

15

LONG LESIONS AND SMALL VESSELS

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A. BALLOON ANGIOPLASTY (Table 15.1)

1. Standard-Length (20 mm) Balloons

a. Success. Although angioplasty success declines as lesion length increases,^{1,5,6} procedural success can still be achieved in most lesions > 20 mm in length (Table 15.1). Long lesions with other complex features (e.g. calcium, angulation) are often treated with long-balloons (30–40 mm) or other devices. In the randomized Amsterdam Rotterdam (AMRO) trial of ELCA vs. PTCA for long coronary lesions,⁹ PTCA success was only 79%. Furthermore, intravascular ultrasound has shown that the actual residual stenosis is frequently underestimated by contrast angiography since the “normal” reference segment used to measure stenosis severity is often diseased itself (Chapter 31). It may be important to distinguish “long lesions” from “diffuse disease,” which are often used interchangeably. We and others consider long lesions to be more than 10 mm in length, and diffuse disease to be the presence of three or more 50% stenoses in at least one-third of the vessel.

b. Complications. The impact of lesion length on major complications is controversial. Several reports indicate that PTCA of long lesions is associated with an increased risk for coronary artery dissection^{6,10} and abrupt closure.^{1,6,12–14} In these studies, the incidence of abrupt closure was 1–6% for lesions < 10 mm and 9–14% for lesions > 10 mm. In contrast, other studies failed to find a relationship between lesion length and acute closure¹⁵ or major complications.^{5,16,18,19} These divergent results may be due to differences in patient characteristics, associated lesion morphologies, the presence of multivessel disease, and the use of long (30–40 mm) balloons and other devices.

c. Restenosis. The influence of lesion length on restenosis is controversial. The Multi-Hospital Eastern Atlantic Restenosis Trial (M-HEART) demonstrated a direct relationship between lesion length and restenosis (lesion lengths of 0.3–2.9 mm, 3.0–4.6 mm, 4.7–7.0 mm, and 7.1–28.0 mm showed restenosis rates of 32%, 33%, 42%, and 49%, respectively).²⁰ Other reports failed to demonstrate any association.^{21,22} Although long lesions may result in a greater loss in lumen diameter at 6 months, these observations do not necessarily correlate with clinical restenosis.²³

2. Long (30–40 mm) Balloons. Considerable clinical experience suggests that long (30–40 mm) balloons may improve acute results—increased success, fewer dissections, less acute closure⁶—by distributing inflation pressure more evenly across the diseased vessel segment and atheroma/vessel junction (Figure 15.1, Table 15.1). In fact, long-balloon angioplasty of long lesions resulted in

success and complication rates similar to those achieved with standard-length balloon angioplasty of focal stenoses.⁷ In a small randomized trial comparing long- and standard-length balloons, long balloons resulted in fewer dissections (18% vs. 55%) and required fewer inflations.²⁴ Collectively, these data suggest that long balloons are associated with higher procedural success and fewer dissections than standard-length balloons.

- 3. Tapered Balloons.** Most branching coronary arteries taper in diameter by at least 0.5 mm over 20 mm of vessel length (average taper = 0.22 mm per 10 mm of arterial length).²⁵ Significant tapering often poses a problem for optimal balloon sizing, especially for long lesions (Figure 15.2).⁵¹ To address this problem, Banka et al²⁵ performed PTCA with a tapered balloon (0.5 mm decrement in balloon diameter over 25 mm of balloon length) to achieve procedural success in 80% and angiographic dissection in only 2% of tapered lesions. It is currently unknown whether tapered balloons offer any advantage, since most manufacturers do not market tapered balloons.

