

12

CALCIFIED LESIONS

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In 1988, the American College of Cardiology/American Heart Association Task Force on Assessment of Diagnostic and Therapeutic Cardiovascular Procedures published a report regarding appropriate utilization of PTCA in the treatment of patients with coronary artery disease. In that report, moderate-to-heavy calcification (Type B characteristic) was considered an important risk factor for procedural failure and acute closure. Recent data suggest that better acute outcomes can be readily achieved using a multi-device revascularization strategy.

A. LIMITATIONS OF ANGIOGRAPHY. Intravascular ultrasound (IVUS) has been used to evaluate the depth and extent of coronary artery calcification, and to determine the sensitivity and specificity of coronary angiography for detecting calcium.^{1,2} The severity of angiographic calcium correlated with increasing arcs and lengths of calcium by IVUS (Table 12.1) and the extent of coronary atherosclerosis.⁴⁷ However, angiography has poor sensitivity for detecting mild or moderate lesion calcium, and only moderate sensitivity for detecting extensive lesion calcium (Table 12.2).⁴⁸ Surprisingly, 11% of lesions with angiographic calcium are not calcified by IVUS (i.e., false positives). A prospective comparison between IVUS- and angiography-guided therapy suggests that IVUS can be useful for assessment of calcified lesions and for guiding therapy (Chapter 31).

Table 12.1. Assessment of Lesion Calcification By Angiography and IVUS

	Angiographic Assessment of Calcification		
	None/Mild	Moderate	Severe
No. lesions	715	306	134
IVUS findings			
Lesion calcium (%)	61	90	98
Arc of calcium (degrees)	71	165	238
Length of calcium (mm)	3.6	7.2	9.7

Table 12.2. Sensitivity of Angiography for Detecting Lesion Calcium

IVUS Finding	Sensitivity of Angiography (%)*	
Arc of calcium (degrees):	< 90	25
	91 - 180	50
	181 - 270	60
	271 - 360	85
Length of calcium (mm):	≤ 5	42
	6 - 10	63
	≥ 11	61
Location of calcium:	Superficial only	60
	Deep only	54
	Superficial + deep	24

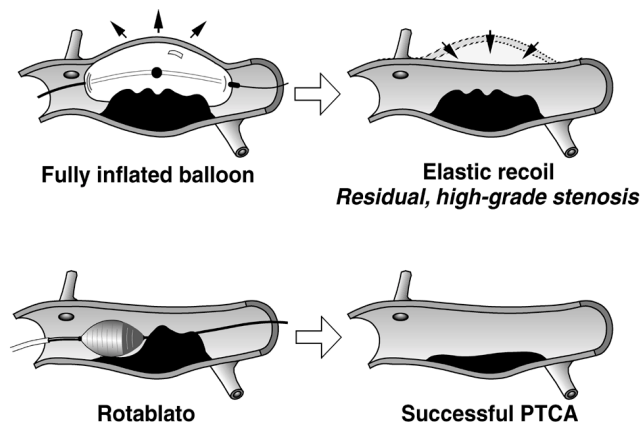
* Percent of calcified lesions on IVUS with calcium on angiography

B. BALLOON ANGIOPLASTY

- 1. Acute Results.** The impact of lesion calcification on PTCA success is variable: One report showed that lesion calcium had an adverse impact on procedural success,³ while another did not⁴ (Table 12.3). In a third report, the presence of lesion calcium was an independent predictor of significant residual stenosis after PTCA.⁵ Mechanisms of suboptimal lumen enlargement include the inability to expand the lesion and elastic recoil (Figure 12.1). The impact of lesion calcification on major ischemic complications also varies: some reports showed a correlation, while others did not (Table 12.4). Differences in these older studies probably reflect the insensitivity of angiography for identifying the depth and extent of lesion calcification.
- 2. Coronary Artery Dissection.** IVUS has shown that lesion calcium plays a direct role in promoting dissection following PTCA. In patients undergoing coronary and peripheral angioplasty, both the incidence and extent of dissection was significantly higher among calcified lesions.⁹ When present, dissection usually originated at the transition between calcified and noncalcified plaque, presumably due to nonuniform shear forces generated by balloon expansion. In another study of calcified lesions, the incidence of dissection increased from 22% after Rotablator to 77% after adjunctive PTCA; there was also a shift in the location of dissection from inside (after Rotablator) to outside the calcified plaque (after PTCA).

Table 12.3. Influence of Lesion Calcium on Acute Outcome After PTCA

Series	Morphology	N	Success (%)
Tan ³ (1995)	Calcified	81	74
	Noncalcified	1076	94
Myler ⁴ (1992)	Calcified	140	92
	Noncalcified	639	95

**Figure 12.1. Elastic Recoil After PTCA of Calcified Lesions**

Rather than cracking the hard, calcified atheroma, PTCA causes stretching of the contralateral plaque-free wall segment and ineffective dilatation. The Rotablator appears particularly well-suited for calcified lesions.

