14 Primary Amputation, Endoaneurysmorrhaphy, Lumbar Sympathectomy, and the Use of Tourniquet

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14.1 Primary Amputation

The extreme variability of the incidence of primary amputation reflects, probably, also the type of activity of the single institutions airing each report. For example, our personal experience was gained at an institution only marginally involved in urgent/emergent surgery; in our earlier activity, we took part in several demolitive procedures on limbs with irreversible acute ischemia or frank gangrene: we don't know how many of those cases were due to thromboembolic complications of a popliteal aneurysm. Suffice it to remember that of the 11 primary amputations reported by Gaylis [1], seven were the consequence of a thrombosed popliteal aneurysm, the presence of which was recognized only at operation. In the experience of Jackaman et al. [2], 3/6 complicated popliteal aneurysms leading to primary amputation were unknown before the operation.

No doubt that increased awareness by physicians and patients and the great potential of modern diagnostic techniques have reduced the cases of undiagnosed popliteal artery aneurysms (PAAs) and the occurrence of unheralded catastrophic consequences. However, several reports deal only with cases amenable to repair; moreover, the suspicion that a complicated PAA is the source of acute ischemia has reached high levels; anyway, it is surprising that several series do not mention the eventual occurrence of primary amputation.

Of papers published after 2000, few [3–6] make mention of primary amputation; several papers, also in the preceding decades, exclude from analysis the cases of primary amputations or simply do not mention them (see footnote to Table 13.1): is it because they never occurred or because non-salvageable limbs were managed by other teams (as probably occurred in our experience)?

Referring to Table 14.1, we can say only that 215 primary amputations were performed in 2972 limbs with a PAA (7.2%); the percentage increases, obviously, if only the 1806 cases of complicated or symptomatic aneurysms are considered (11.9%). The percentage would be certainly higher if only acute situations were considered; however, a number of primary amputations were necessary also in chronically and severely ischemic limbs. So, these numbers are only orientative, sufficient enough, however, to stress the need for early diagnosis, the opportunity of preventive surgery, and the convenience of screening programs.

14.2 Endoaneurysmorrhaphy (EA)

Matas' method of intrasaccular suture [34] represented really a milestone event in the treatment of aneurysms. In 1920 [35], he was able to report on a collected series of 103 PAAs submit-

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Table 14.1 Primary amputation for complication of popliteal artery aneurysm

Author, year	A = aneurysms observed (tot.)	B = aneurysms compl./sympt.	Primary amput.	Percentage of A	Percentage of B
Greenstone [7], 1961	12	6	3	20.0	50.0
Friesen [8], 1962	119	101	17	14.3	16.8
Baird [9], 1966	51	43	10	19.6	23.3
Wychulis [10], 1970	233	111	13	5.6	11.7
Gaylis [1], 1974	55	37	11	20.0	29.8
Buxton [11], 1975	34	22	3	8.8	13.6
Hardy [12], 1975	31	16	3	9.7	18.7
Towne [13], 1976	119	63	4	3.4	6.3
Evans [14], 1976	86	61	9	10.4	14.7
Tompkins [15], 1977	26	22	6	23.1	27.2
Vermilion [16], 1981	147	98	14	9.5	14.3
Laskar [17], 1982	32	23	1	3.1	4.3
Reilly [18], 1983	244	132	23	9.4	17.4
Whitehouse [19], 1983	88	48	4	4.5	8.3
Batt [20], 1985	119	82	10	8.4	12.2
Downing [21], 1985	62	45	3	4.8	6.7
Mellière [22], 1986	65	18	5	7.7	28.0
Anton [23], 1986	160	83	1	0.6	1.2
Schellack [24], 1987	95	51	4	4.2	7.8
Englund [25], 1987	103	64	6	5.8	7.9
Cole [26], 1989	59	34	7	11.9	20.6
Shortell [27], 1991	54	39	3	5.5	7.7
Roggo [28], 1993	252	189	23	9.1	12.2
Lowell [29], 1994	159	65	5	3.1	7.7
Sarcina [30], 1997	67	33	3	4.5	9.1
Davidovic [31], 1998	76	61	10	13.1	16.4
Dijkstra [32], 1998	23	19	1	4.3	5.3
Locati [33], 1999	65	38	2	3.1	5.3
Kauffman [3], 2002	142	102	4	2.8	3.9
Lichtenfels [4], 2008	50	36	4	8.0	11.1
Zimmerman [5], 2010	56	17	2	3.6	11.8
Stone [6], 2013	88	47	1	1.1	2.1

