

VASCUNET REPORT

Contemporary Treatment of Popliteal Artery Aneurysms in 14 Countries: A Vascunet Report

Olivia Grip ^{a,*}, Kevin Mani ^a, Martin Altreuther ^b, Frederico Bastos Gonçalves ^c, Barry Beiles ^d, Kevin Cassar ^e, Lazar Davidovic ^f, Nikolaj Eldrup ^g, Thomas Lattmann ^h, Elin Laxdal ⁱ, Gabor Menyhei ^j, Carlo Setacci ^k, Nicla Settembre ^l, Ian Thomson ^m, Maarit Venermo ⁿ, Martin Björck ^a

^a Department of Surgical Sciences, Section of Vascular Surgery, Uppsala, Sweden

^b Department of Vascular Surgery, St Olavs Hospital, Trondheim, Norway

^c Centro Hospitalar Universitário de Lisboa Central – Hospital de Santa Marta, Lisbon, Portugal

^d Australian and New Zealand Society for Vascular Surgery, Melbourne, Australia

^e Vascular Unit, Department of Surgery, Mater Dei Hospital, Malta

^f Clinic for Vascular and Endovascular Surgery, Serbian Clinical Centre, Belgrade, Serbia

^g Department of Vascular Surgery, Copenhagen University Hospital Rigshospitalet, Denmark

^h Clinic of Vascular Surgery, Cantonal Hospital, Winterthur, Switzerland

ⁱ Department of Vascular Surgery, Landspítalinn University Hospital, Reykjavik, Iceland

^j Department of Vascular Surgery Medical Centre, Pecs University, Pecs, Hungary

^k Università degli Studi di Siena, Siena, Italy

^l Department of Vascular and Endovascular Surgery, Nancy University Hospital, University of Lorraine, Nancy, France

^m Department of Surgical Sciences, Otago University, Dunedin, New Zealand

ⁿ Department of Vascular Surgery, Helsinki University Central Hospital, Helsinki, Finland

WHAT THIS PAPER ADDS

Popliteal artery aneurysms constitute a disease with a low prevalence. Vascunet is a collaboration of vascular registries in Europe, Australia, New Zealand, and Brazil. In this study 10 764 popliteal aneurysm repairs were analysed, showing a great variability in incidence, indications, and surgical techniques. Popliteal aneurysm that presented with acute ischaemia had an increased risk of amputation. The results highlight the need for future comparative studies.

Objective: Popliteal artery aneurysm (PAA) is the second most common arterial aneurysm. Vascunet is an international collaboration of vascular registries. The aim was to study treatment and outcomes.

Methods: This was a retrospective analysis of prospectively registered population based data. Fourteen countries contributed data (Australia, Denmark, Finland, France, Hungary, Iceland, Italy, Malta, New Zealand, Norway, Portugal, Serbia, Sweden, and Switzerland).

Results: During 2012–2018, data from 10 764 PAA repairs were included. Mean values with between countries ranges in parenthesis are given. The incidence was 10.4 cases/million inhabitants/year (2.4–19.3). The mean age was 71.3 years (66.8–75.3). Most patients, 93.3%, were men and 40.0% were active smokers. The operations were elective in 73.2% (60.0%–85.7%). The mean pre-operative PAA diameter was 32.1 mm (27.3–38.3 mm). Open surgery dominated in both elective (79.5%) and acute (83.2%) cases. A medial surgical approach was used in 77.7%, and posterior in 22.3%. Vein grafts were used in 63.8%. Of the emergency procedures, 91% ($n = 2\ 169$, 20.2% of all) were for acute thrombosis and 9% for rupture ($n = 236$, 2.2% of all). Thrombosis patients had larger aneurysms, mean diameter 35.5 mm, and 46.3% were active smokers. Early amputation and death were higher after acute presentation than after elective surgery (5.0% vs. 0.7%; 1.9% vs. 0.5%). This pattern remained one year after surgery (8.5% vs. 1.0%; 6.1% vs. 1.4%). Elective open compared with endovascular surgery had similar one year amputation rates (1.2% vs. 0.2%; $p = .095$) but superior patency (84.0% vs. 78.4%; $p = .005$). Veins had higher patency and lower amputation rates, at one year compared with synthetic grafts (86.8% vs. 72.3%; 1.8% vs. 5.2%; both $p < .001$). The posterior open approach had a lower amputation rate (0.0% vs. 1.6%, $p = .009$) than the medial approach.

Conclusion: Patients presenting with acute ischaemia had high risk of amputation. The frequent use of endovascular repair and prosthetic grafts should be reconsidered based on these results.

Keywords: Aneurysm – popliteal artery, Endovascular, Epidemiology, Open surgery, Registry

Article history: Received 14 March 2020, Accepted 2 July 2020, Available online 15 August 2020

© 2020 The Author(s). Published by Elsevier B.V. on behalf of European Society for Vascular Surgery. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

* Corresponding author. Uppsala University, Department of Surgical Sciences, Section of Vascular Surgery, Akademiska sjukhuset ing. 70, SE75185 Uppsala, Sweden.

E-mail address: olivia.grip@surgsci.uu.se (Olivia Grip).

1078-5884/© 2020 The Author(s). Published by Elsevier B.V. on behalf of European Society for Vascular Surgery. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

<https://doi.org/10.1016/j.ejvs.2020.07.005>

INTRODUCTION

Popliteal artery aneurysms (PAAs) are the most common peripheral arterial aneurysms. Even so, the prevalence is relatively low. Unlike aortic aneurysms, the main clinical presentation is not rupture, which is quite uncommon,¹ but thrombosis and embolism leading to acute or chronic limb ischaemia.^{2,3}

The number of operations for PAA was estimated at 9.6/million person years, but varied considerably between countries.⁴ This low incidence of surgery makes the disease difficult to study, and management remains controversial and differs between institutions, regions, and countries.^{4–6} In many centres, open surgical treatment is the gold standard. The preferred open surgical technique, posterior or medial approach, using vein or a synthetic graft, is controversial.^{7,8} Endovascular treatment has emerged as an alternative treatment, and has been used increasingly often more recently.^{3,6} A minimally invasive procedure with a short hospital stay is attractive, but questions remain about its durability.^{3,9–11}

Vascunet, a collaboration of registries for vascular surgery in Europe, Australia, New Zealand, and Brazil, started in 1997.^{12,13} It reported on PAA treatment in eight countries between 2009 – 2012,⁴ describing great intercountry variability in incidence, indications, and choice of surgical techniques. The authors recommended an update of vascular registries introducing new variables to improve future studies,⁴ which took place and created this new extended analysis.

