21 The Current Role of Endografting

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As a matter of fact, endovascular treatment of popliteal artery aneurysms (PAAs) has dramatically increased, during a relatively short period. This is not a uniform phenomenon; in 2014, Björck et al. [1], reviewing data (from Jan. 2009 to Jan.2013) from eight countries, found a great variability, from zero (Switzerland: 0/87 PAA repairs) to 29.5% (Sweden: 146/495) and a maximum of 34.7% (Australia: 153/441).

Cervin et al. [2], consulting the Swedish Vascular Registry, observed an almost fourfold increase of endovascular procedures (**E**) in the period 2008–2012, compared with the early period 1994–2001. Galiñanes et al. [3], studying the phenomenon through the registries of US Medicare population for the period 2005–2007, observed the increase of **E** from 11.7% to 23.6%; conversely, open procedures (**O**) decreased from 88.3% to 76.4%. Eslami et al. [4], retrieving data from 290 centers in the USA and Canada, observed the increase of **E** from 34.8% in 2010 to 47.6% in 2013.

Trying to analyze the reasons for this really impressive success of **E** is not an easy matter, given the absence of randomized trials (but for the weak attempt of Antonello et al. [5]). A scientific background for the building of statements defining if **E** is superior to **O** or at least represents an equivalent alternative to **O** is still lacking.

On the other side, many cases of PAA could be treated by endografting. Zimmermann et al. [6], reviewing their experience in the period 2000–2007, tried to define how many of the cases they treated surgically could have been managed with endovascular procedure: considering as inclusion criteria for endografting the patency of iliofemoral tract, the existence of landing zones of at least 2 cm, and the patency of at least one outflow vessel, they observed that 22 (60%) aneurysms were considered eligible for endografting, two (5%) relatively eligible (but with complete sac thrombosis), and only 13 (35%) inappropriate.

No doubt that **E**, owing to its truly reduced invasivity, is frankly attractive. With the refinements of the profile of devices, most cases may be treated percutaneously, relying on local anesthesia. General anesthesia is still reported in some experiences, ranging from 10–20% of the

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Table 21.1 Comparison of mean in-hospital stay (days) between open (O) and endovascular (E) procedures

Author	Study period	O	E
Pulli [15]	Jan. 2000 to Dec. 2011	10.4	4.4
Stone [16]	2001–2011	7.3[a]	3.4[a]
		14.0[b]	5.0[b]
[c]Galinanes [3]	2005–2007	4	1
Huang [17]	Jan. 2005 to June 2012	4.2[a]	1.9[a]
[c]Eslami [4]	2010–2013	3.8	1.4
[c]Von Stumm [18]	Jan. 1994 to Nov. 2014	7.3	3.5
Leake [19]	2006–2014	5.8	1.6
		4.6[a]	1.3[a]
Wooster [20]	1999–2013	12	2

[a]Only elective cases
[b]Only urgent cases
[c]Review, non-original data

cases [7, 8] to about 50% [9], but local anesthesia was used in the totality of cases of several series [10–14].

Reduced in-hospital stay is another immediately apparent (and statistically significant) advantage of **E** (Table 21.1).

21.1 Review and Meta-analysis of the Results of Endografting Treatment of PAAs

From 2007, several papers appeared in the literature attempting to compare the global results of endovascular and open surgical treatments of PAAs and to define what should be considered the gold standard. They relied on the available published data as well as on dedicated registries and Medicare database. The search for this El Dorado is still ongoing and will probably remain fruitless until the concept of gold standard does not undergo a more realistic configuration (Tables 21.2 and 21.3).

Some papers offer an approximative survey and a rough evaluation of the problem, without an adequate statistical evidence; however, being based on large numbers (keeping into account the rarity of the disease), they may be orientative, putting into evidence how difficult it is to enunciate precise statements in this field.

More scientific papers attempt to perform a meta-analysis with final statistical strength, but this obliges to include into the study a low number of reports and consequently a number of cases that may be nonrepresentative of the patients effectively treated in daily practice in a certain period of time.

Almost all the papers end with the auspice for a randomized trial, but we all are knowledgeable about the difficulties of such a project, given the relative rarity of PAA. Up to now, only one randomized trial is available, the one launched by Antonello et al. [5], but it was transformed into a prospective comparative study.

In any case, it is highly interesting to follow the evolution of opinions about PAA endografting and the conclusions to which the various authors arrived after a certainly painstaking (and sometime ambitious) survey and analysis of a large amount of nonhomogeneous data.

In 2010, the Journal of Vascular Surgery published a debate between R.D. Moore and A.B. Hill [43] regarding the definition of the gold standard in the treatment of PAA. Each of them accomplished earnestly the respective task, Moore in favor of open surgery and Hill in favor of endovascular repair, but reading between the lines, the impression is that a firm belief was lacking. Hill stressed the concept that surgery for asymptomatic aneurysm is truly prophylactic and that, consequently, the surgical risk should be minimum; elective patients are mostly older males with comorbidities and often associated aneurysms, and open surgery requires multiple or long incisions with the risk of wound complications, leg edema, prolonged hospital stay, and slow return to normal. Endovascular repair offers comparable patency rates without the associated local and/or systemic complications. What emerged from the debate as well as from the commentary of the section editor, T.L. Forbes [44], is that the surgical gold standard is ill defined, as different procedures are part of the open treatment.