ted to obliterative EA followed by gangrene only in six cases (5.2%). In 1925, Weglowski [36], in Poland, used intrasaccular suture of collaterals and performed, probably for the first time, an inlay grafting procedure. In 1935, Bird [37] was the first to treat successfully a PAA with EA protected by a preliminary (25 days before) lumbar sympathectomy; in a previous experience, EA alone had been complicated by gangrene. In 1946, Lilly [38] repeated with success the procedure to treat a PAA complicated by embolism: in this case, alcohol sympathectomy preceded EA by 3 days. Gage [39] considered EA or proximal polar ligation the available techniques to obliterate the aneurysm.

Even with the development of reconstructive surgery by grafting procedures, Matas' method maintained a role in the treatment of PAA. Taber and Lawrence [40] suggested to reserve grafting only to cases in which arteriography showed a satisfactory outflow. In 1957, Lord [41] asserted that resection and grafting should be preferred in good-risk patients with palpable distal pulses, while EA should be the choice in poor-risk patients or when distal pulses are absent. These concepts were furtherly stressed by Greenstone et al. [7], who considered a contraindication to grafting also the lack of an adequate vein conduit and, also, reaffirmed the validity of either EA or Hunterian ligature, especially if associated with lumbar sympathectomy.

In the following, we will try to give an idea about the role of EA through the years, during and after the development and wide diffusion of arterial reconstructive surgery (data are extrapolated from series of PAAs treated surgically, with exclusion of primary amputations and simply explorative procedures).

1951—Janes and Ivins [42] (15 cases): one EA with good result; four EAs preceded by lumbar sympathectomy, with three ok and one amputation.

1957—Lord [41] (16 cases): 12 EAs of which six are associated with lumbar sympathectomy (three preliminary, two complementary, one supplementary), with only one amputation (impending gangrene at presentation).

1966—Baird et al. [9] (25 cases): five reparative EAs, all ok.

1970—Wychulis et al. [10] (65 cases): one EA with associated lumbar sympathectomy, followed by improvement.

1974—Bouhoutsos and Martin [43] (74 cases): one EA (out of 35 cases with tibial artery disease) with good result at 3-year follow-up.

1980—Lord [44]: reported 35 cases of EA (lumbar sympathectomy no more associated since 1965) with only two amputations for irreversible tissue damage from several days before admission.

1983—Whitehouse et al. [19] (52 cases): two EAs.

1983—Reilly et al. [18] (166 cases): two EAs with lumbar sympathectomy out of 37 surgically treated limbs presenting with acute aneurysm thrombosis; limb salvage ok but disabling claudication.

1985—Batt et al. [20] (89 cases): one EA + lumbar sympathectomy, ok.

Successively, EA was frequently performed in association with reconstructive surgery, when direct approach to the aneurysm was deemed important and resection was not the preferred technique.

1994—Carpenter et al. [45]: 45 cases treated with bypass grafting; in 13, EA was performed on account either of very large aneurysm volume or of vein compression.

2005—Antonello et al. [46]: in the first attempt of randomization between open surgery and endografting, EA with grafting was the preferred technique, resection being reserved to small aneurysms.

2005—Stone et al. [47]: 48 cases treated with open surgery; in four, through a posterior approach, EA was performed followed by inlay grafting.

2007—Ravn et al. [48]: 681 cases from the Swedish Vascular Registry; in 37, EA and inlay grafting through a posterior approach.

2007—Huang et al. [49]: 358 treated cases; EA was usually performed in patients with large aneurysms or when preoperative imaging had demonstrated large genicular arteries; medial approach usually without section of medial gastrocnemius; thigh tourniquet to assure a bloodless field; EA performed in 115 cases (excision in 15).

2008—Lichtenfels et al. [4]: 46 cases treated with bypass grafting; EA in 44 and resection in two.

