Treatment with Reestablishment of Circulation

15

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Albeit really successful for avoiding gangrene and maintaining an acceptable limb viability, the operative treatment relying only on collateral circulation to avoid limb loss was not entirely satisfactory. Julian et al. [1], in 1955, observed that "even though apparent freedom from gangrene is obtained…the patient is left with a less than normal circulatory system and a significant occurrence of such symptoms as intermittent claudication may be expected."

The availability of heparin and of improved surgical tools and suture materials, together with the development of homologous and synthetic arterial substitutes, favored the tremendous advancements in arterial reconstructive surgery. The first steps were characterized by ingenuity and audacity, and we are indebted to the surgeons, who, with their clinical experimentation, undoubtedly opened the route.

In 1940, relying on the effective anticoagulant action of heparin, Murray [2], in Toronto, resected a popliteal aneurysm and reestablished the circulation with an interposition graft of external giugular vein (Fig. 15.1); the vein walls were forcefully stretched to achieve an adequate caliber and this, probably, was the cause of a parietal defect giving rise to a pseudoaneurysm requiring a secondary repair procedure; the result was satisfactory at a 14-month follow-up.

In 1945, Blakemore and Lord [3] published a series of arterial lesions repaired with the non-suture method (Fig. 15.2). One of the cases was a femoropopliteal aneurysm which was resected, the remaining gap being bridged with an autologous vein graft (contralateral femoral vein) interposed with the double Vitallium tube technique.

The first series of PAA repair with resection and grafting were published between 1955 and 1962.

Julian et al. [1] reported nine cases (autologous vein 5, arterial homograft 4): one patient died p.o. with patent graft; in six cases the result was defined as fully positive (follow-up 2–24 months, mean 8.5 months); it was less good in two cases, the preoperative rest pain, however, being corrected. After 7 years, the same group [4] updated the experience, now consisting of 27 cases (autologous vein 3, Dacron 16, homograft 8): an excellent long-term (up to 7 years) result was obtained in 18.

Taber and Lawrence [5] reported three cases (in two patients) treated satisfactorily with an arterial homograft.

1957: Lord and Stone [6] analyzed a consistent series of arterial repairs with autologous vein grafts: three cases of arteriosclerotic PAAs were included (two greater saphenous vein, one femoral vein) with uniform success at 17, 18, and 26 months, respectively.

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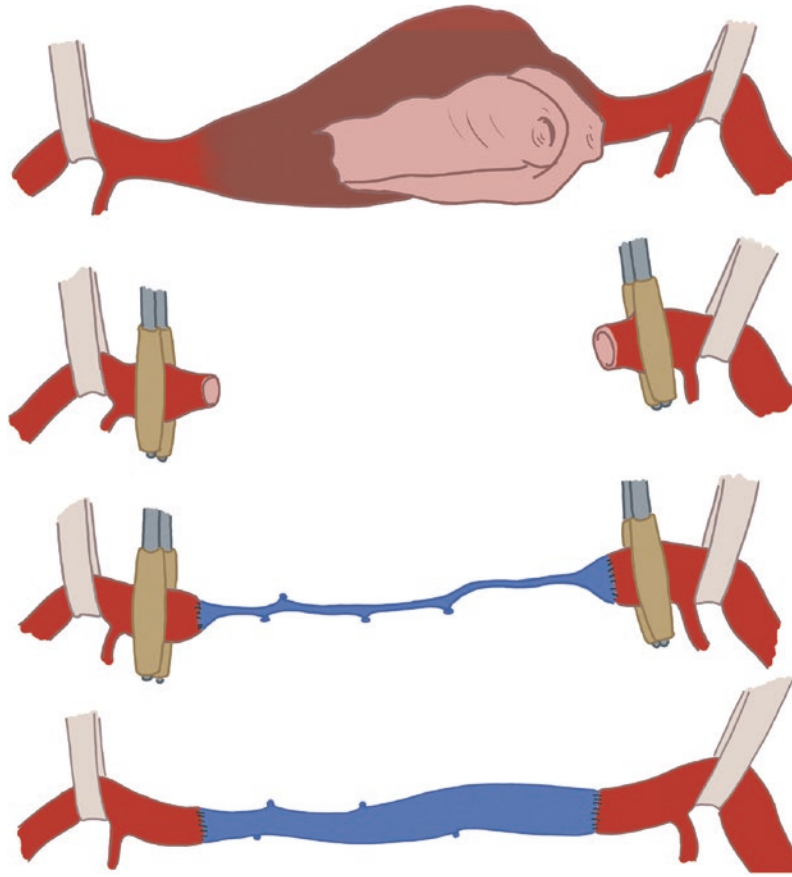

Fig. 15.1 Schematic drawing of the PAA repair (excision ad interposition grafting with autologous external giugular vein) (From Murray [2])

In 1961, Greenstone et al. [7] published one case, treated with autologous great saphenous vein, patent after 4 years.

1962, Friesen et al. [8]: 18 atherosclerotic PAAs were treated (with or without aneurysm resection) with homografts (5) or Teflon grafts (13). Gratifying results were obtained; in one case, patency of the graft was demonstrated by arteriography after 1 year.

In Table 15.1 are listed case series, from 1965, on which we relied for considerations on the technique and the results. Exactness of data may be questionable, as, under the heading "by pass" different operative techniques are included: the only constant is the bypass; as for the aneurysm, this may be simply bypassed, excluded, resected, opened, submitted to endoaneurysmorrhaphy. Under the heading "interposition or inlay graft" are listed cases in which the aneurysm was resected or laid open and the ensuing graft was the shortest possible, being the approach preferentially posterior but also medial.

Of 4689 repair procedures, 79% were performed using the bypass technique for reconstruction. Autologous vein was used as graft material in 69.1% of 5852 reconstructions. Among the non-autologous graft materials, the percentages of use are: synthetic (not specified) 32.7%; PTFE 33.8%; Dacron 20.1%; homograft 1.3%; HUV 1.1%. PTFE has been the preferred graft in alternative to autologous vein. Homografts were used in the early years of the modern era of vascular surgery and abandoned because of the adverse long-term behavior; however, the modern techniques of preservation apparently allow them to have a place again. In 2015, Mezzetto et al. [77] from Verona (Italy), published a series (2005–2013), of 54 PAAs (30 asymptomatic and 8 presenting in the emergency setting) repaired with cryopreserved homografts (artery 49, vein

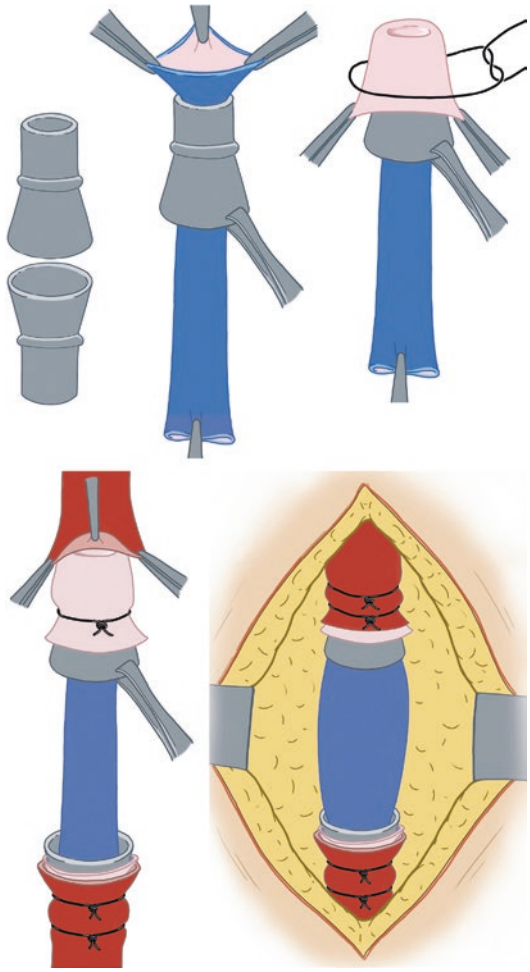

Fig. 15.2 The different steps of the sutureless method of arterial grafting by a vein segment and two Vitallium tubes (From Blakemore and Lord [3] modified)

5); the follow-up ranged 1–96 months (mean 34.8 months). Four grafts failed within 30 days and three were rescued with thrombectomy; one limb was amputated. After 5 years, primary patency was 88.3%, secondary patency 98.1%. Interestingly, imaging study in the long-term revealed an increase in graft diameter but no aneurysmal degeneration.

Human umbilical vein has been used sporadically. Neufang et al. [78], in 2007, published a series of 211 femoropopliteal grafting with HUV, of which nine were for PAA repair: at a follow-up of 1–143 months (mean 44 months) no limb loss was recorded in the whole cohort of patients.

From several years, Dacron grafts look as almost obsolete for PAA repair; however, in our experience, short interposition Dacron grafts allowed excellent results, not inferior to those achieved with PTFE and only slightly inferior to those of autologous veins.

Our policy has been constant through the years: to resect the aneurysm and reestablish circulation by an interposition graft, through a posterior (preferred) or medial access.

In Figs. 15.3, 15.4, and 15.5 resection of bilateral PAA and grafting are illustrated: images come from a video aimed to demonstrate to trainees the chief steps with posterior and medial approach, respectively. The patient gave a written consent. For the present publication, images, obtained in 1993, were revised by computer graphics, to enhance more significant details.

Table 15.1 Series of PAAs treated with grafting procedures: type of reconstruction and type of graft

Author, year	*N* cases	Bypass	Interposition or inlay graft	Autologous vein	Non-autologous graft
Edmunds [9], 1965[a]	68			34	H 21 D 10 N 3
Crichlow [10], 1966	47	8	39	21	H 12 T 14
Baird [11], 1966	12			4	H 3 T 5
Wychulis [12], 1970	44	13	31	21	D 11 T 12
Bouhoutsos [13], 1974	56	50	6	46	H 4 S 6
Buda [14], 1974	68	7	61	17	H 1 D 40 V 10
Gaylis [15], 1974	29	20	9	24	D 4 S 1
Buxton [16], 1975	17			12	D 5
Towne [17], 1976	70	70		9	H 9 D 33 T 16 N 3
Alpert [18], 1977	28	6	22	24	S 4
Chitwood [19], 1978	29		29	24	D2 B 3
Inahara [20], 1978	38	6	32	31	S 7

(continued)

Table 15.1 (continued)

Author, year	*N* cases	Bypass	Interposition or inlay graft	Autologous vein	Non-autologous graft
Szilagyi [21], 1981	50	21	29	30	D 20
Vermilion [22], 1981	99	99		50	D 38 PTFE 11
Reilly [23], 1983[a]	154			114	D 40
Whitehouse [24], 1983	42			38	S 4
Downing [25], 1985	38	31	7	34	PTFE 3 T 1
Anton [26], 1986	123			58	H 26 D 20 PTFE 19
Raptis [27], 1986	28	28		13	PTFE 12 D 1 CO 2
Schellack [28], 1987	60	60		32	D 14 PTFE 9 HUV 5
Lilly [29], 1988	48			37	PTFE 9 CO 2
Farina [30], 1989	45	45		15	D 11 PTFE 19
Dawson [31], 1991	42	42		25	D 11 HUV 2 B 3 T 1
Shortell [32], 1991	51	51		49	PTFE 2
Halliday [33], 1991	47			27	D 12 PTFE 8
Roggo [34], 1993	229	204	25	149	D 34 HUV 25 PTFE 21
Varga [35], 1994[b]	133	133		104	D 2 HUV 1 PTFE 26
Carpenter [36], 1994	45	45		40	PTFE 3 CO 2
Sarcina [37], 1997	61	61		10	D 17 PTFE 34
Davidovic [38], 1998	56	39	17	49	PTFE 5 B 2
Duffy [39], 1998	30	30		29	PTFE 1
Taurino [40], 1998	25			7	PTFE 14 D 4
Borowicz [41], 1998	20	18	2	18	PTFE 2
Locati [42], 1999	59	59		26	PTFE 29 D 3 HUV 1
Palumbo [43], 1999	75	46	29	50	PTFE 23 HUV 2
Irace [44], 2001	49	49		30	PTFE 16 D 1 H 1[c] CO 1
Kauffman [45], 2002	129	93	36	122	D 1 PTFE 6
Galland [46], 2002	55	55		30	S 25
Mahmood [47], 2003	50	30	20	49	CO 1
Bowrey [48], 2003	47	47		46	PTFE 1
Harder [49], 2003	28	26	2	26	PTFE 2
Ascher [50], 2003	29	20	9	23	PTFE 5 CO 1
Blanco [51], 2004	70	70		53	PTFE 17
Laxdal [52], 2004	57	57		51	S 6
Aulivola [53], 2004	51	51		48	D 1 PTFE 2
Martelli [54], 2004	42	42		19	D 1 PTFE 22
Stone [55], 2005	48	44	4	38	PTFE 10
Bourriez [56], 2005	100	100		80	PTFE 20
Pulli [57], 2006	152	73	79	34	S 118
Huang [58], 2007	358	348	10	259	PTFE 94 D3 CO 2
Antonello [59], 2007	27	27		17	PTFE 10
Davies [60], 2007	63	45	18	63	
Ravn [61], 2007[d]	673	497[e]	163[e]	536	S 137
Lichtenfels [62], 2008	46			39	S 5 CO 2
Zimmermann [63], 2010	54	54		42	S 11 CO 1
Bellosta [64], 2010	53	53		11	PTFE 42
Zaraca [65], 2010	49	11	38	39	PTFE 10
Bracale [66], 2011	26	12	14	16	10 (PTFE or D)
Vrijenhoek [67], 2011	65	65		65	
Stone [68], 2013	63	49	14	42	PTFE 20 D 1

Table 15.1 (continued)

Author, year	*N* cases	Bypass	Interposition or inlay graft	Autologous vein	Non-autologous graft
Pulli [69], 2013	178	92	86	66	S 112
Huang [70], 2014	107			86	S 21
Dorweiler [71], 2014	206	190	16	168	HUV 28 CO10
Serrano-H [72]., 2015	139	139		99	S 40
Cervin [73], 2015[d]	451			395	S 56
Mazzaccaro [74], 2015	77	34	43	16	D 7 PTFE 54
Leake [75], 2016	110	90	20	82	S 28
Wooster [76], 2016	52	50	2	36	PTFE 16
Personal series	82	1	81	52	D 16 PTFE 14

A small number (<5%) of non-atherosclerotic aneurysms are included
D dacron, *T* teflon, *H* homograft, *B* bovine graft, *V* vynion, *N* nylon, *CO* composite or sequential graft (prosthesis + autologous vein), *S* synthetic graft in general
[a]Series from MGH, Boston: Edmunds et al. 1948–63; Reilly et al. Jan 1958 to Jun 1982
[b]Homologous vein
[c]Data from 19 UK surgeons
[d]From the Swedish Vascular Registry: Ravn et al. 1987–2002 Cervin et al. 2008–2012
[e]Data related to 660 cases

