and area of the contrast-enhanced lumen were measured at these points. Proximal and distal angles were also measured (Figure 1). The proximal angle (α) is the angle between

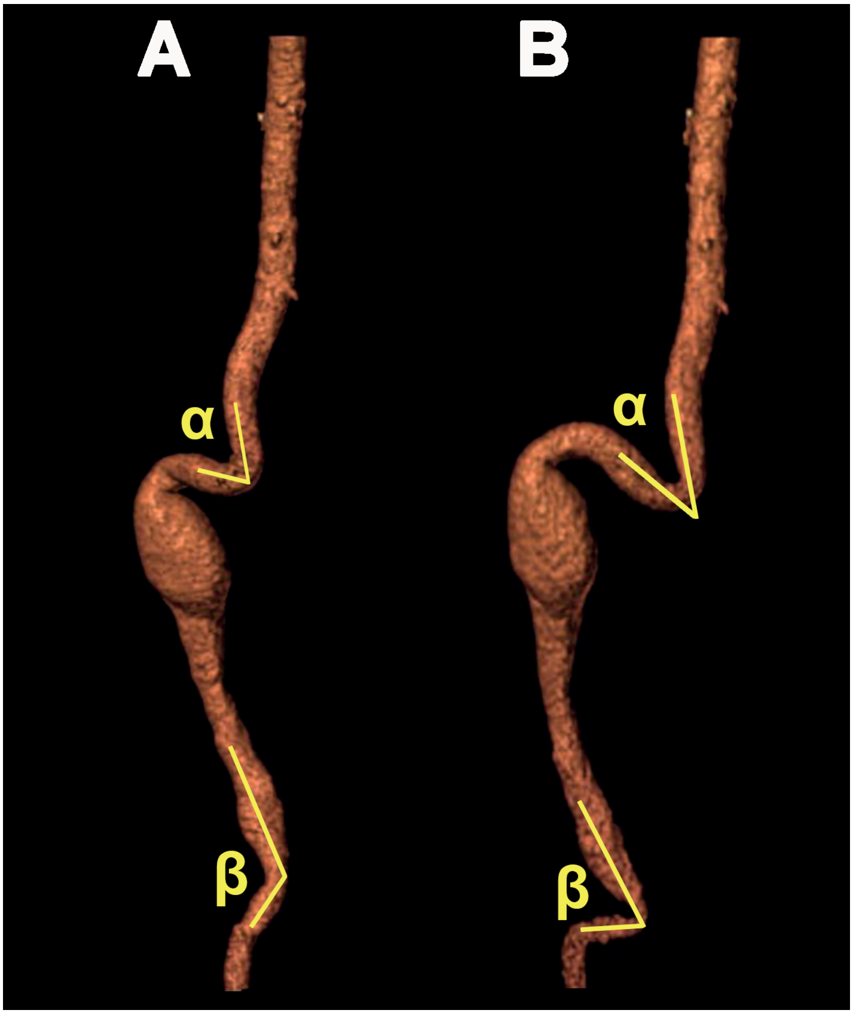


Figure 1. CTA scan of a popliteal artery aneurysm after multiplanar reconstructions of the center lumen line. A extension, B 90° flexion. (α) is the angle between the longitudinal axis of the normal popliteal artery proximal to the aneurysm and the longitudinal axis of the PAA sac. (β) is the angle between the longitudinal axis of the PAA sac and the longitudinal axis of the normal popliteal artery distal to the aneurysm

the longitudinal axis of the normal popliteal artery proximal to the aneurysm and the longitudinal axis of the PAA sac. The distal angle (β) is the angle between the longitudinal axis of the PAA sac and the longitudinal axis of the normal popliteal artery distal to the aneurysm. The sharpest angle of the CLL was considered the true angle of the popliteal axis and was determined according to the angle measurement technique as described by van Keulen et al.[17] Maximum aneurysm diameter, total aneurysm volume, and lumen volume were also determined. The proximal and distal end of the aneurysm was independently determined by two blinded observers (H.Z. and R.K.). Discrepancies in judgment were resolved after discussion and, when necessary, after mediation of a third reviewer (J.V.). The same protocol was followed for the extension and flexion CTA scans.

Statistical analysis

Standard descriptive statistics were used. Continuous data are presented as mean ± standard deviation and range, and as median with interquartile range (IQR) in case of non-normal distributions. Statistical analysis was performed using the Mann-Whitney U test and the $\chi 2$ test. Data were calculated using SPSS 20 software (IBM Corp, Armonk, NY). $P < .05$ was considered statistically significant.

RESULTS

The study included 13 men with 16 asymptomatic PAAs. Table I reports the patients characteristics. Mean PAA diameter was 29 ± 11 mm, median PAA volume was 19 mL (IQR, 10-68 mL), and median PAA length was 63 mm (IQR, 51-112 mm) with knee extension. Median lumen area of the nondiseased popliteal artery directly proximal of the PAA was 57 mm^2 (IQR, 44-87 mm^2) in extension vs 51 mm^2 (IQR, 38-73 mm^2) during 90° flexion ($P = .007$). The nondiseased popliteal artery directly distal to the PAA had a median lumen area of 46 mm^2 (IQR, 32-66 mm^2) in extension compared with 38 mm^2 (IQR, 30-62 mm^2) with 90° flexion of the knee ($P = .03$). When the PAAs were grouped by size <30 mm (n = 8) and ≥30 mm (n = 8), the greatest decrease in lumen area (directly proximal or distal from the aneurysm) after flexion and extension of the knee was a median of 36 mm (IQR, 28-48 mm) in PAAs ≥30 mm compared with 11 mm (IQR, 4-18 mm) in PAAs <30 mm ($P < .05$).

The proximal angulation between the axis of the lumen of the aneurysm and the axis of the lumen of the popliteal artery was a median of 48° in extension (IQR, 27-61) and 75° during flexion (IQR, 46-99; $P = .02$). Distal angulation was a median of 31° (IQR, 21-42) after extension vs 62° (IQR, 33-81) during flexion ($P = .03$). No significant differences were determined between proximal and distal angulation in extension compared with flexion among small and large aneurysms ($P = .87$).

Table 1. Demographics and clinical variables.

Variables	Mean $\pm$ SD or No. (%) (n = 13)
Age, y	67 $\pm$ 7
Abdominal aortic aneurysm	10 (77)
Contralateral PAA	7 (54)
Vascular risk factors	
Coronary heart disease	6 (46)
Cerebrovascular accident	1 (8)
Hypertension	3 (23)
Hyperlipidemia	5 (38)
Diabetes mellitus	0 (0)
Smoking	6 (46)
PAAs	16
PAA diameter, mm	29 $\pm$ 11
Ankle-brachial index	1.1 $\pm$ 0.2
Runoff status, vessels	
0	0 (0)
1	2 (13)
2	7 (44)
3	7 (44)

PAA, Popliteal artery aneurysm; SD, standard deviation.

DISCUSSION

To our knowledge, no previous study has been published regarding changes in the lumen area of the aneurysmatic popliteal artery during flexion and extension. The lumen area of the popliteal artery directly proximal and distal of the PAA was significantly lower during flexion than during extension. The degree of proximal and distal angulation between the axis of the lumen of the aneurysm and the lumen of the popliteal artery were significantly higher after flexion than after extension. The greatest decrease in lumen area (directly proximal or distal from the aneurysm) after flexion of the knee was significantly larger in PAAs $\geq$30 mm than in PAAs <30 mm.

Bending the knee results in a S curve of the popliteal artery to deal with the length surplus of the artery.[18] In older patients, this S curve of the popliteal artery has been seen distal to the adductor canal.[15] Bending the knee when a PAA is present might induce an increase of angulation and a lumen area reduction of the popliteal artery, distal or proximal of the PAA, or both, because the PAA is stiff. Our study confirmed this hypothesis.

Flexion of the knee with a PAA $\geq$30 mm results in a significant lumen reduction compared with a PAA <30 mm. On one hand, this might confirm why large PAAs will become symptomatic more often than smaller PAAs. On the other hand, large aneurysms that do not become symptomatic probably do not have a significant lumen reduction or a significant increase of angulation after flexion of the knee. Another important finding in this study are the huge variations in lumen area reduction and angulation changes during flexion and extension within the group of small aneurysms, as well as within the group with large aneurysms. These measured variability within the groups may explain why some small popliteal aneurysms will still become symptomatic and why some large aneurysms will not become symptomatic. We propose to add a flexion and extension CTA scan in the pre-procedural work-up in patients with PAA and take into account the degree of lumen area reduction and angulation during knee movements. These parameters might be of interest, besides the absolute diameter in order to decide to operate or not.

The degree of proximal and distal angulation between the axis of the lumen of the aneurysm and the lumen of the popliteal artery was significantly higher after flexion than after extension. In 2005, Galland et al[16] reported that the degree of angulation was significantly increased in symptomatic PAAs compared with asymptomatic PAAs. Therefore, a great degree of angulation proximal or distal of the aneurysm might be a predictor of becoming symptomatic. However, in contrast to Galland et al,[19] the current study did not find a relationship between larger aneurysms (PAA $\geq$30 mm) and the degree of angulation of the popliteal artery distally or proximally of the aneurysm. Aneurysm diameters $\geq$30 mm are predictors of becoming symptomatic. Further inclusion of symptomatic PAAs would allow a comparison of the examined lumen area and angulation between asymptomatic and symptomatic PAAs. A significant increase of angulation and a significant decrease in lumen area between the symptomatic and asymptomatic PAAs would further strengthen the value of the proposed predictors.

A preintervention flexion and extension CTA scan might also be useful if placement of an endovascular stent graft is planned. The choice for an endovascular stent graft should probably be reconsidered in the presence of a significant lumen reduction or a significant angulation in flexion because of the increased risk of stent fracture or stent occlusion. Furthermore, a flexion and extension CTA scan can be used to determine the most severe angulations of the popliteal artery during flexion. It must be avoided to land with the proximal or distal border of a stent, or bypass just in this segment of the popliteal artery. Unfortunately, analysis of the intramural thrombus was technically not feasible. The amount of intramural thrombus might be another predictor of becoming symptomatic. Despite of the small number of PAAs included in this study, results clearly indicate that the lumen area in flexion and the level of angulation in flexion might be predictors of whether a PAA will become symptomatic. Widespread consensus has been achieved to repair asymptomatic aneurysms $\geq$30 mm to prevent thromboembolic complications; however, no consensus has been reached for aneurysms between 20 and 30 mm.[20-23] Aneurysm diameter is currently the only factor that determines aneurysm repair in asymptomatic PAAs. A flexion and extension CTA scan to detect the degree of angulation and the possible lumen area reduction might be helpful to decide whether to operate on asymptomatic PAAs between 20 and 30 mm. Furthermore, the amount of thrombus, the number of outflow vessels, the presence of a vein graft, and the patient's sex should be taken into account in deciding whether to repair the PAA. Hence, PAA diameter alone is not the only characteristic in predicting acute thrombosis.

CONCLUSIONS

Knee bending in patients with PAAs will lead to a significant reduction in lumen area proximal and distal of the PAA and produces a significant change in the degree of angulation distal and proximal of the aneurysm, which may be a cause for increased thromboembolic complications. A significant decrease in lumen area was seen in PAAs ≥30 mm compared with PAAs <30 mm. Besides, a substantial variability in angulation and lumen area has been determined in both small and large PAAs. Both parameters may be taken into account in the decision to treat PAAs regardless the diameter alone.