- 3. Restenosis.** Most studies fail to show any association between lesion calcium and restenosis after PTCA.
- 4. Technical Requirements.** Higher inflation pressures are frequently required to dilate calcified stenoses, increasing the risk of balloon rupture and dissection. Although 89% of calcified lesions were successfully dilated with inflation pressures < 10 atm,⁶ Rotablator atherectomy may increase lesion compliance, render the lesion more responsive to PTCA at low inflation pressures, and reduce the incidence of dissection. Rotablator has essentially replaced all other techniques for revascularizing calcified lesions.^{11,46}

Table 12.4. Influence of Lesion Calcium on Ischemic Complications After PTCA

Series	Morphology	N	MACE (%)	Comments
Tan ³ (1995)	Calcified	81	14*	
	Noncalcified	1076	2.5*	
Danchin ⁶ (1994)	Calcified	285	4.3	
	Noncalcified	1801	3.7	
Hermans ⁷ (1993)	Calcified	69	-	Lesion calcium did not predict MACE
Myler ⁴ (1992)	Calcified	140	3.6	
	Noncalcified	639	1.3	
Ellis ⁸ (1990)	Calcified	46	-	Relative risk of MACE = 1.5 for calcified lesions

Abbreviations: MACE = in-hospital major adverse cardiac events (death, MI, PTCA, CABG); - = not reported

* Acute closure

C. NON-BALLOON DEVICES (Table 12.5)

- 1. Rotablator Atherectomy (Chapter 27).** Rotablator is a unique device for the management of calcified lesions. Rotablator preferentially ablates calcified atheroma,^{28,29} results in larger and more concentric lumens with fewer dissections in calcified vs. noncalcified lesions,³⁰ and produces microfractures in calcium deposits to increase lesion compliance and responsiveness to PTCA.²⁹ Procedural success rates > 90% and complication rates < 5% are routinely achieved after Rotablator atherectomy of calcified stenoses.^{13,15,26} In fact, Ellis et al¹⁴ reported more procedural complications in noncalcified lesions treated with Rotablator. Conclusions regarding the impact of lesion calcium on restenosis after Rotablator have varied. In one report, restenosis was no different for calcified and noncalcified lesions (54% vs. 50%),¹⁵ while in another report restenosis was 2-3 times more likely in calcified lesions.²⁷ Preliminary reports from STRATAS (Study To Determine Rotablator and Transluminal Angioplasty Strategy) suggest that aggressive debulking with larger burrs and longer ablation times does not improve immediate or late outcomes compared to more conservative debulking strategies.⁴⁵ In an IVUS study of Rotablator followed by PTCA, DCA, or stents, Rotablator plus stent (Rotastent) achieved the largest lumen and smallest residual stenosis⁴³ (Table 12.5)(Chapter 27). At the present time, Rotablator atherectomy is the preferred method for revascularizing calcified stenoses.

Table 12.5. Non-Balloon Devices for Calcified Lesions: Acute Outcome

Series	Device	Morphology	N	Success (%)	MACE (%)	Comments
Goy ⁵⁴ (2002)	Cutting balloon	Undilatable or highly calcified	34	96	7.1	Failure to cross lesion (18%); need for stent (97%)
Singh ⁵¹ (2001)	PTCA ± Stent ROTA	Calcified	2065 447	- -	10.9 13.0	Residual stenosis < 50% (93% vs. 98%, p < 0.0001)
Kobayashi ⁵² (2001)	Stent	No/mild Ca ⁺⁺ Mod. Ca ⁺⁺ Severe Ca ⁺⁺	215 75 76	- - -	- - -	Final lumen CSA > 6.0 mm ² (71% vs. 60% vs. 58%). Only 72% of severely calcified lesions by IVUS were calcified on angiography
Hoffmann ⁴³ (1998)	ROTA/PTCA Stent ROTA/Stent	Calcified (vessel > 3mm)	147 103 56	99 98 98	1.4 3.0 3.6	FDS (27% vs. 14% vs. 4%); TLR (28% vs. 21% vs. 15%)
Moussa ⁴⁴ (1997)	ROTA/Stent	Calcified	106	93	-	TLR (18%)
Ahmed ⁴⁶ (1996)	ELCA	Undilatable	38	89	8	RS (45%)
Dussailant ⁴¹ (1996)	ROTA/Stent ROTA/DCA ROTA/PTCA	Calcified (vessel ≥ 3mm)	83 120 235	- - -	0 - -	FDS (12% vs. 16% vs. 24%)
MacIssac ¹⁵ (1994)	ROTA	Noncalcified Calcified	1083 1078	95 94	3.4 4.1	RS (50% vs. 54%)
deMarchena ²⁵ (1994)	Holmium-laser	All lesions Calcified	365 111	94 90	2.7 4.5	
Bittl ²² (1993)	ELCA	Undilatable	36	92	-	Non-Q-MI (6%)
Altmann ¹⁶ (1993)	ROTA	No/mild Ca ⁺⁺ Mod. Ca ⁺⁺	182 378	96 96	2.1 2.8	1-yr EFS (67% vs. 75%)
Reisman ¹⁷ (1993)	ROTA	Undilatable	67	96	1.5	RS (36%)
Popma ¹⁸ (1993)	DCA	All lesions Calcified	306 60	95 94	- -	1-yr EFS (72% vs. 80%)
Bittl ²³ (1992)	ELCA	Calcified	170	83	-	RS (43%)
Hinohara ¹⁹ (1991)	DCA	Type A Calcified	105 70	98 87	0 5.7	
Ellis ²⁰ (1991)	DCA	Calcified	47	-	-	Relative risk of failure 1.98
TEC ²¹ database	TEC	Noncalcified Calcified	278 154	96 89	- -	