But, moreover, we believe that the concept of gold standard should be modified, as we take care of patients and not simply of a disease. As a consequence, maybe, it would be better to speak of best option that should be tailored according to

Table 21.2 Summary of original studies comparing the results of E with O (for the characteristics of each study, see Table 19.1)

2007, Curi et al. [21]: **E** 15 and **O** 41						
Comorbidities similar in the two groups; however, **E** patients were older; more symptomatic cases in **O**; and all urgent cases in **O**						
A: *Results at 24-month follow-up*						
	E	**O**				
Primary patency	83%	88%				
Secondary patency	100%	92%				
Survival	90%	90%				
2007, Antonello et al. [22]: **E** 21 and **O** 27 (during the study period, 38.3% of all the observed cases were not included into the study)						
B: *Results up to 72-month follow-up*						
	E			**O**		
	12 months	**36 months**	**72 months**	**12 months**	**36 months**	**72 months**
Primary patency (%)	80.9	71.4	71.4	100	94.4	88.1
Secondary patency (%)	90.5	85.7	85.7	100	94.4	88.1
2012, Pulli et al. [23]: **E** 21 and **O** 43						
Main differences between the two groups: **E**, more asymptomatic cases (25% vs. 48%); **E**, less cases with <2 runoff vessels (20% vs. 44%); **E**, less cases requiring pre-op thrombolysis (9.5% vs. 30.2%); and **E**, 20 cases Hemobahn/Viabahn and one case multilayer Cardiatis						
C: *Results at 24 months*						
	E	**O**				
Mortality	1(4.7%)	0				
Thrombosis	3 (14.2%)	2 (4.5%)				
Amputation	1 (4.7%)	2 (4.5%)				
Reinterventions	4 (19%)	2 (4.5%)				
Primary patency	59.4%	78.1%				
Secondary patency	78.4%	81.6%				
Freedom from reinterv.	61.5%	79%				
Freedom from amputat.	95%	92.7%				
Note: These results were successively included into a larger multicenter study [15]						
2013, Stone et al. [16]: **E** 23 and **O** 64						
E patients significantly older. Cases of acute limb ischemia more frequent in **O** (28% vs. 16.6%). Early complication related to procedure: **O** eight wound infections and **E** one hematoma						
D: *Primary patency rates (%)*						
E			**O**			
1 year	**2 years**	**3 years**	**1 year**	**2 years**	**3 years**	
92.9	72.3	63.7	83.3	77.8	77.8	

(continued)

Table 21.2 (continued)

2007, Curi et al. [18]: **E** 15 and **O** 41						
2013, Pulli et al. [15]: **E** 134 and **O** 178						
E patients were older. **O** patients were significantly worse for clinical presentation (asymptomatic cases 35.5% vs. 71%) and runoff (<2 vessels 37.5% vs. 23%)						
E: *Results up to 48 months (%)*						
	E			**O**		
	12 mo.	**24 mo.**	**48 mo.**	**12 mo.**	**24 mo.**	**48 mo.**
Primary patency	79.1	76.9	73.4	78.8	77.1	63.4*
Secondary patency	90.8	85.5	85	84.7	82.7	76.5
Freedom from reintervention	80.6	77.2	75	87	86.1	72.5
Limb salvage	98.1	96.9	96.9	94.3	92.6	89.7
*Four-year primary patency was significantly better for autologous vein (86.3%) than for synthetic graft (56.3%). In the O group, vein was used in 66 cases (37%)						
2014, Huang et al. [17]: **E** 42 and **O** 107						
E patients were significantly older and had more cardiac comorbidities, and acute presentation was more frequent (12/42 vs. 15/107)						
F: *Results at 30 days*						
	E			**O**		
	Elective	**Emergent**	**Overall**	**Elective**	**Emergent**	**Overall**
Mortality	0/32	2/10	2/42	1/93	0/14	1/107
Wound compl.	1/32	2/10	3/42	19/93	5/14	24/107
Thrombosis	0/32	3/10	3/42	1/93	0/14	1/107
Reintervention	1/32	4/10	5/42	1/93	3/14	4/107
Amputation	0	2/10	2/42	0	0	0
G: *Results at 1 and 3 years (%)*						
	E		**O**			
	1 year	**3 years**	**1 year**	**3 years**		
Prim. patency elective	87	75	90	85		
Prim. patency emergent	54	54	86	77		
Second. patency elective	97	83	94	93		
Second. patency emergent	79	79	93	84		
Freedom from reinterv. elect.	84	72	91	88		
Freedom from reinterv. emerg.	48	48	57	57		
2015, Ronchey et al. [8]: **E** 25, **O** (vein) 28, and **O** (PTFE) 14						
H: *Results at 5-year follow-up (but, at 40 months, E were only two)*						
E	Primary patency 71%	Secondary patency 88%				