Table 15.1. Balloon Angioplasty of Long Lesions: Acute Outcome

Series	Balloon Length	Lesion Length (mm)	N	Success (%)	Complications (%) D / Q-MI / CABG	Dissection (%)	AC (%)
Serruys ⁸⁵ (2001)	20-50	20-50	437	66*	0 ⁺ / 10.7 ⁺ / 1.3 ⁺	-	-
Appelman ⁹ (1996)	-	> 10	157	79	0 / 1.3 / 1.9	55	0.6
Tan ¹ (1995)	20-40	< 10	959	95	-	-	1.5
		10-20	153	85	-	-	11
		> 20	45	74	-	-	16
Kaul ² (1995)	20-40	11-20	112	96	1 / 1 / 1	24	3
		> 20	29	97	0 / 3 / 0	32	3
Cates ³ (1994)	80	> 40	54	91	- / - / 4	-	-
Mooney ⁴ (1993)	-	> 10	327	93	0 / 1 / 1.5	29	5
Myler ⁵ (1992)	-	≤ 10	365	95	2.1	-	-
		11 - 20	278	91	0	-	-
		> 20	136	89	0	-	-
Zidar ⁶ (1992)	20	< 10	579	95	1.2 / - / 4.8	6.6	5.9
	20	> 10	149	90	0.7 / - / 8.1	18.1	14.1
	≥ 30	> 10	90	98	1.1 / - / 3.3	8.9	5.6

Abbreviations: AC = acute closure; CABG = in-hospital coronary artery bypass surgery; D = in-hospital death; Q-MI = in-hospital Q-wave myocardial infarction; - = not reported

* No flow-limiting dissection or diameter stenosis > 50% necessitating bailout stenting

+ Complication rate at 31 days among 149 patients requiring bailout stenting after PTCA

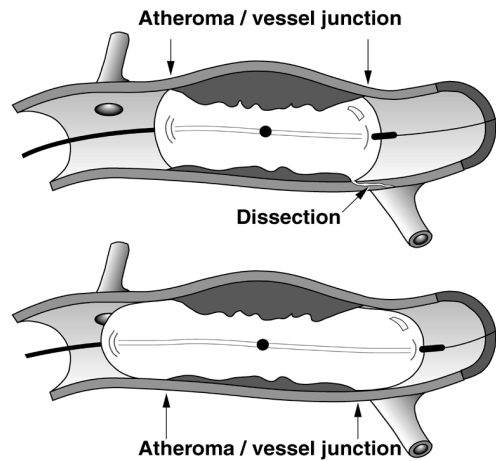


Figure 15.1. Long Lesions: PTCA Technique

Long (30-40 mm) balloons may be employed to more evenly distribute inflation pressure throughout the diseased vessel segment and limit dissection.

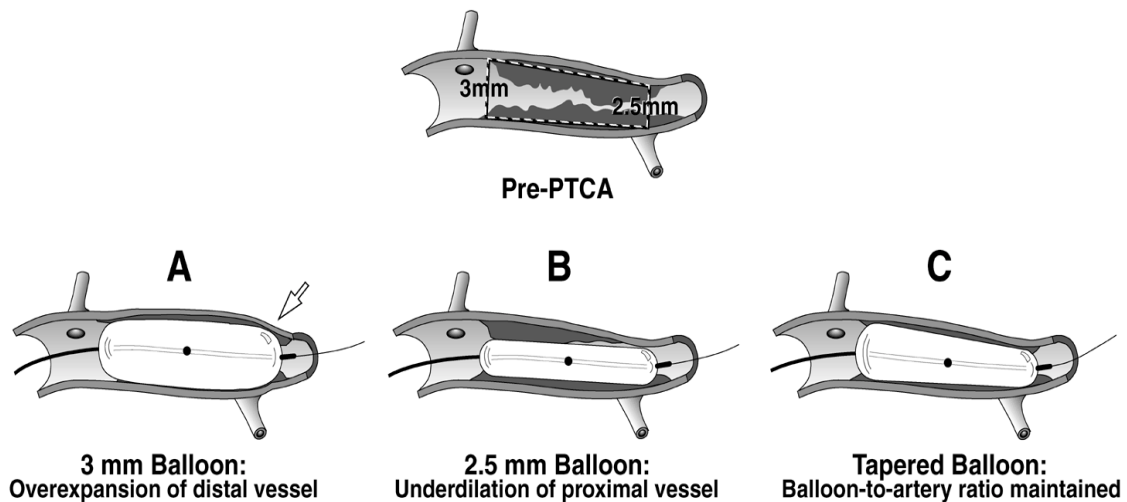


Figure 15.2. Long Lesions in Tapered Vessels: PTCA Technique

Balloon sizing is problematic for long lesions in tapered vessels:

- Sizing the balloon to the proximal segment results in overdilating the distal segment, increasing the risk of dissection
- Sizing the balloon to the distal segment results in underdilating the proximal segment, leaving a significant residual stenosis
- A tapered balloon theoretically ensures better matching of balloon and vessel size

B. NON-BALLOON DEVICES (Tables 15.2, 15.3). Atherectomy, lasers, and stents are used to revascularize long lesions, but interdevice comparisons have been hampered by marked differences in baseline clinical and lesion characteristics. Long lesion length appears to independently predict acute closure³⁹ and coronary perforation⁴⁰ following some devices, emphasizing the importance of device selection.

1. Atherectomy (Table 15.2)

- a. Rotablator Atherectomy.** Although early Rotablator success was possible in only 70% of long lesions,²⁹ recent studies reported success in more than 90% of lesions 16-25mm in length.^{26-28,52} Nevertheless, increasing lesion length has been associated with an increased risk of MI,^{26,28,29} coronary artery perforation,⁴¹ and restenosis.⁴² Despite these complications, many interventionalists believe that Rotablator atherectomy (with adjunctive PTCA as needed) is the preferred method of revascularizing long lesions, especially those with calcium. In such lesions, it is important to use slow passes with a small burr to minimize microcavitation and the generation of particulate debris, which can result in slow-flow and ischemic complications.
- b. Directional Coronary Atherectomy (DCA).** DCA of long lesions resulted in lower success, more abrupt closure and emergency CABG, and higher restenosis rates compared to DCA of focal stenoses^{30,43}. In the CAVEAT trial, lesion length (in addition to calcification) predicted DCA failure.⁴⁴ Although procedural success was reported in 97% of long lesions by making a series of longitudinal cuts through the entire length of the lesion, lesions were highly selected for favorable morphology. Most operators rarely consider DCA a practical strategy for long lesions.
- c. TEC Atherectomy.** Although TEC atherectomy may be used to treat native coronary artery lesions, it may not have an advantage over PTCA except in the presence of thrombus. In small numbers of select long lesions, procedural success for TEC and adjunctive PTCA was > 90%.

2. Lasers (Table 15.2)

- a. Excimer Laser Coronary Angioplasty (ELCA).** Data from the first 3000 patients enrolled into the ELCA Registry indicated procedural success rates of 90% for both short and long lesions.³⁴ Importantly, procedural success was independent of lesion length. Although dissections were more common in long lesions,⁴⁵ major ischemic complications occurred with equal frequency among short and long lesions.^{34,45,46} In the Amsterdam Rotterdam (AMRO) trial, lesions ≥ 10 mm were randomized to ELCA (without saline infusion) or balloon angioplasty. No differences in procedural success, late clinical events, or functional status were observed (Table 15.2).^{9,32} However there was more acute closure (8% vs. 0.8%, $p = 0.005$) and a trend towards more restenosis in the ELCA group (52% vs. 41%, $p = 0.13$);⁹ ELCA was also associated with additional costs of \$4476 per treated segment.⁴⁷ In the Excimer-Laser Rotablator Balloon Angioplasty for C-Lesions (ERBAC) trial, both ELCA and Rotablator resulted in better immediate lumen enlargement, but no difference in restenosis at 6 months compared to PTCA (Chapters 30)