Abbreviations: AC = abrupt closure; CSA = cross-sectional area; DCA = directional coronary atherectomy; EFS = event-free survival; ELCA = excimer laser coronary angioplasty; FDS = final diameter stenosis; MACE = in-hospital major adverse cardiac events; RS = restenosis; TEC = transluminal extraction atherectomy; TLR = target lesion revascularization; - not reported

2. **Directional Coronary Atherectomy (DCA).** DCA has a very limited ability to excise calcified plaque and should be avoided when moderate or heavy lesion calcium is present. IVUS studies clearly show that lesion calcium correlates with ineffective plaque removal after DCA,^{18,31-34} although DCA may be effective after initial Rotablator.^{35,42} DCA should also be avoided when there is significant calcification proximal to the target lesion because of failure to reach the target lesion. Future improvements in DCA technology and the availability of a special calcium-cutter (Flexi-Cut device) may increase the application of DCA to calcified lesions.
3. **TEC Atherectomy.** TEC should not be used for heavily calcified lesions. Because of the excellent flexibility of TEC cutters, vessel calcification proximal to the target lesion is not a contraindication to TEC atherectomy.
4. **Excimer Laser Coronary Angioplasty (ELCA) (Chapter 31).** Among 170 calcified lesions treated with ELCA, procedural success was achieved in 83%, which is slightly lower than for noncalcified stenoses.²³ Better results may be obtained by starting with small fibers and higher fluence (50-60 mJ/mm²). Although one report found an association between lesion calcification and major complications,²³ two reports did not.^{36,37} Restenosis occurs in 40-50% of lesions after ELCA and appears to be independent of lesion calcification.²³ In contrast to Rotablator atherectomy,²⁹ which increases lesion compliance by removing calcium, ELCA renders the lesion more responsive to PTCA by fracturing (rather than removing) calcium.³⁸ Like the Rotablator, ELCA is effective in treating some undilatable stenoses.²² Nevertheless, the high predictability of success with Rotablator has rendered ELCA nearly obsolete for treating calcified lesions.
5. **Holmium Laser Angioplasty.** The Holmium Laser Coronary Registry reported lower procedural success and more ischemic complications among calcified stenoses. Nevertheless, final results were acceptable and similar to those achieved by ELCA.²⁵
6. **Stents.** Heavy lesion calcium increases the risk of incomplete stent expansion³⁴ and restenosis.³⁹ When heavily calcified plaque is first modified by the Rotablator, final lumen cross-sectional area after stenting may be smaller than in lesions without calcification,⁴⁰ although it is still larger compared to Rotablator followed by PTCA^{12,14} or DCA.¹⁴ If a lesion cannot be fully dilated with a balloon, stent placement is contraindicated since incomplete stent expansion increases the risk of stent thrombosis and restenosis.

D. TECHNICAL STRATEGY (Figures 12.2, 12.3)

1. Superficial and Deep Calcium

- a. **Focal Lesions.** If calcification is present on angiography, IVUS may be used to guide therapy based on the depth and extent of lesion calcium and vessel size (Figure 12.3). If IVUS is not available, we recommend Rotablator atherectomy; adjunctive PTCA (with a noncompliant balloon) or stenting often results in excellent lumen enlargement without dissection.