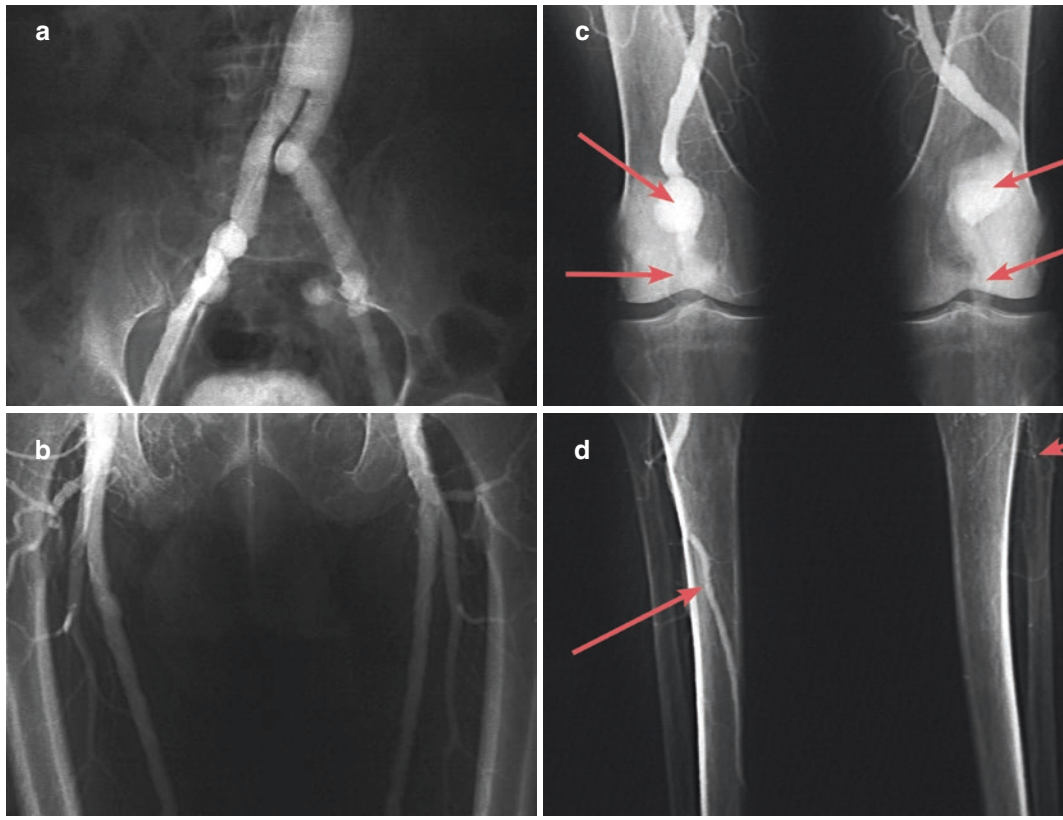

Fig. 15.3 Preoperative angiography, showing patent aorto-bi-iliac graft (**a**), normal femoral arteries (**b**), bilateral popliteal aneurysm (**c**); the outflow looks acceptable, albeit delayed on the left (**d**). Pressure index by cw Doppler was 0.8 right, 0.7 left

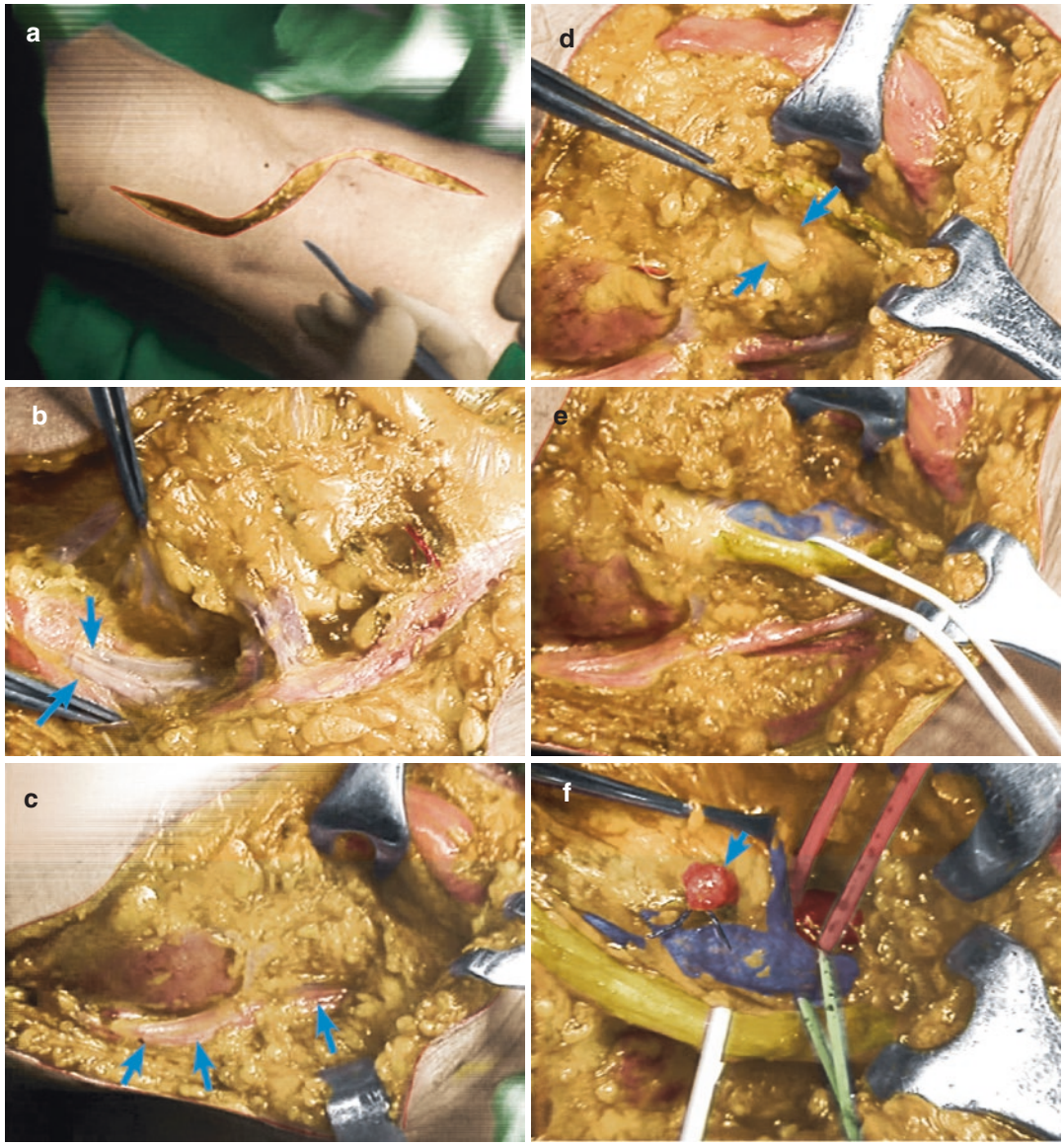

Fig. 15.4 Sequence of operative maneuvers through the posterior access. General anesthesia. Right limb. The patient is prone, with a cushion under the heel. Patient's head on the right. (**a**) Lazy S-shaped incision. (**b**) After opening the fascia lata and the leg fascia, the first structure to be identified is the common peroneal nerve (arrows), particularly at risk with this approach. Following it retrograde may allow an easier identification of the tibial nerve. (**c**) Extended preparation of the common peroneal nerve (arrows). (**d**) Approach to the tibial nerve (arrows). (**e**) Gentle retraction of the tibial nerve with a vessel loop. Approach to the vein, which is displaced by the aneurysm almost in the same plane of the nerve. (**f**) After looping of the vein, the artery, in its supra-aneurysmal segment, coursing in a deeper plane, is identified and looped. The aneurysm appears on the surface (arrow). (**g**) Once achieved proximal control, the distal dissection begins. The main nerve supply to the lateral gastrocnemius is identified and protected. The same will be done for the medial gastrocnemius. (**h**) The two gastrocnemius muscles are gently separated with retractors. The vein and the infra-aneurysmal segment of popliteal artery are prepared. Heparin is administered. (**i**) After clamping the distal popliteal artery, a clamp is applied on the proximal popliteal artery. (**j**) The artery has been transected; the distal stump has been suture-ligated. Gentle traction and digital dissection allow mobilization of the aneurysm; collaterals are identified, ligated, and sectioned (arrow). (**k**) A right angle is passed underneath the neurovascular bundle of the lateral gastrocnemius, to grasp the ligature at the top of the aneurysm. By gentle downward traction and digital pushing from above, the aneurysm will be esteriorized in the bottom of the operative field. (**l**) The right angle indicates the level of section of the distal popliteal artery (the loop on the artery has been removed). Clamp (1) on the popliteal artery, clamp (2) on the inferior medial genicular artery. (**m**) Interposition Dacron graft (8 mmø, ring supported) in anatomic position. (**n**) The operative specimen

Fig. 15.4 (continued)

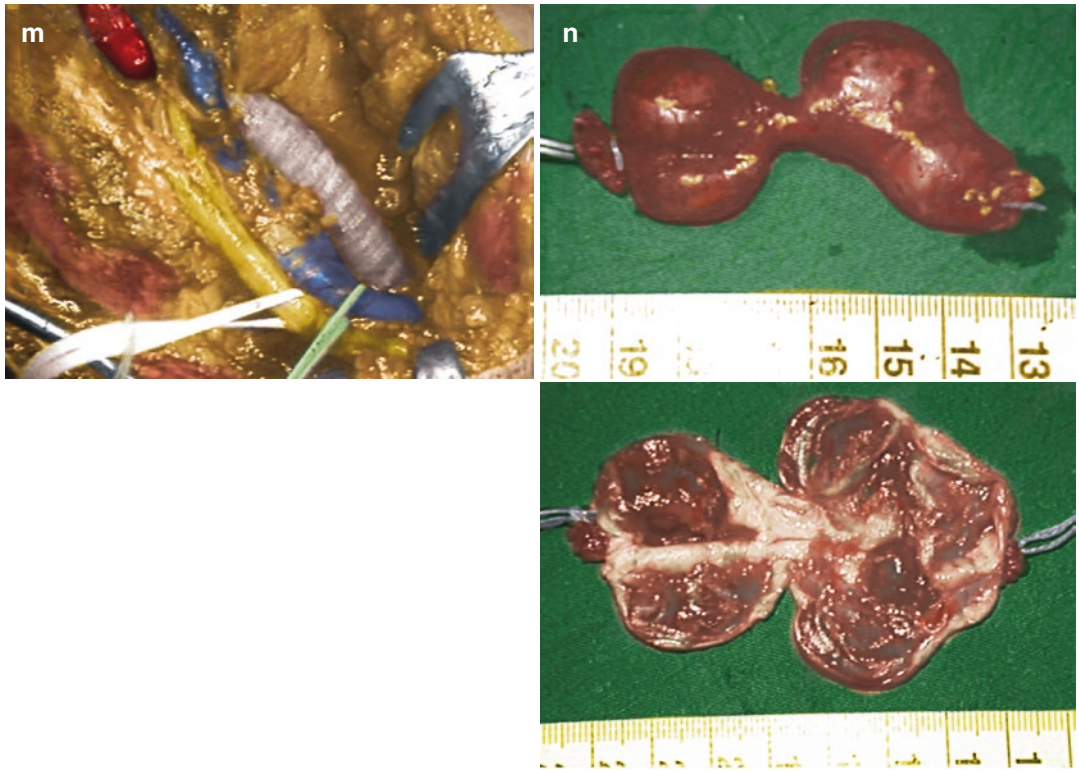

Fig. 15.4 (continued)

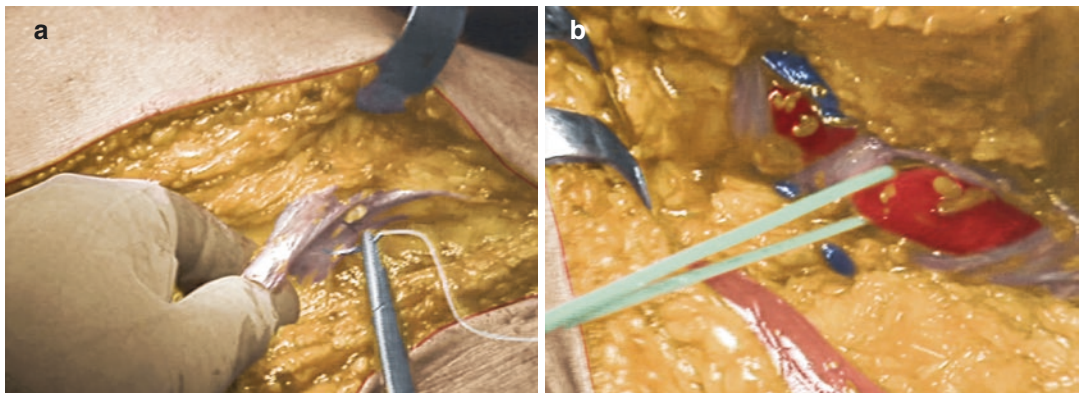

Fig. 15.5 Sequence of operative maneuvers through the medial approach. General anesthesia. Patient supine with moderate flexion of the knee and extrarotation of the limb. Patient's head on the left. Medial incision involving the lower third of the thigh and the upper third of the leg. (**a**) The tendons of the goose paw are individually sectioned, the stumps being marked with different suture filament to allow a precise reconstruction. This apparently minor procedure is relevant for the good function of the limb. (**b**) Looping of the proximal popliteal artery at the end of Hunter's canal; the latter may be opened if control on the superficial femoral artery is required. (**c**) Preparation of the distal popliteal artery. (**d**) After heparin administration, the distal popliteal artery is clamped. The medial gastrocnemius muscle is left intact; it could be sectioned if required for a better control of the aneurysm. (**e**) The proximal popliteal artery has been sectioned and the distal stump suture-ligated. Gentle traction allows the progressive identification of collaterals, which are secured and cut. (**f**) The aneurysm is mobilized and exteriorized in the upper part of the operative field. The medial gastrocnemius is retracted downward. (**g**) Section of the distal popliteal artery; a clamp (1) is applied on the inferior lateral genicular artery. (**h**) Interposition Dacron graft (8 mmø, ring supported) in anatomic position. The white loop encircles the medial gastrocnemius. (**i**) The operative specimen