So, the Matas' technique is not obsolete; intrasaccular ligature of collaterals is routinely applied when performing an inlay graft or an interposition graft without resection. EA is also frequently used to treat an enlarging PAA after exclusion and bypass [24, 50]. Fortunately, it has not been forgotten, as feared by Lord [44], who, in 1980, wrote "it is still an operative procedure of considerable value for the control of popliteal aneurysms in selected patients. It is a sad commentary that few young surgeons have heard of the procedure and truly unfortunate that it does not have an important place in the armamentarium of modern surgery" (Fig. 14.1).

Who is writing will never forget a stormy night in a small bush hospital, in the forest of Southern Cameroun, during the period of great rains, at the beginning of this century. A 35-year-old native was brought in with a painful, pulsating mass behind the left knee; the mass had rapidly enlarged during the last 48 hours, and the knee could not be extended. In the light of three petrol lanterns (the electric generator was out), under the protection of a rudimentary tourniquet made with a bike air tube and tightened with a woodstick, an obliterative endoaneurysmorrhaphy was successfully performed. Dr. Matas' heritage saved the limb, probably the life, of the patient and certainly the reputation of the surgeon as a thaumaturge among the natives (this case, for its particularly wild characteristics, is not included in the personal experience gained in normal Italian hospitals and cited throughout this book).