The aim was to evaluate indications, treatment strategies, and outcome of PAA repair in 14 countries in a contemporary setting.

MATERIALS AND METHODS

In April 2019 all national and regional registries collaborating in Vascunet were invited to participate.

Representative surgeons from all 14 countries that accepted this invitation discussed and agreed upon a set of variables, and definition of these, to include in the study (given in Table S1). The variables were chosen based on previous work with PAA,⁴ as well as two previous Delphi consensus processes on chronic lower limb ischaemia¹⁴ and acute limb ischaemia.¹⁵ The authors of this paper are responsible for the different registries studied and the accuracy of the included variables from respective countries. All data from contributing countries were merged in to one database that was analysed. Only data from inpatient treatments were included. Not all registries could provide all variables (see Table 2).

Data from 14 countries were included (Australia, Denmark, Finland, France, Hungary, Iceland, Italy, Malta, New Zealand, Norway, Portugal, Serbia, Sweden, and Switzerland). Finland submitted population based data from the Helsinki region. France submitted data exclusively from Nancy, Lorraine. Portugal contributed with already merged data, not with individual cases. Thus, the Portuguese data were only included in descriptive tables, not in the statistical analyses. All data were prospectively registered in a registry devoted to quality improvement and research in vascular surgery, covering both open and endovascular surgery in a defined population. Registries not covering endovascular procedures, or a defined population, were not invited to participate in this project.

Only four countries registered a hybrid procedure (open and endovascular surgery performed simultaneously); these 160 cases were classified as open surgery. The Norwegian registry provided age in five year groups rather than exact age. In Hungary it was estimated that 65% of all operations were captured in the registry. France-Lorraine was not included in the calculation of incidence of PAA repairs, as it was impossible to estimate the proportion of captured operations in the French registry due to private institutions in that region that did not contribute to the registry. The

Table 1. Incidence of popliteal artery aneurysm repair based on register data on patients from 13 countries in the Vascunet collaboration

Country/region	Time period	Operations	Population in millions*	Operations/million inhabitants/year	Proportion of emergency surgery – %
Sweden	2012–2018	1 317	9.74	19.3	30.9
Switzerland	2017–2018	289	8.42	17.2	19.0
Norway	2012–2018	578	5.12	16.1	31.0
Portugal	2012–2017	955	10.4	15.3	28.5
Italy	2012–2018	4 976	60.0	11.8	28.4
Australia	2012–2018	1 669	23.7	10.1	20.4
Denmark	2017–2018	95	5.67	8.4	28.4
Finland – Helsinki	2012–2018	75	1.5	7.1	25.3
Hungary	2012–2018	314	6.41	7.0	27.7
Serbia	2012–2018	336	7.11	6.8	17.0
Iceland	2012–2018	15	0.33	6.5	20.0
Malta	2012–2018	17	0.43	5.6	17.6
New Zealand	2012–2018	76	4.60	2.4	18.4
Total	2012–2018	10 712	146.88	10.4	26.8

Data are presented as *n* unless stated otherwise.

* Population is calculated as the mean of the population the first and the last year of the time periods. (Pearson correlation = 0.006, *p* = .57).

Table 2. Pre-operative demographics and risk factors based on register data of 9 587 patients undergoing popliteal artery aneurysm repair electively ($n = 7\,182$) or for acute limb ischaemia ($n = 2\,405$) in 14 countries in the Vascunet collaboration

	Country														
	All	AUS	DEN	FIN	FRA	HUN	ICE	ITA	MAL	NZ	NOR	POR	SER	SWE	SWI
<i>Elective cases</i>															
Number of cases	7 182	1 329	68	56	30	227	12	3 562	14	62	399	683	279	910	234
Incidence per million inhabitants	7.0	8.0	6.0	4.7	NA	5.1	5.2	8.5	4.7	1.9	11.1	9.4	5.6	13.3	13.9
Mean age – years	71.3	71.6	71.3	69.3	66.8*	66.5*	71.1	72.3*	68.1	75.3*	69.9*	NA	64.5*	71.2	69.2*
Female sex	6.7	2.8*	5.9	0.0*	NA	5.3	8.3	9.3*	0.0	6.5	6.0	11.2*	3.6*	4.8*	4.3
ABI pre-surgery – mmHg	0.87	NA	0.93	0.93	0.90	NA	0.97	0.86*	NA	NA	0.94*	NA	0.83*	0.93*	NA
Cardiac history	29.6	46.1*	33.8	26.8	37.9	33.0	25.0	22.6*	50.0	50.0*	31.9	NA	27.9	25.5	36.9*
Cerebrovascular disease	4.0	NA	7.4	16.1*	3.4	10.4*	16.7*	2.3*	0.0	NA	10.8*	NA	NA	9.6*	7.4*
Current smoking	40.0	11.2*	17.6*	35.7	31.0	44.1	41.7	56.7*	42.9	4.8*	31.0*	NA	34.8	23.8*	36.2
Diabetes	15.5	17.5	7.4	25.5*	10.3	18.5	25.0	15.4	35.7*	9.7	11.6*	NA	15.9	11.5	14.7
Mean diameter of PAA – mm	32.1	NA	36.2*	30.6	27.7*	38.3*	27.6	32.2	27.3*	34.4	30.3*	NA	34.1*	29.7*	NA
Hypertension	77.7	80.9*	70.6	78.6	79.3	89.4*	83.3	78.2	100*	79.0	57.8*	NA	80.1	69.3*	79.0
Pulmonary disease	11.3	NA	8.8	17.9	13.8	14.1	16.7	9.5*	14.3	NA	18. *	NA	13.8	11.2	22.9*
Pre-operative/peri-operative thrombolysis	0.7	NA	NA	NA	0.0	NA	0.0	0.1*	0.0	NA	0.8	NA	1.4	2.7*	NA
<i>Acute limb ischaemia</i>															
Number of cases	2 405	320	27	18	20	72	2	1 284	3	14	167	272	52	373	53
Incidence per million inhabitants	2.3	1.9	2.4	1.7	NA	1.6	0.9	3.1	1.0	0.4	4.7	3.7	1.0	5.5	3.1
Mean age – years	71.0	69.4*	67.3*	72.1	67.8	68.9	62.0	72.0*	77.3*	66.7	68.8*	NA	63.8*	72.3*	68.8
Female sex	6.5	1.9*	7.4	16.7	NA	8.3	0.0	8.1*	0.0	28.6*	5.4	16.5	3.8	4.8	1.9
ABI pre-surgery – mmHg	0.41	NA	0.63	0.28	0.50	NA	0.38	0.27	NA	NA	NA	NA	0.26*	0.32*	NA
Cardiac history	25.2	36.6*	29.6	29.4	55.0*	38.9*	0.0	19.4*	66.7	28.6	34.7*	NA	25.0	23.5	44.8*
Cerebrovascular disease	4.8	NA	11.5	16.7*	5.0	13.6*	0.0	3.3*	33.3*	NA	10.2*	NA	NA	5.8	11.8
Current smoking	46.3	23.8*	32.0	35.3	30.0	51.4	100	57.0*	50.0	0.0*	32.9*	NA	34.6	35.5*	47.6
Diabetes	15.5	19.1	3.7	16.7	20.0	26.4*	0.0	15.1	33.3	7.1	13.8	NA	17.3	10.4*	11.1
Mean PAA diameter – mm	35.5	NA	39.0	41.4*	33.3	41.9*	19.5*	35.5	28.7	NA	31.5*	NA	41.4*	34.8	NA
Hypertension	76.6	73.4	59.3*	70.6	90.0	83.3	50.0	81.3*	100	57.1	54.5*	NA	65.4	70.4	76.7
Pulmonary disease	11.4	NA	14.8	11.8	5.0	15.3	0.0	10.7	0.0	NA	15.6	NA	5.8	14.2	12.5
Pre-operative/peri-operative thrombolysis	21.9	NA	NA	NA	30.0	NA	0.0	19.1*	NA	NA	5.4*	NA	15.4	39.7*	NA