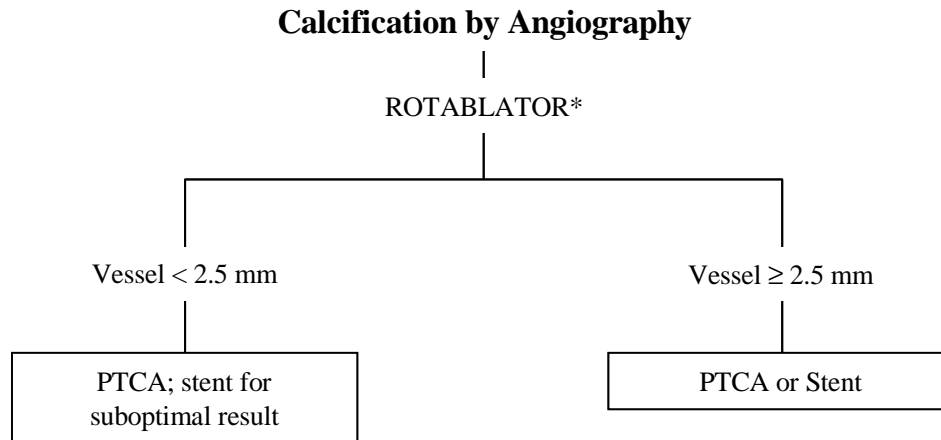


Figure 12.2. Treatment of Calcified Lesions When IVUS is NOT Available

* For angulated lesions use a burr/artery ratio of 0.5; for all other lesions use a burr/artery ratio of 0.6-0.8.

- b. Long Lesions.** The ideal treatment of long, calcified lesions is unknown. PTCA may be attempted using a long balloon, but the risk of dissection or suboptimal result is increased. ELCA is theoretically appealing for long lesions, but disappointing long-term outcomes have resulted in a marked decline in ELCA over the last few years. The Rotablator is effective in treating calcified stenoses, but its use in long lesions may be associated with a higher risk of no-reflow, non-Q-wave MI, and restenosis. Slow passes with a small burr (≤ 1.75 mm) and a stepwise increase in burr size not to exceed 0.25 mm may result in excellent pulverization of calcium, few complications, and good angiographic results.
- 2. Deep Calcium Only.** Unlike superficial calcium located at the intimal-lumen interface, deep calcium (at or near the medial-adventitial border) does not usually interfere with PTCA or stenting. Device selection can be based on associated lesion morphologies, with or without antecedent Rotablator.

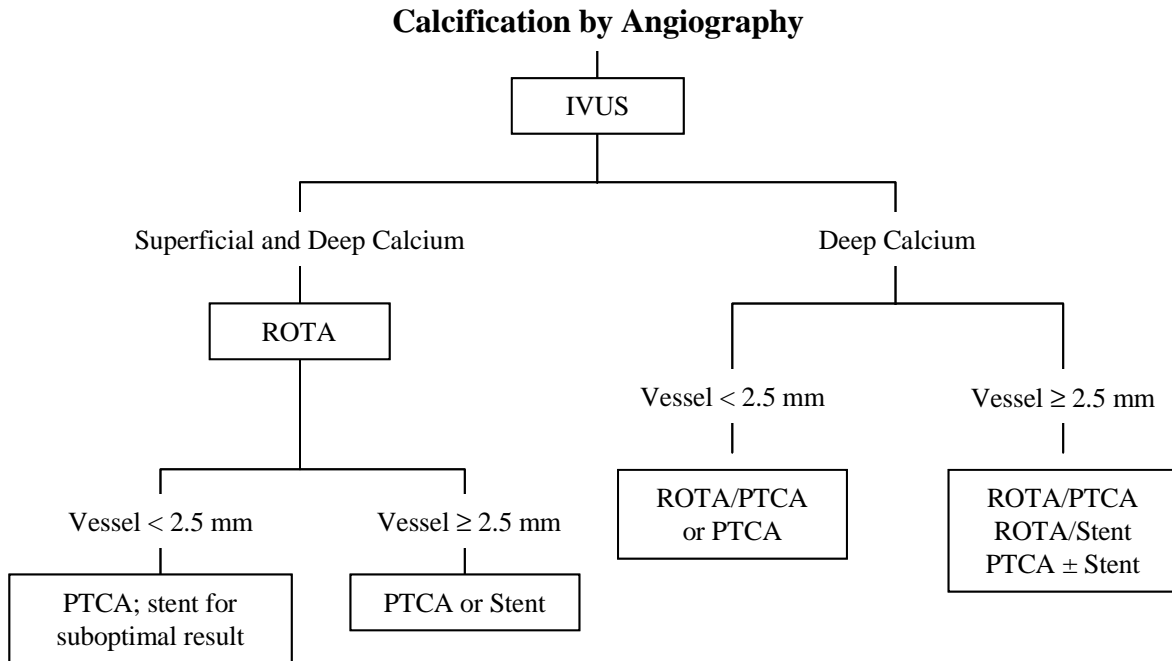


Figure 12.3. Treatment of Calcified Lesions When IVUS IS Available

ROTA = Rotablator

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