Table 16.12. Chronic Total Coronary Occlusion: Time, Equipment, and Cost

Series	Occlusion	Procedure Time (min)	Radiation Time (min)	Equipment Guides / Wires / Balloons	Cost ($)
Stewart[13]	Total	73	30	-	-
(1993)	Nontotal	59	18	-	-
Bell[16]	Total	74	31	2.0 / 2.7 / 1.8	1947
(1991)	Nontotal	59	18	1.5 / 1.5 / 1.3	1398

Abbreviations: - = not reported

4. **Adjunctive Thrombolytic Therapy.** Small reports (using different lytic agents and infusion regimens) suggest that prolonged intracoronary thrombolytic infusions may improve recanalization rates, coronary flow, and PTCA success (Tables 16.14, 16.15).

Table 16.15. Intracoronary Thrombolysis for Occlusions Resistant to PTCA Guidewires

Series	N	Lytic	Results	Other
Zidar[47,110] (1996)	60	UK (1.6-3.2 MU x 8 hrs) via infusion wire + guide catheter	PTCA success 52-59% for all doses	Major bleeding and vascular complications were increased at higher lytic doses. Restenosis (59%) and reocclusion (9%) at 6 months
Ajluni[52] (1995)	25	UK (100,000-240,000 U/hr x 8-25 hrs) via infusion wire + guide catheter	Increase in coronary flow (28%); PTCA success (52%)	MI (8%); significant bleeding (8%); length of stay (5.1 days)
Cecena[53] (1993)	20	UK bolus (120,000 U IC) plus up to 200,000 U/hr x 24 hrs via infusion wire + guide catheter	Increase in coronary flow (90%); PTCA success (94%)	No MI or emergent CABG; blood transfusion (10%)
Vaska[54] (1991)	11	tPA (5-10 mg/hr x 6 hrs) via infusion wire	Increase in coronary flow (91%); PTCA success (82%)	No death, MI, or emergent CABG; acute closure (10%)

Abbreviations: UK = urokinase; MI = in-hospital myocardial infarction; CABG = emergency coronary artery bypass grafting; MU = million units; tPA = tissue plasminogen activator

E. **NON-BALLOON DEVICES.** Failure to cross a chronic total occlusion with a guidewire accounts for 80% of unsuccessful procedures. This limitation is extremely important because all currently available devices (balloon, atherectomy, excimer laser, stent) require initial crossing of the occlusion with a guidewire. Preliminary data suggest that several rotational, laser, and ultrasound devices may be capable of recanalizing 30-50% occlusions resistant to PTCA guidewires (Table 16.13). Once the occlusion is crossed, conventional PTCA, atherectomy, laser, and stents can be used to improve lumen dimensions (Tables 16.15, 16.18).

Table 16.13. Crossing Total Occlusions Resistant to PTCA Guidewires

Series	N	Device Success (%)*	Final Success (%)*	Other Results
Safe-Steer Wire Morales[144] (2002)	30	87	-	No perforations
Frontrunner Catheter Whitlow[143] (2002)	100	71	-	Successful stenting (67%); coronary perforation (6%); no Q-wave MI or emergent CABG
Crosswire				
Kahler[134] (2000)	107	42	-	Hemopericardium (1.8%); contrast staining (4.6%)
Corcos[121] (1998)	56	79	-	Perforation (36%); tamponade (1.8%)
Serial Guidewire				
Reimers[100] (1998)	301	73	62	Tamponade (1%); contrast staining (8%)
Glidewire				
Freed[36] (1993)	59	54	39	No perforations
Rees[37] (1991)	33	58	52	Non-flow-limiting dissections (52%)
Magnum Wire				
Meier[124] (1997)	50	46	-	In-hospital death (1.5%); emergency surgery (0.8%); perforation (4%)
Pande[39] (1992)	28	45	39	See Table 16.14
Laserwire†				
Oesterle[99] (1998)	179	61	56	Coronary perforation (16%); tamponade (1.7%)
Schofer[96] (1997)	66	50	47	Success 68% for lesion length ≤ 10 mm and 25% for lesion length 30-40 mm
Hamburger[82] (1997)	345	59	-	Coronary perforation (21%); tamponade (1.0%); non-Q-wave MI (0.9%). Predictors of success were occlusion duration < 40 weeks and length < 30 mm
Shinobi Wire				
Khanna[136] (1999)	13	69	69	Stiff, torquable, Teflon-coated wire. No perforations, contrast staining, or emergency CABG
Vibrational Angioplasty				
Cannon[138] (2000)	14	71	43	Local perforation (14%); no death or emergency CABG
Rees[42] (1995)	18	89	78	
ROTACS				
Danchin[43] (1995)	50	-	66	See Table 16.14

Abbreviations: ROTACS = Rotational Angioplasty Catheter System; - = not reported

* Device success = cross occlusion with device; final success = procedural success after adjunctive PTCA or stent

† Visible entry port and visualization of distal vessel via collaterals required. PTCA guidewire crossing not attempted prior to laserwire.