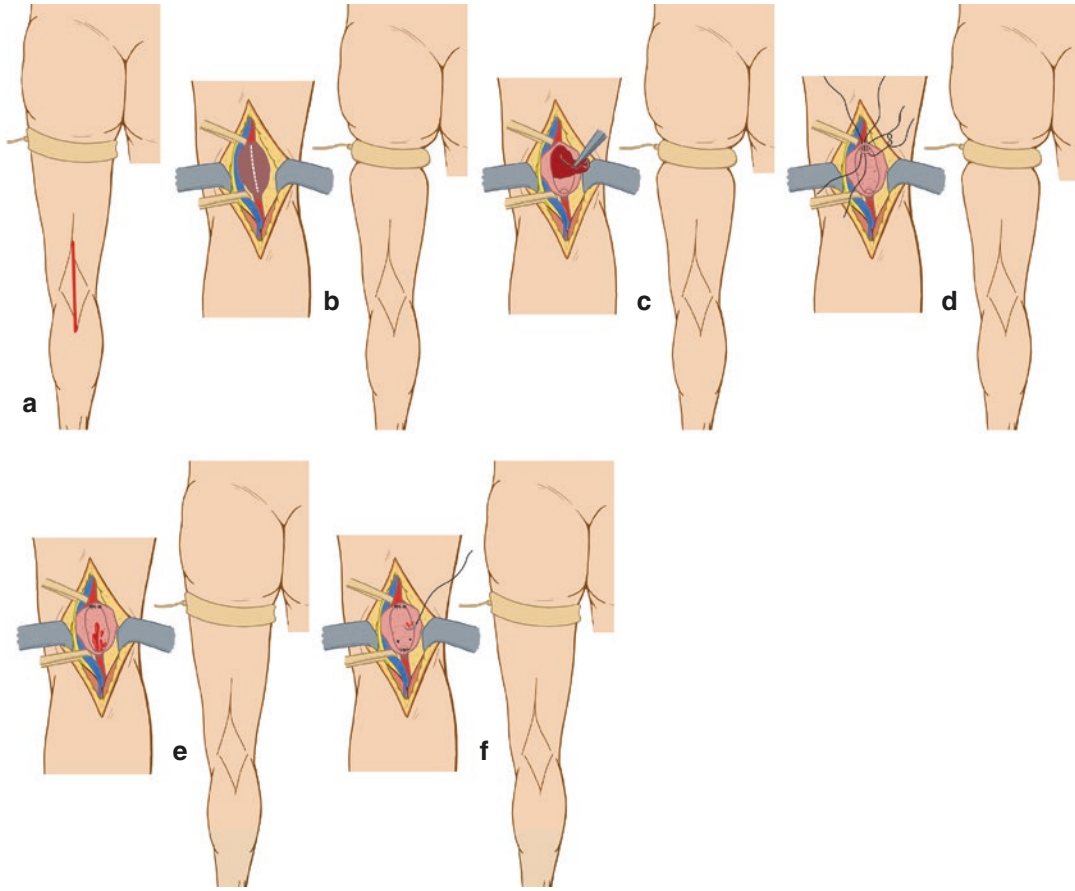

Fig. 14.1 The technique of endoaneurysmorrhaphy as described by Lord [44] (with permission). (**a**) Under the protection of a tourniquet, the aneurysm is approached directly, through a vertical incision in the popliteal lozenge. (**b**) Incision of the aneurysm after identification and protection of vein and nerve. (**c**) Thrombus is evacuated. (**d**) Obliteration by suture of the proximal orifice. (**e**) Deflating the tourniquet, the backflow helps in identifying the distal orifice, which will be closed as the proximal one. In case of sluggish or absent backflow, thrombectomy by Fogarty catheter may be attempted. (**f**) Suture of collaterals from the inside (successively, after a small biopsy on the edge of the aneurysm, its walls may be sutured together) (with permission, modified)

14.3 Lumbar Sympathectomy (LS)

The effects of LS on the collateral circulation of the limbs were put into evidence by a series of experimental researches in dogs in the early 1930s of the last century [51–53]. After more than 40 years, Terry et al. [54] studied, by electromagnetic flowmetry, the behavior of flow through 20 femoropopliteal reconstruction, before and after LS: in the only case operated on for PAA, flow increased from 90 mL/min to 400 mL/min. In 1934, Gage [55] successfully ligated a mycotic aneurysm of the common iliac artery after alcohol block of lumbar sympathetic ganglia. In 1940 [39], he reported on preliminary sympathectomy in the surgical treatment of more than 15 cases of arterial aneurysms (at least two were popliteal) and arteriovenous fistulas with uniform success, i.e., without any limb loss. In 1935, Bird [37], apparently unaware of Gage's operation (in his paper, this is cited as an addendum), performed successfully endoaneurysmorrhaphy of a PAA under the protection of a previous (25 days) LS. In 1942, Richards and Learmonth [56] repeated with good result this operative tactics: in this case, the PAA was resected after (3 weeks) LS.

In 1946, Lilly [38] reported three cases of successful treatment of a complicated PAA: the first

one (ischemia following acute aneurysm thrombosis) was treated by simple alcohol block; in the second case (the aneurysm was pulsating but complicated by distal embolism), ganglion block with alcohol was preceded by 3-day obliterative endoaneurysmorrhaphy; in the third case, a pseudoaneurysm complicated by acute ischemia was treated by LS followed, after 2 days, by ligature and section of both artery and vein.

In 1949, Linton [57] published the first consistent series: 14 cases were treated by LS followed (7–11 days) by resection. One patient died p.o. after LS (retroperitoneal hemorrhage from anticoagulation in coronaropathic patient); in the other 13 patients, the result was highly gratifying, with a functioning limb until patient's death (two cases, respectively, after 12 and 14 months) or the end of follow-up (2 months to 5 years).

Janes and Ivins [42] followed Linton's technique, however, with some modifications. LS (preceding endoaneurysmorrhaphy in four cases and resection in nine cases) was performed, in three occasions, in the same operative session with aneurysm aggression. Furthermore, they obtained a good result in one other case treated only by resection.

In the series published by Friesen et al. [8], LS was associated to a reconstructive procedure in 35/56 (62%) cases of attempted limb salvage, and in 32 (91%), the two procedures were contemporary. Of 34 cases available for follow-up, 22 limbs were of satisfactory function (mean follow-up 57 months), one limb was viable but with claudication, three patients died (after 3, 30, and 60 months, respectively) with a functioning limb, and eight limbs were amputated. The meticulous analysis of the negative outcomes highlighted that failure was attributable, in more than half of the cases, to a compromised outflow either for diffuse atherosclerosis or for repeated embolization.

Greenstone et al. [7] reported five cases of PAA treated with LS alone or associated with other procedures:

- Two cases with only LS ended into amputation
- One case of LS followed by ligation: ok
- One case of LS and excision: excellent at 4 years
- One case of LS, resection and vein graft: ok at 4 years

In Table 14.2, the use of LS in several series of surgically treated PAAs is outlined; worth of mention, after the report of Kauffman et al. [3] in 2002, related to a study period of 32 years, LS in the treatment of PAAs, as far as we know, is no more mentioned.