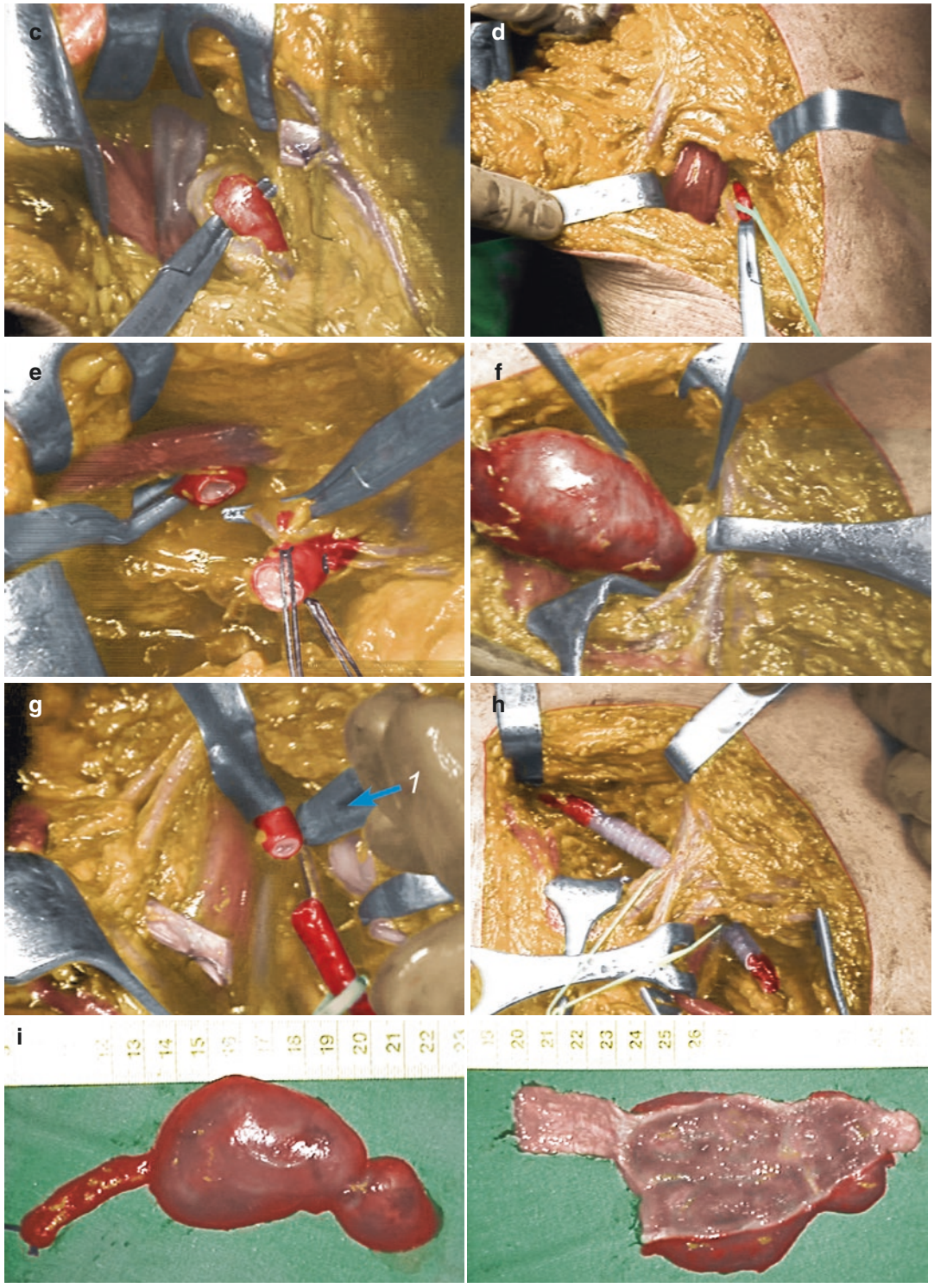

Fig. 15.5 (continued)

Brief clinical history. The patient, a male aged 73, was submitted, in 1992, to elective repair of an aortoiliac aneurysm; on that occasion, bilateral PAA was diagnosed, nearly asymptomatic, causing only mild compression venous symptoms on both lower limbs. After 8 months, bilateral deep vein thrombosis, successfully treated with heparin, followed by chronic oral anticoagulation. Angiographic control confirmed the presence of bilateral PAA, increased in size; ultrasound control did not reveal deep vein obstruction; however, we decided to use synthetic grafts, to spare the greater saphenous veins, as both lesser saphenous veins were clinically rigid and cord-like and, as well, arm veins were not suitable for arterial grafting. Both aneurysms were treated in December 1993, with an interval of 3 weeks. The left graft occluded after 5 years, the limb remaining asymptomatic; the right graft was still patent when the patient died, in 2004, from acute leukemia. After the operations, the patient continued oral anticoagulant therapy; venous insufficiency slowly developed, without any acute event.

In Table 15.2 the different modalities of inflow and outflow of the graft are illustrated. According to the data of the literature, a "high" inflow (common femoral artery, rarely the limb of an aorto-femoral graft or the deep femoral artery) was used in 17.7% of the cases): this means a long bypass, generally due to atherosclerotic involvement of the superficial femoral artery, and, often, the absence of aneurysm exclusion or only distal ligation. In our experience, only one case

Table 15.2 Sites of inflow and outflow for limb revascularization

Author, year	*N* cases	Inflow			Outflow	
		CFA	SFA	AKPA	BKPA	Infrap. A.
Wychulis [12], 1970	44	5	39		43	1
Anton [26], 1986[a]	116	12	102		108	8
Dawson [31], 1991	42				40	2
Shortell [32], 1991	51	19	32		42	9
Varga [35], 1994	136	22	68	46	108	28
Carpenter [36], 1994	45	10	35		40	5
Sarcina [37], 1997	61		26	35	53	8
Duffy [39], 1998	30	6[b]	23	1	16	14
Borowicz [41], 1998	20		20		18	2
Palumbo [43], 1999	75	7	45	23	59	16
Gouny [79], 2000	33	8[c]	25		29[c]	4
Galland [46], 2002	55	17		38	53	2
Mahmood [47], 2003	30				15	15
Bowrey [48], 2003	47	47			43	4
Blanco [51], 2004	70	49	21	57	13	
Aulivola [53], 2004	51	14	25	12	22	29
Stone [55], 2005	48	7	41		38	10
Pulli [57], 2006	152	84		68	142	10
Antonello [59], 2007	27	4	10	13	20	7
Ravn [61], 2007	673	118	324	231	542	131
Bellosta [64], 2010	53	12	22	19	39	14
Zaraca [65], 2010	49	7	4	38	47	2
Pulli [69], 2013	178	111		67	152	26
Serrano-H [72], 2015	139				119	20
Wooster [76], 2016	52	5	35	12	42	10
Personal series	82	1	20	61	65	17

CFA common fem. art., *SFA* superficial fem. art, *AKPA* above knee popl. art, *BKPA* below knee popl. art. *Infrap.A* infrapopliteal arteries tibioperoneal, tibial, peroneal, pedal arteries

[a]Inflow data lacking for two cases

[b]Inflow from limb of aorto-femoral graft in two cases

[c]Inflow from deep fem. art. in two cases, outflow into iuxta-articular popl. art. in three cases

(urgent) was treated with a long bypass. The superficial femoral artery (in general the distal part) was the site of inflow in 55.6% of the cases. The graft arose from the proximal popliteal artery in 33.7% of the cases; this happened in 74% of our cases, depending on our trend of posterior approach, resection, and interposition grafting. The use of the shortest possible graft could be questionable, considering the possibility of recurrence both above and beyond the anastomotic sites, as documented by Towne et al. [17] in six cases; another case was reported by Bowyer et al. [80]. This complication, however, doesn't appear of relevant importance; in general, as observed by Guvendik et al. [81], it should be kept in mind that surgery is a symptomatic, not etiologic, therapy: local favoring factors, may be, are modified (but it is not sure) by the operative maneuvers, but the propensity to arterial dilation, if any, remains certainly unmodified.

As for outflow of the graft, the distal popliteal artery represented the receiving vessel in 82.7% of the cases and 17.3% of the reconstructions ended into an infrapopliteal vessel. Seventeeen (20.7%) tibial grafting were required in our experience: four (tibioperoneal trunk) through the posterior approach and 13 through the medial approach; autologous vein was used in all cases and the distal anastomosis was end-to side. It must be remembered that Evans et al. [82], in 1971, highlighted the importance of searching for patent distal tibial arteries in case of occlusive disease of their proximal tract and reported two successful cases of PAA repair with femorotibial grafting (autologous vein).

Different types of autologous vein have been used in repair and grafting for PAA (Table 15.3).

Obviously, the greater saphenous vein (reversed, non-reversed, in situ) is the preferred (90.5%) autologous arterial substitute, but, when it is not available, other veins can be used; in particular the lesser saphenous vein looks attractive when doing a short graft with posterior approach; however, in our experience, only on one occasion its caliber was adequate, in absence of varicosity; from the table, it was used in 5.1% of the cases. Particularly interesting is the use of arm veins, which have really a place in the treatment of lower

Table 15.3 Autologous veins used for limb revascularization

Author, year	*N* cases	GSV	SSV	AV	DV	Others
Edmunds [9], 1965	34	31			3	
Crichlow [10], 1966	21	Yes	Yes			
Carpenter [36], 1994	42	32	7	1		2
Mahmood [47], 2003	50	36	12	1		1
Harder [49], 2003	26	24	2			
Ascher [50], 2003	24	22		1		1
Aulivola [53], 2004	48	45		2		1
Huang [58], 2007	257	242	7	6		2
Davies [60], 2007	63	50	12	1		
Kropman [83], 2007	48	36	12			
Zimmerman [63], 2010	43	42				1
Zaraca [65], 2010	39	28	11			
Dorweiler [71], 2014	178	165		3		10
Huang [70], 2014	86	80	3			3
Eslami [84], 2015[a]	188	172	3	7		6
Mazzaccaro [74], 2015	16	16				
Leake [75], 2016	82	79		3		
Wooster [76], 2016	36	36				
Personal series	52	48	1	3		

GSV great saphenous vein, *SSV* short saphenous vein, *AV* arm veins, *DV* deep veins (superficial femoral, popliteal), *Others* include spliced veins, composite grafts

[a]From the Vascular Qualitative Index data base, only asymptomatic

limb arterial insufficiency. In 2014, Brochado Neto et al. [85] reported a series (1991–2005) of 120 femoro-distal reconstructions with arm veins: in 2.5% of the cases the graft was used to repair a PAA. Successful use of arm veins for PAA repair has been the object of single case report [86] and of short series; Tal et al. [87] reported five cases on the preferential use of the basilic vein (prepared by a second surgical team) when the approach is posterior. We used the cephalic vein in three cases, with satisfactory outcome. According to the data of Table 15.3, arm veins were used in 2.1% of the cases. The use of deep veins (femoral/popliteal) has been sporadic. Edmunds et al. [9] used them in three cases and then abandoned this type of graft, due to the long-term dilatation. Schulman has been a supporter of the use of deep vein as arterial graft and in 1987 [88] reported a series of femoropopliteal reconstructions with a 3-year primary patency of 82% (secondary 89%).

15.1 Early Results

In considering the early results (Table 15.4) of grafting for PAA repair, we decided to omit the complications not specifically involving the graft and as well the reinterventions, as these,

Table 15.4 Cumulative early (<30 days) results

Author, year	Pts	Limbs	Postoperative mortality	Patent, %	Limbs lost
Edmunds [9], 1965	68	68	1	82.3	9[a]
Crichlow [10], 1966		47	0	91.5	3
Wychulis [12], 1970		44	2	93.2	4[b]
Evans [89], 1971		41		85.4	6
Gaylis [15], 1974	29	29		93.1	1
Buxton [16], 1975		17		58.8	4
Towne [17], 1976	62	70	1	85.7	10[b]
Inahara [20], 1978	30	38	1	97.4	0
Vermilion [22], 1981		99		87.9	12
Reilly [23], 1983		154		86.4	17[a]
Anton [26], 1986	110	123	8	89.4	8
Halliday [33], 1991	40	47		100	
Shortell [32], 1991	39	51	2	94.1	3
Varga [35], 1994[c]		136	2	92%	8[b]
Carpenter [36], 1994		45		95	3
Sarcina [37], 1997		61	0	92	3[d]
Davidovic [38], 1998		56	2	94.6	3[d]
Duffy [39], 1998		30	2	96	1
Taurino [40], 1998	23	28	1	100	0
Borowicz [41], 1998	16	20	0	100	0
Irace [44], 2001		49	0	97.9	1
Mahmood [47], 2003		50	3	96%	1
Bowrey [48], 2003		47	1	93.6	3
Harder [49], 2003		28	0	96.4	0
Blanco [51], 2004	58	70	2	95.7	3
Martelli [54], 2004	38	42	2	92.8	0
Stone [55], 2005	46	48	0	100	0
Bourriez [56], 2005[e]		100		99	1
Pulli [57], 2006[f]	134	156	3		7[a]
Beseth [90], 2006[g]	24	30	0	100	0
Davies [60], 2007	48	63	1		0
Ravn [61], 2007[h]		681		92.4	
Huang [58], 2007	289	358	3	96.4	6

Table 15.4 (continued)

Author, year	Pts	Limbs	Postoperative mortality	Patent, %	Limbs lost
Antonello [59], 2007[i]	23	27	0	100	0
Kropman [83], 2007[j]	66	66	0	100	0
Lichtenfels [62], 2008	40	46	0	95.6	2
Johnson [91], 2008[k]		583	8		6
Zaraca [65], 2010	35	49	1		2
Bracale [66], 2011	26	26	1	96.1	0
Pulli [69], 2013		178	0	98.3	3
Huang [70], 2014	91	107	1	99	0
Dorweiler [71], 2014	154	206	3	96.2	4[l]
Wagenhauser [92], 2015	30	42	0	95.2	2
Serrano-H [72], 2015		139		96.4	5
Cervin [73], 2015[h]		447		96.4	8
Mazzaccaro [74], 2015	65	77	0		0
Leake [75], 2016	96	110	1	98.2	
Personal series	58	82	0	97.6	0

Postoperative mortality refers obviously to patients; not always the number of patients submitted to repair of PAA with revascularization is determinable

[a]One limb amputated in previously asymptomatic patient

[b]One amputation with patent graft

[c]Multicenter study (data from 19 UK surgeons)

[d]One case for graft infection

[e]All elective cases

[f]Both postoperative mortality and amputations refer also to three cases of endografting

[g]Only posterior approach

[h]From the Swedish Vascular Registry

[i]All asymptomatic

[j]Case matched study on medial vs. posterior approach

[k]From 123 US Veterans Affair Med. Centers 1994–2005

[l]Three amputations with patent graft

in several cases, were probably due to technical imperfections; consequently, we mention only the patency at 30 days. We believe that differentiating primary and secondary patency, within the short lag time following the original operation, may be scarcely important, and probably confusing, in the setting of PAA repair.

Both at a glance and at a deeper insight, early results look satisfactory in terms of graft patency and of limb salvage. For the latter issue, however, we think that the term "limb salvage" is not appropriate and really abused, because many of the operated limbs were not actually at risk, being asymptomatic or poorly symptomatic; the risk was potential, albeit consistent, for the unpredictable complications of the disease and, as supporters of conservativism would suggest, for the consequences of the operation itself. The occurrence, rare but certainly deceiving for patient and surgeon, of limb loss in asymptomatic patients should be considered when planning the management of a PAA. Failures, occasional, surprising, and bitterly burning, are a part of the experience of each vascular surgeon; we believe that preventive surgery should be committed to fully experienced surgeon, both for preoperative evaluation and for surgical operativity. Of course, this is not a guarantee against bad surprises; however, the ability and the experience of the surgeon are fundamental for the satisfaction of the old precept "primum non nocere."

Which are the factors influencing early results?

In Table 15.5 early results are listed according to absence/presence of preoperative symptoms. It is evident that asymptomatic cases fare better, in general, than symptomatic ones. In particular, p.o. mortality and amputations are more frequent

Table 15.5 Early results according to preoperative status

	Limbs		P.o.m.		Patent		Limbs lost	
Author, year	A	B	A	B	A, %	B, %	A	B
Reilly [23], 1983	68	86			97	78	1	16
Anton [26], 1986	55	68			91	88		
Duffy [39], 1998	8	22	0	2	87	95	0	1
Mahmood [47], 2003	29	21	0	3	97	95	0	1
Huang [58], 2007	144	214	0	3	98	99	0	6
Zaraca [65], 2010	29	20	0	1			0	2
Wagenhauser [92], 2015	16	26	0	0	100	92	0	2
Cervin [73], 2015[a]	235	216			99	94	0	8
Personal series	48	34	0	0	100	91.2	0	0

P.o.m. postoperative mortality, *A* asymptomatic, *B* symptomatic
[a]From the Swedish Vascular Registry 2008–2012

in the symptomatic cohort. However, a particular significance, not only on a statistical ground, is hardly definable, as the two groups are not homogeneous: first, because the symptomatic group is inclusive also of urgent cases; second, because risk factors (age, comorbidities, etc.) have certainly a reduced negative impact on operative indication, particularly if the limb is really at risk or symptoms are truly invalidating. This brings back to the choice of management in asymptomatic patients, and, as we know, the problem is still open and multifaceted. Our personal opinion is that any patient with PAA should be operated on, if the surgical risk is not particularly high; and this in spite of the sporadic occurrence of bad results in asymptomatic limbs.