Table 16.14. Randomized Trials of Percutaneous Revascularization for Chronic Total Occlusion

Trial	N	Design	1° Success (%)	Comments
Crosswire				
Lafavre[135] (1999)	46 42	Conventional wire Crosswire	35 74	Crosswire required less fluoroscopy (19.2 vs. 24.3 min) and procedure time (42 vs. 57 min)
Laserwire				
TOTAL[101] (1998)	145 160	Laserwire PTCA	64 48	Similar complications; laserwire was useful when conventional wires failed (58% success)
Magnum Wire				
Pande[39] (1992)	100	Magnum PTCA	45 67	Magnum success after PTCA failure (39%); PTCA success after Magnum failure (12%). No difference in fluoroscopy time
Haerer[25] (1991)	102	Magnum PTCA Omniflex	32 68 59	Magnum failures salvaged by other systems in 48%
ELCA				
AMRO[45] (1996)	103	ELCA PTCA	65 61	No difference in 6-month clinical endpoints or reocclusion
ROTACS				
Danchin[43] (1995)	100	ROTACS PTCA	66 60	No advantage for ROTACS
STENTS				
SARECCO[132] (1999)	55 55	Stent PTCA	- -	Stents had higher EFS at 2 years (52% vs. 26%, p < 0.05)
TOSCA[128,139] (1999)	202 208	Stent PTCA	- -	Stents had less TVR (23% vs. 31%, p = 0.03) and similar MACE (40% vs. 46%) at 1-3 years
Hoher[131] (1999)	42 43	Stent PTCA	- -	Stents had less restenosis (32% vs. 64%), less reocclusion (3% vs. 24%), and higher EFS (70% vs. 45%) at 6 months
STOP[103] (1999)	48 48	Stent PTCA	- -	Stents had less TLR at 6 months (19% vs. 39%)
MAJIC[104] (1998)	87 96	Stent PTCA	- -	Stents had less TLR at 6 months (30% vs. 63%)
GISSOC[102] (1998)	56 54	Stent PTCA	- -	Stents had less restenosis (32% vs. 68%), reocclusion (8% vs. 34%), TLR (5% vs. 18%), and recurrent ischemia (14% vs. 46%) at 9 months
SICCO[88,97] (1996)	58 59	Stent PTCA	- -	Stents had less restenosis (32% vs. 74%), reocclusion (12% vs. 26%), and TLR at 10 months (22% vs. 42%) and at 2.8 years (19% vs. 48%)
Thrombolysis				
Zidar[110] (1996)	60	Intracoronary urokinase		PTCA success after lytic regimens (52-56%). More bleeding, vascular complications at higher doses. Clinical improvement (76%); reocclusion (9%); restenosis (59%); target vessel revascularization (36%).

Abbreviations: EFS = event free survival; ELCA = Excimer Laser Coronary Angioplasty; ROTACS = Rotational Angioplasty Catheter System; TLR = target lesion revascularization; MACE = major adverse cardiac events (death, MI, TLR); - = not reported.
Acronyms: AMRO = Amsterdam-Rotterdam Trial; GISSOC = Gruppo Italiano di Studio Sullo Stent Nelle Occlusioni Coronariche; MAJIC = Mayo Japan Investigation for Chronic Total Occlusion; SARECCO = Stent or Angioplasty after Recanalization of Chronic Coronary Occlusions; SICCO = Stenting in Chronic Coronary Occlusion; STOP = Stents in Total Occlusion and Restenosis Prevention; TOSCA = Total Occlusion Study of Canada; TOTAL = Total Occlusions Trial with Angioplasty Using Laser Guidewire