REFERENCES

1. Dent TL, Lindenauer SM, Ernst CB, Fry WJ. Multiple arteriosclerotic arterial aneurysms. Arch Surg 1972;105:338-44.
2. Hirsch AT, Haskal ZJ, Hertzer NR, Bakal CW, Creager MA, Halperin JL, et al. ACC/AHA 2005 Practice Guidelines for the management of patients with peripheral arterial disease (lower extremity, renal, mesenteric, and abdominal aortic): a collaborative report from the American Association for Vascular Surgery/Society for Vascular Surgery, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, Society of Interventional Radiology, and the ACC/AHA Task Force on Practice Guidelines (Writing Committee to Develop Guidelines for the Management of Patients With Peripheral Arterial Disease): endorsed by the American Association of Cardiovascular and Pulmonary Rehabilitation; National Heart, Lung, and Blood Institute; Society for Vascular Nursing; TransAtlantic Inter-Society Consensus; and Vascular Disease Foundation. Circulation 2006;113:e463-e654.
3. Pulli R, Dorigo W, Troisi N, Innocenti AA, Pratesi G, Azas L, et al. Surgical management of popliteal artery aneurysms: which factors affect outcomes? J Vasc Surg 2006;43:481-7.
4. Kropman RHJ, De Vries JPPM, Moll FL. Surgical and endovascular treatment of atherosclerotic popliteal artery aneurysms. J Cardiovasc Surg 2007;48:281-8.
5. Dawson I, Sie RB, Van Bockel JH. Atherosclerotic popliteal aneurysm. Br J Surg 1997;84:293-99.
6. Kropman RHJ, Schrijver AM, Kelder JC, Moll FL, de Vries JPPM. Clinical outcome of acute leg ischaemia due to thrombosed popliteal artery aneurysm: systematic review of 895 cases. Eur J Vasc Endovasc Surg 2010;39:452-7.
7. Aulivola B, Hamdan AD, Hile CN, Sheahan MG, Skillman JJ, Campbell DR, et al. Popliteal artery aneurysms: a comparison of outcomes in elective versus emergent repair. J Vasc Surg 2004;39:1171-7.
8. Davidovic LB, Lotina SI, Kostic DM, Cinara IS, Cvetkovic SD, Markovic DM, et al. Popliteal artery aneurysms. World J Surg 1998;22:812-7.
9. Dawson I, van Bockel JH, Brand R, Terpstra JL. Popliteal artery aneurysms. Long-term follow-up of aneurysmal disease and results of surgical treatment. J Vasc Surg 1991;13:398-407.
10. Halliday AW, Taylor PR, Wolfe JH, Mansfield AO. The management of popliteal aneurysm: the importance of early surgical repair. Ann R Coll Surg Engl 1991;73:253-7.
11. Lowell RC, Gloviczki P, Hallett JW Jr, Naessens JM, Maus TP, Cherry KJ Jr, et al. Popliteal artery aneurysms: the risk of nonoperative management. Ann Vasc Surg 1994;8:14-23.
12. Galland RB, Magee TR. Management of popliteal aneurysm. Br J Surg 2002;89:1382-5.
13. Ramesh S, Michaels JA, Galland RB. Popliteal aneurysm: morphology and management. Br J Surg 1993;80:1531-3.
14. Avisse C, Marcus C, Ouedraogo T, Delattre JF, Menanteau B, Flament JB. Anatomo-radiological study of the popliteal artery during knee flexion. Surg Radiol Anat 1995;17:255-62.
15. Wensing PJ, Scholten FG, Buijs PC, Hartkamp MJ, Mali WP, Hillen B. Arterial tortuosity in the femoropopliteal region during knee flexion: a magnetic resonance angiographic study. J Anat 1995;186:133-9.
16. Galland RB, Magee TR. Popliteal aneurysms: Distorsion and size related to symptoms. Eur J Vasc Endovasc Surg 2005;30:534-8.
17. van Keulen JW, Moll FL, Tolenaar JL, Verhagen HJ, van Herwaarden JA. Validation of a new standardized method to measure proximal aneurysm neck angulation. J Vasc Surg 2010;51:821-8.
18. Smedby O, Hogman N, Nilsson S, Erikson U, Olsson AG, Walldius. Two-dimensional tortuosity of the superficial femoral artery in early atherosclerosis. J Vasc Res 1993;30:181-91.
19. Galland RB. Popliteal aneurysms: controversies in their management. Am J Surg 2005;190:314-8.
20. Cross JE, Galland RB, Hingorani A, Ascher E. Nonoperative versus surgical management of small (less than 3 cm), asymptomatic popliteal artery aneurysms. J Vasc Surg 2011;53:1145-8.
21. Forbes TL, Ricco JB. Editors commentary. J Vasc Surg 2011;53;1145-48.
22. Cross JE, Galland RB. Part one: For the motion asymptomatic popliteal artery aneurysms (less than 3 cm) should be treated conservatively. Eur J Vasc Endovasc Surg 2011;41:448-9.
23. Hingorani A, Ascher E. Part two: Against the motion asymptomatic popliteal artery aneurysms (less than 3 cm) should be repaired. Eur J Vasc Endovasc Surg 2011;41:445-8; discussion 449.

CHAPTER 8

Association of gender on long-term outcomes after popliteal artery aneurysm repair

Accepted with minor revisions in Ann Vasc Surg

R.H.J. Kropman[a]
A. van Meurs[a]
B. Fioole[b]
J.A. Vos[c]
H.C. van Santvoort[d]
M. van Sambeek[e]
F.L. Moll[d]
J.P.P.M. de Vries[a]

[a] Department of Vascular Surgery, St Antonius Hospital Nieuwegein
[b] Department of Vascular Surgery, Maasstad Hospital Rotterdam
[c] Department of Radiology, St Antonius Hospital Nieuwegein
[d] Department of Vascular Surgery, University Medical Center, Utrecht
[e] Department of Vascular Surgery, Catharina Hospital Eindhoven

ABSTRACT

Objectives
To compare initial and long term outcomes between men and women after endovascular and open repair of popliteal artery aneurysm (PAA).

Methods
Between January 1993 and July 2011, 202 patients (185 men, 92%), underwent open (n = 186), or endovascular (n = 16) repair of a PAA. Data were retrospectively analyzed.

Results
Significant differences in baseline characteristics were determined between men and women; diameter of the aneurysm (men 30 mm, range 14-90, women 26 mm, range 13-70, *P* = .02), and age (men 66±10 years, women 71±9 years, *P* = .05). The 30-day mortality rate was 0% in both groups. No significant differences were determined concerning 30-days complications. The median follow-up was 55 months (range 1-121) in men, compared with 35 months (range 1-183) in women (*P* = .74). The primary patency rates at 1,3 and 5 years were were 88%, 82%, 76% in men, compared with 64%, 64% and 48% in women respectively (*P* = 0.007). The limb salvage rates in men at 1, 3 and 5 years were 97%, 97%, and 96% and in women 87%, 87% and 87%, respectively (*P* = .07). When correcting for potential confounders with multivariable regression analysis, gender was independently associated with primary patency HR 2.98 (95%-CI 1.39-6.42), *P* = .005.

Conclusion
No significant differences between men and women were observed in 30-day mortality and morbidity rates after PAA repair. In the long run, women are associated with lower primary patency rates, and a trend towards lower limb salvage rates compared to men.

INTRODUCTION

Arterial vascular disease is a significant problem in men and women. In general, women have smaller arteries than men. This has been proven in the carotid artery1-3, aorta4 and popliteal artery[5,6].

The popliteal artery is the second most frequent location of arterial aneurysms. The incidence in the general population is 0.1-2.8%[7-9]. Combined results of studies focusing on the outcome of bypass surgery in the lower extremity, do not show significant differences in primary patency rates, percentage limb salvage and survival between males and females[10-18].

To our knowledge no studies have been performed to specifically investigate the effect of gender on the outcome of popliteal artery aneurysms (PAA) treatment. A difference in outcome might be relevant for follow-up regimens and the choice whether or not to treat a PAA at a certain diameter in males and females. The aim of the current study is to investigate whether there is a difference in outcome after PAA repair between males and females.

METHODS

This was a retrospective observational cohort study on patients who underwent open or endovascular repair of PAA. The medical ethics committees of all centers approved the study. All patients admitted for a PAA from January 1993 to July 2011 at (SAZ, Nieuwegein, CZ, Eindhoven, MSZ, Rotterdam and UMC, Utrecht; The Netherlands), were identified by a computer database search using the International Classification of Diseases code for PAA. Medical records of all patients were reviewed retrospectively. The diagnosis PAA was confirmed by duplex ultrasonography (preferred imaging modality) followed by Computed Tomography Angiography (CT-A) or Magnetic Resonance Angiography (MRA). In all participating centers, indications for surgery were acute and chronic symptomatic PAAs and asymptomatic PAAs with a diameter > 2 centimeters. The treatment of choice was open surgery. From the year 2000, patients with a PAA with severe cardiopulmonary comorbidity were treated by endovascular means. All implanted endovascular stent grafts were Hemobahn or Viabahn stentgrafts (W.L. Gore & Associates, Inc, Flagstaff, Arizona), and introduced via an antegrade common femoral artery access. Before this date, patients with severe cardiopulmonary comorbidity were offered open repair.

All patients who underwent open repair (posterior and medial approach), with a proximal anastomosis at the supragenual femoral artery and a distal anastomosis at the infragenual popliteal artery, or, endovascular repair of PAA were included in this study. In all hospitals a posterior approach was only performed if the popliteal aneurysm did not extend to the proximal boundary of the P1 segment of the popliteal artery.

Operation technique

Either a posterior or medial approach was used in the patients who underwent open repair. The preferred graft was the great or small saphenous vein. Only in patients with insufficient veins, a prosthetic graft was used.

The posterior approach included a lazy S-shaped incision in the posterior aspect of the knee, with dissection between the medial and lateral heads of the gastrocnemic muscle, taking care not to injure the tibial nerves and popliteal vein. The popliteal artery was clamped proximal and distal of the PAA, after which the aneurysm sac was opened with a longitudinal arteriotomy the mural thrombus, if present, was evacuated. Patent side branches of the genicular arteries were interrupted, and reversed venous or prosthetic (Dacron) interposition grafting was performed using end-to-end anastomoses[19-21].

The medial approach consisted of a combined supra- and infragenicular incision at the medial side of the leg. The popliteal artery was exposed and ligated proximally and distally of the PAA, after which reversed venous or prosthetic (non-reinforced, 6 mm Dacron) bypass grafting was performed using end-to-end or end-to-side anastomoses[22].

All endovascular stent grafts were Hemobahn or Viabahn (W.L. Gore & Associates, Inc, Flagstaff, Arizona), and placed via an antegrade common femoral artery puncture. The choice for a Hemobahn or Viabahn stentgraft was according to the physician's preference. When more than one endograft was used, an overlap of at least 2 centimeters was obtained.

Data collection

The following additional preoperative variables were collected: gender, presence of bilateral PAA, presence of abdominal aortic aneurysm, symptoms (acute, chronic, or asymptomatic), use of preoperative thrombolytic treatment (for acute PAA) (in all hospitals catheter directed Urokinase had been used during the years. Dosage which has been used in the majority of the patients is 90.000 IU / hr via antegrade access), diameter of the PAA, vascular risk factors, type of preoperative imaging. Per-procedurally collected variables were: type of graft (great saphenous vein, small saphenous vein or prosthetic) and 30-day complications. Follow-up variables were hemodynamic stenosis or occlusion of the graft, renewed symptoms, endovascular or surgical re-interventions, absence or existence of flow in the PAA, major amputation of the ipsilateral leg, and mortality.

Follow-up

The surveillance program consisted of post-procedural clinical and duplex ultrasonography or MRA examinations at 1, 6, and 12 months, and yearly thereafter. Graft primary patency was assessed, including the native artery proximal and distal of the anastomoses or stent grafts.

Definitions

Primary patency was defined as uninterrupted flow (< 50% stenosis) in the graft or stent graft with neither an additional procedure performed nor an intervention to solve disease progression in the adjacent native vessel.[23] Acute limb ischemia was retrospectively classified according to the acute limb ischemia classification by Rutherford et al.[23]

Statistical analysis

Standard descriptive statistics were used. Patency rates were computed using the Kaplan-Meier method and compared with the log-rank test. The Kolmogorov–Smirnov test was used to assess whether continuous data were normally distributed. Continuous data are presented as mean $\pm$ standard deviation and in case of non normal distributions as median with range. Values were compared by the Student t test, Mann-Whitney U test, χ^2 test, and the Fisher exact test, as appropriate. To evaluate the true effect of gender on outcome, we also performed regression analysis. First all baseline characteristics were entered in a univariate Cox regression model to investigate the association with primary patency. All factors associated with primary patency with $P < .2$ were entered in a multivariable Cox regression model. Results are presented as hazard ratios with 95%-confidence intervals. $P < .05$ was considered statistically significant. The analysis was performed using SPSS software.

RESULTS

Pre- and per -operative characteristics

Between January 1993 and July 2011 202 patients (185 men, 92%), with a mean age of 67 $\pm$ 10 years underwent PAA repair. In 48 cases the PAA was bilateral, 43 men and 5 women. The PAA diameters and the inflow and outflow arteries were determined using duplex ultrasonography, computed tomography angiography, or magnetic resonance angiography. Table 1 summarizes the pre- and per-operative characteristics of men and women. With regard to the baseline characteristics, diameter of the aneurysm and the presence of an abdominal aortic aneurysm were significantly different in both groups. No significant differences between gender groups were seen in vascular risk factors, the use of a venous graft or prosthetic, the operation technique (endovascular, posterior and medial approach) or the indication for intervention (acute symptomatic, chronic symptomatic (intermittent claudication or mechanical complaints) or asymptomatic).

During the study period 16 additional patients were diagnosed with an acute symptomatic PAA (n=7), chronic symptomatic PAA (n=3) or asymptomatic PAA >2 cm (n=6). Eight of these patients had primary amputations. The remainder were not treated at all because of severe comorbidity in combination with short life expectancy and/ or unsuitable anatomy for endografting. No follow-up was done of these patients.

Thirty-day results

The 30-day mortality was 0% in both groups. No significant differences were seen in amputation rates (1% in men and 0% in women) or in graft obstruction rate (3% in men compared to 6% in women). Nor were there significant differences in complication rate between men and women (Table 2).