Data are presented as % unless stated otherwise. All variables were significantly different ($p < .01$) when tested with analysis of variance. Portuguese data are not included in summarised data. NA = not available; PAA = popliteal artery aneurysm, ABI = ankle brachial index, AUS = Australia; DEN = Denmark; FIN = Finland; FRA = France-Lorraine; HUN = Hungary; ICE = Iceland; ITA = Italy; MAL = Malta; NZ = New Zealand; NOR = Norway; POR = Portugal; SER = Serbia; SWE = Sweden; SWI = Switzerland.

* A statistically significant ($p < .010$) comparison, when an individual country was tested against the other countries.

registries in Denmark, Finland, Italy, Iceland, Malta, and Sweden registered follow up at 30 days; in Serbia and Switzerland it was a mix depending on centre and time period; and in the remaining countries early outcome was registered at discharge. One year follow up data were provided by Denmark, Finland, France-Lorraine, Iceland, Italy, Malta, Serbia, and Sweden. Data were presented according to the STROBE statement.¹⁶

The SPSS software package version 25.0 (IBM, Armonk, New York, USA) was used for statistical analysis. Statistical comparisons were performed with cross tabulation with the chi square test for dichotomous variables with different degrees of freedom and analysis of variance for continuous variables. Each individual country was tested against the sum of all the other countries. A p value $< .01$ was considered significant, adjusting for multiple comparisons. Correlation was tested with the Pearson correlation coefficient. Time trends were not analysed continuously but by comparing entire years. Survival and amputation over time was compared using Kaplan–Meier curves and the log rank test, presented with 99% confidence intervals. Cases with

missing data on surgical techniques or mode of admission (acute/elective) were omitted (20 cases, 0.2%). No imputation procedure was performed.

RESULTS

During 2012–2018 a total of 9 425 cases of definitive surgery for PAA were identified and included from 11 countries. Denmark and Switzerland contributed with 384 cases from 2017 to 2018. This resulted in 9 809 cases of PAA included in the common database from 13 different countries and regions. The Portuguese patients ($n = 955$) were included when comparing countries in the tables, and 10 764 procedures were studied including those.

The largest number of procedures were submitted from Italy, Australia, and Sweden (Table 1). The overall incidence of PAA repair was 10.4 operations/million/year but varied more than eightfold among countries.

Most operations were elective. Among the 26.8% emergency procedures, 2 405 (91.0%) were performed for aneurysm thrombosis and consequent acute limb ischaemia (ALI), and the remaining 236 cases for rupture.

Table 3. Proportion, approach, and graft for open elective surgery (ES) of 6 317 patients with popliteal artery aneurysm based on register data on patients from 12 countries in the Vascunet collaboration. Countries are ranked by results, from higher to lower

Country	Open elective surgery	Country	Medial approach in ES*	Country	Vein graft in ES†
Denmark	100	Malta	100	Iceland	100
Iceland	100	Australia	97.9	Finland	89.1
Serbia	98.6	New Zealand	96.3	Switzerland	88.5
Switzerland	94.8	France	92.0	Sweden	87.8
Finland	92.9	Iceland	83.3	Australia	86.9
Norway	92.1	Italy	73.6	France	86.2
Sweden	85.6	Switzerland	68.2	New Zealand	77.8
France	82.8	Serbia	65.6	Malta	76.9
Italy	79.7	Sweden	65.4	Denmark	61.4
Malta	64.3	Finland	50.0	Norway	59.3
Australia	63.9	Denmark	NA	Italy	50.7
New Zealand	41.9	Norway	NA	Serbia	45.2
Total	79.5	Total	77.7	Total	63.8

Data are presented as %. NA = no data available.

* Posterior is compared with medial approach.

† Vein grafts are compared with synthetic or composite grafts.

The rupture cases were excluded and analysed separately in all of the following analyses.

Elective cases

Patient characteristics of 7 182 elective operations are presented in Table 2. The mean age at the time of surgery was 71.3 years (95% CI 71.1–71.4), ranging from 64.5 years (95% CI 63.4–65.6) in Serbia to 75.3 years (95% CI 73.7–77.0) in New Zealand. Most patients were men (93.3%). The mean pre-operative maximum aneurysm diameter was 31.2 mm (standard deviation 8.3). In 70.0% the diameter of the aneurysm was ≥ 30 mm. In the Swedvasc registry the proportion of asymptomatic patients having elective repair was 73.9% and they had a mean diameter of 29.7 mm compared with symptomatic patients with a mean diameter of 29.8 mm. The information regarding risk factors and comorbidities was almost complete (>90% available information), showing pre-operative differences in study populations between countries that were all statistically significant ($p < .001$).