Other factors correlated with early outcome:

- Graft material. Edmunds et al. [9] remarked that the early success is not related to the graft but "to the technical excellence and experience of the surgeon"; however, all three nylon grafts they used underwent early thrombosis; but certainly the ability of the surgeon represents a very important factor, even if it is impossible to express it quantitatively. Anton et al. [26] observed early failure in 1/58 (1.7%) of autologous vein graft, and in 12/65 (18.4%) of non-autologous graft and this difference was statistically significant; however, the resulting limb loss was 1.7% vs. 12%, not significant. Varga et al. [35], reviewing 133 cases from 19 UK surgeons, found early failure in 6/104 (5.8%) autologous vein grafts and in 5/29 (17.2%) other types of graft; the resulting amputations were 2/6 and 4/5, respectively.

The differences in early outcome of the different types of graft should be considered with a critical eye, even if the superiority of autologous vein is a matter of fact supported by thousands of operative procedures. Almost always patency of a graft is related to the material without making a distinction for other parameters, e.g., the length. Moreover, especially in emergent procedures, a synthetic graft, currently the PTFE graft, is used, reading between the lines of a report, with the aim of sparing time to achieve revascularization the more quickly possible; as well, an unexpressed lack of confidence for a successful outcome may be the cause for the choice of a synthetic graft

- Characteristics of outflow. Martelli et al. [54] analyzed early results according to the runoff: patency was 100% with optimal runoff and 87.5% with a poor runoff; the difference was not statistically significant. Anton et al. [26] observed that 17% of limbs without pedal pulses were amputated, and only 2% of those with pedal pulses.
- Aneurysm thrombosis. The presence of a thrombosed aneurysm did not influence early outcome [54]; however, Buxton et al. [93] observed that only limbs with a thrombosed aneurysm underwent early failure and amputation.

Of the seven early amputations recorded by Pulli et al. [57], six were required in emergency

Table 15.6 Early results according to elective or urgent procedure

	Limbs		P.o.m. (pts)		Patent		Limbs lost	
Author, year	A	B	A	B	A, %	B, %	A	B
Shortell [32], 1991	32	19	0	2	100	84	0	3
Varga [35], 1994	80	56	0	2	99	82	0	8[a]
Galland [46], 2002	33[b]	22	1	0			0	4
Huang [58], 2007	284	74	0	3	98	90	0	6
Lichtenfels [62], 2008	34	12	0	0	100	83	0	2
Zaraca [65], 2010	39	10	0	1			1	1
Pulli [69], 2013	137	41	0	0	99	90	0	3
Huang [70], 2014	93	14	1	0	99	100	0	0
Dorweiler [71], 2014	161	45	2	1	100	98	0	4[c]
Cervin [73], 2015	322	129			97	93	3	5

P.o.m. postoperative mortality, *A* elective, *B* emergent/urgent
[a]One limb amputated with patent graft
[b]Included 14 limbs treated with preoperative intraarterial thrombolysis
[c]Three amputations with patent graft

situations (five acute ischemia, one rupture). In effects, early results appear markedly different, in most experiences, when comparing elective vs. urgent/emergent procedures (Table 15.6).

Emergency treatment of PAA represents really the dark side in the handling of this disease, not only for the reduced rate of graft patency and limb salvage, but also because complications and reinterventions not related to graft failure are more frequent [70].

15.2 The Impact of Intraarterial Thrombolysis on the Outcome of Acutely Ischemic Limbs

In acutely ischemic limbs from PAA thrombosis infrapopliteal vessels may, frequently, be occluded, totally or partially, by secondary thrombosis or embolism. In 1966, Baird et al. [11] observed that this occurrence should not be discouraging for the surgeon as "even if the outflow tract appears severely limited, the Fogarty catheter will often allow a satisfactory channel to be developed." Bouhoutsos and Martin [13] reported that, in 18/67 (27%) cases of PAA thrombosis, attempt to revascularization implied, as preventive step, thromboembolectomy of tibial vessels.

In this setting, fibrinolysis looked really appealing for the possibility of recanalizing acutely occluded vessels in a less traumatic, more physiologic and more reliable way. The progress of endovascular techniques was fundamental also from this view point. In 1974, Dotter et al. [94] stressed the advantages of intraarterial thrombolysis (IAT) over systemic fibrinolysis.

The first successful application of IAT in the treatment of an acutely thrombosed PAA was reported in 1984 by Schwartz et al. [95]: IAT allowed the visualization of the aneurysm (and of the residual inside thrombus) and cleared the outflow (not visible before), reestablishing a satisfactory circulation in the limb; surgery was successfully performed the day after, in nonurgent conditions, by aneurysm opening and reconstruction with a lesser saphenous graft. The chief advantages of IAT were evident: limb salvage and nonurgent surgery. Further, and may be more important, advantages relating to both early and late results are that clots in small and peripheral vessels, not accessible to mechanical thrombectomy, may be affected [96] and that reperfusion of ischemic tissues is slow and gradual, in contrast with the abrupt reperfusion consequent to thromboembolectomy and/or bypass [97].

The pros and cons of IAT were assessed in large series of patients with ischemic limbs, bringing to the definition of indications and contraindications, through the experience of results and complications. Currently, two modalities of IAT are in use, preoperative (but lytic therapy may be the only treatment)

and intraoperative; infusion of the thrombolytic agent may be continuous or pulsed. Referring to thrombosed PAA, preoperative IAT may be performed with the multi-hole catheter tip positioned within (or as close as possible) the intraaneurysmal thrombus or beyond the thrombosed aneurysm; intraoperative IAT is performed introducing the catheter through the distal popliteal artery, after ligation immediately distal to the aneurysm. A complex, but apparently rewarding, modality is isolated limb perfusion, after the technique used for locally recurrent melanoma [98] (Fig. 15.6).

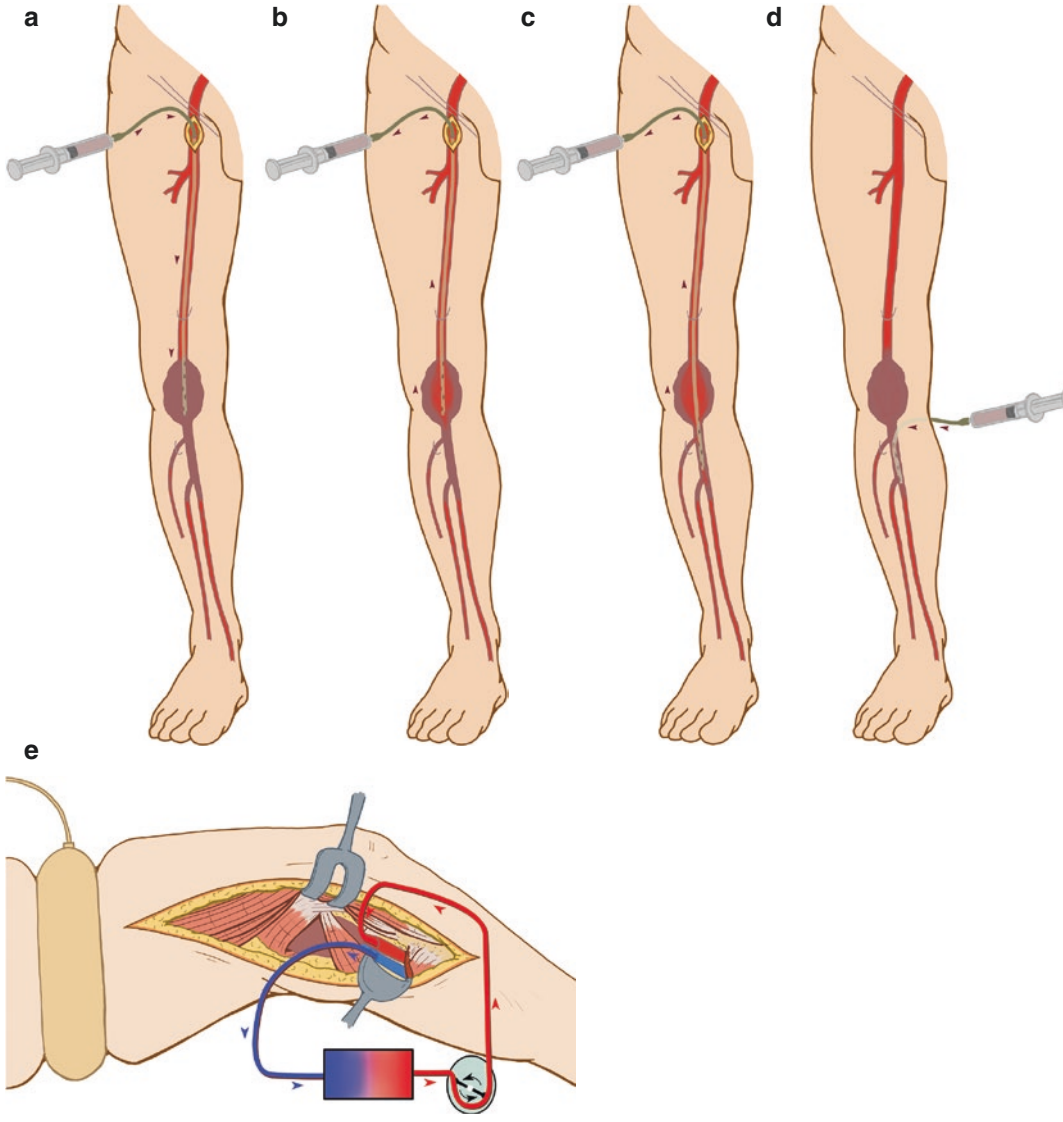

Fig. 15.6 Artist's conception of the different types of intraarterial thrombolysis in the treatment of acutely thrombosed PAA. (**a**) Preoperative: the multi-hole catheter tip is positioned within the thrombosed aneurysm (it will be gradually advanced as the thrombus undergoes dissolution). (**b**) Preoperative: idem, preceded by thromboaspiration. (**c**) Preoperative: catheter tip initially positioned beyond the thrombosed aneurysm. (**d**) Intraoperative: catheter introduced through the low popliteal artery, preceded by ligature distal to the aneurysm; embolectomy before starting lysis (not illustrated in the figure). (**e**) Isolated limb perfusion with oxygenated blood, Ringer lactate and fibrinolytic agent (After the works of May et al. [98], Varga et al. [35], Thompson et al. [99], Greenberg et al. [100])

Current indication to IAT is ischemia of grade I-IIa [101], i.e., mild to moderate ischemia [69], that means a viable/salvageable limb, with only minimal and distal sensory loss: i.e., limbs able to tolerate an additional period of ischemia, also because the result of IAT is unpredictable [102]. Cases with more severe or profound ischemia, with sensory and motor deficits, are candidates to immediate surgery [93, 103].

Contraindications to IAT are clearly indicated by several Authors [103, 104]:

- Acute/ongoing gastrointestinal bleeding <10 days
- Stroke or TIA <6–8 weeks
- Neurosurgery or intracranial trauma <3 months
- Operation or organ biopsy <2 weeks
- Brain tumors
- Arteriovenous cerebral malformations
- Epidural catheter or puncture <3 days
- To the above, Plate et al. [93] add:
- Age over 75, empirically, as most of fatal adverse events manifested in over 75
- Chronic atrial fibrillation, for the risk of embolization with ischemic stroke
- Hematuria <10 days

And Marty et al. [97] add:

- Popliteal vein thrombosis, for the risk of lung embolization (unless previous vena cava filter)
- Coagulopathy
- Pregnancy
- Malignant hypertension
- Dacron graft <3 months
- Graft infection

Complications of IAT were recently (2016) analyzed by Koraen-Smith et al. [103] in a cohort of 252 patients for a total of 281 treatments (240 for lower limb ischemia):

- Minor bleeding 28.1%
- Major bleeding 9.6%
- Stroke 1.8%
- Acute myocardial infarction 2.1%
- Confusion/delirium 3.5%
- Intractable pain 8.2%
- Renal failure 2.8%
- Compartment syndrome 3.9%

Previous reports had similarly highlighted the important occurrence of adverse events. In 2006, Plate et al. [93], in a series of 118 cases, observed: major bleeding 10.2%; cardiac failure 4.2%; stroke 3.4%; peripheral embolization 15.2%; compartment syndrome 1.7%; death occurred in 11% of patients. In eight earlier series (more than 500 cases) reviewed in 1986 by Hamelink and Elliott [105] the occurrence of major complications ranged 4–44%.

In the face of these adverse events, a fair/good percentage of successes were achieved: Berni et al. [106] (1983): 75%; Katzen et al. [102] (1984): 81%; Hamelink and Elliott [105] (1986): 67%.

In 1985, Sicard et al. [107] reported the treatment of 29 cases of native artery thrombosis with a high percentage (55%) of failures and a heavy incidence of complications: severe hemorrhage 16.3%, pulmonary embolism 9.3%, myocardial infarction (fatal) 6.9%, and clot migration 9.3%. In the discussion following his presentation, Tsapogas [108] suggested that probably it would be better to eliminate large thrombi mechanically, followed by lysis to attack the smaller and more peripheral ones.

The Royal College of Surgeons of England, 1992, organized a debate on the opportunity of establishing IAT as the initial treatment of acutely ischemic lower limb. The conclusion was [109]: "at present there is insufficient evidence to accept that intraarterial thrombolysis should become a part of routine management." After more than 25 years, in spite of the progress in catheter manufacturing, the refinements in fibrinolytic drugs and their management, the lot of experience gained in different Centers, this evidence, as far as we know, has not yet been reached.

However, in the specific treatment of acute limb ischemia from thrombosed PAA, things could be different: the outflow may be intrinsically normal, not chronically damaged at the parietal level; effective lysis may be relevant in

posing/confirming the diagnosis and in planning the subsequent treatment, either surgical or endovascular. The starting point is represented by a mass of clot filling the aneurysmal sac and not amenable, in most cases, to mechanical thrombectomy; and by a damaged outflow, which, if not cleared, would represent the premise to failure of any type of reconstruction.

Obviously, indications and contraindications to IAT are the same established in the general experience. PAA repair, in the urgent/emergent setting, offers results clearly inferior to those obtained with elective procedures.

To give an idea about the still debated role of thrombolysis, in the following we are going to make a chronological survey of some of the published experiences (when non-specified, IAT was preoperative), taking into account that the lack of homogeneity and comparability renders difficult to draw conclusive remarks from a collective review.

1990. Bowyer et al. [80] (Royal Surrey County Hospital, UK). Of six cases acutely ischemic from <72 h, one died from Mendelson syndrome, but five were fully successful. Great enthusiasm. Proposal: where IAT is available, asymptomatic PAA should not be operated on, because, in case of thrombosis, arteriography and IAT would assure the favorable outcome of the subsequent grafting procedure.