Long term results. The median follow-up was 55 months (range 1-121) in men, compared to 35 months (range 1-183) in women (P = .74). The primary patency rates at 1, 3 and 5 years were 88%, 82%, 76% in men, compared with 64%, 64% and 48% in women respectively (P = .007). The limb salvage rates in men were 97% (1 year), 97% (3 years), and 96% (5 years) and in women 87%, 87% and 87% respectively (P = .07). Kaplan-Meier life-table analyses of primary patency and limb salvage of men and women are shown in figures 1 and 2.

Table 1. Pre- and per -operative characteristics.

	Men n (%)	**Women** n (%)	***P*-value**
Patient total	185 (92%)	17 (8%)	
Age (years)	66 ± 10	71 ± 9	.05 *
Abdominal aortic aneurysm	107 (58%)	5 (29%)	.02 *
Contralateral PAA	140 (76%)	10 (59%)	.13
Vascular risk factors			
Coronary heart disease	60 (32%)	7 (41%)	.46
Cerebrovascular accident	28 (15%)	1 (6%)	.30
Hypertension	90 (49%)	9 (53%)	.74
Hyperlipidemia	70 (38%)	4 (24%)	.24
Diabetes mellitus	25 (14%)	1 (6%)	.37
Smoking	75 (41%)	6 (35%)	.67
Symptoms/indication for intervention			.18
Symptomatic, acute	45 (24%)	6 (35%)	
Symptomatic, chronic	53 (29%)	7 (41%)	
Asymptomatic	87 (47%)	4 (24%)	
Thrombolysis	18 (10%)	1 (6%)	.60
Diameter PAA (mm)	30 (14-90)	26 (13-70)	.02 *
Operative details			
Operation technique			.18
Medial approach	111 (60%)	14 (82%)	
Posterior approach	59 (32%)	2 (12%)	
Endovascular stent graft	15 (8%)	1 (6%)	
Runoff status (vessels)			.54
0	8 (4%)	2 (12%)	
1	22 (12%)	3 (18%)	
2	47 (26%)	5 (29%)	
3	82 (44%)	5 (29%)	
n.a.	26 (14%)	2 (12%)	
Graft material			.29
Venous graft	141 (76%)	11 (65%)	
Prosthetic graft	44 (24%)	6 (35%)	

The primary patency rates at 1 year were 92% in open repair compared with 81% in endovascular repair (*P* = .10). The standard error in endovascular repair exceeded 10% after 12 months, and therefore no long-term comparison could be made.

Table 2. Thirty-day post-operative complications.

	Men **n (%)**	**Women** **n (%)**	***P*-value**
Patients	185 (92%)	17 (8%)	
No complication	136 (74%)	11 (65%)	.43
Death	0 (0%)	0 (0%)	
Wound infection	11 (6%)	1 (6%)	.99
Wound infection deep	4 (2%)	0 (0%)	.54
Bleeding	10 (5%)	2 (12%)	.29
Occlusion	5 (3%)	1 (6%)	.46
Fasciotomy	5 (3%)	1 (6%)	.46
Amputation	1 (0.5%)	0 (0%)	.76
Others	25 (14%)	3 (18%)	.64

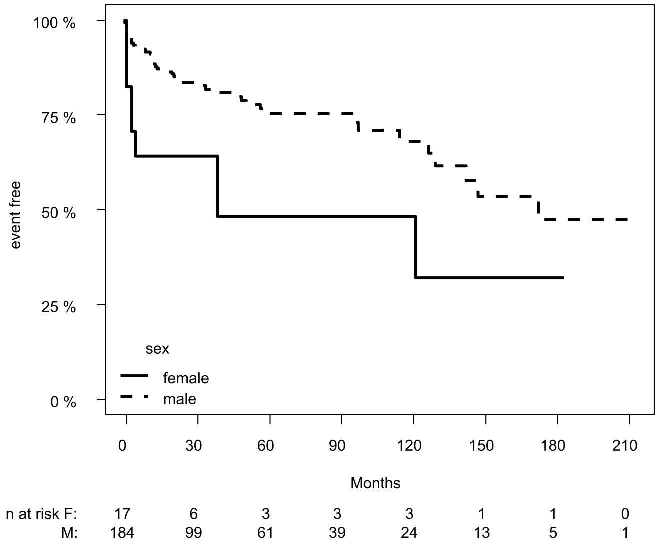


Figure 1. Kaplan-Meier life table analysis of primary patency after repair of popliteal artery aneurysm in men and women (log-rank, *P* = .007).

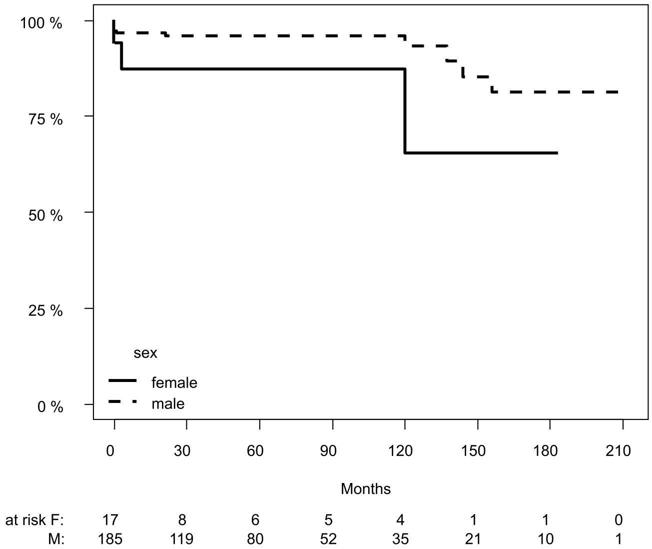


Figure 2. Kaplan-Meier life table analysis of limb salvage after repair of popliteal artery aneurysm in men and women (log-rank, *P* = .07).

The results of Cox regression analysis is shown in Table 3. In univariate analysis, the factors significantly associated with primary patency were: gender, type of graft material and operation technique. When these factors were entered in a multivariate regression model, only gender remained significant. All other factors (including symptoms) were not associated with primary patency. Thus, when correcting for potential confounders with multivariable regression analysis, gender was independently associated with primary patency: HR 2.98 (95%-CI 1.39-6.42), *P* = .005.

DISCUSSION

To our knowledge, this is the first study comparing the initial and long-term outcome between men and women after PAA repair. No significant differences in 30-day mortality and morbidity rates were observed between men and women. Women have significantly lower primary patency rates compared to men. Notably, patency rate drops remarkably at the first year post-intervention in women. When correcting for potential confounders with multivariable regression analysis, gender was independently associated with primary patency.

As in other muscular arteries, the diameter of the popliteal artery increases with age, being affected by age and body size, and is larger in men than in women. With aging, the popliteal artery also suffers from a decreased distensibility, which is more pronounced in men than in women. This distensibility is due to an inflammatory condition in the popliteal

Table 3. Univariate and multivariate analysis.

	Univariable cox regression analysis		Multivariable cox regression analysis	
Characteristic	**Hazard ratio (95%-confidence interval)**	***P*-value**	**Hazard ratio (95%-confidence interval)**	***P*-value**
Gender	2.75 (1.28-5.88)	.009	2.98 (1.39-6.42)	.005
Age	1.01 (0.98-1.04)	.55		
Operation technique	1.51 (0.99-2.28)	.05	1.45 (0.95-2.22)	.09
Diameter	1.01 (0.98-1.04)	.54		
Graft material	1.94 (1.09-3.47)	.03	1.77 (0.98-3.23)	.06
Runoff	1.02 (0.77-1.34)	.91		
Symptoms	0.92 (0.49-1.74)	.81		
Abdominal aortic aneurysm	0.94 (0.54-1.64)	.82		
Bilateral PAA	1.01 (0.54-1.90)	.98		
Cerebrovascular accident	0.95 (0.43-2.11)	.90		
Coronary heart disease	1.06 (0.60-1.89)	.83		
Diabetes mellitus	1.45 (0.73-2.92)	.29		
Hypertension	1.37 (0.78-2.40)	.28		
Hyperlipidemia	1.01 (0.57-1.78)	.99		
Smoking	1.17 (0.67-2.04)	.59		

artery wall5. The demonstrated higher age in women undergoing PAA repair has also been described for abdominal aortic aneurysm repair[24-26]. A possible explanation for the differences in age between both genders in the development of vascular disease could be the difference in hormones. Estrogen might create an atheroprotective environment in premenopausal women through mechanisms that are not totally understood[27-29]. Therefore women might start developing atherosclerosis at higher ages compared to men. Post menopausal estrogen replacement therapy might hence result in even higher ages for developing atherosclerosis. This hypothesis however was disproved in three large prospective trials, on the effect of replacement of estrogen and progestin or estrogen alone on the development of peripheral arterial disease. These trials actually showed more, rather than less vascular events in the active treatment group[30-32].

Graft patency after PAA repair depends on multiple factors. In literature the number of outflow arteries, type of bypass (venous or prosthetic grafts), surgical approach and severity of symptoms have been identified as factors that influence outcome[9,21,32-36]. Several studies state that an asymptomatic PAA, with good runoff, operated via the posterior approach with a venous graft should produce the best long-term outcome. In the current study univariate analysis was used to determine factors that were significantly associated with primary patency: gender, type of graft material and operation technique. When these factors were used in a multivariate regression model, only gender remained significant. All other factors (including symptoms) were not associated with primary patency.

One of the limitations of the present study is the marked difference in number of treated women and men. This difference is to be expected according to literature, since the incidence of PAA is much lower in women compared to men[21,32]. Despite of the small number of women in this series, gender appeared to be an independent factor in uni- and multivariate analysis. A randomized controlled trail comparing the outcome of men and women would further strengthen the independency of the value of gender.
Ravn et al.[38] reported 571 patients with PAA of which 5.8% were women. They found similar patient characteristics between men and women, except that women were more likely to have surgery for symptomatic disease. Current study reports the same tendency although it is not significant in this study.
We did not found a significant difference in complications between men and women, especially no differences in wound infections . In literature women might have more wound complications after infrageniculate bypass surgery[10,11,16].
The treatment of asymptomatic PAAs is still controversial. Although there is no level I evidence, aneurysms > 2 centimeters are an operation indication in asymptomatic PAAs[39-42]. Based on the current study, it may be prudent to exclude asymptomatic PAAs in women at a larger diameter than in men, because women have more complications during follow-up.
Because women have lower primary patency rates after PAA repair compared to men, their follow-up protocol should probably be more intensive in order to detect significant restenosis prior to re-occlusion occurs. Because most of the re-obstructions occur in the first year post-intervention duplex ultrasound is recommended at 6 and 12 months post-intervention. Furthermore, the use of venous grafts should be the preferred treatment, especially in women. It has been shown in former studies that the posterior approach is the surgical method of preference in PAA repair, if the popliteal aneurysm does not extend to the proximal boundary of the P1 segment of the popliteal artery[19,32]. Besides comorbidity, aneurysm diameter, number of outflow vessels, the amount of mural thrombus and type of operation (posterior or medial approach), gender might also be taken into account before deciding to operate or not in patients with PAA.

CONCLUSION

No significant differences between men and women were observed in 30-day mortality and morbidity rates after PAA repair. In the long run, women are associated with lower primary patency rates, and a trend towards lower limb salvage rates compared to men.