Today, it is difficult to give a judgment on the value of this time-honored technique, also because details on long-term results are often lacking. After slightly more than a decade, opinion changed from what Gifford et al. [71] assessed that the absolute operative indication is LS followed by excision to the conclusion of Edmunds et al. [61] who aban-

Table 14.2 Use of lumbar sympathectomy in the treatment of popliteal artery aneurysm

Author, year	Cases treated surgically[a]	Lumbar sympathectomy[b]		
		Total	Alone	Ass. with other procedures
Linton [57], 1949	14	14		14
Janes [42], 1951	15	13		13
Julian [58], 1955	9	1		1
Lord [41], 1957[c]	16	7		7
Friesen [8], 1962	56	35		35
Hunter [59], 1962	31	8	4	4
Bergan [60], 1963	4	2		2
Edmunds [61], 1965	98	22		
Baird [9], 1966	25	13	5	8
Crichlow [62], 1966	48	12		12[d]
Wychulis [10], 1970	65	17	10	7
Ducloux [63], 1972	12	2		2
Bouhoutsos [43], 1974	74	17	17	
Buda [64], 1974	77	4	4	

(continued)

Table 14.2 (continued)

Author, year	Cases treated surgically[a]	Lumbar sympathectomy[b]		
		Total	Alone	Ass. with other procedures
Evans [14], 1976	63	1	1	
Towne [13], 1976	84	38	9	29[e]
Alpert [65], 1977	40	5	5	
Chitwood [66], 1978	31	2	1	1
Inahara [67], 1978	40	8		8
Guvendik [68], 1980	20	3	1	2[f]
Vermilion [16], 1981	102	14	5	9
Laskar [17], 1982	31	5	3	2
Whitehouse [19], 1983	52	1		1
Batt [20], 1986	89	37	11	26
Mellière [22], 1986	49	3	3	
Anton [23], 1986	134	33	11	22
Englund [25], 1987	81	2	2[g]	
Dawson [69], 1991	52	8	8	
Sarcina [30], 1997	64	3	3	
Palumbo [70], 1999	75	8		8[h]
Kaufman [3], 2002	140	5	4	1[i]

[a]Primary amputations and simply explorative procedures are excluded
[b]Surgical or chemical
[c]In a further paper of 1980, Lord [44] declared of having no more performed LS since 1965
[d]Six cases submitted to LS for ischemic symptoms prior to diagnosis of PAA
[e]LS associated to resection and grafting (28 cases) or end-to-end reconstruction (one case) only in the first decade of the 21-year study period
[f]LS associated with Hunterian ligation
[g]In a group of eight limbs with acute ischemia from thrombosis, two LS and six primary amputations
[h]7/8 were treated for acute ischemia (three emergent procedures, four after successful thrombolysis)
[i]Case of rupture, treated with exclusion and LS with excellent result

doned LS since 1961: LS is not useful for symptom clearing; however, it may be useful for limb salvage and should be reserved to the patient who has survived acute occlusion of PAA. According to these authors, it is not demonstrated that LS may improve claudication; however, it may render more tolerable an ischemic limb.

Baird et al. [9] asserted that, in case of ischemic symptoms and poor outflow, LS is a valuable technique.

A detailed description of the results of LS was published by Wychulis et al. [10]:

- Ten cases (nine symptomatic) of LS alone: seven improved, two unchanged, and one amputated
- Six cases (two complicated, four symptomatic) of LS and resection: four improved, one worsened, and one amputated
- One case (symptomatic) of LS and aneurysmorrhaphy: improved

Of the 12 limbs that improved, seven were defined as fully useful at a mean follow-up of 4.8 years.

Raptis et al. [72] reported four cases of LS and Hunterian ligation: all limbs were saved.

On the other side, Bouhoutsos and Martin [43], out of 16 PAA treated with LS on account of tibial disease, registered seven early and six late amputations.

It may be significant that Anton et al. [23], dealing with long-term results, consider nine cases treated only with LS together with the cases not submitted to operative treatment.

Should LS be considered an obsolete technique in the treatment of PAA? Almost certainly yes, even if, in conditions of very poor outflow, it may still represent a last-hope resource for limb salvage or ulcer healing or symptom attenuation. Chemical sympathectomy should anyway be preferred to an operative procedure. Bowyer et al. [73], in 1990, reported two cases of severe ischemia from occluded PAA, in which the limb was saved, great toe amputation being required in one case and forefoot amputation in the other, with chemical LS associated with chronic anticoagulation in the former and PTFE grafting in the latter.