1991. Halliday et al. [33] (St. Mary's Hospital, London, UK): IAT in 2/22 acutely ischemic limbs; no complications, success in both.

1993. Thompson et al. [99] (Bristol Royal Infirmary and other UK hospitals): six cases of intraoperative IAT. In two, initial preoperative IAT was complicated by acute limb deterioration, prompting immediate surgery. The tactics was: ligature beyond the aneurysm; small arteriotomy on distal popliteal; embolectomy of infrapopliteal vessels and infusion of lytic agent; during lysis, tayloring of proximal graft anastomosis. Fasciotomy in three cases. Success in all, but in one residual atheroemboli with nonoptimal ABI index.

1993. Ramesh et al. [110] (Royal Berkshire Hospital, UK). Of 19 cases with acute limb ischemia, 12 were submitted to IAT. Results: six ok; one partial; five failures, consisting on three major bleeding and two limb deterioration. The latter was attributed to thrombus destabilization and distal embolization.

1993. Galland et al. [111] (Royal Berkshire Hospital, UK) reviewed the problem of acute limb deterioration during preoperative IAT, from the experience of five UK Centers. This significant adverse event complicated 11/710 (1.5%) cases of thrombosis of native artery, 3/110 (2.7%) cases of graft thrombosis, and was particularly relevant when treating thrombosed PAA (6/46, 13%).They analyzed the possible causes of limb deterioration and hypothesized: massive embolization, compartment syndrome, reperfusion syndrome, blockage of the outlet of important collaterals by the catheter. To avoid this ominous complication (of 19 patients, 11 were amputated and of these two died) they suggested to place the catheter tip beyond the thrombosed aneurysm or to perform intraoperative IAT.

1994. Varga et al. [35] (from the Joint Vascular Research Group, UK): of 62 cases of acute limb ischemia, 23 submitted to IAT (14 preoperative, 9 intraoperative). Success in 16 (69.6%).

1994. Hoelting et al. [96] (Univ. of Heidelberg, Germany) performed a detailed comparison between IAT + bypass (nine cases) and mechanical thrombectomy+ bypass (11 cases). In case of lysis, no complications and success in all (total six, partial three). Control arteriography demonstrated residual clots in the non-lysed limbs and in 9/11 pedal pulse did not reappear; while in all limbs treated with lysis at least one pedal pulse was palpable. In the simply surgical group, four grafts thrombosed, requiring a reintervention (one amputation). In the long-term (5 months to 11 years, mean 5.2 years), graft failure, requiring reintervention, occurred only in two limbs of the group non-receiving lysis.

1994. Garramone et al. [112] (Univ. of Connecticut, Hartford, CT, USA). Three cases of IAT, all successful, no complications. Subsequent surgical treatment was carried out with excellent results at 7, 21, and 36 months, respectively.

1995. Gawenda et al. [113] (Univ. of Cologne, Germany). Of 14 acutely ischemic limb, treated with IAT, success in 13 (92.8%). Nine were submitted to bypass (four refused surgery) with

long-lasting success (follow-up 1–62 months, mean 24.1 months).

1997. Debing et al. [114] (Academic Hospital, Brussels, Belgium): two cases ok with IAT and bypass (follow-up 20 and 42 months, respectively).

1997. Dawson et al. [115] (University Hospital, Leiden, The Netherlands), in a consistent review article, highlighted the risk of complications with preoperative IAT, which allow success in 58–66% of the cases, assessing that on-table intraoperative IAT looks more advantageous in acutely ischemic limbs with damaged outflow.

1998. Taurino et al. [40] (University "Sapienza," Rome, Italy). Success in 8/9 (89%) cases treated with IAT (out of 13 cases with acute ischemia).

1998. Greenberg et al. [100] (University of Rochester, NY, USA and Malmö Univ. Hospital, Sweden). IAT allowed reconstitution of 1–2 popliteal outflow vessels in five limbs acutely ischemic from <12 to 24 h; subsequent bypass on distal popliteal (4) or peroneal, fasciotomy in four; long-lasting (13–34 months) limb salvage. Two limbs, however, had permanent neurologic deficit (sensory in both, foot drop in one). Isolated limb perfusion in an additional case, ischemic from 4 days, with permanent limb salvage in spite of repeated graft occlusion. Enthusiastic conclusions and once again it was suggested that further improvements of lytic therapy would "render the need for the treatment of asymptomatic disease obsolete."

1999. Palumbo et al. [43] (University of Bologna, Italy). IAT in 27/40 limbs acutely ischemic: two cases of acute limb deterioration successfully treated increasing the perfusion flow; one fatal intracranial hemorrhage; two compartment syndromes requiring fasciotomy before grafting.

2000. Steinmetz et al. [116] (Hopital du Böcage, Dijon, France). Fifteen cases of subacute ischemia treated with IAT; no major complications; success in 14 (93%), but two of the subsequent grafts failed, leading to amputation.

2001. Irace et al. [44] (University "Sapienza," Rome, Italy). IAT in 3/6 acutely ischemic limbs: all ok, no complications.

2002. Dorigo et al. [117] (University of Florence, Italy) compared the results in 38 cases of acute ischemia grade I or IIa, treated with IAT and grafting (delayed surgery 14) or immediately operated on (24). In the second group, three limbs were lost. IAT failed in four, with two limb loss; it was successful in ten. Difference between immediate and delayed surgery was not significant. However, in the ten cases with successful lysis, both primary patency and limb salvage were 100%.

2002. Marty et al. [97] (University of Lausanne, Switzerland). Thirteen cases (12 ischemia grade IIa, 1 grade IIb): three failures, ten successes. Of the three failures: one immediate amputation; two bypass grafts failed for thrombosis and for rhabdomyolysis, respectively, leading to amputation. Conclusion: limbs with failed IAT inevitably are destined to amputation. Identification of such patients, in which reconstructive surgery is useless, *represents the principal advantage of IAT*.

2002. Galland and Magee [46] (Royal Berkshire Hospital, UK): "preoperative lysis for a thrombosed popliteal aneurysm was associated with more complications than operation and on-table thrombolysis ($p < 0.05$)."

2003. Mahmood et al. [47] (University Hospital, Birmingham, UK). IAT in four patients of 17 with acute limb ischemia. Two failures (one for distal embolization), requiring immediate surgery. Interestingly, the Authors stress the importance of a meticulous thrombectomy, that was completed, in 4/12 cases, by retrograde maneuver through an ankle-level access.

2003. Bowrey et al. [48] (Novill Hall Hospital and Morriston Hospital, UK): successful IAT in nine acutely ischemic limbs.

2004. Aulivola et al. [53] (Beth Israel Deaconess Medical Center, Boston, MA, USA). IAT in 4/13 acutely ischemic limbs; treatment stopped in one case for neck hematoma requiring intubation.

2004. Martelli et al. [54] (University "Tor Vergata," Rome, Italy). Eleven cases of acute limb ischemia, IAT in four: success in all, no complications.

2006. Pulli et al. [57] (University of Florence, Italy). IAT in 17 limbs, success in 11, no major complications.

2007. Box et al. [118] (Royal Berkshire Hospital, UK). This up-to-dating report from Royal Berkshire Hosp. represents a negative conclusion on the use of preoperative IAT: of 15 cases, seven experienced significant complications (hemorrhage four, acute limb deterioration three) obliging to stop the treatment. Preoperative IAT was abandoned in 1992.

2007. Ravn and Björck [119] (from the Swedish Vascular Registry). In this important survey of the Swedish experience, the outcome of 235 ischemic legs in 229 patients is analyzed. One hundred and thirty-five limbs were immediately operated on (with intraoperative IAT in 32) and 100 were submitted to preoperative thrombolysis without any major complication. Forty-one limbs were operated <24 h from the end of thrombolysis: these cases, albeit not urgent, were defined as acutely operated. Delayed surgery, truly elective (>24 h after the end of thrombolysis) was performed in 59 cases. Fasciotomy was performed in 30% of the immediate surgery (IS) cases and in 11% of the delayed surgery (DS) cases: this difference is statistically significant; however, from the data of the study, it is impossible to define if the difference is due to the worse conditions of the tissues in the IS group or to the more gradual reperfusion theoretically offered by IAT. The two groups are not really comparable, as, at start, a good popliteal outflow was present in 48% of IS patients vs. only 5% in DS cases. The data deriving from the study are: in IS group, no difference in results in case of intraoperative IAT; better outcome in DS >24 h, followed by DS <24 h, followed by IS. The Authors conclude that IAT allows a better outcome and that more frequent fasciotomy in IS cases would probably reduce the limb loss.

2007. Huang et al. [58] (Mayo Clinic, Rochester, MN, USA): 34/73 acutely ischemic limbs were treated with IAT (preoperative, intraoperative, or both). Thirty-day primary patency was 94% in limbs with IAT vs. 87% in those without; respectively, limb salvage was 91% vs. 92%. The differences were not significant. However, considering only limbs with grade II ischemia, the differences were more marked: primary patency 96% vs. 80%, limb salvage 96% vs. 85%. A significant advantage of preoperative IAT in grade II ischemic limbs was evident in 1-year primary patency: 84% vs. 62%.

2010. Kropman et al. [120] (The Netherlands) reviewed 33 studies (8 prospective, 25 retrospective) totaling 895 cases of acute limb ischemia; of these, 313 (grade I or IIa acute limb ischemia) received IAT (255 preoperative, 58 intraoperative). In 142 cases, no major bleeding was observed, however acute limb deterioration occurred in 3.5% and foot drop in 2.1%. Thirty-day outcome put into evidence that preoperative IAT resulted into a nonsignificant reduction of limb loss. At 1, 3, and 5 years primary patency in the lysis group were 79%, 77%, and 74% vs. 71%, 54%, and 45% in the non-lysis group, respectively. The difference was significant only at 1 year. No significant effect on amputation rates. Conclusions: *the additional value of thrombolysis prior to bypass surgery remains to be proven*.

2015. Cervin et al. [73] (from the Swedish Vascular Registry 2008–2012). 118/174 acutely ischemic limbs received thrombolysis, with success in 78%. The treatment was stopped in 28 cases for a major complications, among which: intracranial hemorrhage one, major bleeding six, compartment syndrome six, massive embolization one, lack of effect five; type of adverse event non-specified in nine cases.

2014. Huang et al. [70] (Mayo Clinic, Rochester, MN, USA). In 20 IAT (out of 24 acutely ischemic limbs) major complications occurred in five (20%).

The above list about IAT (mainly preoperative) may be annoying, however we believe that it allows a comprehensive view on the enthusiasm, disillusions and doubtful thinking on its value as the first step in the management of acute ischemia from thrombosed PAA. Certainly it is not the panacea, as initially hoped; on the other side, no doubt that it may be effective in obtaining a satisfactory popliteal outflow thus allowing the subsequent definitive treatment to have reasonable chances of success. To avoid an intervention in urgent/emergent conditions means also the possibility of correction of the consequences of

some comorbidities, the reestablishment of the hydroelectrolytic balance if needed and, why not, the field descent of the best surgical either angioradiological team. However, complications are frequent, some of them often lethal (stroke, acute myocardial infarction) or catastrophic, as the acute limb deterioration obliging to emergency intervention in conditions worse than at starting. Results and complications are hardly predictable. Moreover, it is a complex procedure, involving multidisciplinary expertises, may be not available in any hospital and in any moment. The results vary in the different experiences both for early and late results; and while the formers are quite evident, outlining the latter may be very difficult. We tried to analyze long-term results from some reports in which these data are clearly expressed [36, 46, 53, 58, 95, 117] for a total of 78 cases with IAT (A) and 111 without (B): the primary patency at 1, 3, and 5 years was 84%, 76%, and 72% for A; 65%, 58%, and 58% for B, respectively. These differences are not statistically significant. Apparently, immediate surgery with thrombectomy and on-table IAT while managing the aneurysm and tayloring the proximal graft anastomosis would look as a method effective and less prone to complications. But reported cases do not allow a firm conclusion; as for other aspects of PAA management, the debate remains open; and randomized trials are only a theoretical requirement.

15.3 Mid- and Long-Term Results

Survival of operated patients in 12 series is reported in Table 15.7. Other interesting data on survival may be found in other reports, generally emphasizing the high percentage of deaths during follow-up, and in particular of deaths for cardiovascular diseases, almost never related to the operation for PAA. Schellack et al. [28] observed that, among the patients affected with PAA, mortality rate was similar between operated and non-operated ones. Towne et al. [17] recorded that, in their cohort of 60 patients submitted to resection and grafting, 33 (55%) died during the follow-up (extended up to 20 years) and two-thirds of these for cardiovascular problems. Also in the experience of Inahara and Toledo [20] more than half of the patients died during the follow-up (max 14 years). According to Szilagyi et al. [21], 17/50 (34%) patients died within 16 years from operation, most of them (13) within 10 years. Dawson et al. [71] reported, in 50 patients operated on, a survival of 35% at 10 years, significantly lower than the 62% observed in a matched population: factors significantly influencing mortality were the occurrence of multiple aneurysms and the presence of coronary artery disease. Less dramatic look the data reported by Johnson et al. [91] for 583 patients from 123 US Veterans Administration Medical Centers, however within a short follow-up: survival was 97.6 at 1 year and

Table 15.7 Repair of PAAs: cumulative survival (%) after grafting procedures

Author, year	*N* patients	Age (mean)	1 year	3 years	5 years	10 years
Anton [26], 1986[a]	102	35–82 (62)	97	88	75	50
Lowell [121], 1994	54	[b]	94	89	80	42
Laxdal [52], 2004[a]	49	33–88 (69)			57	
Aulivola [51], 2004	39	18–89 (67)	98		84	
Huang [58], 2007	289	17–80 (70)			75	
Davies [60], 2007	48	40–88 (69)	95	92	76	67
Bisdas [122], 2010	50	49–85 (59)	96	96	74	
Zimmermann [63], 2010	46	31–95 (71)	90	72	54	
Dorweiler [71], 2014	154	40–95 (67)	91	74	63	41
Mazzaccaro [74], 2015	65	48–96 (78)			92	74
Del Tatto [123], 2018	87	48–89 (79)	98	98	98	
Personal series	58	52–88 (64)	97	90	80	71

Not always possible to consider late mortality independently from postoperative mortality
[a]Survival significantly lower than that of a normal matched population
[b]From a cohort of 106 patients aged 50–96 years (mean 64)

96.2 at 2 years. In the experience of Martelli et al. [54], survival was 82.6 at 6 years.

A particular way of looking at survival is considering freedom from reintervention or major adverse events. Davies et al. [60] report a freedom from reintervention in 73%, 65%, and 51% at 3, 5, and 10 years, respectively (vs. a cumulative survival of 92%, 76%, and 51%).

An exhaustive survey on mid-term (1 year) results was published in 2015 by Cervin et al. [73], relying on the data of the Swedish Vascular Registry, comprehensive of 473 cases: group A acute ischemia (emergent/urgent treatment) 138; group B elective symptomatic 90; group C asymptomatic 245. Survival, primary patency, secondary patency, and limb salvage were distributed as it follows:

- Group A: 95.5%, 78.8%, 86.8%, 93.2%.
- Group B: 94.4%, 81.1%, 86.5%, 91.6%.
- Group C: 98.8%, 89.0%, 93.5%, 99.1%.
- Groups A + B (all symptomatic): 95.2%, 79.6%, 86.7%, 93.5%.