REFERENCES

1. Hansen F, Mangell P, Sonesson B, et al. Diameter and compliance in the human coomon carotid artery—variations with age and sex. Ultrasound Med Biol 1995;21:1-9.
2. Williams MA, Nicolaides AN. Predicting the normal dimensions of the internal and external carotid arteries from the diameter of the common carotid. Eur J Vasc Surg 1987;1:91-6.
3. Scheel P. Ruge C, Schoning M. Flow velocity and flow volume measurements in the extracranial carotid and vertebral arteries in healthy adults: reference data and the effects of age. Ultrasound Meed Biol 2000;26:1261-6.
4. Pedersen OM, Aslaksen A, Vik-MoH. Ultrasound measurements of the luminal diamter of the abdominal aorta and iliac arteries in patients without vascular disease. J Vasc Surg 1993;17:596-601.
5. Debasso R, Astrand H, Bjarnegård N, et al. The popliteal artery, an unusual muscular artery with wall properties similar to the aorta: implications for susceptibility to aneurysm formation? J Vasc Surg 2004;39:836-42.
6. Wolf YG, Kobzantsev Z, Zelmanovich L. Size of normal and aneurysmal popliteal arteries: A duplex ultrasound study. J Vasc Surg 2006;43:488-92.
7. Duffy ST, Colgan MP, Sultan S, et al. Popliteal aneurysms: a 10-year experience. Eur J Vasc Endovasc Surg 1998;16:218-22.
8. Hirsch AT, Haskal ZJ, Hertzer NR, et al. ACC/AHA 2005 Practice Guidelines for the management of patients with peripheral arterial disease (lower extremity, renal, mesenteric, and abdominal aortic): a collaborative report from the American Association for Vascular Surgery/Society for Vascular Surgery, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, Society of Interventional Radiology, and the ACC/AHA Task Force on Practice Guidelines (Writing Committee to Develop Guidelines for the Management of Patients With Peripheral Arterial Disease): endorsed by the American Association of Cardiovascular and Pulmonary Rehabilitation; National Heart, Lung, and Blood Institute; Society for Vascular Nursing; TransAtlantic Inter-Society Consensus; and Vascular Disease Foundation. Circulation 2006;113:e463-e654.
9. Pulli R, Dorigo W, Troisi N, et al. Surgical management of popliteal artery aneurysms: which factors affect outcomes? J Vasc Surg 2006;43:481-7.
10. Belkin M, Conte MS, Donaldson MC, et al. The impact of gender on the results of arterial bypass with in situ greater saphenous vein. Am J Surg 1995;170:97-102.
11. Frangos SG, Karimi S, Kerstein MD, et al. Gender does not impact infrainguinal vein bypass graft outcome. Surgery 2000;127:679-86.
12. Harris EJ, Jr, Taylor LM, Jr., Moneta GL, et al. Outcome of infrainguinal arterial reconstruction in women. J Vasc Surg 1993;18:627-36.
13. Kalman PG, Johnston KW. Predictors of long-term patient survival after in situ vein leg bypass. J Vasc Surg 1997;25:899-904.
14. Magnant JG, Cronenwett JL, Walsh DB, et al. Surgical treatment of infrainguinal arterial occlusive disease in women. J Vasc Surg 1993;17:67-76.
15. Mays BW, Towne JB, Fitzpatrick CM, et al. Women have increased risk of perioperative myocardial infarction and higher long-term mortality rates after lower extremity arterial bypass grafting. J Vasc Surg 1999;29:807-13.
16. Roddy SP, Darling RC, 3rd, Maharaj D, et al. Gender-related differences in outcome: an analysis of 5880 infrainguinal arterial reconstructions. J Vasc Surg 2003;37:399-402.
17. Voser T, Oertli D, Gurke L, et al. [Is infra-inguinal venous bypass less successful in the woman?]. Schweiz Med Wochenschr 1998;128:900-5. German.
18. Henke PK, Proctor MC, Zajkowski PJ, et al. Tissue loss, early primary graft occlusion, female gender, and a prohibitive failure rate of secondary infrainguinal arterial reconstruction. J Vasc Surg 2002;35:902-9.
19. Beseth BD, Moore WS. The posterior approach for repair of popliteal artery aneurysms. J Vasc Surg 2006;43:940-5.
20. Graham L. Femoral and popliteal aneurysms. In: Rutherford RB, editor. Vascular surgery. 5th ed. Philadelphia, PA: Saunders; 2000. p. 1345-55.
21. Mahmood A, Salaman R, Sintler M, et al. Surgery of popliteal artery aneurysms: a 12 year experience. J Vasc Surg 2003;37:586-93.
22. Edwards WS. Exclusion and saphenous vein bypass of popliteal aneurysms. Surg Gynecol Obstet 1969;128:829-30.
23. Rutherford RB, Baker JD, Ernst C, et al. Recommended standards for reports dealing with lower extremity ischemia: Revised version. J Vasc Surg 1997;26:517-38.
24. Dillavou ED, Muluk SC, Makaroun MS. A decade of change in abdominal aortic aneurysm repair in the United States: Have we improved outcomes equally between men and women? J Vasc Surg 2006;43:230-8.
25. McPhee JT, Hill JS, Eslami MH. The impact of gender on presentation, therapy, and mortality of abdominal aortic aneurysm in the United States, 2001-2004. J Vasc Surg 2007;45:891-9.
26. Mofidi R, Goldie VJ, Kelman J, et al. Influence of sex on expansion rate of abdominal aortic aneurysms. Br J Surg 2006; 93: 85.

27. Ridker PM, Hennekens CH, Buring JE, et al. C-reactive protein and other markers of inflammation in the prediction of cardiovascular disease in women. N Engl J Med 2000;342:836-43.
28. Stefanska A, Sypniewskay G, Senterkiewicz L. Inflammatory markersand cardiovascular risk in healthy polish women across the menopausal transition. Clin Chem 2005;51:1893-5.
29. Vural P, Canbaz M, Akgul C. Effects of menopause and postmenopausal tibolone treatment on plasma TNFalpha, IL-4, IL-10, IL-12 cytokine pattern and some bone turnover markers. Pharmacol Res 2006;53:367-71.
30. Anderson GL, Limacher M, Assaf AR, et al. Effects of conjugated equine estrogen in postmenopausal women with hysterectomy: the women's health initiative randomized controlled trial. JAMA 2004;291:1701-12.
31. Hulley S, Grady D, Bush T, et al. Randomized trial of estrogen plus progestin for secondary prevention of coronary heart disease in postmenopausal women. Heart and Estrogen/progestin Replacement Study (HERS) Research Group. JAMA 1998;280:605-13.
32. Rossouw JE, Anderson GL, Pretice RL, et al. Risks and benefits of esotrogen plus progestin in healthy postmenopausal women: principal results from the women's health initiative randomized controlled trial. JAMA 2002;288:321-33.
33. Kropman RH, van Santvoort HC, Teijink J, et al. The medial versus the posterior approach in the repair of popliteal artery aneurysms: a multicenter case-matched study. J Vasc Surg 2007;46:24-30.
34. Martelli E, Ippoliti A, Ventoruzzo G, et al. Popliteal artery aneurysms. Factors associated with thromboembolism and graft failure. Int Angiol 2004;23:54-65.
35. Pulli R, Dorigo W, Castelli P, et al. A multicentric experience with open surgical repair and endovascular exclusion of popliteal artery aneurysms. Eur J Vasc Endovasc Surg 2013;45:357-63.
36. Ravn H, Wanhainen A, Bjorck M. Surgical technique and long-term results after popliteal artery aneurysm repair: Results from 717 legs. J Vasc Surg 2007;46:236-43.
37. Shortell KS, DeWeese JA, Ouriel K et al. Popliteal artery aneurysms: A 25-year surgical experience. J Vasc Surg 1991;14:771-9.
38. Ravn H, Bergqvist D, Björck M. Nationwide study of the outcome of popliteal artery aneurysms treated surgically. Br J Surg 2007;94:970-77.
39. Cross JE, Galland RB, Hingorani A, et al. Nonoperative versus surgical management of small (less than 3 cm), asymptomatic popliteal artery aneurysms. J Vasc Surg 2011:53:1145-8.
40. Forbes TL, Ricco JB. Editors commentary. J Vasc Surg 2011:53;1145-48.
41. Cross JE, Galland RB. Part one: For the motion asymptomatic popliteal artery aneurysms (less than 3 cm) should be treated conservatively. Eur J Vasc Endovasc Surg 2011;41:448-9.
42. Hingorani A, Ascher E. Part two: Against the motion asymptomatic popliteal artery aneurysms (less than 3 cm) should be repaired. Eur J Vasc Endovasc Surg 2011;41:445-9.

CHAPTER 9

Summary, General discussion and Future perspectives

SUMMARY AND GENERAL DISCUSSION

Popliteal artery aneurysms (PAAs) are the most common peripheral aneurysms. Patients with unrecognized aneurysms may present with acute limb ischemia and are at a considerable threat for limb loss due to thromboembolic complications. Physical examination remains difficult, and once the diagnosis is suspected, it must be confirmed by duplex ultrasonography, computed tomography angiography (CTA), or magnetic resonance arteriography (MRA). Awareness of the terminal branching pattern of the popliteal artery before intervention enhances the planning for lower limb surgery and preoperative planning of below-the-knee bypasses and should reduce the incidence of serious, unexpected arterial injury during vascular surgery, percutaneous endovascular procedures, and even orthopedic surgery (**Chapter 2**).

Abdominal aortic aneurysms (AAAs) frequently coincide with PAAs in almost 40% of patients with a PAA, and 5% to 10% of patients with an AAAs are also affected with a PAA. In 40% of patients with a PAA, both sides are affected. For this reason, patients with PAAs should be screened to see if there is a contralateral aneurysm and if an aortic aneurysm is also present (**Chapter 4**). The frequency and nature of the symptoms of AAAs and PAAs differ. Approximately 60% of patients with a PAA will be symptomatic at the time of diagnosis, most frequently with thromboembolic complications, and less than 2% of patients present with a ruptured PAA. In contrast, patients with an AAA are mostly asymptomatic at the time of diagnosis, and when symptomatic, rupture is the most frequently observed symptom.

This might be explained by important differences in the pathophysiology of aneurysm formation between these locations. PAA walls show more signs of previous microscopic hemorrhages compared with walls of AAAs. In addition, inflammation in PAAs is mainly located in the intima, whereas its focus is in the adventitia in AAAs. This might explain the difference in symptoms between the two types of aneurysm, because the intimal infiltrate in PAA is adjacent to the intraluminal thrombus and could potentially cause processes such as thromboembolism and thrombosis. This is reported in an immunohistochemical study in **Chapter 3**.

Despite earlier published scientific research, a few important questions still need to be addressed regarding repair of PAAs. The main controversies or ambiguities in PAA repair will be discussed and recommendations will be given. These issues are related to (1) endovascular treatment as an alternative to open surgery, (2) the type of surgical approach, (3) the strategy for acute leg ischemia due to a thrombosed PAA, (4) diameter indication for treatment, and (5) gender-related differences in outcome.

Open surgical versus endovascular repair

The first endovascular treatment with a stent graft was offered to a patient with a PAA in 1994[1]. Stent grafts can be inserted without the need for dissection of the diseased segment. Endovascular repair of PAAs has other advantages compared with open surgery. There is a decreased need for anesthesia and a reduced need for blood transfusions. Moreover, it will lead to quicker recovery, a shorter hospital stay, and causes fewer wound infections.

Chapter 4 provided an overview of the literature regarding open surgical repair and endovascular repair of PAAs. To prefer endovascular treatment over open surgery, the patency rate of endovascular stent graft placement in the popliteal artery should not be inferior to that obtained by open repair. Recently, some relevant studies about symptomatic and asymptomatic PAA repair with endovascular stent graft placement were reported[2-5]. With all the literature in mind, it is not clear if endovascular stent graft placement of PAA will produce the same patency rates in the long-term in all patients with PAAs. This remains unclear, especially for young patients, acute symptomatic patients, and patients with poor outflow. Furthermore, little is known about long-term stent-related complications such as the occurrence of endoleak, stent infolding, and stent fracture.

It therefore seems reasonable that at this moment, stent grafting should be performed only in trials. However, the primary treatment in patients with severe cardiopulmonary comorbidity should be by endovascular repair.

Type of surgical approach

Several surgical approaches and techniques for PAA repair have been proposed. The medial approach, described by Edwards et al.[6], is the most commonly performed surgical technique for PAA repair. It consists of a combined supragenicular and infragenicular incision at the medial side of the leg. This technique does not exclude side branches with their origin in the PAA, which can be responsible for retrograde perfusion in the ligated aneurysm sac and eventually lead to aneurysm enlargement and worse, rupture[7-12]. An alternative technique is the posterior approach. This approach includes a lazy S-shaped incision in the posterior aspect of the knee, with dissection between the medial and lateral heads of the gastrocnemius muscle, taking care not to injure the tibial nerves and popliteal vein.

Chapter 5 describes the initial and mid-term outcomes of both the medial and posterior approach in the treatment of PAAs. It may be concluded from this head-to-head comparison that in the long-term, no significant differences in patency rates between the posterior and medial approach could be reported. Considering the risk of persistent PAA growth (up to 22%) after distal and proximal ligation, the posterior approach is the preferred surgical method of PAA repair in the end. Furthermore, it can be concluded that irrespective of the approach, venous reconstructions resulted in significantly higher patency rates compared with prosthetic reconstructions at the 3-year follow-up.

Strategy of acute leg ischemia

The consequences of acute thrombosis of a PAA are threatening to both life and limb. Despite emergency interventions, an important risk of major amputation exists because of thromboembolization. Historically, surgical thrombectomy of the crural arteries and additional femoropopliteal or femorocrural bypass grafting was the treatment of choice. In the 1980s, however, intra-arterial catheter-directed thrombolysis succeeded in improving arterial runoff before surgical revascularization to increase patency rates of peripheral bypass surgery[13]. In **Chapter 6**, a systematic review was performed to summarize the outcomes of acute thrombosed PAAs treated with thrombolysis or thrombectomy from inflow and outflow arteries and the PAA itself, followed by a bypass. This review showed that preoperative and intraoperative thrombolysis did not result in a significant reduction in amputations compared with thrombectomy. The 1-year primary patency rates of surgical interventions after thrombolysis were significantly better compared with surgery alone, and primary patency rates at 3 and 5 years were not significantly different. Furthermore, no distinction could be made between the groups concerning the secondary patency rate and the limb salvage rate. In acute ischemic PAAs, thrombolysis has been advised for the treatment of acute ischemia Rutherford class I to IIa[14], if no contraindications are present. When sensory loss or motor deficit exists (class IIb to III), there is no time for thrombolysis, and surgery must be performed immediately.

