The use of percutaneous coronary intervention (PCI) to treat ischemic coronary artery disease (CAD) has expanded dramatically over the past three decades. Coronary balloon angioplasty, or percutaneous transluminal coronary angioplasty (PTCA), was first performed by Andreas Gruentzig in 1977 using a fixed-wire balloon catheter. The procedure was initially limited to the fewer than 10% of patients with symptomatic CAD who had a single, focal, noncalcified lesion of a proximal coronary vessel. As equipment design and operator experience evolved over the next decade, the use of PCI expanded to include an increasing spectrum of coronary anatomy including Left main disease, multivessel disease, chronic total occlusions, diseased saphenous vein grafts (SVGs), and patients with acute ST segment elevation myocardial infarction (STEMI), among other complexities.

New coronary devices were developed in the late 1980s to improve on the limitations associated with balloon angioplasty. Coronary stents were designed to scaffold the inner arterial wall to prevent early and late vascular remodeling. Directional, rotational, and extraction atherectomy devices removed atherosclerotic plaque and were developed as stand-alone therapy or to be used in combination with coronary stent. By early 2000, a number of other devices were developed to protect the distal circulation from atherothrombotic embolization (i.e., embolic protection devices) and to remove large thrombi from within the vessel and prevent distal embolization (i.e., aspiration and thrombectomy catheters). Fractional flow reserve technique (FFR) was designed to evaluate which lesions were significant requiring stenting and which could be left alone.

1. Coronary Atherectomy

Directional coronary atherectomy (DCA) (Abbott Vascular, Santa Rosa, CA) uses a rotating cup-shaped blade within a windowed cylinder to directionally excise plaque (average total weight approximately 20 mg) from the vessel wall. This tissue removal and subsequent mechanical dilation with balloon angioplasty provides a larger acute lumen than balloon angioplasty alone.

Rotational coronary atherectomy (RA) (Boston Scientific, Natick, MA) removes the atheromatous plaque by the abrasion of inelastic calcified plaque using microscopic (20 to 50 microns) diamond chips on the surface of a rapidly rotating (160,000 rpm) olive-shaped atherectomy burr. This abrasion generates 2- to 5-micron microparticles that pass through the coronary microcirculation for removal by the reticuloendothelial system. Burrs travel over a specialized 0.009-inch guidewire and are available in diameters ranging from 1.25 to 2.50 mm. In the setting of severe calcification, smaller (1.25 mm) burrs can be initially used followed by larger burrs in 0.25 to 0.50 mm increments up to 70 percent of the reference vessel diameter. Current use of RA is reserved for ostial and heavily calcified lesions that cannot be dilated with balloon PTCA or those that prevent delivery of coronary stents.

2. Thrombectomy and Aspiration Devices

Conventional angiography has poor sensitivity for the detection of coronary thrombus, but the presence of a large, angiographically apparent coronary thrombus heightens risk for procedural complications. Large coronary thrombi may
fragment and embolize during PCI, or may extrude through gaps between stent struts placed in the vessel, risking lumen compromise or thrombus propagation and acute thrombosis of the treated vessel.

The Angiojet rheolytic thrombectomy catheter (Possis Medical, Inc., Minneapolis, MN) was introduced as a dedicated device for thrombus removal through the dissolution and aspiration of the thrombus. High-speed saline jets within the tip of the catheter create intense local suction via the Venturi effect, pulling surrounding blood, thrombus, and saline into the lumen of the catheter opening, propelling the debris proximally through the catheter lumen (fig 1, 2, 3).

Newer lower profile aspiration catheters that use 6F guiding catheters have been developed as alternatives to rheolytic thrombectomy in patients with thrombus-containing lesions (eg – thrombuster).

3. Embolic Protection Devices

The advent of embolic protection systems has reduced the risk of postprocedural adverse events following SVG and selective native vessel PCI. Although embolization of atherosclerotic debris was not considered a major complication during the early years of native coronary balloon angioplasty, it is now recognized as one potential cause of distal myocardial necrosis after PCI, particularly in friable SVG lesions.