Open surgery was used more frequently (79.5%) than endovascular (20.5%) (Table 3). The choice of technique differed between countries, and depended on indication and age, but did not change over time (Fig. 1). Patients receiving endovascular repair (ER) were older than those treated by open repair (OR) (73.2 vs. 70.8 years, $p < .001$). The proportion of ERs was 11.6% < 60 years, 17.2% 60–69 years, 19.7% 70–79 years, and 28.2% ≥ 80 years, $p < .001$.

Ten of the 14 countries registered the surgical approach used in cases treated by OR. A medial approach was used more often (77.7%) than a posterior one (Table 3). In the 5 350 cases with available information on graft type, 3 415 (63.8%) had a vein graft, 1 894 (35.4%) a synthetic graft, and 41 (0.8%) a composite graft.

Acute limb ischaemia

A total of 2 405 cases (24.5%) were operated on for ALI. Patient characteristics are presented in Table 2. The

incidence varied from 0.4/million inhabitants/year in New Zealand to 5.5/million inhabitants/year in Sweden. The mean age was 71.0 years and the mean diameter 35.5 mm. In 84.1% the diameter of the aneurysm was 30 mm or more. Patients presenting with ALI were more often active smokers (46.3% vs. 40.0%, $p < .001$), and had a lower frequency of cardiac history (25.2% vs. 29.6%, $p < .001$) than elective cases. Other risk factors and patient characteristics were similar when comparing emergency and elective surgery. OR dominated even more in the emergency cases (83.2%).

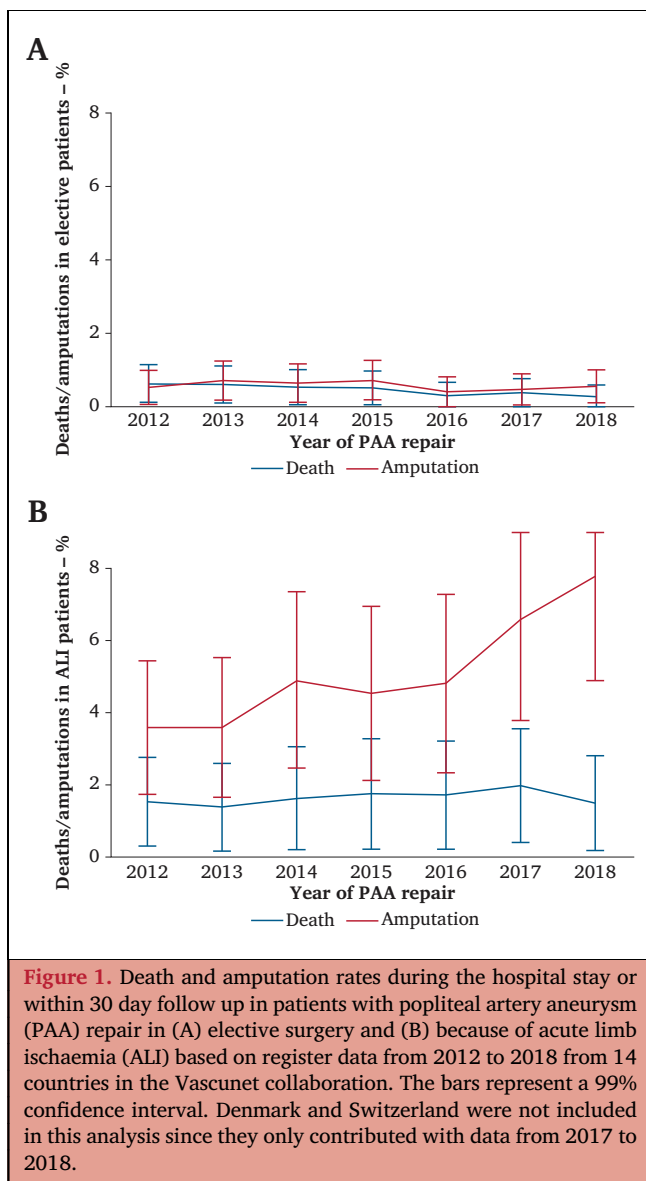
The use of pre- or peri-operative thrombolysis was registered in six countries. In those, 21.9% of emergency cases received thrombolysis compared with 0.7% of elective cases. The use of thrombolysis varied considerably between countries, being most frequent in Sweden (39.7% in ALI; 2.7% in elective cases, $p < .001$).

Ruptured popliteal artery aneurysms

Patients operated on for ruptured PAA ($n = 236$, 2.4%) were older (74.7 years vs. 71.3, $p < .001$) and had larger aneurysms (49.2 mm vs. 32.7 mm, $p < .001$) than those operated on for other indications. Other pre-operative characteristics were similar. Ruptured PAAs were treated by open surgery in 78.5%; and 100% were operated on with a medial approach. During the hospital stay or within 30 days from surgery, 9.1% of the patients had a major amputation and 8.1% died.

In hospital and 30 days outcome

The frequencies of major complications, including death and amputation, were difficult to compare among countries, since some only reported events during the in hospital episode; others reported follow up 30 days after surgery. The results after elective treatment, and for ALI, are given in Table 4. Complication rates were similar if the countries that were outliers in terms of number of patients (Italy, Iceland, and Malta) were excluded.



As expected, many complications were more common after operation for ALI than after elective surgery. After elective surgery, graft occlusions were registered in 2.3% of cases, amputations in 0.7% and death in 0.5%, compared with 9.6%, 5.0%, and 1.9% after treatment for ALI ($p < .001$ for all comparisons).