Diameter indication for treatment

Patients with symptomatic PAAs, mechanical complaints by compression of the PAA, acute ischemia by thrombosis of the PAA, or chronic ischemia by partial thrombosis of the PAA, should undergo intervention because the risk of limb loss due to thromboembolic complications increases with the onset of symptomatic disease[15-18]. The diameter in those symptomatic aneurysms does not influence this decision. However, no consensus has been reached when patients are asymptomatic. Many authors recommend elective surgical intervention in patients with asymptomatic aneurysms larger than 20 mm with mural thrombus because of the increased risk of thromboembolic complications[19-25]. Others suggest a diameter of 30 mm as the most suitable cutoff point[26-28]. There is no level I evidence regarding this topic. It is not entirely clear which characteristics of an asymptomatic PAA will lead to acute thrombosis. Diameter alone might not be the only predicting factor.

Chapter 7 describes a prospective study to improve intervention criteria for asymptomatic PAAs between 20 and 30 mm. In this study, all patients with asymptomatic aneurysms underwent a computed tomography angiography to perform measurements of the popliteal artery, including the PAA at 0° extension and 90° flexion of the knee in a specially prepared brace. Knee-bending in patients with PAAs led to a significant reduction in lumen area proximal and distal of the PAA. Moreover, it produced a significant change in the degree of angulation distal and proximal of the aneurysm. These two characteristics may be a cause for increased thromboemboli. Flexion of the knee with a PAA $\geq$ 30 mm results in a significant lumen reduction compared with a PAA < 30 mm. Another important finding in this study are the huge variations in lumen area reduction and angulation changes during flexion and extension within the group of small aneurysms as well as within the group with large aneurysms. This measured variability within the groups can explain why some small PAAs will still become symptomatic and why some large PAAs will not become symptomatic. Performing a flexion and extension CTA scan, as described above, should be implemented when deciding whether a patient with an asymptomatic PAA is eligible for intervention.

Gender-related differences in outcome

Arterial vascular disease is a significant problem in both men and women. In general, women have smaller arteries than men. Combined results of studies focusing on the outcome of bypass surgery in the lower extremity did not show significant differences in primary patency rates, percentage of limb salvage, and survival between men and women[29-37]. No studies have been performed to specifically investigate the effect of gender on the outcome of PAA treatment. This was the main focus of the study described in **Chapter 8**, which compared initial and long-term outcome between men and women after PAA repair. Despite the small number of women in this series, gender was independently associated with primary patency in univariate and multivariate analysis. There were no significant differences in 30-day mortality and morbidity rates between men and women after PAA repair. In the long-term, women have significantly lower primary patency rates and a trend toward lower rates of limb salvage. On the basis of these results, it may be prudent to exclude asymptomatic PAAs in women at a larger diameter than in men because women have more PAA-related complications during follow-up. Furthermore, the follow-up protocol for women should be intensified compared with men because women have higher risks for restenosis before reocclusion.

FUTURE PERSPECTIVES

Screening for PAAs

All patients with an AAA and patients with other peripheral aneurysms should be screened for PAAs. Furthermore, when the diagnosis of a PAA is suspected, it must be confirmed. The least invasive diagnostic tool is duplex ultrasound, and it is therefore the preferred screening device, although CTA and MRA are good alternatives.

Prevention of PAAs becoming symptomatic

Future research should especially focus on predicting which PAAs will become symptomatic. Besides diameter, decrease of lumen area and increase of the degree of angulation after flexion of the knee might not be the only predictors of becoming symptomatic. A flexion and extension CTA scan should be made to detect the lumen reduction and degree of angulation after bending the knee in patients with an asymptomatic PAA diameter between 20 and 30 mm. Because no level I evidence is available to aid in the decision to operate on asymptomatic PAAs at 20 or 30 mm, more effort should be on developing diagnostic tools to predict the change on becoming symptomatic. For instance, correlation of pathology of a PAA wall with preoperative single photon-emission computed tomography (SPECT) imaging can be helpful to predict the vulnerability of the aneurysm and may thus differentiate between stable and instable PAAs. Further, correlation with SPECT scan and flexion and extension CTA scan will lead to more insight of vulnerability of the PAA. New studies that investigate the correlation between the lumen area and the degree of angulation after knee bending, with clinical follow-up, are also needed.

Optimization of treatment

At this moment, open surgical repair of the PAA is the gold standard. Figure 1 shows a proposal of treatment of patients with a PAA, based on findings described in this thesis. First, symptoms have to be determined. In the event of a symptomatic aneurysm, acute or chronic complaints must be determined. In case of an asymptomatic PAA < 20 mm, follow-up is recommended, whereas for an asymptomatic PAA > 30 mm, an intervention is advised. In case of an asymptomatic PAA between 20 and 30 mm, a flexion and extension CTA scan should be made and further risk stratification for patency of the bypass performed. When there is lumen reduction and angulation with the flexion-extension CTA scan, an intervention should be considered, provided that outflow is sufficient, an acceptable vein is present, and the patient is male. The amount of thrombus in the aneurysm is also a consideration. Second, comorbidities should be analyzed. If the patient has extensive comorbidities, endovascular repair should be pondered. Third, the anatomy of the PAA must be examined.

Endovascular repair is promising, but data from the total PAA population and solid long-term follow-up are missing. A randomized controlled trial comparing open repair versus endovascular repair with long-term follow-up is required to determine the optimal PAA management.

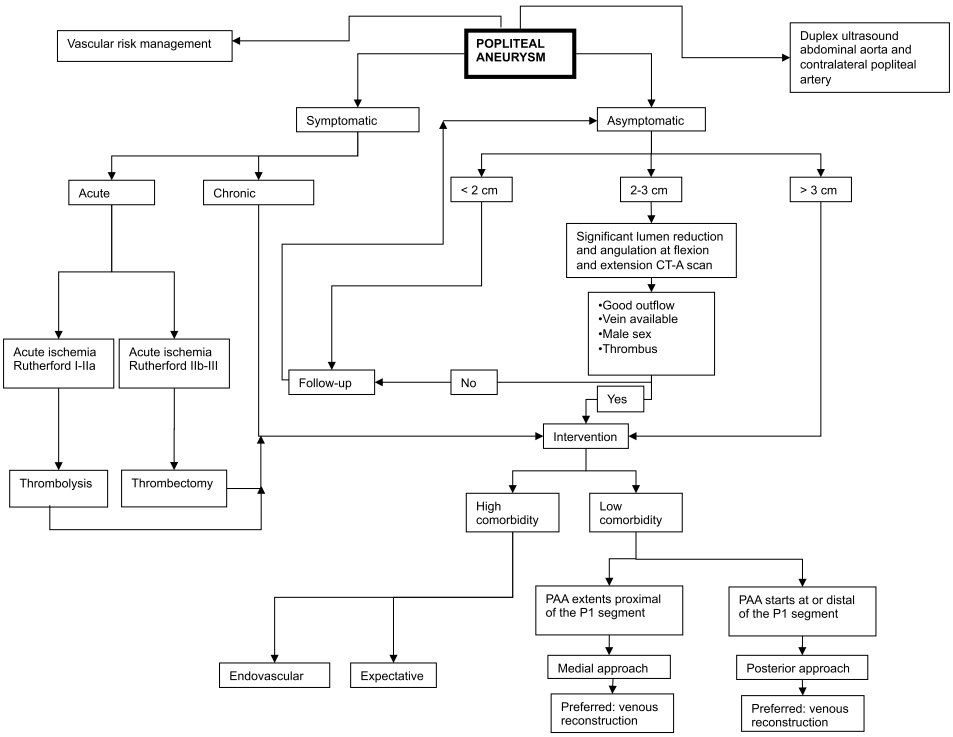


Figure 1. Proposed treatment of PAA.

Additionally, the selection of specific subgroups of patients who would benefit from endovascular repair, for instance, patients with extensive comorbidities or elderly patients with asymptomatic aneurysms and good runoff, will further clarify whether endovascular stent graft placement will provide comparable or even better results than open repair. Further refinement of stent graft design, such as increased flexibility and less thrombogenicity, will probably produce even better results, even in the long-term.
A preintervention flexion and extension CTA scan might be useful if placement of an endovascular stent graft is planned. The choice for an endovascular stent graft should probably be reconsidered in the presence of a significant lumen reduction or a significant angulation in flexion because of the increased risk of stent fracture or stent occlusion. Furthermore, a flexion and extension CTA scan can be used to determine the most severe angulations of the popliteal artery during flexion. Landing the proximal or distal border of a stent, or a bypass, just in this segment of the popliteal artery must be avoided.

Treatment for acute ischemia due to thrombosed PAAs

When failing to predict whether an aneurysm will become symptomatic, new thrombolysis techniques, for instance, ultrasound accelerated thrombolysis (EKOS), might improve current thrombolysis techniques[38,39]. If the lysis from the thrombus needs less time, EKOS might be an indication for acute ischemia Rutherford IIb as well, if the patient is checked frequently for deterioration of the leg.