Two distal occlusion devices are available for clinical use. The Guardwire (Medtronic Vascular, Santa Rosa, CA) and The Triactive Device (Kensey-Nash, Exton, PA) The device is passed across the target lesion and inflated with a saline contrast admixture to occlude flow; the debris liberated by intervention remains trapped in the stagnant column of blood and is aspirated using a specially designed aspiration catheter before the occlusion balloon is deflated to restore antegrade flow.

Embolic protection filters- Distal filters are advanced across the target lesion in their smaller collapsed state, and a retaining sheath is withdrawn, allowing the filters to open and expand against the vessel wall. The filters then remain in place to catch any liberated embolic material larger than the filter pore size (eg Guard wire and the FilterWire, Boston Scientific, Natick, MA).

The third type of embolic protection device occludes flow into the vessel using a balloon on the tip of or just beyond the tip of the guiding catheter. Two proximal occlusion devices are currently in use: the Proxis catheter (St Jude Medical, Minneapolis MN) and Kerberos embolic protection system (Kerberos, Sunnyvale, CA). With such inflow occlusion, retrograde flow generated by distal collaterals or infusion through a “rinsing” catheter can propel any liberated debris back into the lumen of the guiding catheter. These approaches have the potential advantage of providing embolic protection even before the first wire crosses the target lesion.

4. Vascular Closure Devices

Vascular access site complications occur after 3 to 7 percent of PCIs and lead to significantly increased length of hospital stay, total costs, and morbidity and mortality. Currently ap-
proved vascular closure devices fall into three categories. Sealant devices include collagen- and thrombin-based systems that leave no mechanical anchor inside or outside the vessel. Mechanical closure devices include suture-mediated and nitinol clip-based systems, and provide immediate secure closure to the vessel. Hybrid closure devices, such as the dissolvable AngioSeal device (St. Jude Medical, Minneapolis, MN), use a combination of collagen sealant with an internal mechanical closure to effect rapid hemostasis.

5. **Chronic Total Occlusions.**

Chronic total occlusions occur in 50 percent of patients with severe (>70 percent stenosis) CAD and are the most important factor leading to the referral of patients to coronary bypass surgery rather than PCI. Successful guidewire recanalization of total coronary occlusions depends on the occlusion duration and on the presence of bridging collaterals, occlusion length greater than 15 mm, and the absence of a “nipple” to guide wire advancement (fig 4, 5, 6). The CTO can be approached either through antegrade or by the more complex retrograde technique. There are dedicated hard ware available for addressing these complex stenosis. Some of the examples are the Miracle (Asahi Ltd) wires, CTO balloons like Sequent and Rijyun are some of the materials which is a must. These procedures need a very dedicated team, the radiation exposure to the operator should be understood. Although newer guidance technologies (eg IVUS and OCT) have been used to recanalize refractory occlusions, better guidewires and wire techniques have accounted for much of the improvement in crossing success over recent years. Once the chronic total occlusion has been crossed, drug-eluting stents may be used to reduce late clinical recurrence 11-15.
SVG administration of arterial vasodilators may improve the flow into the distal native circulation, but there is still a substantial increased risk for death and myocardial infarction. More extensive SVG degeneration and bulkier lesions (larger estimated plaque volume) are associated with higher complication rates than SVGs that have less extensive disease. In the setting of "high-risk" SVG anatomy, alternative approaches using the native coronary artery should be pursued whenever possible.

Lower rates of restenosis in SVG lesions are found after coronary stent placement than after balloon angioplasty. Although drug-eluting stents may provide even lower angiographic restenosis rates, the sirolimus-eluting stent is poorly suited to SVGs larger than 4.5 mm in diameter and large, and bare metal stents are preferred in this setting.