When countries reporting in hospital and 30 day outcomes were compared, the frequencies of wound complication, renal failure, and graft occlusion were higher after elective surgery in countries reporting 30 day outcome (Table 5). The frequency of complications also depended on surgical technique (Table 5). In elective cases, the frequencies of wound complication (0.9% vs. 6.2%; $p < .001$), acute coronary syndrome (0.1% vs. 1.0%; $p < .001$), renal failure (0.1% vs. 1.5%; $p = .001$), and graft occlusion (1.1% vs. 2.7%; $p < .001$) were lower after endovascular than open surgery. A posterior approach was more often associated with wound complications (7.6% vs. 4.9%, $p = .001$), renal insufficiency (4.5% vs. 1.0%, $p < .001$), and early graft occlusion (4.6% vs. 2.2%, $p < .001$) compared with a medial approach in elective cases.

Table 4. Outcome after elective and acute repairs of 9 587 patients with popliteal artery aneurysm based on register data on patients from 14 countries in the Vascunet collaboration

	Elective cases (<i>n</i> = 7 182)	ALI cases (<i>n</i> = 2 405)	<i>p</i> value
Wound complication	5.3	4.8	.47
Haemorrhage	1.6	3.2	<.001
Compartment syndrome, fasciotomy	0.2	5.7	<.001
Acute coronary event	0.8	1.5	.004
Major stroke	0.4	0.5	.57
Renal replacement therapy	1.2	2.0	.010
Graft occlusions	2.3	9.6	<.001
Amputation	0.7	5.0	<.001
Death	0.5	1.9	<.001

Data are presented as % unless stated otherwise. Outcome after surgery was recorded 30 days after surgery in Finland, Italy, Iceland, Malta, and Sweden; in Serbia and Switzerland it was a mix; and the other countries registered outcome at discharge. ALI = acute limb ischaemia.

The amputation and mortality rates after elective surgery were stable during the study period. In the ALI group, however, an increase in the amputation rate at the end of the study period (2017–2018) was identified, log rank $p = .007$ (Fig. 1). This increase in amputation rate in the ALI group remained when outliers in terms of patient numbers (Italy, Iceland, and Malta) were excluded. This time trend in amputation rate remained also when open and ERs were analysed separately. The proportion of patients treated for ALI decreased during the study period, from 29.7% in 2012 to 23.8% in 2017, $p < .001$.

One year outcomes

One year follow up data were provided by eight of the registries (Denmark, Finland, France-Lorraine, Iceland, Italy, Malta, Serbia, and Sweden). One year data on amputation were available for 42.6%–100% (mean 85.0%) of the procedures in those countries. In total, information on amputation within one year was available in 3 439 of the PAA repairs, and was 1.0% after elective repair and 8.5% after ALI. Information on one year patency was available in 3 314 cases, and was 83.1% after elective and 74.4% after ALI treatment. Elective OR had a one year amputation rate similar to endovascular treatment (1.2% vs. 0.2%; $p = .095$), although better one year patency (84.0% vs. 78.4%; $p = .005$). Patients operated on with vein grafts had higher patency and lower amputation rates at one year than those operated on with synthetic grafts (86.8% vs. 72.3% and 1.8% vs. 5.2%; both $p < .001$). In subgroup analysis of surgical technique in elective cases (data available for 1551 repairs) the posterior approach had a lower amputation rate (0.0% vs. 1.6%, $p = .009$) than the medial approach and a trend towards better patency at one year (84.0% vs. 78.7%, $p = .021$).

Mortality data at one year were available after 1 814 repairs (all repairs from Denmark, Finland, Iceland, Malta,

Table 5. Early outcomes after elective popliteal artery aneurysm repair

	Open	Endovascular	p value	Medial approach	Posterior approach	p value	Discharge*	30 days*	p value
Number of repairs	5 571	1 446		4 710	1 054		3 134	6 448	
Wound complication†	6.3	0.9	<.001	4.9	7.6	.001	3.7	5.5	.008
Haemorrhage	1.6	1.5	.89	1.6	0.9	.070	2.2	1.9	.38
Compartment syndrome, fasciotomy	0.3	0.1	.16	0.2	0.3	.50	0.5	0.6	.56
Acute coronary event	1.0	0.1	.001	1.0	0.9	.67	0.9	1.0	.55
Major stroke	0.4	0.6	.46	0.3	1.0	.004	0.0	0.7	<.001
Renal replacement therapy‡	1.5	0.1	<.001	1.0	4.5	<.001	0.1	2.2	<.001
Early graft occlusions	2.7	1.1	<.001	2.2	4.6	<.001	2.1	5.1	<.001
Amputation	0.7	0.6	.49	0.8	0.5	.31	1.0	2.0	<.001
Death	0.5	0.2	.12	0.5	1.0	.035	0.5	1.0	.023

Data are presented as % unless stated otherwise. Outcome after surgery was recorded 30 days after surgery in Finland, Italy, Iceland, Malta, and Sweden; in Serbia and Switzerland it was a mix; and the other countries registered outcome at discharge.

* Comparing results for countries that report outcome at discharge or 30 day follow up.

† Wound complication refers to complications leading to surgical intervention.

‡ Post-operative renal failure requiring renal replacement therapy.

Serbia, and Sweden) and were 1.4% after elective repair and 6.1% after treatment for ALI ($p < .001$).

DISCUSSION

The Vascunet collaboration made it possible to amalgamate contemporary data on treatment of PAA across several countries and regions, enabling geographical comparisons and study of time trends. The present study represents by far the largest cohort on PAA ever reported.

The number of operations per million inhabitants per year varied more than eightfold between the studied countries. In the previous Vascunet PAA report,⁴ the highest incidence of treatment by population for PAA was found in Sweden, verified in this report (Table 1). New Zealand had the lowest incidence of PAA repair, and the lowest proportion of active smokers. An increase in incidence over time was noted in Sweden: 8.3/million/year from the same registry (1994–2001),² 17.6/million/year (2009–2011),⁴ and 19.3/million/year in this report. In Norway the incidence increased from 11.9/million/year (2009–2012) to 16.1 (2012–2018), and in Switzerland from 5.2 (2009–2011) to 17.2 (2017–2018). The great increase in Switzerland is partly thought to be explained by improved coverage of the registry. The Swiss-vasc registry was rebuilt in 2016 and more units joined. It is likely that with this revision of Swissvasc a more accurate prevalence of PAA has been captured.