1. Devices for Occlusions Resistant to PTCA Guidewire Crossing (Table 16.13)

a. Laserwire. An 0.018" excimer laser guidewire (PrimaWire, Spectranetics) has been developed to recanalize chronic total occlusions that cannot be crossed with conventional guidewires (Figure 16.2). Use of this guidewire requires meticulous technique and careful patient selection to avoid severe dissection and perforation. Only a small fraction of total occlusions may be suitable for the laserwire since its use must be limited to short segments of occlusion in straight vessels, and the operator must be able to visualize the proximal and distal extent of the occlusion throughout the ablation procedure. To perform this technique safely, frequent use of orthogonal views or biplane angiography are required to ensure the laserwire is directed along the major axis of the vessel. If contralateral collaterals are present, the donor vessel should be engaged with a second guiding catheter from the contralateral femoral artery to identify the distal end of the occlusion. Even partial penetration of the occlusion may allow successful crossing with a conventional wire. Once a channel is formed, the lesion is treated with PTCA or another device. Observational and randomized trials suggest that the laserwire may have slight incremental benefit for crossing refractory total occlusions, but there is a high incidence of coronary perforation and tamponade.[82,83,92,96,99,101]

b. Ultrasound Probe. Therapeutic ultrasound catheters that transmit vibrational energy via ball-tipped guidewires are now being used to recanalize total occlusions. Ongoing studies, including the multicenter European CRUSADE trial, hope to clarify the mechanism of action and define acute and long-term outcomes.

c. Vibrational Angioplasty. This technique involves the use of a guidewire attached to a motor. When activated, the motor causes rapid oscillation of the advancing guidewire. Among 18 lesions resistant to conventional techniques, vibrational angioplasty was successful in 78%.[42]

d. ROTACS: Low-Speed Rotational Angioplasty Catheter System. This battery-driven, over-the-wire catheter is comprised of several helical stainless-steel coils, a moveable polyethylene or polyolefin sheath, and a 1.3-1.8 mm olive-shaped ball-tip. Using an 8F guiding catheter, the ROTACS is advanced over a conventional angioplasty guidewire until it abuts the occlusion. After removing the guidewire, the electric motor is activated and continuous forward pressure is applied to the catheter while it rotates at 200 rpm. The central lumen of the catheter is used to deliver contrast injections and assess progress. If unsuccessful, the sheath can be advanced to increase support. If the catheter crosses the occlusion, the guidewire should be reinserted and the ROTACS system exchanged for a conventional balloon catheter. ROTACS was used to successfully recanalize about half of resistant occlusions, including vessels occluded up to 12 months.[44] The BAROCCO trial, a randomized study of ROTACS vs. PTCA in 100 chronic total coronary occlusions, revealed ROTACS success in 40% and PTCA success in 52% of lesions ($p = NS$).[43] PTCA was able to salvage 59% of ROTACS failures, whereas only 17% of PTCA failures could be salvaged by ROTACS. The investigators concluded that initial use of ROTACS does not offer an advantage over PTCA, but could be reserved for PTCA failures. This device is rarely used and is not available in the United States.

e. **Optical Coherence Reflectometry (OCR).** The Safe-Steer Guidewire (Intraluminal Therapeutics, Inc) is a new system that is currently under evaluation for revascularization of chronic total occlusions which cannot be crossed with a guidewire. The system relies on optical reflectance to differentiate plaque, thrombus, and blood from vessel wall, facilitating guidewire advancement.

2. Devices Used for Wire-Crossable Occlusions (Tables 16.16, 16.17)

a. **Lasers**. In the multicenter Amsterdam-Rotterdam (AMRO) trial, 103 patients with total occlusions were randomized to excimer laser angioplasty (ELCA) or PTCA. No differences were observed in procedural success (65%), late reocclusion (ELCA 33%, PTCA 23%), or 6-month event-free survival.[45] Most procedural failures were due to inability to cross the occlusion with a guidewire, but if the occlusion was crossed, success rates were 90%.[59,63,71] Major ischemic complications were infrequent, although restenosis rates approached 50%.[63] ELCA is rarely utilized today for chronic total occlusions.

b. **Atherectomy (Chapters 27-29).** Among 145 total occlusions crossed with a guidewire in multicenter Rotablator Registry, procedural success was achieved in 91%.[57] Acute closure occurred in 7.2%, half of which developed after the patient left the catheterization laboratory. Rotablator may be especially useful if a rigid chronic total occlusion cannot be crossed or dilated with a balloon. Few data are available regarding the ability of DCA or TEC to recanalize chronic total occlusions. In one report, DCA was successful in 15 of 17 occlusions after crossing the occlusion with a guidewire.[55,56]

c. **Stents (Table 16.17).** Although the presence of a chronic total occlusion was once a relative contraindication to stenting, recent data indicate a definite role. Most randomized trials demonstrated less restenosis, less reocclusion, and less target lesion revascularization with stents,[88,89,97,102-104] although some did not.[107,108,120] Risk factors for restenosis are similar to those for stenting nontotal occlusions, and include final MLD, length of stent, final balloon/artery ratio, and dissection.[98,109] Older stent trials frequently used original warfarin-based strategies, which may have had an adverse impact on late outcome; more contemporary antiplatelet strategies have enhanced the safety and efficacy of stenting.