7. Bifurcation lesions

Optimal management of lesions involving both branches of a coronary bifurcation remains controversial. "Snowplowing" of plaque into the adjacent parent vessel or side branch is a major limitation of conventional balloon angioplasty. Atheroablative devices, such as directional atherectomy, have only partially reduced this risk. A number of strategies have been used, including simultaneous kissing stents and "crush," culotte, and T stenting. There is 1 stent or 2 stent approach. The more reasonable approach would be to plain balloon dilation of the side branch and stent the main branch. However, provisional stenting of the side branch should be kept as an option. The recent Medina classification has made the bifurcation stenosis to understand easily. Irrespective of the bifurcation strategy used, a final "kissing" balloon inflation in
the parent vessel and side branch should be performed (fig 7, 8, 9). Newly developed bifurcating coronary stents are currently in clinical trials with promising initial results 20, 21.

8. Unprotected Left main stenting

In the 1980s, early attempts at balloon angioplasty of the unprotected left main coronary artery (UPLM) were associated with poor early outcomes because of coronary dissection, abrupt closure, and restenosis. Mortality rates as high as 30% at 1 year were reported. In the 1990s, bare-metal stents helped reduce acute complications, but high rates of repeat revascularization (20% to 30%) were observed because of restenosis. In the early 2000s, the introduction of drug-eluting stents (DES), with the promise of vastly reduced rates of restenosis, raised the possibility of improved late outcomes for UPLM patients receiving stents. Although use of DES for UPLM is currently a class III indication in patients who are candidates for coronary artery bypass graft (CABG), many patients are currently undergoing this procedure (fig 10, 11, 12). Published registries indicate the procedural and in-hospital risks are acceptable and seem to be the same or lower than the procedural risks of CABG. Unprotected left main ostial and midshaft lesions have excellent early and midterm outcomes that will likely (although not yet proven) be similar to those of CABG. Distal left main lesions involving the bifurcation are technically more challenging and associated with a higher rate of late revascularization 27.

9. IVUS and OCT

These vulnerable plaques consist of a thin fibrous cap and a large lipid core with abundant macrophage infiltration. Proper identification of these plaques with appropriate treatment can theoretically prevent the catastrophic event of AMI or even sudden death. Intravascular ultrasound (IVUS) has been used to identify coronary atherosclerotic plaque burden and assess vessel size. Spatial analysis of the IVUS
signal (IVUS-Virtual Histology (VH)) can provide further details of the composition of the plaque, which can be categorized into necrotic, fibro-fatty, fibrous and calcified tissue. By using IVUS-VH, Gaston et al. could identify a significantly higher prevalence of IVUS-derived thin-cap fibroatheroma (TCFA) in patients presenting as acute coronary syndrome, as compared to stable angina patients. Ruptured TCFA was the culprit for 60% of the coronary artery thrombi. Kubo et al. evaluated the ability of optical coherence tomography (OCT) for assessment of the culprit lesion morphology in AMI as compared to IVUS and coronary angiography (CAS). The incidence of plaque rupture observed by OCT was significantly higher than CAS and IVUS (73% vs. 47% vs. 40%). Fibrous cap erosion and intracoronary thrombus were also more readily identified by OCT. Once a vulnerable plaque is identified, it is reasonable to cover the lesion and reinforce the cap by a stent which can also release pharmaceutical agents targeting to stabilise the necrotic core.

10. Fractional flow reserve

Fractional flow reserve (FFR) is a technique used in to measure pressure differences across a coronary artery stenosis to determine the likelihood that the stenosis impedes oxygen delivery to the heart muscle. Normal value of FFR is 1. FFR < 0.8 distinguishes significant from non-significant lesion.

The Fractional Flow Reserve versus Angiography for Multivessel Evaluation (FAME TRIAL) study evaluated the role of FFR in patients with multivessel coronary artery disease. In 20 centers in Europe and the United States, 1005 patients undergoing percutaneous coronary intervention with drug eluting stent implantation were randomized to intervention based on angiography or based on fractional flow reserve in addition to angiography. In the angiography arm of the study, all suspicious-looking lesions were stented. In the FFR arm, only angiographically suspicious lesions with an FFR of 0.8 or less were stented.