In Finland and New Zealand a falling incidence was observed: in Finland from 13.9 (2009–2011) to 7.1 (2012–2018), and in New Zealand from 7.0 (2010–2012) to 2.4 (2012–2018). This great variability in incidence and time trends of PAA repair between countries can be explained by a true difference in prevalence of the disease, differences in diagnostic activity, different indications for PAA treatment, and also by differences in how well the registries capture these particular procedures. In Denmark a more precise reporting of the anatomy of peripheral aneurysms was introduced in 2017. Otherwise, the authors of this paper,

who are also responsible for the different registries studied, report no great changes in how the registries capture PAA repair during the studied time period. A national AAA screening program may increase the detection of PAAs since the prevalence of PAA among patients with AAA is high. This may partially explain the highest incidence of elective procedures in Sweden,¹⁷ the only country with such a programme among those contributing to this study. The proportion of emergency surgery is also high in Sweden (30%), contradicting this possible explanation.

Some controversy in indication for treatment of asymptomatic PAAs exists and may affect the incidence of PAA repairs. The primary aim in the management of asymptomatic PAA is to prevent thrombo-embolism, acute ischaemia and subsequent risk of amputation. Approximately 30% of patients treated for PAAs have ALI,¹⁸ and they are known to have poorer outcomes,¹⁹ confirmed in the present study. The present study, however, includes no data on the natural history of PAAs, since only treated patients were studied. Some advocate that all PAAs should be repaired, regardless of size, because of the high complication and amputation rates after ALI.²⁰ Even when PAAs are initially asymptomatic, patients will develop symptoms at a mean rate of 14% per year (range, 5%–24%),²¹ and one third will develop ALI within five years.²² In patients selected for anticoagulation and/or routine surveillance due to small aneurysm size (2–3 cm) or coexisting cardiovascular or malignant disease, 33%–45% eventually need surgical management anyway.²² Others suggest that asymptomatic PAAs can safely be observed.^{23,24} The presence of thrombus in a PAA, however, appears to increase the risk of developing symptoms and the rate of expansion.²⁵ Consequently, no international consensus regarding the indications for treatment of asymptomatic PAAs exists. Few registries in this study included information on whether the elective repair was performed for an asymptomatic patient or not, but in the Swedish registry the majority of elective cases were asymptomatic (73.9%). The majority of elective cases in this study were

probably asymptomatic, although the exact proportion is unknown. The mean pre-operative diameter of elective PAAs in this report varied from 27.3 mm in Malta to 38.3 mm in Hungary.

The proportion of emergency surgery ranged from 14% in Iceland to 40% in France-Lorraine. No correlation between incidences of PAA repair and the frequency of elective/emergency treatment for PAA was found, however, suggesting a true difference in prevalence of PAA in the studied populations. The fact that PAA is often associated with multiple aneurysmal disease, and that a family history is common, suggests genetic mechanisms, explaining why ethnic differences may play a role.²⁶ The only variable that existed to enable classification of the pre-operative degree of ischaemia was the ankle brachial index, and that was only available in eight of 14 registries. There was a great variability, however, since the mean value ranged between 0.26 in Serbia and 0.63 in Denmark (Table 2). Although Rutherford classification would probably have been better, one of the conclusions of the 2020 Clinical Practice Guidelines on the management of Acute Limb Ischaemia was that the classification of ALI needs to be updated and revised.⁵

Elective cases were more often treated by ER. Although ER of PAAs decreases length of hospital stay and peri-operative morbidity, its durability is inferior compared with OR.^{27,28} The results from the present study show that ER in elective cases had a lower frequency of wound complications, acute coronary events, renal failure and early graft occlusions during hospital stay or 30 day follow up. At one year the endovascular group had a similar amputation rate (0.2% vs. 1.2%; $p = .095$) but inferior patency (78.4% vs. 84.0%; $p = .005$). As the primary concern regarding ER is durability, adding long term follow up to the registries is important.

The type of open surgical approach was documented in ten countries (Table 3). The medial approach dominated for both elective and emergency surgery (77.7% and 91.3%, respectively), but varied greatly between countries (50%–100%). The medial approach has the advantages of being familiar to all vascular surgeons, providing easy access to the entire great saphenous vein (without turning the patient during the procedure) and being the only logical option for bypass grafts that must extend to the distal tibial or pedal vessels.²⁹ However, multiple studies have reported that late expansion is common after this technique. The aneurysm continues to enlarge if collateral blood flow into the aneurysm sac persists, a situation analogous to that of a type II endoleak with endovascular aneurysm repair.^{30,31} Continued expansion can result in pain, swelling or thrombosis due to vein compression, and even rupture.³² Ravn *et al.*⁷ reported late expansion in 33% of PAA repairs (57/174 cases) after a mean of 7.2 years when the medial approach was used, which was symptomatic in most cases. Late expansion was almost non-existent after an operation with a posterior approach. Thus, follow up beyond 30 days is recommended in patients operated with a medial approach to exclude late sac expansion.³³ In the present study the posterior approach was associated with higher rates of wound complications and early graft occlusion, but with superior patency and a lower amputation rate at one year. Thus

in this study, the posterior approach was associated with more early complications but better long term outcome. The groups are not quite comparable, however, since patients with aneurysms extending above the adductor hiatus, or below the origin of the anterior tibial artery, cannot be operated on from behind. The graft material differed greatly between countries (Table 3), similar to a previous Vascunet report on infringuinal bypass surgery.³⁴ Since a venous graft is associated with better long term outcome, countries using more prosthetic grafts should review their practice.

This great variation in choice of treatment among countries regarding open or endovascular treatment, and the choice of open surgical approach, emphasises the lack of consensus recommendations for treatment. When comparing outcomes for different countries and after different surgical techniques, there are residual confounders that were not possible to address in this observational study. While multiple randomised control trials (RCTs) were performed to guide the choice of open or ER of AAA, there are no similar data on how to treat PAA. The need of RCTs in the future to answer the question of preferred treatment strategy for PAAs is highlighted. International collaboration in this field is needed, given the relatively low frequency of these procedures. Although there is a lack of randomised data, the recently published ESVS Guidelines on ALI issued a strong recommendation against using ER for PAAs with ALI (Class III, Level B).⁵

When analysing time trends, stable amputation and mortality rates were found after elective surgery. The amputation rate increased during 2017–2018 after ALI, however, and simultaneously the proportion of ALI cases decreased. Few previous studies report the results separately for PAAs that present with ALI, but in those that do, the amputation rate varies between 5% and 28%.^{3,18,29} In the present study, the amputation rate was 3.6% in 2012 and 7.2% in 2018, so the reported results still compare favourably. This increased amputation risk after treatment for ALI remains a matter of concern. It should be emphasised, however, that the registries only report treated patients, and those undergoing primary amputation are not reported. Thus, a possible explanation for the increased proportion being amputated could be that patients are being treated more aggressively, even those with the most severe ischaemia that previously would have been treated by primary amputation. However, data are lacking on patients who underwent primary amputation without a prior revascularisation attempt.