O (vein)	Primary patency 81%	Secondary patency 85%						
O (PTFE)	Primary patency 69%	Secondary patency 84%						
2015, Serrano-Hernando et al. [13]: **E** 32 and **O** 139								
Trend to be older in **E** patients, also higher incidence of diabetes and chronic renal failure in **E**, more asymptomatic cases in **E** (23/32 vs. 68/139, near significant) Median follow-up: **E** 22 months and **O** 49 months (26 patients lost during the first year)								
I: *Results up to a 2-year follow-up: patency (%)*								
	6 months		**12 months**		**18 months**		**24 months**	
	Primary	**Secondary**	**Primary**	**Secondary**	**Primary**	**Secondary**	**Primary**	**Secondary**
E	83.8	89.8	79.7	89.3	79.7	88.7	79.7	88.3
O (vein)	99.3	100	94.9	100	94.9	100	94.9	100
O (PTFE)	83.3	93.3	83.3	93.3	83.3	93.3	79.0	80.3
2016, Leake et al. [19]: **E** 76 and **O** 110								
O patients were significantly worse for acute ischemia, rest pain, aneurysm thrombosis, and runoff score Early complications much more frequent in **O** (10% incision breakdown and infection, 5.5% bleeding) than in **E** (one hematoma). No differences in reinterventions (**E** 9.2%, **O** 3.6%) and amputations (**E** 1.3%, **O** 3.6%)								
J: *Results at 1 and 3 years*								
	E			**O**				
	1 year	**3 years**		**1 year**	**3 years**			
Primary patency	88.8%	73.2%		89.1%	79.5%			
Primary patency (elective)	89%	69.8%		96.7%	88.3%			
Secondary patency	95.4%	83%		92.1%	85%			
Secondary patency (elective)	94.8%	82%		96.7%	90.2%			
2016, Wooster et al. [20]: **E** 25 (20 Viabahn, 5 Wallgraft) and **O** 52 (aut. vein 36, PTFE 16)								
E patients much older (82 ± 9.5 vs. 69.9 ± 6.8). **E** failures were preferentially converted to surgery; this does not allow a realistic comparison between the two groups								
K: *Results of the study*								
	E	**O**						
Amputation	1	2						
Early complications	2	9 (6 superf. infections)						
Primary patency 1 year	<70%	>80%						
Primary patency 4 years	<70%	<70%						
Secondary patency 1 year	<70%	90%						
Secondary patency 4 years	<70%	<80%						
Freedom from reinterv. 1 year	65%	80%						
Freedom from reinterv. 4 years	≈50%	50%						

Hemobahn/Viabahn stent grafts are, almost always, the devices used in original comparative studies

Table 21.3 Review and meta-analysis of the results of endografting treatment of PAAs

2007, Kropman et al. [24]: Review of the English language literature in Jan. 1990–Dec. 2006. **O** 1711 cases and **E** 176 cases

Early (30 days) complications (percentage from 31 series)

	O	**E**				
Mortality	2.0	1.3				
Amputation	3.2	0				
Occlusion	3.5	3.6				
Wound infection	4.7	0				
Foot drop	1.3	0				
Deep vein thrombosis	1.6	0				
Hematoma	3.4	0.5				
Endoleak	--	4.5				

Primary patency, secondary patency, and limb salvage (%)

	1 year		**3 years**		**5 years**	
	O	**E**	**O**	**E**	**O**	**E**
Primary pat.	72–100 (16)	47–89 (8)	71–95 (13)	72–75 (2)	66–85 (11)	72 (1)
Second. pat.	91–100 (7)	75–100 (6)	75–94 (6)	77–100 (3)	84–94 (5)	77 (1)
Limb salvage	93–100 (17)	100 (6)	88–100 (12)	100 (2)	86–99 (11)	100 (1)

Note: In brackets, the number of series from which the data are retrieved. The 5-year data for E derive from the study of Tielliu et al. [25]

Conclusion of the authors: *Both intervention modalities have acceptable early results, 1-year patency rates and limb salvage rates. Endovascular treatment lacks long-term follow-up…. More randomized studies comparing both intervention modalities are needed*

2008, Lovegrove et al. [26]: Meta-analysis for non-thrombosed PAAs; review up to July 31, 2007. Only three studies [5, 21, 27] were included for a total of 104 **O** and 37 **E** (5 Wallgraft, 32 Viabahn). The resulting two cohorts were comparable for gender, age, aneurysm size, clinical presentation, bilaterality, smoking state, diabetes, and hypertension. **E** presented significantly reduced in-hospital stay and significantly higher incidence of 30-day thrombosis and reinterventions; medium-term patency was similar in the two groups