Table 16.16. Results of Atherectomy and Lasers for Chronic Total Occlusion

Device	N	Success (%)	In-hospital MACE (%)	Other
DCA				
Dick[55] (1991)	7	86	0	Occlusion duration 41 days (range 5-105 days)
Hinohara[56] (1991)	10	90	0	
Rotablator				
Braden[142] (2001)	139	-	3.2	Clinical restenosis (19%)
Levin[87] (1996)	15	100	0	Dissection (18%); acute closure (7.2%)
Omoigui[57] (1995)	145	91	5.7	
ELCA				
Schofer[111] (1996)	80	90	1.2	Minor dissection (45%); restenosis (53%, including 20% reocclusion)
Klein[59] (1994)	172 (> 3 months) 107 (< 3 months)	85 90	2.0	Acute closure (4.5% vs. 2.7%); perforation (0% vs. 0.9%)
Baumbach[61] (1993)	212	-	-	Total occlusion predictive of perforation
Holmes[62] (1993)	172	90	3.7	
Bittl[64] (1992)	127	84	-	
Holmium Laser				
deMarchena[65] (1994)	25	100	0	

Abbreviations: ELCA = excimer laser coronary angioplasty; DCA = directional coronary atherectomy; RS = restenosis; MACE = major adverse cardiac events; - = not reported

Table 16.17. Results of Stents for Chronic Total Occlusion

Series	Device	N	Results
TOSCA[128,139,145] (2002)	PTCA Stent	202 200	Randomized trial. At 6 months, stents were associated with a 45% reduction in clinically-driven TVR. At 1-3 years, stent group had less TLR (23% vs. 31%, p = 0.03) and similar MACE (40% vs. 46%). Acute gain and TLR at 1 year was similar in diabetics and nondiabetics
Gruberg[133] (2000)	Debulk*/stent Stent alone	44 108	In-hospital MACE (2.3% vs. 6.5%); no difference in TLR (14.4% vs. 16.3%) or MACE (19.6% vs. 25.6%) at 14 months
Azuma[130] (2000)	Debulk⁺/stent Stent alone	52 224	Debulk/stent with less restenosis (odds ratio 0.38 [CI 0.19-0.78])
SARECCO[132] (1999)	PTCA Stent	55 55	Randomized trial. 2-year EFS higher with stents (52% vs. 26%, p < 0.05).
Hoher[131] (1999)	Stent PTCA	43 42	Randomized trial. Success (95% vs. 88%); in-hospital MACE (1.5% vs. 0.5%). At 6 months, stenting was associated with less restenosis (32% vs. 64%), less reocclusion (3% vs. 24%), and higher EFS (70% vs. 45%)
STOP[103] (1999)	Stent PTCA	48 48	Randomized trial. Less TLR (19% vs. 39%) at 6 months with stents
Anzuini[94] (1998)	Stent	89	Success (98%); in-hospital MACE (5.6%); restenosis (32%) and reocclusion (4%) at 19 months; MACE at 1 year (13%) and 3 years (28%)
Suttorp[95] (1998)	Stent	38	Restenosis (40%) and reocclusion (23%) at 6 months
GISSOC[102] (1998)	Stent PTCA	56 54	Randomized trial. Stents had less restenosis (32% vs. 68%), reocclusion (8% vs. 34%), TLR (5% vs. 18%) and recurrent ischemia (14% vs. 46%) at 9 months
MAJIC[104] (1998)	Stent PTCA	87 96	Randomized trial. Stents had less TLR at 3 months (15% vs. 41%) and at 6 months (30% vs. 63%)
Yamasaki[106] (1998)	Stent PTCA	143 75	Stents with greater patency at 3 years (88% vs. 63%)
Carere[107] (1998)	Stent OPTCA SOPTCA	194 122 74	Substudy of TOSCA. OPTCA and stents with similar 6-month patency, TLR, angiographic restenosis. Both were significantly better than SOPTCA
Title[108] (1998)	Stent PTCA	54 83	Substudy of TOSCA in vessels < 3 mm. At 6 months, stents had similar restenosis (53% vs. 63%) and TLR (11% vs. 11%), more non-Q-MI (17% vs. 4%), and higher patency (98% vs. 87%)
Rau[968] (1998)	Stent	143	Restenosis (22%) and reocclusion (7%) at 4.5 months
SICCO[109] (1998)	Stent	143	Randomized trial. Stents has less restenosis (32% vs. 74%), less reocclusion (12% vs. 26%), less TLR at 10 months (22% vs. 42%) and 2.8 years (19% vs. 48%), and less MACE at 2-8 years (6% vs. 24%)
Elezi[90] (1997)	Stent (CTO) Stent (no CTO)	54 972	CTO group had more restenosis (40% vs. 26%) and reocclusion (14% vs. 3%)
Mathey[91] (1997)	Stent	143	Restenosis (28%); reocclusion (7%)