Limitations

A potential limitation with all registry studies is the risk of selection bias due to insufficient external validity. Many of the included registries have been validated (Table S3),^{35–39} but a specific validation of PAA treatment has rarely taken place. The Swedish registry used the fact that many patients have bilateral PAA and found that among 146 bilateral procedures, 141 (96.6%) had reported the contralateral operation to the registry.² Comorbidities are defined slightly differently in the various registries, affecting the internal validity. The fact that patients from 14 different countries were studied results in

inhomogeneity, but also that results may be relevant for patients worldwide. The fact that a small proportion of patients (30%, although it was 85.0% among the eight countries that reported one year follow up) had one year follow up makes it difficult to assess medium term outcome, and outcome beyond one year is unknown. Since the registries only report patients operated on, it was not possible to investigate at what threshold diameter a PAA should be repaired.

Conclusions

This report on definitive repair of PAA from 14 countries sheds light on a great variability and the lack of consensus recommendations to guide treatment of PAA. OR dominates in both the elective and emergency scenarios, and the results of this study support this strategy. There is a great need for future RCTs and consensus recommendations.

CONFLICT OF INTEREST

None.

FUNDING

None.

APPENDIX A. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ejvs.2020.07.005>.

REFERENCES

- Cervin A, Ravn H, Björck M. Ruptured popliteal artery aneurysm. *Br J Surg* 2018;105:1753–8.
- Ravn H, Bergqvist D, Björck M, Swedish Vasc R. Nationwide study of the outcome of popliteal artery aneurysms treated surgically. *Br J Surg* 2007;94:970–7.
- Cervin A, Tjarnstrom J, Ravn H, Acosta S, Hultgren R, Welander M, et al. Treatment of popliteal aneurysm by open and endovascular surgery: a contemporary study of 592 procedures in Sweden. *Eur J Vasc Endovasc Surg* 2015;50:342–50.
- Björck M, Beiles B, Menyhei G, Thomson I, Wigger P, Venermo M, et al. Editor's Choice: contemporary treatment of popliteal artery aneurysm in eight countries: a report from the Vascunet collaboration of registries. *Eur J Vasc Endovasc Surg* 2014;47:164–71.
- Björck M, Earnshaw JJ, Acosta S, Bastos-Gocalves F, Cochenne F, Debus ES, et al. European Society for Vascular Surgery (ESVS) 2020 clinical practice guidelines on the management of acute limb ischaemia. *Eur J Vasc Endovasc Surg* 2020;59:173–218.
- Galinales EL, Dombrovskiy VY, Graham AM, Vogel TR. Endovascular versus open repair of popliteal artery aneurysms: outcomes in the US Medicare population. *Vasc Endovasc Surg* 2013;47:267–73.
- Ravn H, Wanhainen A, Björck M. Surgical technique and long-term results after popliteal artery aneurysm repair: results from 717 legs. *J Vasc Surg* 2007;46:236–43.
- Berglund J, Björck M, Elfstrom J. Long-term results of above knee femoro-popliteal bypass depend on indication for surgery and graft-material. *Eur J Vasc Endovasc Surg* 2005;29:412–8.
- Joshi D, James RL, Jones L. Endovascular versus open repair of asymptomatic popliteal artery aneurysm. *Cochrane Database Syst Rev* 2014;30:CD010149.
- Golchehr B, Zeebregts CJ, Reijnen M, Tiellu IFJ. Long-term outcome of endovascular popliteal artery aneurysm repair. *J Vasc Surg* 2018;67:1797–804.
- Moore RD, Hill AB. Open versus endovascular repair of popliteal artery aneurysms. *J Vasc Surg* 2010;51:271–6.
- Björck M, Gibbons CP, Jensen LP, Laustsen J, Lees T, Moreno-Carriles R, et al. Vascular registries join to create a common international dataset on AAA surgery. *Eur J Vasc Endovasc Surg* 2007;34:257–9.
- Behrendt CA, Venermo M, Cronenwett JL, Sedrakyan A, Beck AW, Eldrup-Jorgensen J, et al. VASCUNET, VQI and the International Consortium of Vascular Registries – unique collaborations for quality improvement in vascular surgery. *Eur J Vasc Endovasc Surg* 2019;58:1–2.
- Behrendt CA, Bertges D, Eldrup N, Beck AW, Mani K, Venermo M, et al. International Consortium of Vascular Registries consensus recommendations for peripheral revascularisation registry data collection. *Eur J Vasc Endovasc Surg* 2018;56:217–37.
- Behrendt CA, Björck M, Schwaneberg T, Debus ES, Cronenwett J, Sigvant B. Recommendations for registry data collection for treatment of acute limb ischaemia: a Delphi Consensus from the International Consortium of Vascular Registries. *Eur J Vasc Endovasc Surg* 2019;57:816–21.
- von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol* 2008;61:344–9.
- Wanhainen A, Hultgren R, Linne A, Holst J, Gottsater A, Langenskiöld M, et al. Outcome of the Swedish nationwide abdominal aortic aneurysm screening program. *Circulation* 2016;134:1141–8.
- 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.
- Johnson ON, 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.
- 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.
- Michaels JA, Galland RB. Management of asymptomatic popliteal aneurysms: the use of a Markov decision tree to determine the criteria for a conservative approach. *Eur J Vasc Surg* 1993;7:136–43.
- Bowyer RC, Cawthorn SJ, Walker WJ, Giddings AE. Conservative management of asymptomatic popliteal aneurysm. *Br J Surg* 1990;77:1132–5.
- Galland RB, Magee TR. Management of popliteal aneurysm. *Br J Surg* 2002;89:1382–5.
- Schellack J, Smith RB, Perdue GD. Nonoperative management of selected popliteal aneurysms. *Arch Surg* 1987;122:372–5.
- 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.
- Björck M, Ravn H, Nilsson TK, Wanhainen A, Nilsson PM. Blood cell telomere length among patients with an isolated popliteal artery aneurysm and those with multiple aneurysm disease. *Atherosclerosis* 2011;219:946–50.
- Lovegrove RE, Javid M, Magee TR, Galland RB. Endovascular and open approaches to non-thrombosed popliteal aneurysm repair: a meta-analysis. *Eur J Vasc Endovasc Surg* 2008;36:96–100.
- 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.
- Zhang D, Tarabochia M, Janssen SJ, Ring D, Chen N. Acute compartment syndrome in patients undergoing fasciotomy of the forearm and the leg. *Int Orthop* 2019;43:1465–72.
- Mehta M, Champagne B, Darling 3rd RC, 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.