14.4 Tourniquet

Tourniquet was used very frequently in the past in operative procedures involving a straightforward approach to a PAA, as endoaneurysmorrhaphy [37, 41], but also for aneurysm excision [56], being sometimes omitted when ligature was the first operative step, eventually followed by aneurysm opening and intrasaccular ligature [71].

Linton [57], however, warned against its use, relying on the availability of efficient vascular clamps, for the following:

- Risk of fracture of atherosclerotic plaques of the femoral artery
- Shutoff of all arterial inflow with risk of not recognizing collaterals
- Risk of the so-called tourniquet shock at release

The optimal management of inflation/deflation of a pneumatic tourniquet was illustrated by Lord [44].

Currently, in general, the use of tourniquet in the repair of a PAA is not a routine component of the surgical armamentarium; however, it may still represent a useful accessory tool.

In 1979, Scheinin and Lindfors [74] proposed a simplified technique for PAA repair by inlay grafting, based on the preliminary achievement of a bloodless operative field by elastic bandage followed by application of a pneumatic tourniquet at midthigh level (Fig. 14.2): extended medial approach was used to directly aggress the

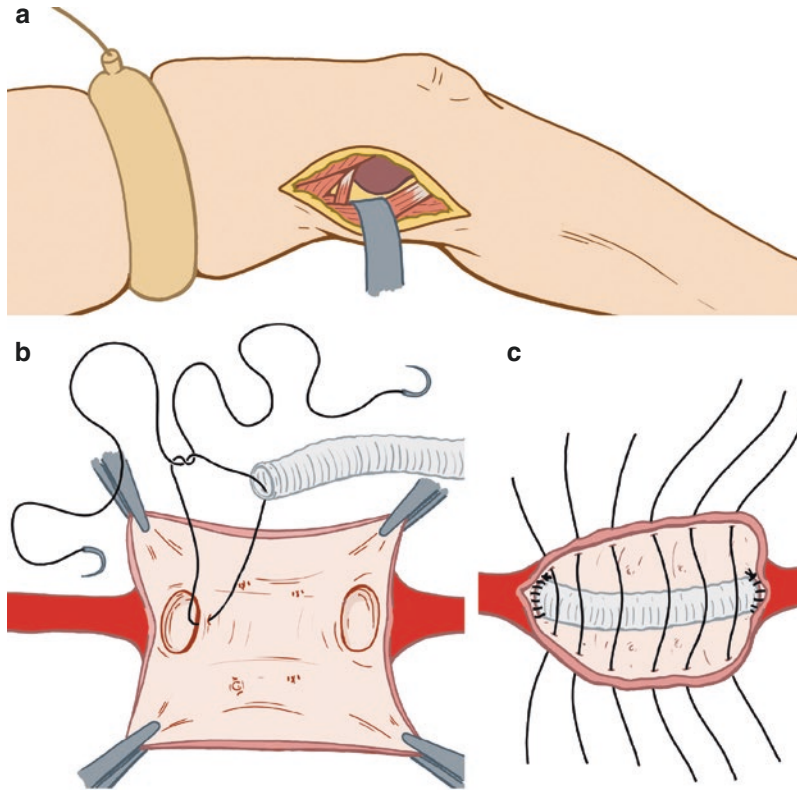

Fig. 14.2 Schematic drawing of the technique proposed by Scheinin and Lindfors [74] (modified with permission). (**a**) Extended medial approach to a bloodless field and visualization of the medio-dorsal aspect of the aneurysm (preventive elastic bandage followed by pneumatic tourniquet application). (**b**) After clearing of thrombus and eventual proximal/distal Fogarty thrombectomy, an inlay grafting (autologous vein in the original description) is performed. (**c**) After suture of eventual backbleeding collaterals (not indicated in the figure), the aneurysm wall (after excision of any redundant portion) is sutured over the graft (with permission, modified)

aneurysm. Four cases were successfully treated, one of them presenting with acute ischemia and requiring also thrombectomy of the anterior tibial artery. Diameter of the aneurysms was 3.5 cm or more.

Huang et al. [49], in bypass grafting procedures, perform aneurysm obliteration (in case of large aneurysms or important collaterals visualized in preoperative imaging) under the protection of a tourniquet, to achieve an easier handling of the intrasaccular method, in a bloodless field.

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