Table 16.17. Results of Stents for Chronic Total Occlusion

Series	Device	N	Results
Mori[105] (1996)	Stent PTCA	43 53	Stents had less restenosis (28% vs. 57%) and rePTCA (28% vs. 49%) at 6 months, and less MI + CABG (2.3% vs. 11%). Stenting (not PTCA) was associated with improvement in LV ejection fraction
Saito[120] (1996)	Stent PTCA	34 35	Randomized trial. Stents had similar reocclusion (6.3% vs. 11.4%), restenosis (36.7% vs. 34.4%), and TLR (20% vs. 25%)
Ozaki [86] (1996)	Stent PTCA	20 66	Similar restenosis (29% vs. 45%)
Ooka[67] (1995)	Stent PTCA	47 65	Stents had less restenosis (44% vs. 68%) and reocclusion (10% vs. 35%)
Goldberg[163] (1995)	PSS	60	Restenosis (20%); 14-month EFS (77%)

Abbreviations: TLR = target lesion revascularization; CTO = chronic total occlusion; MACE = major adverse cardiac events (death, MI, repeat revascularization); OPTCA = optimal PTCA; SOPTCA = suboptimal PTCA
Acronyms: See Table 16.14
* DCA, ELCA, or Rotablator prior to stenting
\+ DCA or Rotablator prior to stenting

SAPHENOUS VEIN GRAFT OCCLUSION

Of the more than 600,000 saphenous vein bypass grafts placed each year, 10-15% will be occluded at one year and 50% by 10 years after operation. Among the 10-20% of patients who require reoperation within 10 years, repeat bypass surgery is technically more difficult and has been associated with increased morbidity and mortality compared to the initial operation (Chapter 17).

A. PATHOLOGY. The etiology of saphenous vein graft occlusion is dependent on the time interval following bypass surgery.[73,74] In the first month, graft occlusion is almost always due to graft thrombosis from poor surgical technique (suture line stenosis, intraoperative vein trauma) or poor distal run-off. Between 1-12 months, initial hyperplasia is the most common cause. After 1 year, occlusion is caused by graft atherosclerosis, which is indistinguishable from coronary arteriosclerosis. Once graft occlusion occurs, retrograde thrombosis to the aorto-ostial junction is common.

B. PTCA. Although PTCA can successfully revascularize approximately 70% of occluded vein grafts, there is a high incidence of distal embolization (11%), late graft occlusion (40-50%), and late cardiac events (event-free survival of 54% at 1 year and 34% at 3 years).[75] When distal embolization occurs, 50% are associated with vessel closure or CK elevation.[75] Embolization may present as abrupt cutoff of distal vessels (amenable to repeat dilation or lytics), or may be inferred on the basis of no-reflow. PTCA alone is rarely utilized as sole therapy for occluded vein grafts.

C. NON-BALLOON DEVICES. Recanalization of occluded vein grafts using atherectomy, thrombectomy, laser, stent, and embolic protection devices is discussed in detail in Chapter 17.

