Percutaneous coronary intervention

Peter F Ludman

Abstract

Percutaneous coronary intervention (PCI) is the most common technique to improve myocardial perfusion when treating coronary artery disease. It is very efficacious in improving symptoms for patients with stable angina, and improves prognosis in acute coronary syndromes, particularly in the emergency treatment of patients presenting with ST elevation myocardial infarction. It is performed via a small intra-arterial sheath. A balloon is used to dilate the coronary stenosis, and a stent is implanted to scaffold the vessel. Re-narrowing at the treated site can occur but has been greatly reduced by drug-eluting stents. Most acute complications of PCI are mediated by platelet activation, so drugs blocking platelet aggregation are pivotal to the procedure's safety. Early complications include haemorrhage from the arterial access site (reduced by a radial approach). Abrupt vessel closure, stroke, vessel perforation and tamponade are rare. The requirement for emergency cardiac surgery is <0.1%, and in-hospital mortality is mainly determined by the indication for PCI – about 0.2% in patients with stable angina, 5% after ST elevation myocardial infarction and 30–50% in the context of cardiogenic shock. Technical advances mean that patients with complex coronary artery disease and co-morbid conditions can now be treated by PCI.

Keywords Angioplasty; clopidogrel; distal protection; drug-eluting stent; intravascular ultrasound; laser; MRCP; optical coherence tomography; percutaneous coronary intervention; prasugrel; pressure wire; radial; rotablation; stent; thrombectomy; ticagrelor

Key points

- Percutaneous coronary intervention (PCI) is the most frequent method for mechanically improving myocardial perfusion
- Coronary revascularization can be performed by PCI or coronary artery bypass grafting (CABG), depending on the clinical and technical features. Although more complex disease is better treated by CABG, many such patients have co-morbidity that precludes open surgery, leaving PCI the preferred option
- Emergency 'primary PCI' is the preferred treatment for ST elevation myocardial infarction, and has replaced thrombolysis in the UK
- Drug-eluting stents have become more refined. They have improved short- and long-term outcomes, with a lower risk of late stent thrombosis than bare metal stents
- Antiplatelet agents are key to preventing stent thrombosis, but benefits must be weighed against bleeding risk. A more tailored patient specific approach is being developed
- Radial artery access reduces bleeding complications and is associated with lower mortality

Introduction

Atherosclerosis in coronary arteries usually manifests clinically by causing stenoses or occlusions that reduce myocardial blood flow. The term 'percutaneous coronary intervention' (PCI) applies to various procedures that reopen obstructed coronary arteries to improve myocardial perfusion without resorting to coronary artery bypass surgery (CABG). PCI usually starts by inflating a balloon within the coronary artery stenosis (percutaneous transluminal coronary angioplasty), followed by implantation of one or more stents. Variations of this basic procedure, described below, are used in some patient subsets. More than 100,000 PCI procedures were performed in the UK in 2016, with more than five times as many patients treated by PCI than by CABG.

Role of PCI in clinical syndromes

Revascularization in the treatment of coronary artery disease aims to improve symptoms and/or prognosis. Appropriateness is determined by the patient's clinical presentation, symptoms and co-morbidities.

Stable angina

Mechanical revascularization (CABG, PCI) should be considered in patients who have angina despite medical therapy or who tolerate medication poorly because of adverse effects. PCI is safe and effective in reducing angina in such patients, and may improve prognosis where high-risk features are present on non-invasive testing. PCI is associated with better outcomes than medical therapy alone when use is guided by invasive assessment of the functional significance of coronary stenoses (see below).

The choice between PCI and CABG is determined by a combination of clinical and technical considerations. Patients with more extensive atheroma generally have better long-term outcomes with CABG than PCI. A method to score coronary disease complexity in patients with three-vessel disease (SYNTAX score) has been derived from randomized trials, and is often used to inform the decision on optimal revascularization.[1] Patients in the lowest tertile of the SYNTAX score (score ≤22) are well suited to PCI, with those in the middle and upper tertiles best treated by CABG. PCI is, however, still used in those with higher complexity scores when co-morbidity and frailty mean that open surgery carries a particularly high risk.

Some studies suggest that individuals with diabetes mellitus are better treated by CABG than PCI, particularly if surgery can include use of the left internal mammary artery to bypass disease in the left anterior descending coronary artery; this particular bypass graft appears to provide the best long-term benefit. In

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patients who do not have diabetes mellitus and have less widespread disease, PCI offers equivalent long-term mortality with a lower risk of stroke than CABG, albeit with increased need for repeat PCI.