- b. Holmium Laser Angioplasty.** Results from the Holmium Laser Coronary Registry indicate that high procedural success ($\geq 90\%$) and low complication rates ($\leq 3\%$) can be achieved for lesions > 10 mm in length, although success rates were lower for lesions > 20 mm.³⁵
- 3. Stents (Table 15.3).** The use of stents for long lesions remains controversial, since there appears to be a strong relationship between lesion length and restenosis. Two stent approaches include “spot stenting” of more focal areas of severe disease amidst longer segments of diffuse disease, and stenting long segments of disease between “normal” proximal and distal vessel. The best approach is unknown (Chapter 26).
- C. APPROACH TO LONG LESIONS (Figure 15.3).** The approach to long lesions is dependent on the presence of thrombus, calcification, and vessel size. Intracoronary thrombus is best treated with adjunctive platelet glycoprotein IIb/IIIa receptor antagonists and/or mechanical thrombectomy with TEC or the AngioJet, whereas target lesion calcification is best treated with the Rotablator. Definitive lumen enlargement is usually achieved with PTCA with or without stenting. Provisional stenting is a reasonable strategy particularly in small vessels (Table 15.4): stenting may be deferred if an excellent result is achieved by PTCA alone, reserving future stenting for focal restenosis.
- D. CONCLUSIONS.** Balloon angioplasty of long lesions may be performed with acceptable procedural success rates, although the risk of acute closure and restenosis appears to be increased when compared to focal stenoses. Atherectomy and laser with or without adjunctive PTCA, have not been shown to be superior to PTCA alone, and the value of stents for long lesions awaits further definition.

Table 15.2. Results of Atherectomy and Laser for Long Lesions

Series	Device	Lesion Length (mm)	N	Success (%)	MACE (%)	Other Results
Kiesz ³⁴ (1999)	Rotablator	≥ 15	101	98	0	RS (28%); TLR (19%)
AMRO ^{9,32,33} (1996)	ELCA	> 10	151	80	5.8	TLR at 6 months (26% vs. 24%); RS (52% vs. 41%)
	PTCA	> 10	157	79	3.2	
Litvack ³⁴ (1994)	ELCA**	< 10	1832	91	6	
		10-19	1042	92	4.6	
		20-29	467	89	6.6	
		≥ 30	251	87	7.3	
Warth ²⁶ (1994)	Rotablator	≤ 10	588	-	0.2	
		11-25	195		2.1	
Ellis ²⁷ (1994)	Rotablator	0-4	286	-	4.2	
		5-8	69		10.1	
		9-12	27		18.5	
		13-16	6		50	
Reisman ²⁸ (1993)	Rotablator	< 10	953	95	3.9	Non-Q-MI (4% vs. 5.5% vs. 6.2%)
		11-15	180	97	1.7	
		15-25	143	92	6.3	
Tierstein ²⁹ (1992)	Rotablator	≤ 10	12	92	-	RS (22% vs. 75%)
		> 10	30	70	-	
Mooney ⁴ (1993)	DCA	> 10	88	97	2	Acute closure (4.6%); dissection (19%)
Robertson ³⁰ (1990)	DCA	< 10	250	93	2	RS (33% vs. 53% vs. 62%)
		10-19	59	90	5	
		≥ 20	19	79	10	
Favereau ⁹³ (1992)	Rotablator	10-20	215	95	-	
		> 20	73	84	-	
TEC ³¹ Registry	TEC	< 10	266	93	-	
		10-20	220	93	-	
		> 20	38	95	-	
deMarchena ³⁵ (1994)	Holmium-laser	≤ 10	123	97	2.7	
		11-20	193	94	3.1	
		> 20	49	90	0	

Abbreviations: AMRO = Amsterdam Rotterdam trial; DCA = directional coronary atherectomy; ELCA = excimer laser coronary angioplasty; MACE = in-hospital major adverse cardiac events (death, MI, rePTCA, CABG); RS = restenosis; TEC = transluminal extraction catheter; TLR = target lesion revascularization; - = not reported