Conclusion of the authors: *With the technology currently available, it is difficult to justify endovascular repair for patent popliteal aneurysms*

2010, Cinà [28]: Meta-analysis on papers published in 1994 to June 2009. The analysis was made on four studies [5, 21, 22, 27] (of which, three already analyzed by Lovegrove et al. [26]), for a total of 116 **O** and 43 **E** (5 Wallgraft, 38 Viabahn)

Primary and secondary patencies at 1 year and 3 years

	1 year		**3 years**			
	O	**E**	**O**	**E**		
Primary patency	99/116–85.3%	36/43–83.7%	60/75–80%	22/28–78.5%		
Secondary patency	110/116–94.8%	37/43–86%	69/75–92%	25/28–89.8%		

No difference between the two groups; 1-year secondary patency better for **O**, but not significantly. Coincidentally, the author calculated the cumulative patency of 320 cases of PAA endografting from 31 series: 30-day patency was 94%, primary patency was 83% at 1 year and 74% at 3 years, and secondary patency was 86% at 1 year and 85% at 3 years

Author's conclusions: *Endovascular repair, in the presence of suitable anatomy and good tibial runoff, is feasible and safe with midterm results that are clinically acceptable and probably not different from open repair*

2013, Galiñanes et al. [3]: The study, already summarized in 2011 [29], was performed on US Medicare population, searching the cases with popliteal aneurysm repair in people over 65, evaluated for mortality, morbidity, readmissions, and reinterventions, for the period 2005–2007. **O** were 2513 and **E** 549. E comprised a higher percentage of over 85 (106/549, 19.3%, vs. 247/2513, 10.2%). More cardiac, respiratory, and infectious complications were observed in **O**. Reinterventions were significantly more frequent in **E** (7.42% vs. 2.11% at 30 days; 11.84% vs. 4.55% at 90 days). The total cost for **E**, in spite of an initial significantly lower in-hospital stay, was about 160% of the cost of **O**, due to the higher need for diagnostic and operative procedures within 90 days from the first treatment

The authors recognized that **E** patients were older and probably presented an increase in comorbidities and a poorer overall health but concluded that ..*the open approach appeared to convey greater durability and greater fiscal benefit than that of endovascular approach*

(continued)

Table 21.3 (continued)

2007, Kropman et al. [24]: Review of the English language literature in Jan. 1990–Dec. 2006. **O** 1711 cases and **E** 176 cases						
2013, Tsilimparis et al. [30]: Review of the literature of 25 years, including all reports with more than five cases treated for PAA. The authors collected 3815 **O** and 267 **E**						
Early complications (within 30 days)						
	O	**E**				
Cardiac	39/1670 (2%)	1/42 (2%)				
Respiratory	14/845 (2%)	–				
Wound infection	50/1411 (4%)	0/90				
Thrombosis	116/2201 (5%)	22/196 (11%)				
Major amputation	105/2855 (4%)	0/237				
Mortality	60/2138 (2%)	1/237 (0.4%)				
Endoleak	–	9/165 (5%)				
Late outcome (>30 days)						
	O	**E**				
Endoleak	49/524 (9%)	17/265 (7%)				
Aneurysm growth	55/784 (7%)	2/65 (3%)				
Primary assisted patency 1 year	627/719 (87%)	125/169 (74%)				
Primary assisted patency 3 years	507/585 (86%)	159/195 (87%)				
Secondary patency 1 year	760/845 (90%)	111/167 (87%)				
Secondary patency 3 years	636/785 (81%)	87/102 (85%)				
Amputation 1 year	163/2227 (7%)	1/42 (2%)				
Amputation 3 years	62/1429 (4%)	3/90 (3%)				
Authors' conclusions: *Open surgical repair of PAA remains the gold standard, although endovascular repair is being performed more commonly with acceptable results*						
2015, Von Stumm et al. [18]: Review of studies from Jan. 1994 to Nov. 2014, English and German languages. Meta-analysis based on five studies [17, 21–23, 27] for a total of 652 PAA repairs in 597 patients: **O** 416 and **E** 236 **E** patients were significantly older and had fewer symptoms; however, emergency cases and poor runoff cases were similar in the two groups. Significant differences in the 30-days outcome were observed in favor of **O**: thrombosis 7/302, 2.5%, vs. 17/191, 9%; reinterventions 14/302, 4%, vs. 18/191, 9%. The 4-year cumulative patency rate ranged 63–88% for **O** and 54–86% for **E**. At the complete follow-up of the five studies (mean 33 months, range 1–156), the analysis of hazard ratios did not show any significant difference in the risk of graft thrombosis but only a slightly reduced patency for **E** Authors' conclusions: …*Endovascular aneurysm repair may be a safe and efficient therapeutic method for PAAs with suitable anatomy…. Midterm primary patency rates did not differ between OSR* (open surgical repair) *and EVR* (endovascular repair)*, but 30 day reintervention and thrombosis rates following EVR were greater than OSR. Currently, the quality evidence for EVR is low….*						
2015, Patel et al. [31]: Review of the English language literature in 1996–2010, reports with at least ten cases. The final review included nine retrospective case series [11, 13, 32–38], four retrospective comparative studies [15–17, 21], and one randomized study [5]. Primary patency of 514 **E** was 95% at 30 days, 85.3% at 1 year, and 69.4% at 5 years. These results, at the authors' analysis, were not significantly different from those of **O**. No sufficient data were found to compare secondary patency between **O** and **E**: for the latter procedure, secondary patency was 96% at 30 days, 90.8% at 1 year, and 77.4% at 5 years. Based on six studies [11, 13, 15, 17, 33, 36], 4.3%–40% of E patients underwent reoperation after 7–54 months from the initial procedure. Authors' conclusions: *Endovascular popliteal aneurysm repair should be considered selectively… on a case by case basis and particularly in patients at high surgical risk… or those well informed patients who elect to proceed with stent-graft repair in spite of the available weak evidence*						