Equivalent outcomes for CABG and PCI have been shown for the treatment of left main stem disease, in the absence of disease at the bifurcation or other complex coronary disease. The decision on optimal revascularization strategy for an individual patient can be complex, and should take into account symptoms, coronary anatomy, co-morbidity and patient choice. Guidelines recommend that these decisions be taken by a multidisciplinary 'heart team'.[2]

Acute coronary syndromes

PCI improves survival in patients presenting with acute ST elevation myocardial infarction (STEMI). When PCI is performed as an emergency in this setting, it is called 'primary' PCI. It is safer and more efficacious than thrombolysis and now used throughout the UK. In patients presenting with non-ST elevation myocardial infarction (NSTEMI) and unstable angina, routine early mechanical revascularization (PCI or CABG, determined by clinical and technical considerations), combined with appropriate medical therapy, also reduces later myocardial infarction and cardiovascular mortality.

The mechanics of PCI

When the balloon is inflated in a narrowed coronary artery, the atheromatous plaque is disrupted, deep fissures extend through the intima into the media, and some atheromatous material is displaced outwards into the vessel wall. Any plaque-free segments are stretched. When the balloon is deflated, arterial wall elasticity causes some recoil. If no stent is implanted, there is a 5% risk of acute vessel occlusion in the first 24 hours (acute vessel thrombosis). This is caused by a combination of dissection flaps and platelet-rich thrombosis at the dilated site (Figure 1). Slow blood flow and focal arterial spasm can worsen this. Without a stent, the dilated segment heals over the next 6 months.

Two aspects of healing threaten to re-narrow the newly opened lumen – the external arterial diameter can decrease (negative remodelling), and smooth muscle cells in the media proliferate and migrate to re-line the damaged arterial lumen with a neo-intimal layer (Figure 2). If the lumen becomes sufficiently re-narrowed to obstruct blood flow ('re-stenosis'), symptoms can recur after an initial angina-free period of a few weeks. After 6 months, cellular proliferation and vessel remodelling become quiescent, so the artery usually remains patent in the long term if re-stenosis has not occurred by then. Re-stenosis rates without stent implantation are 20–50%.

Stents

Stents were introduced in 1990 and revolutionized PCI. The acute results of PCI became much more predictable, with a greatly reduced risk of sudden early vessel occlusion. Stents are now used in >90% of all PCI procedures. The first stents were made of metal mesh (usually stainless steel or cobalt–chrome alloy). They prevented acute elastic recoil and held back dissection flaps. This reduced the risk of vessel occlusion in the first 24 hours (acute stent thrombosis) to <1%. During healing, the mesh's rigidity prevented negative remodelling, leaving neo-intimal hyperplasia as the only factor causing re-stenosis. This resulted in a re-stenosis rate of about 10–30%. It remained significant not only because of recurrent symptoms, but also because re-stenosis presents as an acute coronary syndrome in over one-third of patients.

Drug-eluting stents

In the next iteration of therapy, drug-eluting stents were developed, now used in most PCI procedures. These stents have been modified to elute antimitotic drugs into the vessel wall for a few weeks after implantation. The stent is usually coated with a polymer that releases the drug. The inhibition of cellular proliferation reduces neo-intimal formation and profoundly decreases the re-stenosis rate to about 5%. This is a relative reduction of about 70% in every patient subgroup so far tested, including situations with a high risk of re-stenosis, such as long lesions and small vessels, and patients with diabetes mellitus.

Nevertheless, these benefits came at a cost. The lack of a proliferative response left some stent struts uncovered. It also became apparent that the polymer itself could promote an inflammatory response. This resulted in occasional episodes of stent thrombosis occurring much later after stent implantation than previously observed. Patients treated with first-generation drug-eluting stents had an annual rate of 'late stent thrombosis' of 0.4–0.6% for at least 3 years after PCI.

Current 'third-generation' drug-eluting stents have a much better long-term safety profile because of a changes in design. They have thinner stent struts and a more inert or absorbable polymer coating, which may be restricted to the stent's abluminal surface. Some stents elute drug without needing a polymer coating. Late stent thrombosis rates are now <1% at 6 years and less than those with bare metal stents.[3]

Absorbable stents

Modern drug-eluting stents have allowed PCI to be predictable, efficacious and safe in the short and long term. Nevertheless, they remain as permanent implants in the coronary arteries. Their rigidity alters flow dynamics, abolishes vasoreactivity and can promote continuing inflammation. Bioabsorbable materials have been explored in the hope they will perform like conventional stents but later be fully absorbed, leaving a coronary artery that might be able to regain normal vascular responses. Initial trial results have been disappointing, with higher stent thrombosis rates and no evidence of the hoped-for preserved late vasoreactivity. However, the concept is attractive, and this remains an area of continuing research.

Adjunctive pharmacotherapy for PCI

Antiplatelet treatment during PCI

Early work with bare metal stents demonstrated that antiplatelet agents were pivotal to reducing stent thrombosis, both during the procedure and in the first few weeks after implantation. Dual antiplatelet therapy (DAPT) was introduced to minimize stent thrombosis. Aspirin (an irreversible inhibitor of the cyclooxygenase

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