- 31 Ravn H, Wanhainen A, Björck M. Risk of new aneurysms after surgery for popliteal artery aneurysm. *Br J Surg* 2008;**95**:571–5.
- 32 van Santvoort HC, de Vries JP, van de Mortel R, Wille J, van de Pavoordt ED. Rupture of a popliteal artery aneurysm 10 years after surgical repair. *Vascular* 2006;**14**:227–30.
- 33 Venermo M, Sprynger M, Desormais I, Björck M, Brodmann M, Cohnert T, et al. Editor's choice – follow-up of patients after revascularisation for peripheral arterial diseases: a consensus document from the European society of cardiology working group on aorta and peripheral vascular diseases and the European society for vascular surgery. *Eur J Vasc Endovasc Surg* 2019;**58**:641–53.
- 34 Lees T, Troeng T, Thomson IA, Menyhei G, Simo G, Beiles B, et al. International variations in infrainguinal bypass surgery – a VASCUNET report. *Eur J Vasc Endovasc Surg* 2012;**44**:185–92.
- 35 Beiles CB, Bourke BM. Validation of Australian data in the australasian vascular audit. *ANZ J Surg* 2014;**84**:624–7.
- 36 Altreuther M, Menyhei G. International validation of the Danish vascular registry karbase: a Vascunet report. *Eur J Vasc Endovasc Surg* 2019;**58**:609–13.
- 37 Bergqvist D, Björck M, Lees T, Menyhei G. Validation of the VASCUNET registry – pilot study. *VASA Z Gefasskrankheiten* 2014;**43**:141–4.
- 38 Eldrup N, Debus ES. International validation of the population-based Malta vascular registry: a Vascunet report. *EJVES Vasc Forum* 2020 (In press).
- 39 Venermo M, Lees T. International Vascunet validation of the Swedvasc registry. *Eur J Vasc Endovasc Surg* 2015;**50**:802–8.

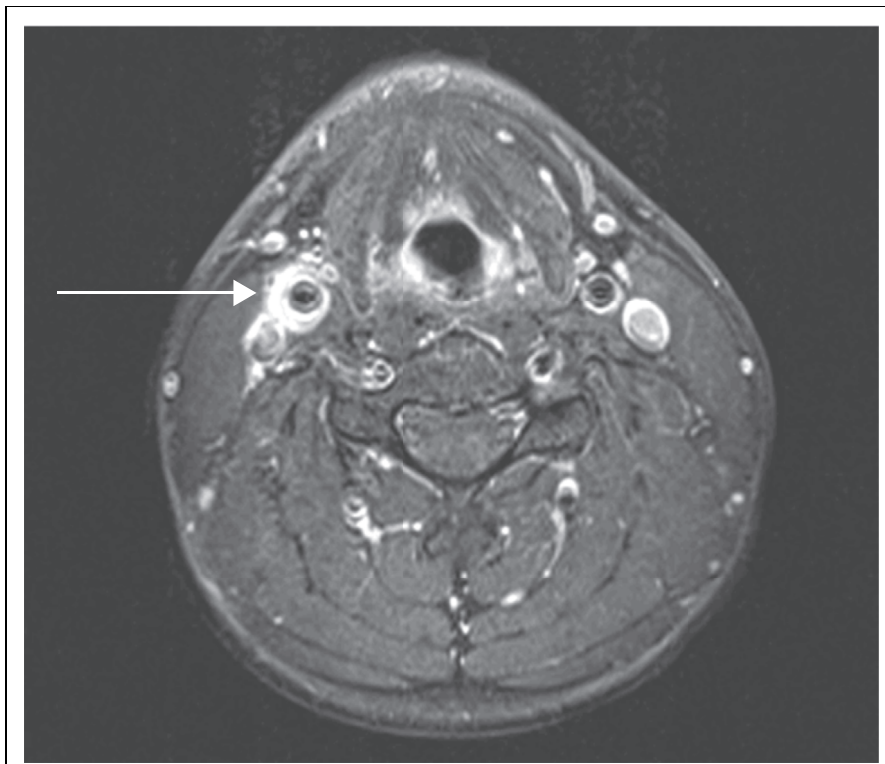
Eur J Vasc Endovasc Surg (2020) 60, 729

COUP D'OEIL

Transient Perivascular Inflammation of the Carotid Artery

Darja Kremel^{*}, Andrew Tambyraja

Edinburgh Vascular Service, Royal Infirmary of Edinburgh, Edinburgh, United Kingdom



A 31 year old, normotensive male smoker, employed as a chef, presented with acute right sided neck pain, tenderness, and frontal headache. Computed tomography angiography excluded carotid dissection. T1 weighted magnetic resonance imaging revealed unilateral eccentric perivascular infiltration of the right carotid artery with vascular wall enhancement post-gadolinium. Ultrasound demonstrated soft tissue material lining the carotid. Infection and vasculitic screens were negative. The appearances were typical of the distinct clinico-radiological entity named transient perivascular inflammation of the carotid artery syndrome, previously known as carotidynia or Fay syndrome. The patient received oral anti-coagulation and had complete symptom and radiological resolution within two months.

^{*} Corresponding author. Edinburgh Vascular Service, Royal Infirmary of Edinburgh, 51 Little France Crescent, Edinburgh, EH16 4SA, United Kingdom.

E-mail address: darja.kremel@nhs.net (Darja Kremel).

1078-5884/© 2020 European Society for Vascular Surgery. Published by Elsevier B.V. All rights reserved.

<https://doi.org/10.1016/j.ejvs.2020.06.041>