Table 15.3. Results of Stents for Long Lesions

Series	Stent (lesion)	N	Success (%)	MACE (%)		ARS (%)	TLR (%)
				Early	Late		
Oemrawsingh ⁹⁴ (2001)	GFX XL (> 20 mm): With IVUS	48	-	-	-	18	-
	Without IVUS	52	-	-	-	36	-
ADVANCE ^{85*} (2001)	Stent (> 20 mm)	145	93	3.4	23.4	27	34
	PTCA (> 20 mm)	145	90	7.0	23.1	42	28
Kornowski ⁷⁴ (2000)	Stent (> 25 mm)	116	96	3.4	-	-	14.5
	Stent (< 20 mm)	1110	98	1.0	-	-	13.8
Hong ⁷⁵ (2000)	Multiple (≥ 20 mm)	246	-	-	-	32	-
Ormiston ⁷⁸ (2000)	MultiLink (25, 35 mm)	120	98	-	3	32	14
DeGregorio ⁶⁵ (2000)	Spot stenting (IVUS)	101	-	3.0	22	26	20
	Long stent	143	-	3.5	36	38	32
Kobayashi ⁶⁶ (1999)	Stent (≤ 20 mm)	565	96	-	-	24	-
	Stent (21-35 mm)	278	98	-	-	35	-
	Stent (> 35 mm)	247	92	-	-	47	-
Schalij ⁷⁶ (1999)	Micro Stent II	119	98	5.4	10.1	-	-
Williams ⁷⁷ (1999)	Wallstent	182	99	3.7	-	41	-
Nakagawa ⁷¹ (1999)	GFX ≤ 18	64	97	-	-	23.4	14.1
	GFX 24	56	96	-	-	35.7	21.4
	GFX 30	26	96	-	-	46.2	34.6
Kerr ⁸⁶ (1998)	Various	34	94	-	-	18	24 (SAT 3%)
Rankin ⁶⁷ (1998)	Stent (< 16 mm)	-	-	-	-	-	6.3
	Stent (16-32 mm)	-	-	-	-	-	13.2
	Stent (> 32 mm)	-	-	-	-	-	17.8
Kobayashi ⁶⁸ (1998)	PSS	-	92	-	-	16.5	-
	Nir 16	-	93	-	-	13.3	-
	Nir 32	-	93	-	-	51.3	-
Elezi ⁶⁹ (1998)	Stent (≥ 15 mm)	371	-	-	28.3	33.7	-
	Stent (< 15 mm)	1420	-	-	21.8	25.2	-
LeBreton ⁷² (1998)	Nir 32	187	93	3.5	19.6	-	6
Antoniucci ⁷³ (1998)	Freedom (> 20 mm)	27	100	0	11	38	11

Abbreviations: ARS = angiographic restenosis; GRS = Gianturco-Roubin stent; MACE = major adverse cardiac events (death, MI, CABG, rePTCA); PSS = Palmaz-Schatz stent; SAT = subacute thrombosis; TLR = target lesion revascularization; - = not reported