REFERENCES

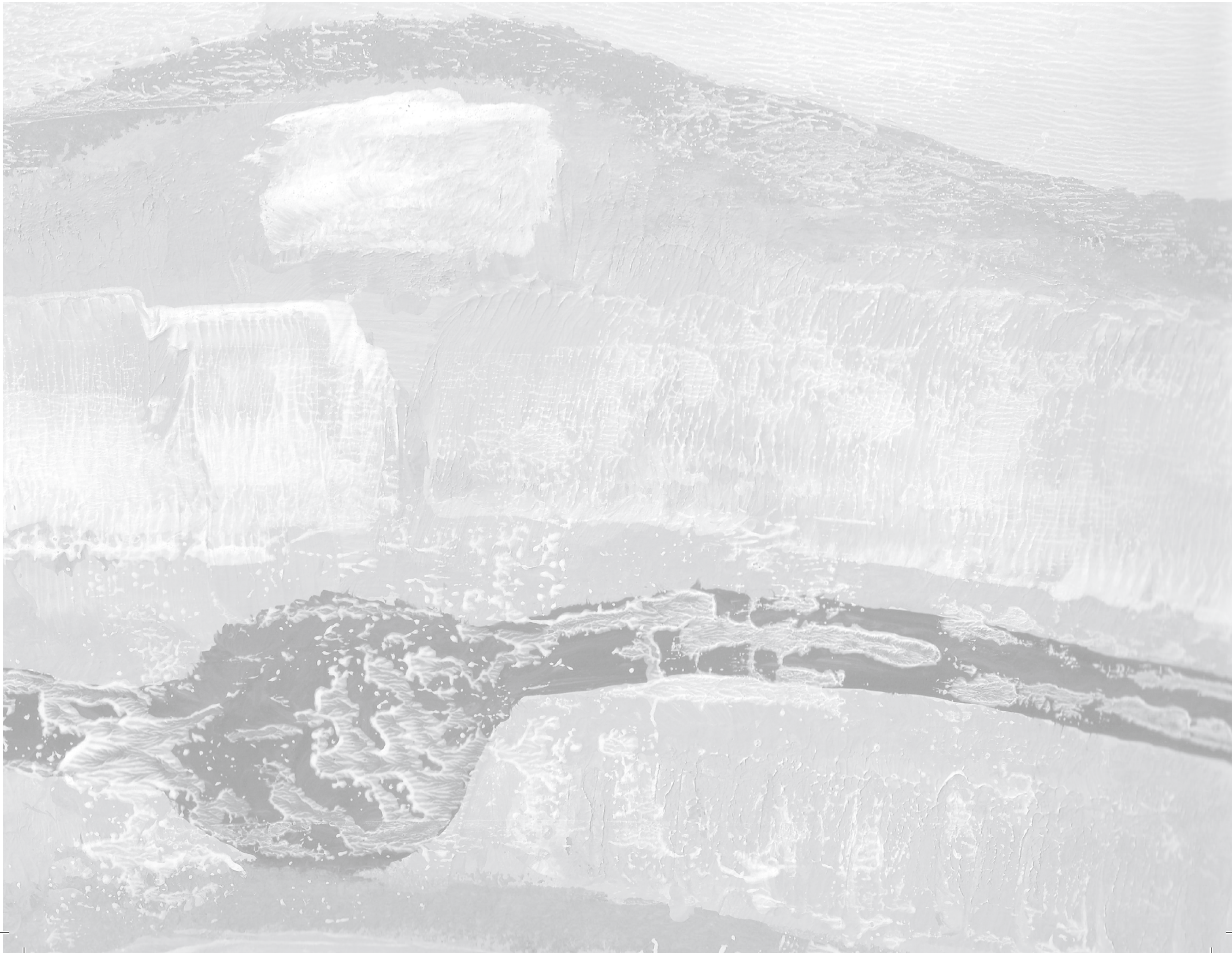
1. Marin ML, Veith FJ, Panetta TF et al. Transfemoral endoluminal stented graft repair of popliteal artery aneurysm. J Vasc Surg 1994;19:754-7.
2. Pulli R, Dorigo W, Castelli P, Dorrucci V, Ferilli F, De Blasis G et al. A Multicentric experience with open surgical repair and endovascular exclusion of popliteal artery aneurysms. Eur J Vasc Endovasc Surg 2013 Feb 4. doi: 10.1016/j.ejvs.2013.01.012.
3. Trinidad-Hernandez M, Ricotta JJ 2nd, Gloviczki P, Kalra M, Oderich GS, Duncan AA et al. Results of elective and emergency endovascular repairs of popliteal artery aneurysms. J Vasc Surg 2013 Jan 31. doi: 10.1016/j.jvs.2012.10.112.
4. Galinanes EI, Dombrovsky VY, Graham AM, Vogel TR. Endovascular versus Open Repair of Popliteal Artery Aneurysms: Outcomes in the US Medicare Population. Vasc Endovascular Surg 2013 Feb 6.
5 Stone PA, Jagannath P, Thompson SN, Campbell JE, Mousa AY, Knackstedt K et al. Evolving treatment of popliteal artery aneurysms. J Vasc Surg 2013 Jan 30. doi: 10.1016/j.jvs.2012.10.122
6. Edwards WS. Exclusion and saphenous vein bypass of popliteal aneurysms. Surg Gynecol Obstet 1969;128:829-30.
7. Ebaugh JL, Morasch MD, Matsumura JS, Eskandari MK, Meadows WS, Pearce WH. Fate of excluded popliteal artery aneurysms. J Vasc Surg 2003;37:954-9.
8. Jones WT 3rd, Hagino RT, Chiou AC, Decaprio JD, Franklin KS, Kashyap VS. Graft patency is not only clinical predictor of success after exclusion and bypass of popliteal artery aneurysms. J Vasc Surg 2003;37:392-8.
9. Kirkpatrick UJ, McWilliams RG, Martin J, Brennan JA, Gilling-Smith GL, Harris PL. Late complications after ligation and bypass for popliteal aneurym. Br J Surg 2004;91:174-77.
10. Mehta M, Champagne B, Darling RC 3rd, Roddy SP, Kreienberg PB, Ozsvath KJ, et al. Outcome of popliteal artery aneurysms after exclusion and bypass: Significance of residual patent branches mimicking type II endoleaks. J Vasc Surg 2004;40:886-90.
11. Van Santvoort HC, de Vries JPPM, Van de Mortel R, Wille J, Van de Pavoordt EDWM. Rupture of a popliteal artery aneurysm 10 years after surgical repair. Vascular 2006;14:227-30.
12. Wakassa TB, Matsunaga P, Da Silva ES, Pinto CA, Kauffman P, Aun R, et al. Follow-up of the aneurismal sac after exclusion and bypass of popliteal artery aneurysms. Clinics 2006;61:107-12.
13. Schwarz W, Berkowitz H, Taormina V, Gatti J. The preoperative use of intraarteial thrombolysis for a thrombosed popliteal artey aneurysm. J Cardiovasc Surg 1984;25:465-8.
14. Rutherford RB, Baker JD, Ernst C, Johnston KW, Porter JM, Ahn S, et al. Recommended standards for reports dealing with lower extremity ischemia: Revised version. J Vasc Surg 1997;26:517-38.
15. Carpenter JP, Barker CF, Roberts B, Berkowitz HD, Lusk EJ, Perloff LJ. Popliteal artery aneurysms: current management and outcome. J Vasc Surg 1994;19:65-72.
16. Gouny P, Bertrand P, Duedal V, Cheynel-Hocquet C, Lancelin C, Escourolle F, Nussaumeand O, Vayssairat M. Limb salvage and popliteal aneurysms: advantages of preventive surgery. Eur J Vasc Endovasc Surg 2000;19:496-500.
17. Roggo A, Brunner U, Ottinger LW, Largiader F. The continuing challenge of aneurysms of the popliteal artery. Surg Gynecol Obstet 1993;177:565-72.
18. Shortell CK, DeWeese JA, Ouriel K, Green RM. Popliteal artery aneurysms: a 25-year surgical experience. J Vasc Surg 1991;14:771-6.
19. Dawson I, Sie R, van Baalen JM, van Bockel JH. Asymptomatic popliteal aneurysm: elective operation versus conservative follow-up. Br J Surg 1994;81:1504-7.
20. Lowell RC, Gloviczki P, Hallett JW, Jr., Naessens JM, Maus TP, Cherry KJ, Jr., Bower TC, Pairolero PC. Popliteal artery aneurysms: the risk of nonoperative management. Ann Vasc Surg 1994;8:14-23.
21. Aulivola B, Hamdan AD, Hile CN, Sheahan MG, Skillman JJ, Campbell DR, Scovell SD, LoGerfo FW, Pomposelli FB, Jr. Popliteal artery aneurysms: a comparison of outcomes in elective versus emergent repair. J Vasc Surg 2004;39:1171-7.
22. Davidovic LB, Lotina SI, Kostic DM, Cinara IS, Cvetkovic SD, Markovic DM, Vojnovic BR. Popliteal artery aneurysms. World J Surg 1998;22:812-7.
23. Halliday AW, Taylor PR, Wolfe JH, Mansfield AO. The management of popliteal aneurysm: the importance of early surgical repair. Ann R Coll Surg Engl 1991;73:253-7.
24. Ramesh S, Michaels JA, Galland RB. Popliteal aneurysm: morphology and management. Br J Surg 1993;80:1531-3.
25. Hingorani A, Ascher E. Part two: Against the motion asymptomatic popliteal artery aneurysms (less than 3 cm) should be repaired. Eur J Vasc Endovasc Surg 2011 Apr;41(4):445-9.
26. Galland RB, Magee TR. Management of popliteal aneurysm. Br J Surg 2002;89:1382-5.
27. Ramesh S, Michaels JA, Galland RB. Popliteal aneurysm: morphology and management. Br J Surg 1993;80:1531-3.

28. Cross JE, Galland RB. Part one: For the motion asymptomatic popliteal artery aneurysms (less than 3 cm) should be treated conservatively. Eur J Vasc Endovasc Surg 2011 Apr;41(4):448-9.
29. Belkin M, Conte MS, Donaldson MC, Mannick JA, Whittemore AD. The impact of gender on the results of arterial bypass with in situ greater saphenous vein. Am J Surg 1995;170:97-102.
30. Frangos SG, Karimi S, Kerstein MD, Harpavat M, Sumpio B, Roberts AB, et al. Gender does not impact infrainguinal vein bypass graft outcome. Surgery 2000;127:679-86.
31. Harris EJ, Jr, Taylor LM, Jr., Moneta GL, Porter JM. Outcome of infrainguinal arterial reconstruction in women. J Vasc Surg 1993;18:627-36.
32. Kalman PG, Johnston KW. Predictors of long-term patient survival after in situ vein leg bypass. J Vasc Surg 1997;25:899-904.
33. Magnant JG, Cronenwett JL, Walsh DB, Schneider JR, Besso SR, Zwolak RM. Surgical treatment of infrainguinal arterial occlusive disease in women. J Vasc Surg 1993;17:67-78.
34. Mays BW, Towne JB, Fitzpatrick CM, Smart SC, Cambria RA, Seabrook GR, et al. Women have increased risk of perioperative myocardial infarction and higher long-term mortality rates after lower extremity arterial bypass grafting. J Vasc Surg 1999;29:807-13.
35. Roddy SP, Darling RC, 3rd, Maharaj D, Chang BB, Paty PS, Kreienberg PB, et al. Gender-related differences in outcome: an analysis of 5880 infrainguinal arterial reconstructions. J Vasc Surg 2003;37:399-402.
36. Voser T, Oertli D, Gurke L, Stirnemann P. [Is infra-inguinal venous bypass less successful in the woman?]. Schweiz Med Wochenschr 1998;128:900-5.
37. Henke PK, Proctor MC, Zajkowski PJ, Bedi A, Upchurch GR, Jr., Wakefield TW, et al. Tissue loss, early primary graft occlusion, female gender, and a prohibitive failure rate of secondary infrainguinal arterial reconstruction. J Vasc Surg 2002;35:902-9.
38. Doomernik DE, Schrijver AM, Zeebregts CJ, de Vries JP, Reijnen MM. Advancements in catheter-directed ultrasound-accelerated thrombolysis. J Endovasc Ther 2011 Jun;18(3):418-34.
39. Schrijver A, Vos J, Hoksbergen AW, Fioole B, Fritschy W, Hulsebos R,et al. Ultrasound-accelerated thrombolysis for lower extremity ischemia: multicenter experience and literature review. J Cardiovasc Surg (Torino) 2011 Aug;52(4):467-76.

CHAPTER 10

Samenvatting in het Nederlands

(voor niet-ingewijden)



Een verwijding van de slagader in de knieholte wordt een arteria poplitea aneurysma (APA) genoemd. In de algemene bevolking heeft 0.1% tot 2.8% een verwijding van de knieslagader. Poplitea aneurysma's zijn de meest voorkomende aneurysma's na het aneurysma van de grote lichaamsslagader, de aorta. De aandoening treft vooral mannen boven de 60 jaar, de man:vrouw ratio is 20:1. De meest voorkomende oorzaak voor het krijgen van een APA is atherosclerose (aderverkalking). De belangrijkste risicofactoren voor het ontstaan van atherosclerose zijn: roken, een familiegeschiedenis voor hart- en of vaatziekten, diabetes mellitus, eerdere hart- en of vaatziekten, een verhoogde bloeddruk, en een verhoogd of verkeerd cholesterolspectrum.
Patiënten met een niet herkend aneurysma in de knieholte, kunnen zich presenteren met een acute vaatafsluiting van het aangedane been. Dit kan eventueel resulteren in de noodzaak tot het amputeren van het been. Hoewel lichamelijk onderzoek bij deze aandoening lastig is, kan door middel van duplex ultrasonografie, computed tomografie angiografie (CTA), of magnetic resonance angiografie (MRA) de diagnose vastgesteld worden. Oplettendheid op het vertakkingspatroon van de knieslagader voorafgaand aan een interventie of operatie verkleind het risico op ernstige onverwachte letsels gedurende een vaatchirurgische of dotter procedure en zelfs bij een orthopedische operatie. (**hoofdstuk 2**)
Patiënten met een APA moeten gescreend worden of aan de andere zijde ook geen aneurysma aanwezig is, en of zij geen verwijding van de buikslagader hebben, abdominaal aorta aneurysma genaamd (AAA). Bij patiënten met een APA wordt namelijk in 40% ook een AAA gevonden, en in 5-10% wordt bij een patiënt met een AAA ook een APA vastgesteld. (**hoofdstuk 4**) De frequentie en aard van de symptomen tussen beide soorten aneurysma's zijn verschillend. Bij het stellen van de diagnose is ongeveer 60% van patiënten met een APA symptomatisch, meestel uit dit zich in tromboembolische klachten (loopklachten, mechanische klachten van druk in de knieholte, acute afsluiting van enkele bloedvaatjes in de tenen of acute klachten van afsluiting van het aneurysma), minder dan 2% presenteert zich met een gebarsten APA. Dit in tegenstelling tot patiënten met een AAA, die bij het stellen van de diagnose meestal zonder klachten zijn, en wanneer er klachten zijn, dit meestal een scheur in het AAA is. Een mogelijke verklaring hiervoor zou kunnen liggen in belangrijke verschillen in pathofysiologie van de beide type aneurysma's. Zo worden er bij APA-wanden meer tekenen van bloedingen gevonden in vergelijking met wanden van AAA. Daarnaast, bevindt de ontsteking (oorzaak van atherosclerose) in APA's zich met name in de intima (binnenlaag), waar dit bij AAA's met name in de adventitia (buitenlaag) wordt gevonden. Dit zou een verklaring kunnen zijn voor het verschil in symptomatologie tussen de twee genoemde aneurysmata, omdat de ontsteking van APA's grenzend aan de intraluminale trombus potentieel processen kan initiëren als tromboembolieën (losgeschoten bloedpropjes) en trombose (stolling van bloed). Deze bevindingen worden beschreven in een immunohistochemische studie in **hoofdstuk 3**.
Ondanks alle eerder gepubliceerde wetenschappelijke onderzoeken, blijven er een aantal belangrijke vragen onbeantwoord bij het herstel van APA's. De belangrijkste controversies en onduidelijkheden binnen het herstel van APA's worden bediscussieerd en er worden

aanbevelingen gegeven. Deze vragen zijn gerelateerd aan: (1) endovasculaire behandeling als een alternatief voor open chirurgie, (2) type chirurgische benadering, (3) strategie voor behandeling bij het ontstaan van acute ischemie bij een getromboseerd APA, (4) diameter indicatie voor behandeling, (5) geslacht gerelateerde verschillen in de behandeluitkomsten.