(continued)

Table 21.3 (continued)

2007, Kropman et al. [24]: Review of the English language literature in Jan. 1990–Dec. 2006. **O** 1711 cases and **E** 176 cases

2015, Eslami et al. [4]: The database of 290 centers in the USA and Canada participating to the Vascular Quality Initiative [39] was interrogated for the period 2010–2013 on the treatment and results for asymptomatic PAAs. 221 **O** and 169 **E** were available.
O patients were younger, with a larger number of nonsmokers and less comorbidities. While the one-year patency rate was similar between the two groups (**O** 95.9%, **E** 92.3%), **O** fared significantly better for major adverse limb events and survival and loss of primary patency
Authors' conclusion: *Open repair should be preferentially offered to patients who can tolerate either therapeutic option*

2015, Cervin et al. [2]: Study from the Swedish Vascular Registry in 2008–2012. 473 **O** and 95 **E**

Results (%) of O and E procedures, according to the type of clinical presentation

	O			**E**		
	AI	**ES**	**EA**	**AI**	**ES**	**EA**
Number	138	90	245	27	13	55
Prim. patency 30 days	**88.3**	93.2	95.1	**63**	77	94.3
Second. pat. 30 days	**93.1**	94.4	98.8	**70.4**	92.3	94.5
Amputation 30 days	3.7	3.3	0	14.8	0	1.8
Death 30 days	1.4	0	0	3.7	0	0
Amp.-free surviv. 30 days	94.8	96.7	100	85.1	100	98.1
Prim. patency 1 year	**78.8**	81.1	**89**	**42.9**	57.1	**67.4**
Second. pat. 1 year	**86.8**	86.5	93.5	**47.6**	85.7	83.7
Amputation 1 year	6.8	8.6	0.9	17.4	0	2
Death 1 year	4.5	5.6	1.2	14.8	7.8	5.4
Amp.-free surviv. 1 year	89.3	88	97.8	76	100	92.3

Numbers in bold indicate statistically significant difference with p-value 0.001 or less. AI, acute ischemia; ES, elective symptomatic; *EA* elective asymptomatic
There was no statistically significant difference between **O** and **E** cohorts for each type of clinical category considered, but for the asymptomatic cohort, in which age was significantly higher in **E** and in the same subgroup, cardiac comorbidities were more frequent.
Authors' conclusions: *All the numerical trends disfavor endovascular repair…. The study shows a clinically important difference in outcome, favoring open repair…. The magnitude of difference in outcome, in particular among those treated for acute ischemia,… puts in question the use of endovascular repair for PA outside trials*

2016, Shahin et al. [40]**:** Performed a meta-analysis of a total of 4654 **O** and 1287 **E**. Operative time was shorter for **E**. Length of hospital stay was significantly shorter after **E**. As for 30-day outcome, graft occlusion was three times more frequent in **E,** and the reintervention rate was significantly higher after **E**. The primary patency rate at 12 months was significantly better for **O**, while no difference was evident in secondary patency rates
Authors' conclusion: *Endovascular repair of PAAs should be limited to a selected group of patients who are elderly with multiple comorbidities who are considered high risk for open surgery. The increased postoperative complications after endovascular repair prevent it from being used over open repair as a first line treatment for PAAs*

2017, Leake et al. [41]: Performed a meta-analysis (the largest up to now) on 14 studies of which nine were retrospective single center [8, 16, 17, 19–21, 23, 27, 42], one retrospective multicenter [15], and one prospective partially randomized [22]; the other three were based on data from USA Medicare [3], Vascular Quality Initiative [4], and Swedish Vascular Registry [2], for a total of 3915 **O** and 1210 **E**.
O patients were significantly younger and presented a worse tibial runoff
The incidence of 30-day complications was similar in the two groups: However, **O** had a significantly higher number of wound complications, while **E** had a significantly higher number of thrombotic events. There was no difference in mortality and limb loss. Significant differences were observed for in-hospital stay (in favor of **E**) and reinterventions (in favor of **O**). The analysis of primary and secondary patencies showed that **O** had a significantly lower risk of losing primary patency up to 3 years; the difference in secondary patency was only marginally in favor of **O**