* Randomized trial. Early MACE at 31 days; late MACE at 300 days

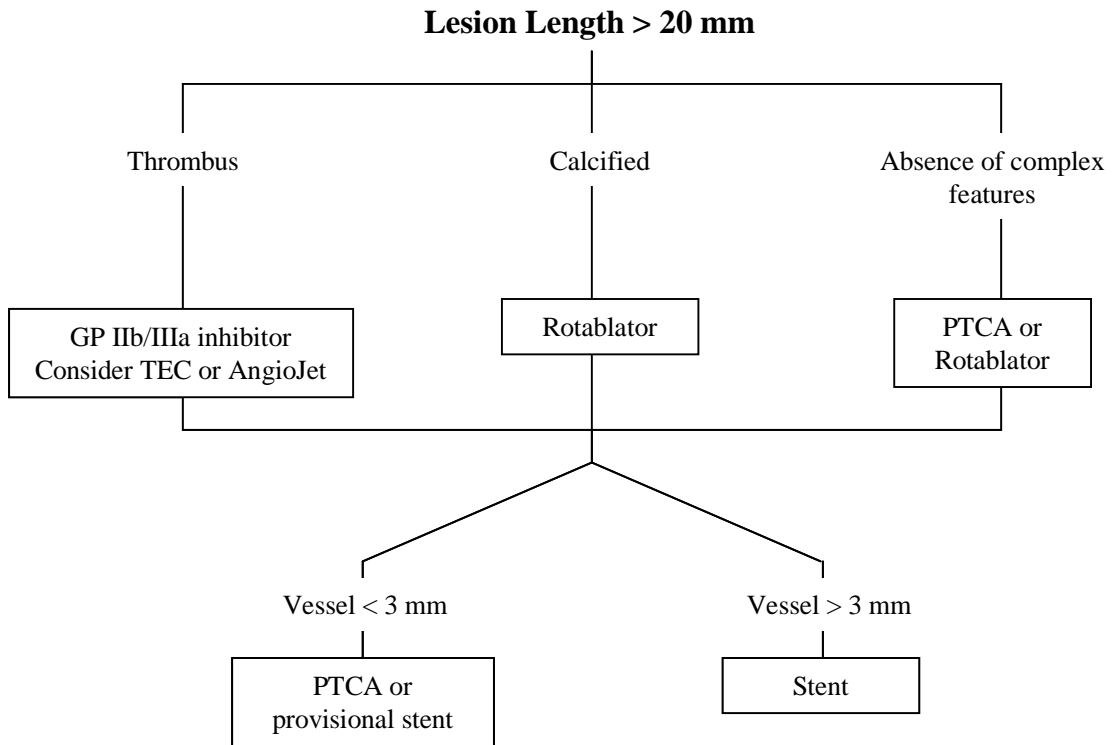


Figure 15.3. Approach to Long Lesions

Table 15.4. Results of Percutaneous Intervention in Small Vessels

Series	Device (vessel diameter)	N	Success	Early MACE	Other Results
RAVEL ¹⁰² (2002)	Sirolimus-eluting stent	120	97	-	Restenosis rates lower with sirolimus stent for vessel diameters ~ 2 mm (0% vs. 37%), ~ 2.5 mm (0% vs. 21%), and ~ 3.2 mm (0% vs. 20%)
	Standard stent	118	93	-	
SIRIUS ¹⁰³ (2002)	Sirolimus-eluting stent	190	-	3.7	Restenosis rates lower with sirolimus stent for vessel diameters ~ 2.3 mm (8.8% vs. 23%), ~ 2.8 mm (3.0% vs. 13.4%), and ~ 3.25 mm (1.8% vs. 14.5%)
	Standard stent	210	-	1.0	
CHIVAS ¹⁰⁰ (2002)	MultiLink stent	148	-	-	Stent group had less restenosis (29% vs. 44%) and a trend toward less TLR (10.3% vs. 19.2%)
	PTCA	154	-	-	
Grenadier ⁹⁹ (2002)	Stent	123	93	-	MACE at 11 months (6.7%)
Kawaguchi ¹⁰¹ (2002)	Stent	35	97	-	No difference in restenosis rates (41% vs. 32%) or TLR (38% vs. 32%) at 6 months. All patients had diabetes
	Cutting balloon	51	81	-	
Feres ⁹⁵ (2001)	Stent (≤ 2.5 mm)	397	98	-	Less TVR at 9 months for balloon diameter > 2.5mm vs. ≤ 2.5 mm (12.3% vs. 21.7%, $p = 0.005$)
SISA ⁷⁹ (2001)	PTCA	353	98	8.8	No difference in MACE at 6 months (23% vs. 19%) or 1 year (27% vs. 22%); similar ARS (32% vs. 28%)
	BeStent		98	3.9	
RAP ⁹⁶ (2001)	BeStent (2.2-2.7mm)	212	-	-	Randomized trial. Stents had less restenosis (27% vs. 37%, $p < 0.05$) and reocclusion (1.4% vs. 3.7%, $p < 0.01$), but similar MACE (11% vs. 14%) at 6 months
	PTCA	214	-	-	
SISCA ⁹⁷ (2001)	BeStent (2.1-3.0mm)	74	95	-	Less MACE at 6 months after stenting (2.4% vs. 9.5%, $p = 0.025$)
	PTCA	71	80	-	
Stankovic ⁹⁸ (2001)	Final balloon < 3mm	124	-	5.6	Late MACE, restenosis, and TLR were similar between groups. All vessels ≤ 2.8 mm
	Final balloon = 3mm	385	-	6.3	
Germing ⁸⁸ (2000)	Stent (< 3 mm)	128	-	-	No difference in hospital MACE or SAT (1.6% vs. 1.1%); more late TLR in small vessels
	Stent (> 3 mm)	92	-	-	
Briguori ⁸⁹ (2000)	PTCA (< 3mm)	97	95	-	No difference in hospital or late MACE; trend towards more restenosis after PTCA; SAT after stenting (0.9%)
	Stent (< 3 mm)	12	97	-	
Caputo ⁸⁰ (2000)	XT Stent	178	-	-	Late MACE (18% vs. 12%); TLR (12% vs. 18%); RS (41% vs. 32%)
	PSS	160	-	-	
Al Suwaidi ⁸¹ (2000)	Stent (2.5 mm)	108	97	-	Late MACE (35% vs. 21%)
	Stent (≥ 3.0 mm)	4077	97	-	
Mori ⁸² (2000)	PTCA/stent (3.0/2.5 mm)	31	-	-	RS (12% vs. 53%); TLR (10% vs. 35%)
	PTCA/stent (2.5/2.5 mm)	53	-	-	