No significant difference was found, in any of the groups, favoring the medial either the posterior approach, even if, considering the totality of operations, the posterior approach allowed better results than the medial one.

A further analysis about the effect of graft material on mid-term results revealed a significant difference in favor of autologous vein vs. synthetic grafts in the acute ischemia group. The difference was so striking as to condition significant better results of autologous grafts also when considering all cases. However, the small number of prosthetic cases in the acute ischemia group (13/119) and the lack of significant differences in the elective cases (but for secondary patency in the asymptomatic cohort) reduce the importance of this finding. On a whole, however, autologous vein fared better than prosthetic grafts, with a limb loss of 3.5% vs. 9.8%; the difference was statistically significant in the asymptomatic group: no amputations after 176 vein grafts, 2/36 amputations when a prosthetic graft was used.

The first consistent series with extended follow-up was reported in 1962 by Friesen et al. [8] (Mayo Clinic, Rochester, MN, USA, 1950–1960): 15/18 cases were available for follow-up and the results were considered highly satisfactory both for homografts (four cases followed-up for 39–53 months) and Teflon grafts (11 cases, followed-up 12–22 months). In particular, for the latter group, the Authors stressed that no failures, no reinterventions, and no limb loss were observed.

Three years later, Edmunds and Darling [9] (Massachusetts General Hospital, Boston, MA, USA, 1948) reported their experience 1948–63:

- Homografts: 12/21 available for a 5-year follow-up; all grafts patent, but three aneurysmatic.
- Dacron grafts: 9/10 followed-up 2–6 years; seven patent, but one limb was amputated owing to nonhealing foot ulcer.
- Autologous saphenous vein: 31 cases (but two were only patch grafts) of which 27 available for follow-up (12 for 3 years or more); only one failure, no amputation.

The Authors remarked the good results obtained in ischemic but still viable extremities; 24/28 (86%) patients were discharged with complete relief of their ischemic symptoms.

In 1966, Crichlow e Roberts [10] (University of Pennsylvania, Philadelphia, PA, USA; since 1953) confirmed the good chances of success in limbs moderately ischemic: 16/24 (66.6%) had an excellent result and 5/24 (20.8%) a good result; of cases with profound ischemia, only one had an excellent result, but two had a good result. A very satisfactory outcome was observed in 4/5 (29%) cases of chronic thrombosis and in 9/11 (82%) of acute thrombosis, in spite of a poor or very poor back-flow. The superiority of autogenous vein grafts was quite evident: all 21 grafts fared satisfactorily at a mean follow-up of 3.3 years (max 11.8 years); of 10/12 Teflon grafts with a mean follow-up of 4.1 years, 5 (50%) failed; and of 10/12 homografts followed-up for a mean of 8.3 years, 3 (30%) failed.

The Mayo Clinic experience 1961–1968 was reported by Wychulis et al. [12]. Different modalities of aneurysm treatment were used (endoaneurysmorrhaphy, resection, ligation or simply a

bypass) and the results were thoroughly analyzed according to the type of procedure and the type of graft. Of 17/21 limbs with autologous vein grafts available for follow-up (2 months to 5.5 years, mean 1.5 years) 12 (71%) were asymptomatic and five complained of claudication (severe in one case); of 20/22 limbs with a prosthetic graft followed-up for 1 month to 9 years (mean 3.5 years), only seven (35%) were symptom-free.

Bouhoutsos and Martin [13] (Hammersmith Hospital, London, and Chelmsford Hospital, Chelmsford, UK; 1958–1972) analyzed the late results of a large series of PAAs treated with reestablishment of arterial flow, according to the preoperative status of the aneurysm, the characteristics of outflow, and the type of graft:

- Thrombosed aneurysm + tibial artery disease: autologous vein 13 (follow-up <6 months to 15 years): six patent (46%), seven failed, seven amputations; synthetic graft three (follow-up <3 years): failed three, amputations three.
- Thrombosed aneurysm, patent tibial arteries: autologous vein 12 (follow-up 1–6/7 years): patent 11 (92%), failed one, amputation one; synthetic graft two (follow-up 6 months and 5 years): patent two (100%).
- Uncomplicated aneurysms (including two luetic): autologous vein 21 (follow-up 1–10/12 years): patent 19 (90%), failed two, amputations two; synthetic graft one: failed at 18 months, amputation.

Buda et al. [14] (Columbia University and Presbyterian Hospital, New York, USA; 1951–1972) did not observe any limb loss in a series of 50 cases treated by resection/grafting or exclusion/bypass, followed-up for a mean of 6 years:

- Autologous vein 16: patent 14 (87%), failed two.
- Synthetic graft 44 (Dacron 36, Nylon 8): patent 35 (79%), failed nine.

In 1976 Towne et al. [17] (Baylor University Medical Center, Dallas, TX, USA; study period 21 years) were the first to report the late results of PAA treatment with the life table method. Their report is peculiar, because it highlights the risk of aneurysm recurrence: six cases observed after 6 months to 10 years from resection; two cases bilateral, both proximal and distal to the graft, two unilateral distal to the graft.

Vermilion et al. [22] (St. Anthony Hospital, Columbus, OH, USA; 1960–1980) reported the following late results in a series of 90 cases:

- Autologous vein 45 (follow-up 1 month to 14 years, mean 47 months): patent 35 (78%), failed ten, reinterventions six, amputations zero.
- Dacron 34 (follow-up 2 months to 10 years, mean 59.4 months): patent 27 (79%), failed seven, reinterventions two, amputations three.
- PTFE 11 (mean follow-up 11 months): patent four (36%), failed seven, reintervention three, amputations four. All amputations in cases symptomatic/complicated; late patency was 96% in 29 asymptomatic cases.

Whitehouse et al. [24] (University of Michigan Medical School, Ann Arbor, MI, USA; 1943–1982) followed-up for a mean of 62 months 40/42 treated cases (autologous vein graft in 38/42), observing that 37 (92.5%) were patent; of three failures, two ended into amputation. The Authors stressed the uniformly excellent results in asymptomatic cases and, as well, that the operative approach and tactics should be individualized.

In Table 15.8 cumulative patency in 29 series is outlined (*in this table, as in the following eight, percentages are reported without decimals, with down—up to 0.5—or up-grading—from 0.6—approximation. Numbers in italics are extrapolated from graphics, and therefore they may be not properly exact. In bold are numbers expressing differences with statistical significance*). The primary assisted patency may be defined, according to Dorweiler et al. [71], as follows: patency never lost, but maintained using prophylactic interventions such as patch, endovascular procedures, partial graft replacement retaining most of the graft and at least one anastomosis in continuity. The importance of primary assisted patency is a consequence of the careful duplex surveillance and was stressed by the experience of Stone et al.

Table 15.8 Repair of PAAs: overall cumulative patency (%) of grafting procedures (with exclusion of autologous arterial grafting)

Author, year	*N* cases	12 months			36 months			60 months			120 months		
		A	B	C	A	B	C	A	B	C	A	B	C
1. Towne [17], 1976	28 (A)	55			50			42					
	42 (B)	75			65			53					
2. Inahara [20], 1978	40	92			83			76			76		
3. Szilagyi [21], 1981	50	94			72								
4. Batt [124], 1985	75	97			78			65					
5. Schellack [28], 1987	62							61		75			
6. Lilly [29], 1988	48	90			78			74					
7. Farina [30], 1989	45							62			62		
8. Shortell [32], 1991	51	90			75			72					
9. Dawson [31], 1991	42	85			85			75			64		
10. Carpenter [36], 1994	45	88			78			71			71		
11. Sarcina [37], 1997	61	95			82			78			75		
12. Duffy [39], 1998	30	85		92	81		85						
13. Borowicz [41], 1998	20							73		100			
14. Locati [42], 1999	5	59						49			29		
15. Mahmood [47], 2003	50	78		92	70		88	69		87			
16. Ascher [50], 2003	29	72											
17. Blanco [51], 2004	70	89		91	82		82	79		79	71		75
18. Laxdal [52], 2004	57							60					
19. Aulivola [53], 2004	51	96		100				85		97			
20. Beseth [90], 2006	30				92[a]	96[a]	96[a]						
21. Huang [58], 2007	354							76		87			
22. Antonello [59], 2007	27	100			94			88					
23. Davies [60], 2007	63							75		95	63		95
24. Zaraca [65], 2010[b]													
Posterior approach	38	90	94	97	90	94	97	90	94	97			97
Medial approach	11	100			70	70	78	55	60	78			78
25. Dorweiler [71], 2014	206	91	94	98	90	33	97	88	92	96	77	84	90
26. Mazzaccaro [74], 2015													
Posterior approach	43	85	95	89	68	86	98	60	86	98	52	78	82
Medial approach	34	84	87	98	72	80	86	65	73	79	65	72	79
27. Leake [75] 2016	110	89	92	92	79	84	85						
28. Del Tatto [123], 2018	103	95	96	99	83	85	97	78	85	93			
29. personal experience	81	100			100			94			85		88

A primary patency B assisted primary patency C secondary patency

When patency is mentioned tout court, numbers are somewhat arbitrarily put under the heading "primary patency"

Graft material: *V* autologous vein, *H* homograft, *Te* teflon, *D* dacron, *N* nylon, *PTFE* polytetrafluoroethylene, *B* bovine graft, *HUV* human umbilical vein, *P* synthetic graft in general

1. Baylor University Medical Center, Dallas, TX, USA; study period 21 years. A resection, grafting and lumbar sympathectomy; graft material: V3, H8, Te5, D9, N3. B resection and grafting; graft material: V6, D24, Te11, H1

2. St. Vincent Hospital, Portland, OR, USA. 1963–1977. Graft material: V31, P7. Data refer also to two cases of endoaneurymorrhaphy

3. Henry Ford Hospital, Detroit, MI, USA. 1964–1979. All aneurysms atherosclerotic but one. Graft material: V30, D20. Cumulative patency is probably calculated somewhat differently than in other series. In the interval 4–5 years, 30/31 grafts were patent. For the successive intervals (up to >16 years) no failure was observed

4. Clinique Chirurgicale, Université de Nice, France. 1968–1984. Follow-up 6–132 months (mean 40 months). Graft material: V46, D22, HUV 1, PTFE4, H2. Available for follow-up 63 cases: patent 46

5. Emory University, Atalanta, and Veterans Administration Medical Center, Decatur, GA, USA. 1965–1985. Graft material: V32, P28 (+2 end-to-end). Asymptomatic 20, symptomatic 42. Follow-up 2–240 months, mean 63 months.

Table 15.8 (continued)

Failures: vein 5/22 (16%), reintervention 1 ok, amputations 0; prosthesis 17/28 (60%), reintervention 3 ok, amputations 3 (18%)

6. Northwestern Medical School, Chicago, IL, USA. 1978–1987. Elective cases 26, urgent 22. Graft material: V39, PTFE9. Late failures 10, reinterventions 7, amputations 2

7. Creighton University, Omaha, NE, USA. 1972–1988. 47/50 PAAs atherosclerotic, 3 entrapment. Surgery in 45: asymptomatic or local symptoms 14, ischemic symptoms 31. Graft material: V15, PTFE19, D11

8. Univ. of Rochester Medical Center, Rochester, NY, USA. 1964–1990. Elective 32, urgency 19. Asymptomatic 15, symptomatic 36. Graft material: V49, PTFE2. Follow-up: mean 51.5 months

9. University Hospital, Leyden, The Netherlands. 1958–1985. All atherosclerotic aneurysms. Graft material: V25, D11, B3, HUV2, Te1. Follow-up 1 month to 23 years, mean 5 years

10. University of Pennsylvania, Philadelphia, PA, USA. 1979–1992. Graft material: V40, PTFE3, composite 2. Follow-up 1–172 months, mean 62 months. Late failure 11, of which three ending into amputation

11. University of Milan, Italy. 1971–1994. Asymptomatic 44, symptomatic 17. Graft material: V10, D17, PTFE34. Follow-up 8–122 months, mean 55 months

12. St. James's Hospital, Dublin, Ireland. 1987–1997. Asymptomatic 8, symptomatic 22. Graft material: V29, PTFE1. Follow-up 17 days to 100 months, mean 36.5 months. Late failures 3, reintervention ok 1, amputations 0

13. Medical University of South Carolina, Charleston, SC, USA. Study period 8 years. Asymptomatic 10, symptomatic 10. Nineteen atherosclerotic, 1 entrapment. Graft material: V18, PTFE2. Follow-up 2–92 months, mean 36 months. Late failures 3, reinterventions ok 3, amputations 0

14. Busto Arsizio Hospital, Busto Arsizio, Italy. 1982–1998. Graft material: V26, ringed PTFE21, non-ringed PTFE8, D3, Omniflow 1. Fifty-nine treated aneurysms are part of a cohort of 65 lesions (63 atherosclerotic, 2 post-entrapment) of which 38 symptomatic. Follow-up 2 months to 10 years, mean 6.5 years

15. University Hospital and Selly Oak Hospital, Birmingham, UK. 1988–2000. 24 asymptomatic, 26 symptomatic. Graft material: V49, 1 composite sequential PTFE+ vein. Mean follow-up 26 months

16. Maimonides Medical Center, Brooklyn, New York, USA. Study period 4 years. Graft material: V23, PTFE5, composite 1. 7/29 ending onto a tibial vessel. Follow-up 1–48 months, mean 13

17. Hospital Clinico S. Carlos, Universidad Complutense, Madrid, Spain. Study period 11 years. Asymptomatic 33, sympt. Chronic 19, sympt. Acute 18. Graft material: V53, PTFE17. Mean follow-up 53.2 months

18. Haukeland University Hospital, Bergen, Norway. 1974–2000. Asymptomatic 17, symptomatic 40. Graft material: V51, P6. Mean follow-up 42 months

19. Beth Israel Deaconess Medical Center, Boston, MA, USA. 1992–2002. Fifty atherosclerotic, 1 Marfan (?). Asymptomatc 15, symptomatic 36. Graft material: V48, PTFE2, D1. Mean follow-up 47.8 months

20. David Geffen School of Medicine at UCLA, Los Angeles, CA, USA. 1981–2003. Thirty cases treated by posterior access and interposition prosthetic graft (Dacron or PTFE). Median follow-up 21.5 months

21. Mayo Clinic, Rochester, MN, USA. 1985–2004. 358 aneurysms; atherosclerosis (microscopy) in 232/236). Asymptomatic 144: graft material V108, PTFE34, D2. Chronic ischemia 140: graft material V101, PTFE38, D1. Acute ischemia 74: graft material V50, PTFE22, composite/sequential 2

22. University of Padua, Padua, Italy. 1999–2006. All asymptomatic. Graft material: V17, PTFE10. Mean follow-up: 10–97 months, mean 46.7 months

23. University Hospital, Birmingham, UK. Partial overlapping with 15). 1988–2006. All grafted with autologous vein

24. Regional Hospital Bozen, Bozen, Italy. 1991–2009. Preferred the posterior approach. Aneurysm length, posterior approach: 58.6 mm; aneurysm length, medial approach: 173.2 mm. Asymptomatic 29, symptomatic chronic 10, symptomatic acute 10. Graft material: V 39, PTFE 10

25. University Hospital Center, Johannes-Gutenberg University, Mainz, Germany. 1998–2010. Asymptomatic 117, symptomatic 89. Graft material: V168, HUV or Omniflow 28, composite 10. Follow-up 1–164 months, median 137. Freedom from reintervention or amputation: 1 year, 85.9%; 3 years, 84.3%; 5 years, 84.3%; 10 years, 69.8%

26. S. Carlo Borromeo Hospital, Milan, Italy. 1998–2011. Asymptomatic 42, symptomatic chronic 18, symptomatic acute 17. Graft material: V16, PTFE54, D7. Follow-up 5 days to 166.7 months, mean 58.8 months

27. University of Pittsburgh Medical Center, Pittsburgh, PA, USA. 2006–2014. Acute ischemia 27/110. Graft material: V82, P23. Mean follow-up 34.9 months

28. University Hospital Strasbourg and Hospital Mercy Metz, France. 2004–2016. Asymptomatic 62, symptomatic chronic 14, symptomatic acute 27. Graft material: V67, PTFE32, vein homograft 1, arterial autograft 3. Follow-up 0.1–10 years, mean 4 years

29. First Dept. of Surgery, "Sapienza" University, Rome, Italy. 1981–2005. Asymptomatic 48, chronic ischemia 33. All elective. Graft material: V52, D16, PTFE13. Follow-up 1–17 years, mean 7 years

[a]Patency at 48 months

[b]Eight-year patency for medial approach reported under the heading 10 years

[55]: in a series of 48 cases treated with open surgery (graft material: vein 38, PTFE 10) and seven endovascular cases, a primary patency of about 30% was transformed in a primary assisted patency of about 80% through 20 revisions in 18 limbs.