(continued)

Table 21.3 (continued)

2007, Kropman et al. [24]: Review of the English language literature in Jan. 1990–Dec. 2006. **O** 1711 cases and **E** 176 cases

Primary and secondary patency rates (%)

	O		**E**			
	1 year	**3 years**	**1 year**	**3 years**		
Primary patency	88.3	79.4	81.2	68.2		
Secondary patency	92.3	86.6	86.3	80.0		

Authors' conclusion: *Endovascular repair for PAA has a lower wound complication rate and shorter length of hospital stay compared with open repair. This comes at the cost of an inferior primary patency but not secondary patency out to 3 years. Studies reporting long-term outcomes are lacking and necessary*

the clinical judgment. This may apparently render more difficult the attempts to classify patients in order to draw statistical data on which statements may be built up. However, this is really the situation: great variability of patients, of clinical presentations, and of anatomical details. And as the ideal surgical procedure is not exactly defined, the ideal stent graft is still wanted, in spite of the largely acceptable results of the currently available devices.

In 2014, Hogendoorn et al. [45], in a collaborative USA-Netherlands study, tried to use a Markov decision model[1] to define the best treatment for asymptomatic PAAs. They performed an extensive literature review in 1991–2013 and selected 35 papers [5, 11, 14, 21–25, 27–30, 33, 34, 38, 46–64]. The results of their investigation and analysis are summarized in Table 21.4.

Thirty-day mortality was 1.4% for open repair with autologous vein and 0.4% for endografting. The amputation rate (%) was four/year for open repair with autologous vein, three/year for endografting, and 30/year for patients treated medically. The cost of the procedure (including reinterventions, amputations, rehabilitation) was about double for endovascular treatment compared with open repair with autologous vein.

The authors concluded that open repair with autologous vein remains the best option and that the results of PTFE are worse than those of endografting. As a consequence, endovascular repair looks as the best option in high-risk patients and when an autologous vein is not available. Very elderly patients (>95) and those with a life expectancy of <1.5 years should be managed by optimal medical treatment (OMT).

Leake et al. [41] at the end of their meta-analysis (see above) propose an algorithm, which can be summarized as follows:

- Acute ischemia (no rupture) with immediate limb threatening: emergent surgical repair
- Acute ischemia with viable or marginally threatened limb: catheter-directed thrombolysis
- If successful thrombolysis or claudication or compression symptoms or asymptomatic (if diameter is > 20 mm or lumen >50% thrombus): study of PAA anatomy, of eventual landing zones, and of tibial runoff
- If anatomy is not suitable for endovascular repair: proceed with open repair
- If anatomy is suitable for endovascular repair: high-risk patients, prefer endovascular; lack of autologous vein, consider endovascular as a good alternative; and low-risk patients, consider equivocal both for open and endovascular

All the acquired experience and the current knowledge do not allow to define precisely the role of endografting: this procedure, anyway, has gained favor on the basis of the acceptable results and the reduced invasivity, especially if the frequent postoperative local complications of open procedures are considered.

From this point of view, endografting looks particularly attractive in the emergency setting,

[1]A.A. Markov (1856–1922) was a Russian mathematician. The Markov process is used for decision-making in situations where outcomes are partly random and partly under the control of a decision-maker.

Table 21.4 Synthesis of the results of the study of Hogendoorn et al. [45]

	1 year	2 years	3 years	4 years	5 years
Primary aut. vein	89	86	85	82	80
Secondary aut. vein	98	95	94	92	90
Primary PTFE	77	67	58	54	50
Secondary PTFE	84	78	71	66	63
Primary endovasc.	87	82	77	74	70
Secondary endovasc.	90	88	85	81	77
OMT	76	50	41	35	32

Numbers express the patency percentage. For optimal medical treatment (OMT), numbers express the percentage of cases remaining asymptomatic

Table 21.5 Reports on endovascular treatment of PAAs: cases of emergent procedure

Author, year	Emergent	Total	%
Gieskes [65], 1995	1	3	33
Spoelstra [66], 1996	6	11	55
De Blas [67], 1999	2	2	100
Laganà [10], 2006	5	15	33
Tielliu [38], 2010	6	78	8
Etezadi [34], 2010	1	18	6
Ascher [68], 2010	1	15	7
Pulli [23], 2012	3	18	17
Stone [16], 2013	3	24	12
Pulli [15], 2013	10	134	7
Saunders [42], 2014	5	34	15
Huang [17], 2014	12	42	29
Wissgott [69], 2014	1	10	10
Cervin [2], 2015	27	95	28
Ronchey [8], 2015	4	25	16
Borges Domingues [70], 2015	6	18	33
Leake [19], 2016	7	76	9