D. PROLONGED INTRAGRAFT THROMBOLYSIS. Hartmann and associates[77] were the first to systematically study the use of prolonged urokinase infusions for chronically occluded vein grafts. In the multicenter ROBUST trial,[78] 107 patients with one occluded vein graft received intragraft urokinase for at least 24 hours. Successful recanalization was achieved in 69% of patients, but there was a high incidence of major complications (death 6.5%, Q-wave MI 5%, non-Q-wave MI 17%, emergency CABG 4%, stroke 3%). Six-month angiography revealed sustained vessel patency in only 40%. Lytic infusion through the central lumen of an inflated balloon (Balloon-Occlusive-Intravascular-Lysis-Enhanced-Recanalization; BOILER) is also feasible.[79]

CONCLUSIONS

Successful recanalization of chronic total coronary occlusions often results in marked improvements in long-term symptomatic status and exercise capacity, and reduces the need for late CABG by 50%. The benefits of revascularization may be improved by stents and contemporary antiplatelet regimens. However, the management of totally occluded saphenous vein bypass grafts remains problematic. PTCA should be abandoned as sole therapy in vein grafts due to the high incidence of acute embolization and late revascularization. Stents hold promise as a means of reducing late reocclusion and restenosis, but progressive disease at non-stented sites is a persistent cause of late graft failure. The role of mechanical and pharmacologic strategies will require further prospective, randomized evaluation. Our approach to the patient with chronic total occlusion is summarized in Figure 16.5.

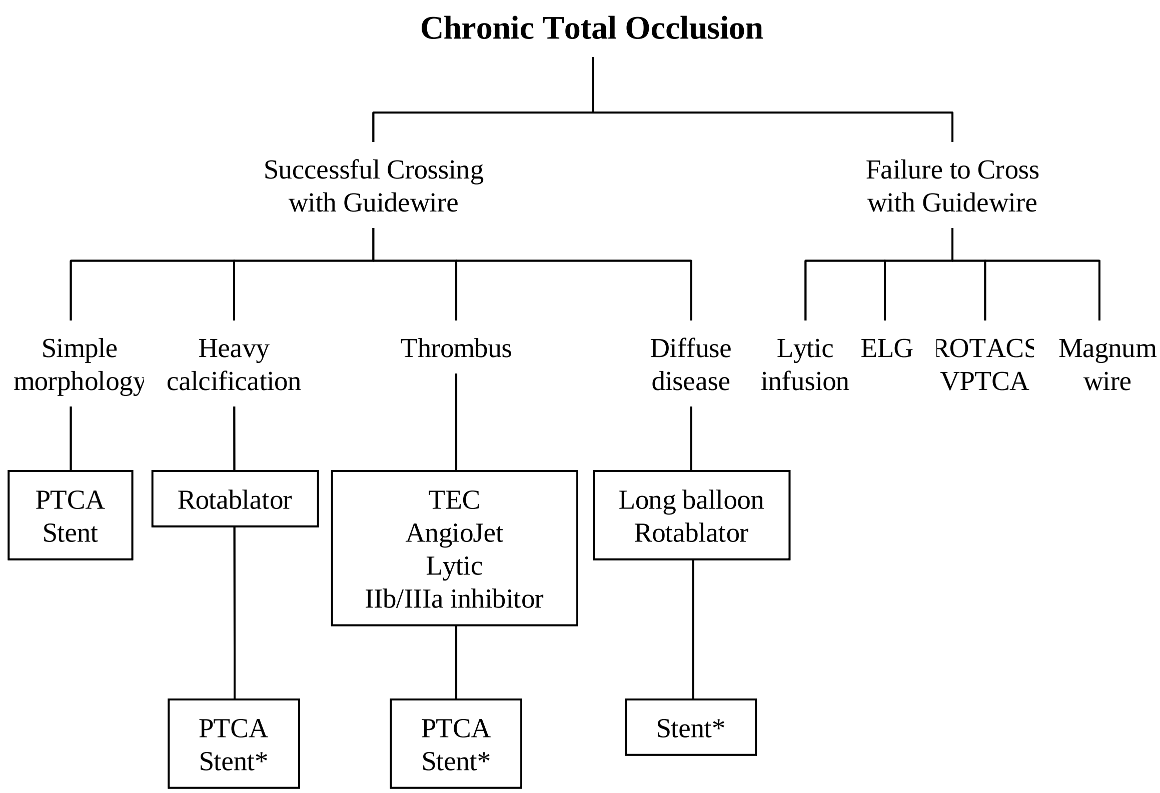

Figure 16.5. Approach to Chronic Total Coronary Occlusion

Abbreviations: ELG = excimer laser guidewire; TEC = transluminal extraction catheter; ROTACS = rotational angioplasty catheter system; VPTCA = vibrational angioplasty

* Consider provisional stenting for suboptimal PTCA (residual stenosis > 30% or dissection)

* * * * *

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