Data differ in the various experiences, but, on a whole, considering the different compositions in terms of clinical presentation and graft materials, they may be defined as satisfactory. The rate of attrition was defined as similar to that observed in the treatment of occlusive disease by Batt et al. [124] within a mean follow-up of 40 months; however Reilly et al. [23], relying on a longer follow-up, observed that this applies up to 5 years after operation, later on the attrition continues progressively for occlusive disease but remains almost stable for popliteal aneurysms.

It is a general finding that late failure in patency rates is not matched by a corresponding decline in limb salvage [39], as many limbs remain viable after graft failure even in lack of reintervention. No doubt that an early occlusion of the graft entails worse consequences than a late one, as the latter represents often the end of a slow process allowing the development of an effective collateral circulation. E.g., Dorweiler et al. [71] stressed that 4/9 (44%) early failures ended into limb loss in spite of eight reinterventions; while amputation was necessary in only 1/12 (8%) late failures (seven reinterventions). Reilly et al. [23] calculated a likelihood of limb loss of 72% after early failure and of 1.4% after late failure.

A synthetic survey on available data is illustrated in Tables 15.9 and 15.10.

15.4 Factors That May Influence Late Results

15.4.1 Symptoms at Presentation

Preoperative symptoms and clinical presentation affect long-term results [34, 74], even if this is not confirmed in some experiences [23, 36, 46, 53, 72]. This finding is not constant during the follow-up. Batt et al. [124] observed that asymptomatic cases fared better by 15 percentage points during the first year; later on, attrition rate was similar in asymptomatic and symptomatic limbs. According to Farina et al. [30] the difference persisted for the first 4 years. Others [31, 34], contrarily, observed a significant difference only late in the follow-up (at 5 and 10 years). In effects, a statistically significant difference may manifest at different intervals during the follow-up (Tables 15.9 and 15.10). Moreover, the impor-

Table 15.9 Repair of PAAs: failures and limb loss during follow-up after grafting procedures

Author, year	*N* limbs	Follow-up (mean)	Failures	Reinterventions	Amputations
Inahara [20], 1978	40	2 months to 14 years	9	3	2
Schellack [28], 1987	60	2–240 months (63)	22	8	3
Lilly [29], 1988	48		10	7	2
Batt [124], 1989	63	2–132 months (40)	17		10
Taurino [40], 1998	23	3 months to 15 years (48 months)	2		1
Davidovic [38], 1998	54	6 months to 26 years	12	6	6
Dorigo [117], 2002	91	1–106 months (36)	10		2
Antonello [59], 2007	37	10–97 months (47)	2		0
Leake [75], 2016	109	(40 months)	11		4

Table 15.10 Repair of PAAs: cumulative limb salvage (%) after grafting procedures

Author, year	*N* limbs	1 year	3 years	5 years	10 years
Shortell [32], 1991	51	94	94	94	
Dawson [31], 1991	42	95	95	95	95
Carpenter [36], 1994	45			90	
Lowell [121], 1994	59	95	95	94	90
Sarcina [37], 1997	61	97	88	86	83
Duffy [39], 1998	30	96	96		
Borowicz [41], 1998	20			100	
Mahmood [47], 2003	50			87	
Ascher [50], 2003	29		94[a]		
Aulivola [53], 2004	51	98		98	
Beseth [90], 2006[b]	30	100	100[a]		
Huang [58], 2007	358			97	
Davies [60], 2007	63			95	95
Dorweiler [71], 2014	206			97	97
Del Tatto [123], 2018	103	94	94	89	
Personal series[c]	81	100	100	100	100

[a]At 24 months
[b]Only posterior approach
[c]All elective cases

tance of this parameter may change along time in the experience of the same Center: Pulli et al. [57], analyzing the cases treated 1994–2004, found a significant difference between asymptomatic/symptomatic lesions both at univariate and multivariate analysis; in the further experience 2005–2010 [125], no significant difference was observed.

In the subset of symptomatic cases, Dawson et al. [31] observed, at 10 years, a difference between acute and chronic presentation, nonsignificant as for patency but significant for limb salvage; this finding was not confirmed by others [47].

A significant difference is observed by several Authors in the late results regarding patent or thrombosed aneurysms at presentation. At 5 years, Carpenter et al. [36] report a patency of 85% for patent aneurysms vs. 58% for thrombosed ones. In the series by Gouny et al. [79], the values at 48 months are 82% and 38% for primary patency, 91% and 52% for secondary patency, respectively. In a large series from the Mayo Clinic [58] patency at 5 years is 80% for 260 patent aneurysms and 66% for 98 thrombosed ones.

An interesting analysis of late failures in relation with clinical presentation was aired in 1983 from the Massachusetts General Hospital [23]:

- 66 asymptomatic: late failures seven (10.6%)
- 23 acute thrombosis: late failures four (17.4%)
- 12 chronic thrombosis: late failures six (50%)
- 9 acute embolism: late failures three (33.3%)
- 14 chronic embolism: late failures one (7.1%)
- 8 local symptoms: late failures two (25%).

Authors' conclusion was that late outcome was independent from initial presentation (Tables 15.11 and 15.12).

15.4.2 Quality of Popliteal Outflow

The importance of the characteristics of popliteal outflow in determining clinical presentation has been already evaluated.

Lilly et al. [29] observed that a poor outflow was also significantly associated with the demand for urgent/emergent treatment: this was necessary in only 5/21 (22%) limbs with 2–3 vessel

Table 15.11 Repair of PAAs: patency (%) according to clinical presentation (asymptomatic vs. symptomatic)

	N cases		1 year				3 years				5 years				10 years	
			A		S		A		S		A	S			A	S
Author, year	A	S	I	II	I	II	I	II	I	II	I	II	I	II	I	II
Anton [26], 1986	55	68	86		80		86		66		81		57		81	48
Schellack [28], 1987	20	42		100		84		100		78	77	97	53	66		
Farina [30], 1989	14	31	100		75		100		68		80		65		55	65
Sarcina [37], 1997	44	17	97		88		85		76		82		67		78	67
Dorigo [117], 2002	58	51	92		75		92		64							
Mahmood [47], 2003	24	25		100		81		100		74		100		74		
Laxdal [52], 2004	17	40	90		60		85		54		83		49			
Aulivola [53], 2004[a]	15	22	100		94	100					87	87	84	100		
Pulli [57], 2006	61	79	90		70		86		60		86	89	52	80		
Huang [58], 2007[b]	144	140									88		71			
		74									88		63			
Personal experience[a]	48	33	100		100		100		100		96		88		96	74

I primary patency II secondary patency

[a]All elective cases

[b]One hundred and forty symptomatic chronic, 74 symptomatic acute

Table 15.12 Repair of PAAs: limb salvage (%) according to clinical presentation (asymptomatic vs. symptomatic)

	N limbs		1 year		3 years		5 years		10 years	
Author, year	A	S	A	S	A	S	A	S	A	S
Anton [26], 1986	55	68	90	89	93	87	93	82	93	79
Sarcina [37], 1997	44	17	100	88	94	75	91	75	87	75
Locati [42], 1999[a]	27	19	98	68			90	52		
Laxdal [52], 2004	17	40	100	68	100	64	100	64		
Aulivola [53], 2004	15	36					100	97		
Pulli [57], 2006	61	79	93	92			93	80		
Wagenhauser [92], 2015	16	36	100	96	100	96	100	96	100	87
Personal series[a]	48	33	100	100	100	100	100	100	100	100

[a]Only elective cases

popliteal outflow, but in 17/26 (65%) limbs with 0–1 vessel outflow. As for late results, the quality of outflow was considered important but not significant by some Authors [43, 63], while Serrano-Hernando et al. [72] found that poor runoff was an independent factor for worse primary patency.

Farina et al. [30] observed that, at 4 years, grafts with at least one tibial vessel outflow had a patency of 92% while patency with zero tibial outflow was 30%. In their experience the significant difference in patency according to runoff was constant for the first 4 years, then disappeared.

Carpenter et al. [36] found a significant difference in patency, at 5 and 10 years, between grafts with 2/3 vessel outflow and those with 0–1 outflow, no graft with zero outflow remaining patent after 1 year. As for limb salvage, the difference was equally striking at any interval up to 10 years: 100% for 2/3 vessel runoff, 78% for one vessel outflow, 25% for zero vessel outflow (Table 15.13).

A particularly interesting classification of results based on distal pulse recovery after operation comes from the Group headed by Hertzer [26] (Table 15.14). They observed that 9/14 late amputations were needed in limbs with isolated popliteal pulse after grafting; as well, that limbs recovering pedal pulses allowed unrestricted function in 71/81 (88%); this was observed in 17/25 (68%) when no pedal pulse was recovered (Table 15.14).

Table 15.14 Repair of PAAs: patency (%) and limb salvage (%) after grafting procedures according to recovery of pedal pulse(s) (from Anton et al. [26])

	1 year	3 years	5 years	10 years
A: Two pulses recovered: 47 limbs	94 (96)	87 (96)	79 (96)	64 (96)
B: One pulse recovery: 33 limbs	93 (96)	85 (96)	64 (92)	64 (85)
C: Only popliteal pulse: 39 limbs	57 (83)	40 (73)	32 (65)	32 (65)

Limb salvage in brackets. Both for patency and limb salvage, statistically significant difference between A and C and between B and C

Table 15.13 Repair of PAAs: patency (%) and limb salvage (%) after grafting procedures, according to preoperative popliteal outflow

	N limbs		1 year		3 years		5 years		10 years	
Author, year	A	B	A	B	A	B	A	B	A	B
Patency										
Lilly [29], 1988	24	26					84	65		
Shortell [32], 1991	30	11	90	70	89	40	89	39	64	0
Sarcina [37], 1997	51	10	95	90	85	65	85	65		
Borowicz [41], 1998	12	8			83[a]	83[a]				
Blanco [51], 2003[b]	51	16	96	65	86	65	86	55		
Huang [58], 2007[c]	145	204					99–83	77–48		
Limb salvage										
Shortell [32], 1991	30	11	93	91	93	91	93	91		
Sarcina [37], 1997	51	10	95	90	80	89	82	75		

A 2–3 vessel runoff B 0–1 vessel runoff

[a]At 42 months

[b]Secondary patency

[c]Three vessel runoff 18 limbs 5-year patency 93%; two vessel runoff 127 limbs, 5-year patency 83%; one vessel runoff 147 limbs, 5-year patency 77%; zero vessel runoff 57 limbs, 5-year patency 48%

15.4.3 Graft Material

There is a general consensus about the superiority of autologous vein grafts in assuring extended patency rates [65], even if not always reaching a statistically significant weight [43]. Schellack et al. [28] report 5/32 (16%) failures with autologous vein grafts and 17/28 (60%) with non-autologous grafts. In the experience of Irace et al. [44], 25/27 (92%) autologous grafts remained patent vs. 10/15 (67%) when PTFE was used. According to Serrano-Hernando et al. [72], excluding early failures, 14/35 (40%) PTFE grafts failed vs. 6/96 (6%) autologous vein grafts. Pulli et al. [69], in an Italian multicenter survey, found, at 4 years, a significant difference in patency between autologous and synthetic grafts: 86% vs. 56%.

Anton et al. [26] analyzed the late functional results of 106 grafts:

	Asymptomatic, %	Claudication	Limb loss
Autologous			
Vein 57	96	4	0
PTFE 18	78	17	5
Others 31	58	23	19

They stressed that the divarication of patency curves between autologous and non-autologous grafts started at the beginning and increased steadily and continuously during the follow-up; as for limb salvage rates, this divarication was also present but much less evident.

Lowell et al. [121] observed that only 1/42 (2.4%) limbs grafted with autologous vein got lost, while 7/31 (22.6%) limbs grafted with PTFE were amputated; of the latters, 5/26 (19.2%) were elective cases.

From the Swedish Vascular Registry [61], comprehensive of 681 grafting procedures, limb salvage at 5 years was: cumulative 89%; autologous vein, medial approach 96%; synthetic graft, medial approach 77%; autologous vein, posterior approach 94%; synthetic graft, posterior approach 87%.

An interesting observation comes from Blanco et al. [51]; they observed that, at 1 and 5 years, secondary patency was respectively 95% and 85% for long vein grafts and—significantly different—70% and 46% for long synthetic grafts; the difference, however, ceased to be significant when considering short vein grafts vs. short synthetic grafts, being respectively 100% and 90% vs. 85% and 85%. If confirmed, such finding should be an indication to perform the shortest possible grafting procedure (interposition or inlay), as, in this setting, non-autologous grafts may behave quite satisfactorily (Tables 15.15, 15.16, and 15.17).

15.4.4 The Emergency Setting

According to several Authors [23, 46, 47, 53, 71, 127] late results are not influenced by the characteristics of the operative procedure, if elective or emergent/urgent. Dawson et al. [31] observed no difference as for patency but a significant difference in limb salvage rates. Mazzaccaro et al. [74] found a significant difference in late patency rates only for operations performed trough the medial approach.

Carpenter et al. [36] recorded, during the follow-up, 11 failures, of which three ended into amputation: none in limbs operated on electively. Locati et al. [42] observed that reinterventions and amputations were particularly frequent after urgent treatment:

Davies et al. [60] observed, at 10 years, a significant difference in patency between limbs operated on electively or in urgence (Table 15.18).

	Reinterventions, %	Amputation
Emergent/urgent	37	37
Elective symptomatic	16	26
Elective asymptomatic	4	4

15.4.5 The Need of Performing a Tibial Bypass

Intuitively, grafts ending onto the tibial arteries should offer a reduced chance of patency with respect to those ending onto the popliteal artery. Few Authors have addressed this issue.