Open chirurgie versus endovasculaire behandeling

In 1994 werd de eerste patiënt met een APA endovasculair behandeld met een stent. Stents kunnen geplaatst worden via een slagaderlijke vaattoegang, zonder de noodzaak van het volledig blootleggen van het aangedane slagader gedeelte. Deze endovasculaire behandeling van het APA heeft verschillende voordelen in vergelijking met open chirurgie. Zo zijn er minder anesthesiemiddelen noodzakelijk, en is er een verminderde noodzaak tot bloedtransfusie. Daarnaast leidt het gebruik van deze methode tot een sneller herstel van de patiënt, kortere ziekenhuisopnames en geeft het minder wondinfecties. In **hoofdstuk 4** wordt een overzicht van de huidige literatuur over open chirurgie en endovasculaire behandeling van het APA gegeven. Om de voorkeur te geven aan endovasculaire behandeling boven open behandeling dient de patency rate (het percentage van doorgankelijke arteriën) van endovasculaire stentplaatsing in de knieslagader minstens gelijkwaardig te zijn aan die van open herstel. Met de huidige literatuur is het niet duidelijk of endovasculaire stentplaatsing bij APA dezelfde lange termijn patency rates zal geven bij alle patiënten. Dit blijft onduidelijk, met name bij jonge patiënten, acuut symptomatische patiënten en patiënten met een slechte outflow (slechte onderbeenslagaderen). Daarnaast is er nog te weinig bekend over stent gerelateerde complicaties zoals endoleak (lekkage van bloed langs de stent in de aneurysma zak) en stentbreuk.

Derhalve zou op dit moment stentplaatsing alleen in onderzoeksvorm verricht moeten worden. In geval van ernstige hart -en of longziekten, zouden patiënten wel primair met endovasculaire stentplaatsing behandeld moeten worden.

Type van chirurgische benadering

Diverse benaderingen en technieken voor herstel van een APA zijn reeds beschreven en verricht. De mediale benadering is de meest toegepaste chirurgische techniek bij de uitschakeling van een APA. Het omvat een gecombineerde snede boven en onder de knie aan de binnenzijde van het been. Deze techniek schakelt helaas niet de eventuele zijtakken van een APA uit, waardoor er alsnog vulling in het aneurysma kan ontstaan, en eventueel zelfs groei van het aneurysma, resulterend in een mogelijke scheur. Een alternatieve techniek is de dorsale benadering (via de achterzijde van de knie). Deze benadering bestaat uit een S-vormige snede in de knieholte, met inachtneming van zenuwen en enkele aderen. **Hoofdstuk 5** beschrijft de korte en middellange resultaten van de mediale en dorsale benadering bij de behandeling van APA's. Geconcludeerd kan worden dat op de lange termijn geen significante verschillen in patency rates tussen de mediale en dorsale benadering gevonden kunnen worden. Aangezien er na de mediale uitschakeling een persisterend risico op groei van het aneurysma blijft bestaan (tot 22%), is de dorsale benadering uiteindelijk de voorkeursbenadering bij de behandeling van het APA. Daarnaast, heeft het gebruik van een ader als bypass de voorkeur boven het gebruik van kunststof, onafhankelijk van de benadering bij het herstel van APA's.

Strategie bij acute ischemie van een been

De consequenties van acute stolling van een APA zijn zowel een bedreiging voor het behoud van het been als van het leven. Ondanks spoedinterventies, blijft er een belangrijk risico bestaan op amputaties door stolling van de onderbeenslagaderen. Historisch gezien was een trombectomie (het chirurgisch verwijderen van stolsel) van de onderbeenslagaderen gevolgd door een bypass de gouden standaard. Echter, sinds 1980 wordt trombolyse (een stolseloplosmiddel toegediend via de slagader) succesvol toegepast, om de onderbeenslagaderen voor chirurgische revascularisatie te verbeteren. In **hoofdstuk 6** wordt een overzicht van de literatuur gegeven om de uitkomsten van acute stolling van APA's door trombectomie of trombolyse gevolgd door een bypass weer te geven. Dit literatuuroverzicht toont dat pre- en intraoperatieve trombolyse geen significante reductie in het aantal amputaties oplevert vergeleken met trombectomie. De 1-jaars primary patency van chirurgische interventie na trombolyse was significant hoger vergeleken met chirurgie alleen. De primary patency na 3 en 5 jaar was niet significant verschillend tussen beide groepen. Bovendien, kon er geen onderscheid gemaakt worden tussen de groepen wat betreft secondary patency (percentage doorgankelijke slagaders, na één behandeling om de slagader doorgankelijkheid te waarborgen) en het percentage patiënten waarbij geen amputatie noodzakelijk was. Geconcludeerd kan worden dat indien er sprake is van een acute vaatafsluiting door een APA met milde kliniek, het gebruik van trombolyse geadviseerd wordt mits er geen contra-indicaties zijn. Bij een acute vaatafsluiting door een APA met ernstige kliniek, zich uitende in uitgebreide gevoelsstoornissen en of motorische stoornissen, dient chirurgie direct plaats te vinden.

Diameter indicatie voor behandeling

Vanwege het toenemend risico op verlies van het aangedane been bij het ontstaan van klachten (mechanische klachten door compressie van het APA, acute ischemie door trombose van het APA, of chronische ischemie door partiële trombose van het APA) zouden patiënten met een dergelijk symptomatisch APA behandeling moeten ondergaan. De diameter van het symptomatische aneurysma heeft geen invloed op deze beslissing. Echter, er is geen consensus over asymptomatische APA's (klachtenvrij). Meerdere auteurs adviseren geplande chirurgische uitschakeling bij patiënten met een asymptomatisch aneurysma groter dan 20 mm. Andere suggereren dat een diameter van 30mm het juiste afkappunt is. Het is niet geheel duidelijk welke karakteristieken van een asymptomatisch APA leiden tot een acute trombose. Diameter alleen lijkt niet de enige voorspellende factor. **Hoofdstuk 7** beschrijft een prospectieve studie om de interventiecriteria van asymptomatische APA's tussen 20 en 30mm te verbeteren. In deze studie ondergingen alle patiënten met een asymptomatisch APA een CT-angiografie om berekeningen aan de arteria poplitea te verrichten, inclusief het APA met het strekken en 90° buigen van de knie in een speciaal geprepareerde brace. Kniebuigingen bij patiënten met een APA lijden tot een significante lumenreductie boven en onder het aneurysma. Daarnaast, geeft het een verandering in de buigingsgraad (angulatie) van de slagader boven en onder het aneurysma. Deze twee kenmerken kunnen een oorzaak zijn voor het verhoogde risico op tromboembolieën. Kniebuigingen met een APA $\geq$ 30 mm geeft een significante lumenreductie vergeleken met PAA < 30 mm. Een andere belangrijke bevinding in deze studie is de grote variatie in lumenreductie en angulatie veranderingen gedurende strekken en buigen binnen de groep met kleine aneurysma's als ook in de groep met grote aneurysma's. Deze gemeten variabiliteit binnen de groepen kan verklaren waarom enkele kleine APA's toch symptomatisch worden en waarom sommige grote aneurysma's niet symptomatisch worden. Het verrichten van een CT-A scan tijdens het strekken en buigen van de knie, zoals hierboven beschreven, zou geïmplementeerd moeten worden in het beslisproces of een patiënt met een asymptomatisch APA geopereerd dient te worden.

Geslacht gerelateerde verschillen in uitkomst

Vaatziekten zijn een belangrijk volksgezondheidsprobleem in zowel mannen als vrouwen. In het algemeen, hebben vrouwen kleinere slagaderen dan mannen. Gecombineerde resultaten van studies die zich richtten op de uitkomst van bypass chirurgie in het onderbeen, geven geen significant verschil in primary patency, percentage patiënten waarbij geen amputatie noodzakelijk was, en overleving tussen mannen en vrouwen. Op dit moment zijn er geen studies verricht die specifiek het effect van het geslacht op de uitkomst van de behandeling van APA onderzocht hebben. Dit was het belangrijkste doel van de studie beschreven in **hoofdstuk 8**, waarin de korte en lange termijn uitkomsten van het herstel van APA's tussen mannen en vrouwen werden vergeleken. Ondanks het kleine aantal vrouwen in deze studie, was het geslacht onafhankelijk geassocieerd met primary patency. Er werden geen significante verschillen in 30-dagen sterfte en het aantal complicaties tussen mannen en vrouwen geconstateerd. Op de lange termijn, hebben vrouwen een significant lagere primary patency en een trend tot een hoger amputatiepercentage. Op basis van deze resultaten, zou het verstandig zijn om asymptomatische APA's in vrouwen bij een grotere diameter te behandelen dan in mannen, omdat vrouwen meer APA gerelateerde complicaties hebben gedurende follow-up. Daarnaast, dient het follow-up protocol voor vrouwen geïntensiveerd te worden in vergelijking met mannen, omdat vrouwen een grotere kans op hernieuwde vernauwing van het bloedvat voor afsluiting van het bloedvat hebben.

In **hoofdstuk 9** worden de bovengenoemde hoofdstukken samengevat en bediscussieerd, en tevens een visie voor de toekomst gegeven.

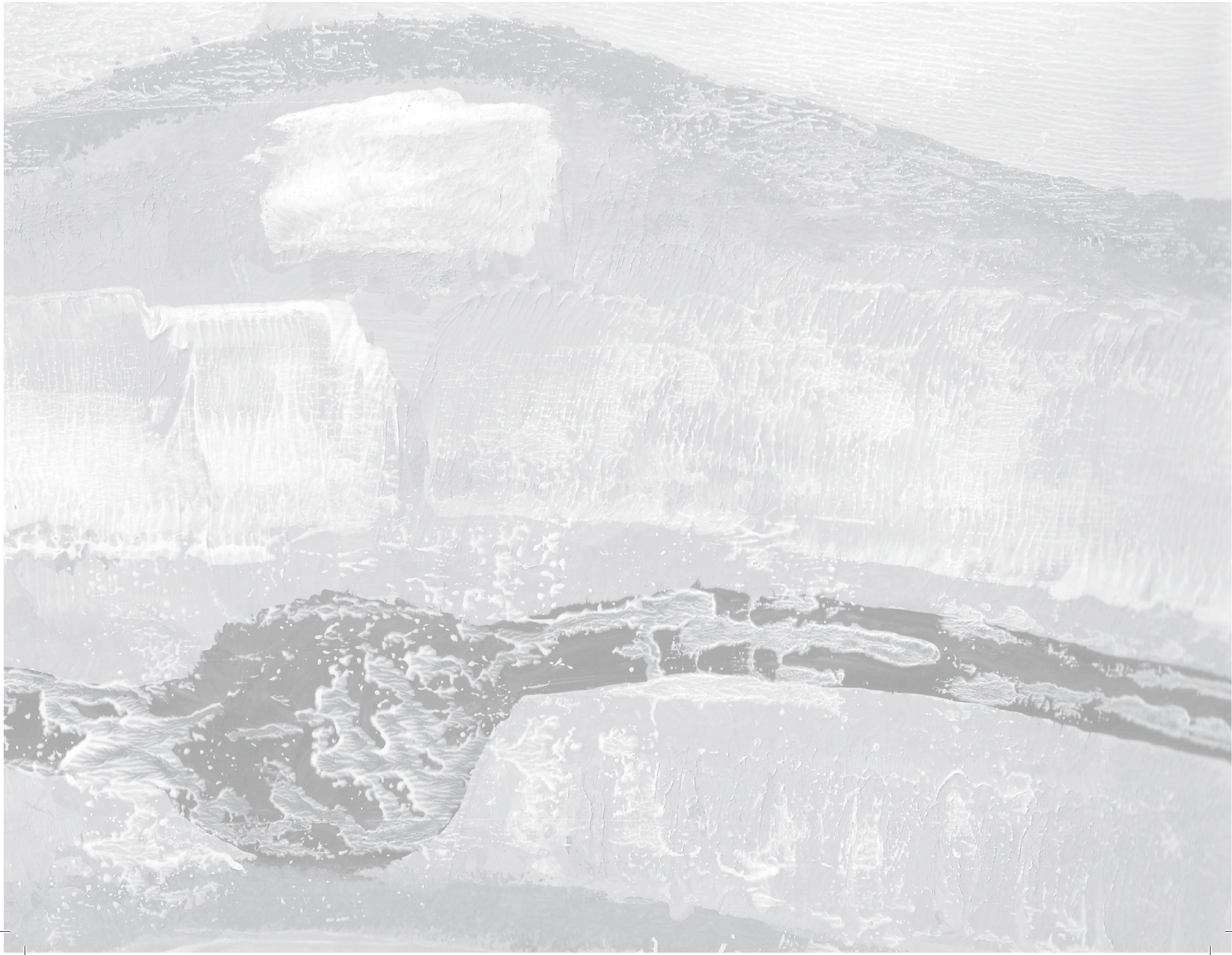
CHAPTER 11

REVIEW COMMITTEE

DANKWOORD

PUBLICATIONS

CURRICULUM VITAE



REVIEW COMMITTEE

Prof.dr. R.L.A.W. Bleys
Department of Pathology
University Medical Center Utrecht
Utrecht, The Netherlands

Prof.dr. J.A.W. Teijink
Department of Vascular Surgery
Maastricht University Medical Center
Maastricht, The Netherlands

Prof.dr. M.A.A.J. van den Bosch
Department of Radiology
University Medical Center Utrecht
Utrecht, The Netherlands

Prof.dr. J.R. Lahpor
Department of Cardio-Thoracic Surgery
University Medical Center Utrecht
Utrecht, The Netherlands

DANKWOORD

Klaar!!!! Het is allemaal wel omgevlogen. Alle mensen die hebben bijgedragen aan de totstandkoming van dit boekje wil ik van harte bedanken voor alle jaren samenwerking. In het bijzonder wil ik een aantal mensen speciaal bedanken:

Prof. dr. F.L. Moll, beste Frans, inmiddels alweer jaren geleden dat we het promotieplan maakten over poplitea aneurysma's. U zei nog "Dat je met zo'n kleine arterie een boekje vol kan krijgen". Dat is gelukt. En er is zelfs nog voldoende stof over. Bedankt voor de vaak verhelderende gesprekken, ook juist niet over het promotie onderwerp. Naast uw brede ervaring heb ik van uw internationale contacten gebruik mogen maken. Bedankt.