Table 21.6 Comparison of the results of open and endovascular treatments of PAAs presenting with acute limb ischemia from thrombosis/embolism, from the Swedish Vascular Registry [2]

	Open	Endovascular
Number of cases	138	27
Percentage of total cases	24% (138/573)	28% (27/95)
Preoperative thrombolysis	61% (84/138)	78% (21/27)
Improvement with thrombolysis	86% (72/84)	90% (19/21)
30 days primary patency	**88.3% (113/128)**	**63% (17/27)**
30 days secondary patency	**93.1% (122/131)**	**70.4% (19/27)**
1 year primary patency	**78.8% (89/113)**	**42.9% (9/21)**
1 year secondary patency	**86.8% (99/114)**	**47.6 (10/21)**
1 year amputat.-free survival	89.3% (109/122)	76% (19/25)

In bold, differences with *p*-value 0.001 or less

i.e., in patients with acute ischemia from thrombosis/embolism: to avoid surgical aggression and dissection on tissues damaged from ischemia would add an important meaning to the concept of reduced invasivity. Already in earlier experiences [65–67], the possibility of achieving satisfactory results was ascertained. However, on a whole, experience is still limited, and comparisons between elective and emergent endovascular procedures and between emergent open and endovascular procedures are scanty. In the different reports on endografting of PAAs, the percentage of emergent procedures varies greatly (Table 21.5).

Trinidad-Hernandez et al. [36], from the Mayo Clinic, compared the results of elective (19 cases) and emergent (12 cases, including one case of rupture) endografting procedures, observing that, at 1-year follow-up, the primary patency rate was in favor of elective procedures (95% vs. 69%) but the secondary patency was similar in the two groups (100% vs. 91%).

Cervin et al. [2] compared the outcomes of open and endovascular procedures in cases of acute ischemia as clinical presentation: the experience, from the Swedish Vascular Registry in May 2008–May 2014, is illustrated in Table 21.6. A similar comparison was performed on the results obtained at the Mayo Clinic during the period Jan 1, 2005 to Jan 30, 2012 by Huang et al. [17] (Table 21.7).

Table 21.7 Comparison of the results of open and endovascular treatments of PAAs presenting with acute limb ischemia from thrombosis/embolism, from Huang et al. [17]

	Open	Endovascular
Number of cases	14	12
Percentage of the whole experience	13 (14/107)	29 (12/42)
30 days mortality	0	2
30 days occlusion	0	3
30 days amputation	0	2
Mean follow-up	3.8 years	2.6 years
Freedom from major adverse events	50%	40%
3 years primary patency	77%	54%
3 years secondary patency	84%	79%
3 years freedom from reintervent.	57%	48%

While the data from the Swedish Vascular Registry are clearly not in favor of the endovascular treatment of PAAs presenting with acute limb ischemia, those offered by the Mayo Clinic, albeit relative to a smaller number of cases (but certainly deriving from more homogeneous sources), appear quite acceptable, especially if one considers the fact that endografted patients were older (for about 10 years) than those treated with open surgery and had more frequent cardiac comorbidities. Consequently, adjunctive experience with endovascular treatment of patients presenting with acute limb ischemia appears fully justified.

In general, we believe that the clinical judgment, case by case, should rule the choice of the therapeutic option and that patients should be objectively informed about the pros and cons of each type of procedure. Also, the centers with large experience in endografting should continue their research work and collaborate with other industries for further improvement of the devices.

It is evident, in facts, that even the more widely used device, the Viabahn stent graft, is not yet the ideal for popliteal artery endografting and that its behavior is not fully clarified; e.g., the incidence and significance of stent fracture are still obscure. The Gröningen group [38] performed a very careful follow-up (1–137 months, mean 50 months) on 78 endografting procedures in 64 patients. X-ray of the knee (fully extended in the anteroposterior projection, fully extended and 90° flexed in the lateral projection) was used to investigate the presence of circumferential stent fractures. One stent fracture was observed when only one stent graft was used (21 cases), and 14 fractures (in 12 procedures) were observed when two or more devices had been used (57 cases). The location of fracture was mainly related to one of the borders of the overlapping zone (93.3%) and to the major hinge point of the PA, the adductor tubercle (73.3%). Stent fracture was significantly more frequent in younger individuals; the cumulative primary patency rate was not different between fractured and non-fractured stent grafts. The authors observed that stent-graft fractures are probably more frequent than reported in the literature and that the availability of longer and/or tapered devices would reduce the need for more than one stent graft in each procedure and avoid placement of overlapping at the hinge point.

The endovascular procedures have certainly gained an important place in the treatment of PAAs; however, the high incidence of early reinterventions and the lack of adequate long-term follow-up still represent an obstacle for a more extensive use. On the other side, it is to be kept in mind that the criteria of high surgical risk and lack of autologous vein are sometimes overused and are at risk of being misused. In effect, most of the surgical procedures for PAA treatment may be performed in locoregional or spinal anesthesia, and a segment of autologous vein (greater saphenous, lesser saphenous, basilic, cephalic) long enough to perform an inlay or interposition grafting at the popliteal level may be found in most individuals, and also synthetic grafts, in this type of procedure, fare satisfactorily.