Table 15.15 Repair of PAAs: patency (%) after grafting procedures with autologous vein

Author, year	*N* limbs	1 year		3 years		5 years		10 years	
		I	II	I	II	I	II	I	II
Batt [124], 1985	46	98		80		80			
Anton [26], 1986	58	94		94		94		94	
Schellack [28], 1987	32	95	97	89	92	89	92		
Farina [30], 1989	15	100		100		100		100	
Dawson [31], 1991	25	96		96		84		84	
Sarcina [37], 1997	10	100		90		88			
Locati [42], 1999	26	92				85		62	
Martelli [54], 2004	19	88		66					
Bourriez [56], 2005[b]	80	96	99	94	99	90	99		
Huang [58], 2007	242					85	94		
Zimmermann [63], 2010	39	97		87		87			
Serrano-Hernando [72], 2015	99	85	95	78	90	78	90	76	86
Ronchey [126], 2015	28					81	85		
Personal series[c]	52	100	100	100	100	100	100	92	92

I primary patency II secondary patency
Series in which only (or almost only) autologous vein graft was used and series in which only (or almost only) synthetic grafts were used are not included in the tables
Anton: significant difference vein vs. non-autologous grafts at 10 years
Schellack: significant difference vein vs. non-autologous grafts at 5 years
Farina: significant difference vein vs. Dacron at 5 and 10 years
Dawson: significant difference vein vs. non-autologous grafts at 5 and 10 years
Sarcina: significant difference vein vs. non-autologous grafts and PTFE vs. Dacron at 5 years
Bourriez: significant difference vein vs. PTFE at 3 and 5 years
Huang: significant difference vein vs. PTFE at 5 years (throughout the follow-up in acute cases)
Serrano-Hernando: significant difference vein vs. PTFE at 5 and 10 years
[a]Only acute cases
[b]Only asymptomatic or with claudication intermittent
[c]Only elective cases

Table 15.16 Repair of PAAs: patency (%) after grafting procedures with non-autologous material

Author, year	*N* limbs	1 year		3 years		5 years		10 years	
		I	II	I	II	I	II	I	II
Batt [124], 1985	29	87		58		40			
Anton [26], 1986	65	73		59		43		27	
Schellack [28], 1987	28	70	82	62	82	29	55		
Farina [30], 1989									
PTFE	19	74		74		74		74	
Dacron	11	72		62		34		34	
Dawson [31], 1991	17	76		76		60		41	
Sarcina [37], 1997									
PTFE	34	100		88		80			
Dacron	17	80		72		47			
Locati [42], 1999									
Ringed PTFE	21	43				29		5	
Non-ringed PTFE	8	25				13		5	
Dacron	3	33							
Martelli [54], 2004	23	61		55					
Bourriez [56], 2005[b]	PTFE 20	83	95	61	88	50	88		

(continued)

Table 15.16 (continued)

Author, year	*N* limbs	1 year		3 years		5 years		10 years	
		I	II	I	II	I	II	I	II
Huang [58], 2007	PTFE 94					50	63		
	PTFE 22	61	67				30		
Zimmermann [63], 2010	12	80		66					
Serrano-Hernando [72], 2015	PTFE 40	80	82	60	65	54	61	45	45
Ronchey [126], 2015	PTFE 14					69	84		
Personal series[c]									
PTFE	13	100	100	100	100	97	97	90	90
Dacron	16	100	100	100	100	85	85	62	70

I primary patency II secondary patency
Series in which only (or almost only) autologous vein graft was used and series in which only (or almost only) synthetic grafts were used are not included in the tables
Anton: significant difference vein vs. non-autologous grafts at 10 years
Schellack: significant difference vein vs. non-autologous grafts at 5 years
Farina: significant difference vein vs. Dacron at 5 and 10 years
Dawson: significant difference vein vs. non-autologous grafts at 5 and 10 years
Sarcina: significant difference vein vs. non-autologous grafts and PTFE vs. Dacron at 5 years
Bourriez: significant difference vein vs. PTFE at 3 and 5 years
Huang: significant difference vein vs. PTFE at 5 years (throughout the follow-up in acute cases)
Serrano-Hernando: significant difference vein vs. PTFE at 5 and 10 years
[a]Only acute cases
[b]Only asymptomatic or with claudication intermittent
[c]Only elective cases

Table 15.17 Repair of PAAs: limb salvage (%) after grafting procedures, according to graft material

Author, year	*N* cases	1 year	3 years	5 years	10 years
Anton [26], 1986	Vein 58	98	98	98	98
	Others[a] 65	86	82	75	66
Dawson [31], 1991	Vein 25				100
	Others[b] 17				88
Roggo [34], 1993	Vein 148			97	94
	Others 81			88	74
Sarcina [37], 1997	Vein 10	100	90	88	
	Dacron 17	90	80	70	
	PTFE 34	100	92	88	

[a]Homografts 26, Dacron 20, PTFE 19
[b]Dacron 11, bovine heterograft 3, human umbilical vein 2, Teflon 1

Mahmood et al. [47] stated that the site of distal anastomosis was without influence on late results. However, Pulli et al., in two successive issues at the distance of 6 years [57, 125] asserted that this, both at univariate and multivariate analysis, resulted to be a significant factor for lower patency rates; and Huang et al. [58] found highly significant the site of distal ending of the graft.

15.5 Arterial Autografts

In 1964, at the 18th annual meeting of the Society for Vascular Surgery, Wylie [128] reported a stimulating experience with 23 reconstructive arterial procedures performed using iliac artery autografts. Primary indication was arterial replacement adjacent to an active joint and the presence of local infection. Five popliteal aneu-

Table 15.18 Repair of PAAs: primary patency (%) and limb salvage (%) after grafting procedures, elective vs. emergent/urgent

	N limbs		1 year		3 years		5 years		10 years	
Author, year	A	B	A	B	A	B	A	B	A	B
Primary patency										
Lilly [29], 1988	26	22	100	80	93	65	90	54		
Shortell [32], 1991	32	19	100	70	95	40	92	39		
Palumbo [43], 1999	62	13			79[a]	44[a]				
Aulivola [53], 2004	37	14	100	85	86	85	86	85		
Huang [58], 2007	325	33	–	–	–	–	80	45		
Lichtenfels [62], 2008	34	16	94	67						
Huang [70], 2014	93	14	90	86	85	75				
Limb salvage										
Shortell [32], 1991	32	19	100	84	100	84	100	84		
Palumbo [43], 1999	62	13	–	–	88[a]	54[a]				
Aulivola [53], 2004	37	14	–	–	–	–	100	93		
Pulli [57], 2006	46	22	98	73	90	73	90	59		
Lichtenfels [62], 2008	34	16	97	62						
Dorweiler [71], 2014	161	45	–	–	–	–	99	91	99	91

A elective B emergent/urgent
[a]At 46–48 months

rysms and one false aneurysm were part of this experience, and all grafts were patent at a follow-up of 15–39 months (mean 24.5): in three of them, however, a full-length (non-anastomotic) luminal constriction was observed, attributed to an excess of tension. The Author was particularly enthusiastic with the fact that the arterial autograft complied to knee movements just like a native normal artery. Of course, criticism to this original technique was the need of entering the retroperitoneum and of using a synthetic graft to replace the harvested artery.

The use of arterial autograft in the treatment of PAAs revived with Reix et al. [129] from Amiens, France: during the period 1992–1998 they repaired 18 PAAs in 12 patients, using an arterial autograft obtained from the ipsilateral superficial femoral artery; this technique avoided the aggression to the abdomen; however, a synthetic graft (PTFE) was required to reestablish continuity of the femoral tract. Eight cases were asymptomatic and four presented with acute ischemia requiring urgent treatment. The operation was performed trough a medial approach, the PAA being excluded or obliterated by endoaneurysmorrhaphy. Two types of reconstruction were used, both involving the end-to-end anastomosis between the arterial autograft and the distal PA; if possible, the autograft was anastomosed proximally with the distal superficial femoral artery and the lack of continuity of the latter was treated with an interposition PTFE graft; alternatively (six cases including the four urgent cases), a composite PTFE/arterial graft was used to bridge the distance between the proximal superficial femoral artery and the distal popliteal artery. It is interesting to observe that, initially, the use of arterial graft was reserved to cases in which the autologous saphena was absent or not adequate (it is not known if other veins were taken into consideration); in the last cases, the autologous arterial graft represented the first choice. Early and 2-years primary and secondary patencies were 91% and 100%, respectively. Duplex control during the follow-up (2–60 months, mean 22) did not reveal any stenosis or significant enlargement of the autograft. The same Group [130] updated the experience in 2017, reporting on 77 cases in 69 patients treated from 1996 through 2016 (apparently excluding the first 3 years of the earlier experience). Thirty-one PAAs (41%) were symptomatic or complicated. The arterial autograft was electively used, as the preferred

option, in 12 cases, to treat small retroarticular lesions. The graft was sequential in most cases and composite only in 13%; 25% of the procedures were performed in emergency. Limb salvage was 96% (i.e., three limbs were amputated). Primary patency was 84% at 3 years and 74% at 10 years; the corresponding secondary patencies were 96% and 92%. With a larger group of patients and a longer follow-up (with respect to the early report), several adverse events manifested, implying a reintervention rate of 19%: seven times for thrombosis (of the autograft or of the synthetic graft or both), three times for enlargement of the excluded aneurysm, and one time for degeneration of the autograft; four additional cases of thrombosis were not reoperated one. The Authors observed that primary patency was negatively affected by emergency procedure and by poor runoff.

Other reports on the transposition of superficial femoral artery in the treatment of PAA were aired from France.

Puppink et al. [131] described two cases, presenting with local symptoms, successfully treated with a follow-up of 40 and 46 months, respectively.

In 2008, Paraskevas et al. [132] reported 37 cases (in 32 patients) representing about 20% of the entire casuistic of 195 cases treated in the period 1997–2007. Most of these (26 = 70%) were asymptomatic and three (8%) presented with acute limb ischemia. Management of the PAA varied: 17 resection, 5 exclusion by ligation, 15 opening and intrasaccular obliteration of collaterals. No early complications specifically linked to operative technique were registered. At 3 years (follow-up ranged 7–103 months) limb salvage was 100%, primary patency 86%, and secondary patency 96%. No aneurysmal dilatation of the graft was observed at duplex control.

In 2009, Lemonnier et al. [133] reported an experience of 29 cases (the aneurysm was excluded in 16 and submitted to endoaneurysmorrhaphy in 13) in which *transposition of homolateral superficial femoral artery was systematically chosen when this artery could be used to treat an isolated popliteal aneurysm*. Fourteen cases (48.3%) were asymptomatic and only one case was treated in emergency. The harvested superficial femoral artery was replaced with PTFE (22 cases) or dacron (seven cases). When a long segment of superficial femoral artery was required, the final reconstruction was a composite graft. No early problems were registered. At a mean follow-up of 39.2 months (1–114) no limb was lost and no aneurysmal degeneration of the autologous graft was observed. Primary patency was 100% at 1 year and 92% at 3 years; correspondingly, secondary patency was 100% and 100%. Two cases of synthetic graft thrombosis with patent autograft were observed: at 29 months, successfully treated by thrombectomy; at 50 months, asymptomatic.

Recently, a 26-year experience (1991–2017) of 67 cases has been reported by Bounkong et al. [134], from Pitié Salpetrière Hospital, in Paris. Asymptomatic cases were 34 (50.8%) and acute ischemia was present in 7 (10.5%). In 16 young patients defined as arteriomegalic the arterial autograft was protected against possible enlargement with an external synthetic graft, with multiple holes to prevent fluid collections. Postoperatively, no deaths and no limb loss. The results may be tabulated as it follows (Table 15.19).

Table 15.19 Repair of PAAs: patency (%) after grafting with autologous artery (from Bounkong et al. [134])

	1 year		3 years		5 years		10 years	
	Prim	Second	Prim	Second	Prim	Second	Prim	Second
All limbs 67	93	96	85	90	78	87	56	87
1 vessel outflow 6	100	100	80	80	80	80		
2 vessel outflow 14	92	100	73	86	63	69		
3 vessel outflow 47	91	94	87	94	82	94		

During the same period, 104 patients were grafted with autologous greater saphenous vein, the primary patency at 1, 3, and 5 years being respectively 96%, 92%, and 90%)

Arterial autografting for repair of PAA represents an appealing technique, offering gratifying results in the hands of the few surgeons who have experienced it. However, it adds to the complexity of the procedure and may not, at the moment, be considered a preferential alternative to the autologous vein. Its use should be restricted to cases in which a short reconstruction is required, i.e., when the superficial femoral artery is in good conditions and, as well, when a distal ending on tibial vessels is not required. As now, we think that it is premature to make a comparison also with short interposition or inlay synthetic grafting. However, it is instinctive to share Wylie's idea that an autologous artery, in the popliteal space, behind the continuously moving knee, would represent the best alternative to the native artery.

15.6 Resection and End-to-End Anastomosis

This apparently simple procedure has been scantily performed, because it is not frequent that the aneurysm is so small that the defect resulting after resection is short enough to allow a direct reconstruction [4], even if, in general, aneurysmatic PA is also lengthened in some way. We found only 14 series in which this procedure was, in some cases, technically possible.

Crawford et al. [135] were able to perform it in one-third of the operated cases: extensive mobilization of the artery was often required and in some cases, going back to Enderlen's suggestion [136], a convenient approximation of the two arterial stumps was obtained by flexion of the knee (this was maintained postoperative for 1 week by a posterior plaster splint); two reconstructions failed at 6 and 8 months, respectively, without limb loss.

Edmunds et al. [9] reported three cases with excellent long-term result.

Alpert et al. [18] performed end-to-end reconstruction in 20% of reconstructed cases, when approximation without tension was possible; however, in two cases (29%) early disruption obliged to reintervention and vein graft interposition.

Feasibility of this type of reconstruction was stressed in 2005 by Alsac et al. [137]: they used an extended medial approach, with artery mobilization from the superficial femoral artery (above the adductor hiatus) to the origin of anterior tibial artery; aneurysms as long as 3.5 cm could be resected leaving the possibility of a satisfactory stump approximation. They could operate in this way four of eight patients with PAA: three aneurysms were patent (two symptomatic) and one was thrombosed with ischemic symptoms. A positive result was obtained at 3, 6, 7, and 14 months, respectively.

In the other experiences, the results of this type of reconstruction are mixed with those of grafting procedures. However, Wychulis et al. [12] report them separately: four aneurysms were operated in this way (three asymptomatic, one local symptom); one limb presented mild claudication after 2.9 years; three were asymptomatic at 4 months, 1.7 years, 2.7 years, respectively (Table 15.20).

Table 15.20 Cases of PAA treated by resection and end-to-end anastomosis

Author, year	*N* reconstructive procedures	Resection and end-to-end anastomosis
Crawford [135], 1959	30	10 (33.3%)
Edmunds [9], 1965	71	3 (4.2%)
Crichlow [10], 1966	48	1 (2.1%)
Wychulis [12], 1970	48	4 (8.3%)
Buda [14], 1974	72	5 (6.9%)
Evans [138], 1976	61	1 (1.6%)
Towne [17], 1976	71	1 (1.4%)
Alpert [18], 1977	35	7 (20.0%)
Whitehouse [24], 1983	44	2 (4.5%)
Reilly [23], 1983	163	9 (5.5%)
Schellack [28], 1987	62	2 (3.2%)
Dawson [31], 1991	44	2 (4.5%)
Davidovic [38], 1998	59	3 (5.1%)
Alsac [137], 2005	8[a]	4 (50%)
Pulli [57], 2006	156	4 (2.5%)
Ravn [61], 2007	673	2 (0.3%)[b]

[a]Eight patients

[b]Data from the Swedish Vascular Registry. The two cases belong to the group of 60 in which a posterior approach was used

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