In the patients whose care was guided by FFR, less stents were used (2.7±1.2 and 1.9±1.3, respectively). After one year, the primary endpoint of death, nonfatal MI, and repeat revascularization was lower in the FFR group (13.2% versus 18.3%). There also was a non-significant higher number of patients of residual angina sufferers (81% versus 78%). In the FFR group, hospital stay was slightly shorter (3.4 vs 3.7 days) and procedural costs were less ($5,332 vs $6,007). FFR did not prolong procedure (around 70 minutes in both groups).

11. Primary angioplasty (PAMI)

Primary angioplasty for acute myocardial infarction especially ST elevation Myocardial infarction has helped to save millions of life. A meta-analysis of 10 multicenter randomized trials indicates that primary angioplasty in AMI lowers the rates of death, stroke, recurrent ischemia and reinfarc-
tion compared with fibrinolytic therapy.

Early restoration of epicardial coronary blood flow reduces infarct size in patients with acute myocardial infarction (AMI) and has a beneficial effect on post-infarction myocardial infarct healing and left ventricular (LV) remodeling.

PAMI has become the treatment of choice especially in large anterior MI. The simple strategy would be to extract the thrombus and subsequently stent it. Balloon dilation if possible should be avoided as there are chances that thrombus would be pushed in the distal circulation causing slow flow and no flow phenomena. Intra coronary administration of nitroglycerine, nikorandil and even diluted doses of adrenaline may be helpful to restore the distal circulation. The operator who performs the PAMI should be very experienced and should have the entire team geared for any complication that arise.

An invasive strategy is generally preferred if:

- Skilled PCI lab is available with surgical backup
- Medical contact-to-balloon or door-to-balloon less than 90 min*
- (Door-to-balloon)–(door-to-needle) less than 1 hr
- High risk from STEMI
- Cardiogenic shock
- Killip class ≥3
- Contraindications to fibrinolysis including increased risk of bleeding and ICH
- Late presentation
- Symptom onset was more than 3 hr ago
- Diagnosis of STEMI is in doubt

II. Optimizing reperfusion

GPIIb/IIIa antagonist are associated with improved clinical outcomes in setting of Primary PCI, early delivery before the procedure improves the rate of epicardial artery patency at angiography. All studies employing angiographic perfusion scores, invasive measurement of coronary flow, myocardial contrast echocardiography have shown that GPIIb/IIIa reduce distal microemboli and formation of platelet microparticle and achieving TIMI III flow.

In the HORIZON − AMI trial. A total of 1800 patients were randomized to treatment during PCI with bivalirudin and 1802 to UFH plus GP IIb/IIIa inhibitor. Results at 30 days as follows:

For the primary endpoint, the incidence of net adverse clinical events at 30 days, bivalirudin significantly reduced the composite of major adverse cardiac events or major bleeding by 24% (9.2% vs. 12.1%, p = 0.006). Bivalirudin also significantly reduced the incidence of major bleeding by 40%.
There were comparable rates of major adverse cardiac events in the two groups (5.4% vs. 5.5%, p = 1.0). At 30 day follow-up, bivalirudin significantly reduced the incidence of cardiac-related mortality by 38% (1.8% vs. 2.9%, p = 0.035). There was no significant difference in stent thrombosis at 30 days between the groups (2.5% with bivalirudin vs. 1.9% with UFH plus GP IIb/IIIa inhibitor; p = 0.33), but rates of acute stent thrombosis within 24 hours were higher in the bivalirudin group (1.3% vs. 0.3%, p = 0.0009).

The trial concluded that among patients undergoing planned primary PCI for STEMI, use of a strategy of bivalirudin was associated with a reduction in the composite endpoint of death, MI, target vessel revascularization, stroke, and major bleeding at 30 days compared with UFH plus GP IIb/IIIa inhibitors, driven by a reduction in major bleeding with no difference in major adverse cardiac events.1

REFERENCES

2. Braunwald textbook of cardiology, 8th edition