Is this personal way of thinking modifiable by recent updates on this debated topics?

The Gröningen group [71] published, quite recently, the complete results of the entire experience from June 1998 to November 2014, relying on 75 cases (64 patients) treated with the Hemobahn/Viabahn stent graft. What emerges, at a first glance, is that no limb was lost, even in complicated procedures. Strength to this paper is added by the fact that it represents the continuing experience of a dedicated single center, pioneer in this field. At a second glance, only 11 cases (15%) were symptomatic: of these, only four (5.3% of the total) required treatment in the urgent setting. Morphological characteristics rendering suitable the endografting (adequate length of landing zones and eventual mismatch between them not superior to 3 mm) and patency of at least one outflow vessel were the fundamental prerequisites to discuss the endovascular option with the patient. The follow-up ranged 1–157 months (median 58), and only two patients were lost (in the mid- and long-term, respectively). Primary patency was 84%, 60%, and 51% at 1, 5, and 10 years; secondary patency was slightly superior (89%, 71%, and 60%). The reintervention-free survival was 93% at 1 year and 79% at 5 and 10 years. Occlusion affected 25 grafts during the follow-up: of these, 14 (52%) presented only mild claudication and were managed conservatively; acute ischemia characterized the other 11 cases, the limb was saved always, and only in three cases, on a whole, conversion to open surgery was required. No risk factor was identified as a predictor of occlusion. Regarding the complications inherent to the stent-graft design and structure, stent fractures occurred in 21 cases (28%), all diagnosed in the long term (after a median follow-up of >5 years); most fractures (62%) occurred in the overlapping zone, and in one-third of the cases, the graft occluded (no difference vs. occlusion in non-fractured stents), causing acute ischemia only in one case. So, if stent fracture may occur more frequently when using multiple stent grafts or in younger and active subjects, the significance of this adverse behavior of the device remains undefined. Worth of consideration is the fact that few cases were added, in this study, to the preceding report [38], but the continuing, extended, and meticulous follow-up is certainly important. The authors' conclusion is that a better design of the stent graft is required to properly define the role of endografting in the treatment of PAA.

The report from Gröningen confirms that endografting may be a reliable procedure but that parameters to define it a first-choice treatment are lacking; a moderate caution emerges from the discussion and the conclusions.

A more precise word of caution derives from Maraglino et al. [72] after reviewing their experiences in 2006–2014: 65 cases in 57 patients, albeit with a shorter follow-up (35 +/− 25 months and six patients lost) and a different composition of the cohort (60% asymptomatic, 8% ruptured, 20% acute ischemia). At 5 years, primary patency was 57%, secondary patency was 73%, and eight limbs were amputated (four for massive irreversible ischemia at presentation). Predictor of loss of patency was poor runoff and symptoms at presentation. The authors suggested that the role of endografting is not yet clarified and that open repair should be offered as the first option to symptomatic or poor runoff cases.

On a whole, we may say that endografting of PAA, through the years, has found a place; it may allow, in general, acceptable results and brilliant solutions in acute [73] and difficult cases [74]. However, its currently principal advantages (relatively reduce invasivity, avoidance of incisions and dissection in the knee region, clearly reduced in-hospital stay) do not allow to support a preferential use with respect to open surgery.

Del Tatto et al. [75] tried to compare the results of 103 open and 50 endovascular procedures: the series was continuous in 2004–2016 for open repair and 2010–2016 for endografting, and the choice between the two types of treatment was made on the basis of clinical presentation and preoperative morphological assessment. Five-year primary and secondary patencies were, respectively, 77.8% and 92% for open repair and 29.5% and 79.6% for endografting. The 5-year limb salvage was practically identical in the two groups: open repair 89.5% and endografting 87.9%. These results witness the frequent requirement of reintervention after endografting and allow the conclusion that the introduction of endografting did not change the results of treatment of PAA.

On the other side, we are probably only in the dawn of a full knowledge about the effects of environmental forces on the popliteal artery. Available data are poorly homogeneous and may be rather confusing, when considered in their complex [76]; e.g., the exact role of the multiple small branches tethering the popliteal artery to the surrounding tissues, observed by MacTaggart et al. [77], remains to be clarified. Poulson et al. [78] studied 28 femoropopliteal arteries in 14 lightly embalmed cadavers, using limb perfusion and endovascular markers; the limbs were studied with the knee at 180° (standing), 110° (walking), 90° (sitting), and 60° (gardening). They observed that axial compression and bending were particularly evident in the popliteal artery; these morphological changes looked of the same type but more severe than previously demonstrated and could be an effective aid in the construction of improved devices [79, 80].

So, much work is to be made to approach the ideal endovascular device and, consequently, for considering endografting as the preferential option to treat PAA (or, at least, a significant percentage of them).

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