Dr. J.P.P.M. de Vries, beste Jean-Paul, wat een inspirator ben jij. Je bent een drijfveer achter veel onderzoek. Weet iedereen te motiveren, op jouw eigen directe manier. Dit houdt iedereen scherp. Mijn doel was vaak om een artikel eerder naar je te sturen voordat jij met een mail me herinnerd had. Volgens mij heb ik gewonnen. De congressen die we samen bezochten waren altijd gezellig. Naast je wetenschappelijke ervaring, heb ik ook veel van je als dokter geleerd. Niet alleen als vaatopleider, maar ook als mens. Altijd betrokken, open voor overleg en altijd de beste zorg voor patiënten eisend, ook om 3 uur s nachts. Ik begin nu aan mijn fellowship, de laatste horde naar zelfstandig vaatchirurg. Met trots zeg ik dat jij een van mijn opleiders bent. Ik hoop in de toekomst nog menig biertje met jou en Debby te drinken. Bedankt.

Geachte leden van de leescommissie: Prof.dr. R.L.A.W. Bleys, Prof.dr. J.A.W. Teijink, Prof.dr. M.A.A.J. van de Bosch, Prof.dr. J.R. Lahpor, heel hartelijk dank voor het kritisch beoordelen van mijn proefschrift.

Dr. P.M.N.Y.H. Go, beste perifere opleider!!, beste Peter, als AGNIO ben ik begonnen in Nieuwegein, om vervolgens de laatste 4 jaar van mijn opleiding weer terug te komen en met een fellowship vaatchirurgie te vervolgen. De tweede benoeming in de eerste zin, beschrijft u exact. Altijd staat u klaar voor uw assistenten, de opleiding bewakend. Dit wordt door alle assistenten zeer gewaardeerd. Dank voor het plaatsnemen in de oppositie.

Prof.dr. I.H.M. Borel Rinkes, beste Inne, je wist al toen ik binnen kwam dat ik vaatchirurg ging worden, en gelijk heb je. Bedankt voor de leerzame periode in het UMC Utrecht, de mooiste regio van Nederland.

Dr. J.P.P.M. de Vries, Dr. H.D.W.M. van de Pavoordt, Dr. J. Wille, Drs. R.H.W. van de Mortel, beste Jean-paul, Eric, Jan en Rob, ik kan nu al met veel dank terug kijken op een zeer leerzame periode in het Antonius. En ik kan nog meer kennis en ervaring op doen in een van de mooiste ziekenhuizen van Nederland tijdens mijn fellowship. Van een ieder van jullie heb ik het vak geleerd! Ieder op zijn eigen manier. Bedankt voor het attenderen op en includeren van nieuwe patiënten voor mijn studie. Veel dank.

Maatschap Heelkunde St. Antonius ziekenhuis. Dank voor jullie enthousiaste ondersteuning van en interesse in mijn promotieonderzoek. Grote dank voor jullie opleiding en alle mogelijkheden die mij geboden werden.

Dr. J.A. Vos, Drs. M. van Leersum, Dr. M.J.L. van Strijen, Drs. D.A.F. van de Heuvel, bedankt voor de mogelijkheid om extra ervaring in endovasculaire behandelingen op te doen. Jan-Albert bedankt dat je in de oppositie plaats wilde nemen.

Chirurgen en assistenten UMC Utrecht. Veel dank voor de mooie tijd in het UMC Utrecht.

Dr. B. Verhoeven, Drs E. Cancrinus, beste Bart en Ernst, jullie zijn me voor gegaan en hebben allebei een mooie plek te pakken. Ik heb veel geleerd door gezamenlijk met jullie te opereren. Bedankt.

Jeroen Hagendoorn, Marc Besselink, Wouter te Riele, Eva Madsen, Hjalmar van Santvoort, Çağdaş Űnlű, Wouter Derksen, Stijn Esser, Frederick Hoogwater, collega middenwachten, wat een mooie tijd hebben we in het Anton gehad!! Mede dankzij jullie is mijn tijd in het Antonius omgevlogen door de top werksfeer en grote collegialiteit. Dank.

Co-auteurs. Dank voor de hulp bij het verwerven van de data van enkele artikelen en het kritisch lezen van diverse manuscripts. Met name grote dank voor Hjalmar van Santvoort voor de statistische ondersteuning!

Vaat-OK dames: Lieve Laurien, Ilse, Julia en Barbera. Bedankt voor de fijne samenwerking en goede sfeer op OK.

Jolanda, Mieke en Ans, secretariaat Heelkunde St. Antonius ziekenhuis, bedankt voor jullie ondersteuning. Het was altijd gezellig om even bij jullie binnen te lopen.

Cobie en Susan, secretariaat vaatchirurgie UMC Utrecht. Dank voor jullie ondersteuning.

Poli dames Vaatchirurgie en Heelkunde St. Antonius ziekenhuis, bedankt voor de goede hulp tijdens de poli.

Paranimfen. Frodo Gaymans en Izhar van Eijk. Frodo, van studiegenoten naar 15 jaar vriendschap. Respect voor je eeuwige enthousiaste en creatieve ingevingen. Dank voor je blijvende interesse gedurende alle jaren. Geweldig dat je op deze gelegenheid naast mij wil staan. Izhar, onze vriendschap is ontstaan in een garage. Wat een mooie reis hebben we gehad. Onuitputtelijke stof voor mooie verhalen. Wat een klein driehoekje. Bedankt dat ik vandaag op je terug mag vallen, al vraag ik me wel af: "Who's going to the echo tonight".

Familie. Karlijn, Jorus, André, Sandra, Stijn, Bianca. Lieve familie, bedankt voor alle interesse en steun ook al was het soms natuurlijk moeilijk te begrijpen wat ik precies aan het doen was. Lieve zus, jij gaat als een rode draad door mijn leven. Ik hoop dat we nog meer tijd samen kunnen vrijmaken. Sandra heel erg bedank voor het maken van deze mooie cover!

Ouders. Lieve Pa en Ma, jullie staan aan de basis van alles wat ik toe nu toe heb bereikt. Ik had me geen betere ouders voor kunnen stellen. Door jullie onvoorwaardelijke steun en stimulatie heb ik mijn studie, opleiding en promotie zover af kunnen ronden. Eeuwige dank.

Fabian. Kleine boef van me. Wat een heerlijke afleiding ben jij. De opgelopen vertraging door jou is me alles waard. Ik dacht dat mijn leven al compleet was, maar jij bent een top verrijking. Wat gaan we samen nog een heleboel mooie dingen beleven.

Lieve Floor, mijn allerliefste, wat vinden we het beide heerlijk dat het boekje af is. Het dankwoord was tot nu toe eenvoudig te schrijven, voor jou is dat anders. Geen zin dekt de lading om mijn dank voor jou te kunnen omschrijven. Ik kijk uit naar de tijd die komen gaat als gezin met jou. Je bent onweerstaanbaar.

PUBLICATIONS

Kropman RHJ, van Meurs A, Fioole B, Vos JA, van Santvoort HC, van Sambeek M, Moll FL, de Vries JPPM.
Association of gender on long-term outcomes after popliteal artery aneurysm repair.
Accepted with minor revisions in Ann Vasc Surg.

de Vries JPPM, **Kropman RHJ**, Wille J, van de Mortel RHW, van de Pavoordt HDWM.
Endovascular aortic sealing with the Nellix sac-anchoring endoprosthesis: update of technique and results.
Ital J Vasc Endovasc Surg. In press.

Kropman RHJ, Moll FL.
Stent graft for popliteal aneurysms if preferred; Against the motion.
Book chapter in: *Vascular and Endovascular Controversies Update by Greenhalgh RM, BIBA Publishing, London, 2012.*

Kropman RHJ, Kiela G, Moll FL, de Vries JP.
Variations in anatomy of the popliteal artery and its side branches.
Vasc Endovascular Surg. 2011 Aug;45(6):536-40.

Kropman RHJ, Schrijver AM, Kelder JC, Moll FL, de Vries JP.
Clinical outcome of acute leg ischaemia due to thrombosed popliteal artery aneurysm: systematic review of 895 cases.
Eur J Vasc Endovasc Surg. 2010 Apr;39(4):452-7.

Kropman RHJ, Bemelman M, Segers MJ, Hammacher ER.
Treatment of impacted greenstick forearm fractures in children using bandage or cast therapy: a prospective randomized trial.
J Trauma. 2010 Feb;68(2):425-8.

Kropman RHJ, de Vries JP, Segers MJ.
Surgical repair of a gunshot injury to the left carotid artery: case report and review of literature.
Vasc Endovascular Surg. 2008 Apr-May;42(2):180-3.

Kropman RHJ, van Santvoort HC, Teijink J, van de Pavoordt HD, Belgers HJ, Moll FL, de Vries JP.
The medial versus the posterior approach in the repair of popliteal artery aneurysms: a multicenter case-matched study.
J Vasc Surg. 2007 Jul;46(1):24-30

Kropman RHJ, De Vries JP, Moll FL.
Surgical and endovascular treatment of atherosclerotic popliteal artery aneurysms.
J Cardiovasc Surg (Torino). 2007 Jun;48(3):281-8.

Veenhof AA, **Kropman RHJ**, Engel AF, Craanen ME, Meijer S, Meijer OW, van der Peet DL, Cuesta MA. 7.
Preoperative radiation therapy for locally advanced rectal cancer: a comparison between two different time intervals to surgery.
Int J Colorectal Dis. 2007 May;22(5):507-13.

Kropman RHJ, Bemelman M, Vos JA, van den Berg JC, van de Pavoordt HD, van de Mortel RH, Moll FL, de Vries JP. 8.
Long-term results of percutaneous transluminal angioplasty for symptomatic iliac in-stent stenosis.
Eur J Vasc Endovasc Surg. 2006 Dec;32(6):634-8.

Kropman RHJ, Besselink MGH, Keller BPJA, Go PMNYH.
Foto van de maand. Ned Tijdschr Heelk 2006;15:142.

Hurks R, **Kropman RHJ**, Pennekamp CWA, Hoefer IE, de Vries JPPM, Pasterkamp G, Vink A, Moll FL.
Wall composition of popliteal artery aneurysms differs from abdominal aortic aneurysms.
Submitted to Eur J Vasc Endovasc Surg.

Kropman RHJ, Zandvoort HJA, van den Heuvel DAF, Wille J, Moll FL, de Vries JPPM.
CT angiography to evaluate hemodynamic changes in popliteal artery aneurysms during flexion and extension of the knee joint.
Submitted to J Vasc Surg.

CURRICULUM VITAE

The author of this thesis was born on November 3rd, 1978 in Nijmegen. In 1997 he graduated from high school at the Kandinsky College in Nijmegen and started the medical program of the Free University of Amsterdam. Before his clinical rotations in 2001, he performed cardiovascular research in Brisbane, Australia (Prof.dr. L. Brown). During his clinical rotations, he started research with Prof.dr. M.A. Questa on rectal cancer. He obtained his medical degree in July 2004 and in August of this year he started as a resident at the Department of Surgery in the St Antonius Hospital, Nieuwegein, until august 2006. In this period he started scientific research on the results of popliteal artery aneurysms which has become the basis for this thesis (supervisors: Prof.dr. F.L. Moll and Dr. J.P.P.M. de Vries). Until July 2007 he worked as a resident in the Department of Surgery of the Diakonessenhuis, Utrecht (supervisor: Dr. G.J. Clevers). Then he started the general surgery residency program at the University Medical Center Utrecht (supervisor: Prof. dr.I.H.M. Borel Rinkes). From July 2009, he returned to Nieuwegein to complete his surgical training (supervisor: Dr.P.M.N.Y.H. Go). The last 2 years he differentiated into Vascular Surgery (supervisor: Dr.J.P.P.M. de Vries). This summer he will start with a fellowship Vascular Surgery in the same hospital (supervisor: Dr. J.P.P.M. de Vries).