Table 15.4. Results of Percutaneous Intervention in Small Vessels

Series	Device (vessel diameter)	N	Success	Early MACE	Other Results
Kastrati ⁸³ (2000)	PTCA (diabetes)	49	-	-	Similar death (4%), MI (4%), TLR (20% vs. 25%), and RS (44%) at 7 months
	Stent (diabetes)	51	-	-	
Hamasaki ⁶⁴ (1999)	PTCA	199	87	-	ARS: 56% TLR: 40%
	PSS	1005	92	-	31% 19%
	MLS	303	92	-	23% 13%
Zidar ⁹¹ (1998)	GR II	258	99	2.4	
Adiyana ⁹⁰ (1998)	Stent (≥ 3 mm)	696	95	-	No difference in in-hospital MACE or SAT; 1-yr EFS better for small vessels (71% vs. 63%, $p < 0.01$)
	Stent (< 3 mm)	602	96	-	
Shuhlen ⁵⁴ (1998)	Stent	574	-	-	SAT (2.8%); ARS (38%); 1-yr TLR (24%); 1-yr MACE (26%). No difference in ARS or EFS at 6 months between high- and low-pressure inflations
Farshid ⁵⁵ (1998)	BeStent	135	99	-	SAT (0.7%); ARS (12.6%)
Michael ⁵⁶ (1998)	PTCA	83	84	-	TLR at 6 months (10.8% vs. 11.1%)
	Stent	54	93	-	
Schunkert ⁶² (1999)	PCI (≤ 2.5 mm)	819	92	3.4	
	PCI (> 2.5 mm)	1493	96	2.0	
Deutsch ⁶³ (1999)	Stent-DM (≥ 3.0 mm)	10	-	-	ARS: 22%
	Stent-no DM (≥ 3.0 mm)	88	-	-	25%
	Stent-DM (< 3.0 mm)	20	-	-	50%
	Stent-no DM (< 3.0 mm)	122	-	-	34%
Elezi ⁵⁷ (1998)	Stent (< 2.8 mm)	870	-	4.5	SAT (2.4% vs. 2.5% vs. 2.0%);
	Stent (2.8-3.2 mm)	866	-	3.3	ARS (39% vs. 28% vs. 20%)
	Stent (> 3.2 mm)	866	-	2.9	
Koning ⁵⁹ (1998)	Stent	50	100	2	ARS (30%); TLR (13%)
Savage ⁶⁰ (1998)	PTCA	168	92	-	ARS (55% vs. 34%); 1-yr EFS (67% vs. 78%)
	Stent	163	100	-	
Waksman ⁶¹ (1998)	PTCA	148	95	-	Late MACE (31% vs. 34%); TLR (22% vs. 27%)
	Stent	284	92	-	
STRESS I-II ⁹² (1997)	PSS (< 3 mm)	-	-	-	ARS (35% vs. 54%); EFS (78% vs. 67%)
	PTCA (< 3 mm)	-	-	-	
Lau ⁵⁸ (1997)	Stent	44	100	0	ARS (41%)

Abbreviations: ARS = angiographic restenosis; DM = diabetes mellitus; GR II = Gianturco-Roubin II stent; MACE = major adverse cardiac events (death, MI, CABG, rePTCA); MLS = MultiLink stent; PCI = percutaneous coronary intervention; PSS = Palmaz-Schatz stent; RS = restenosis; SAT = subacute stent thrombosis; TLR = target lesion revascularization; - = not reported. *Acronyms:* RAP = Restenosis en Arteries Pequenas; SISA = Stenting In Small Arteries; SISCA = Stenting In Small Coronary Arteries; STRESS = Stent Restenosis Study

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