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Advances in Percutaneous Coronary Intervention

Manar Mostafa EL Zaky, Hisham Samir Roshdy, Ahmed Abdelhalim Abdel Kawy, Mohammed Maher Allam

Cardiology Department, Faculty of Medicine, Zagazig University, Egypt

***Corresponding author:** Ahmed Abdelhalim Abdel Kawy

Email: dr.ahmed.abozeid@gmail.com,

Abstract:

Percutaneous Coronary Intervention (PCI) is a cornerstone revascularization strategy for the management of coronary artery disease (CAD), aiming to restore myocardial perfusion by relieving obstructive coronary lesions. Since its introduction, PCI has evolved significantly with advances in device technology, pharmacotherapy, and imaging guidance, leading to improved procedural success and patient outcomes. Contemporary PCI techniques include balloon angioplasty, drug-eluting stent implantation, and adjunctive use of intravascular imaging and physiological assessment. PCI plays a pivotal role in the treatment of acute coronary syndromes, including ST-segment elevation myocardial infarction, as well as in selected patients with stable ischemic heart disease. Despite its benefits, PCI is associated with potential complications such as restenosis, stent thrombosis, and periprocedural myocardial injury, necessitating careful patient selection and optimal peri-procedural management. Ongoing research continues to refine indications, techniques, and long-term strategies to maximize the clinical benefit of PCI.

Keywords: Percutaneous coronary intervention; coronary artery disease; drug-eluting stents; acute coronary syndrome; myocardial revascularization; intravascular imaging.

Introduction:

To improve blood flow to the heart muscle, percutaneous coronary intervention (PCI) is a non-operative invasive technique that may open narrowed or blocked coronary arteries. Managing coronary artery disease (CAD), a leading cause of death globally, requires percutaneous coronary intervention (PCI). Coronary artery disease (CAD) is defined by the buildup of plaque within the coronary arteries, which narrows their diameter and reduces the amount of oxygen that can reach the heart. Angina (chest discomfort), dyspnea, or a full-blown myocardial infarction (MI) may develop from the decreased oxygen supply. Regular blood flow and CAD symptoms may be alleviated by percutaneous coronary intervention (PCI) (1).

With over two million operations carried out every year, PCI has rapidly become one of the most prevalent methods for treating coronary artery disease (CAD) globally. Nevertheless, there are limits and hurdles to PCI. Some of them include radiation exposure, cost-effectiveness, bleeding problems, stent thrombosis, restenosis (re-narrowing of the artery), and radiation. Hence, to enhance PCI safety and results, continuous research and innovation are required (1).

Improvements in PCI procedures have led to better long-term results and fewer problems for patients. New imaging technologies, such as intravascular ultrasound (IVUS) and optical coherence tomography (OCT), have been integrated into percutaneous coronary intervention (PCI) procedures, and bioresorbable vascular scaffolds (BVS) are one example of a recent innovation that dissolves over time as the artery heals (2).

The treatment of CAD now mostly involves percutaneous coronary intervention (PCI). Restoring blood flow in coronary arteries that have been constricted or obstructed requires the use of medical devices and pharmaceutical medicines. New percutaneous coronary intervention (PCI) methods aim to boost procedural success rates, decrease complication rates, and improve patient outcomes. New technologies, imaging modalities, pharmacological agents, procedural methods, patient selection criteria, and quality measures for percutaneous coronary intervention (PCI) are all part of these improvements (3).

Patient-Specific Indications for Percutaneous Coronary Intervention (PCI)

The therapy of coronary artery disease (CAD) often involves PCI in certain clinical situations. When medical treatment for stable CAD fails or when a serious illness significantly reduces the patient's quality of life, this procedure is carried out. Preventing myocardial infarction (MI) requires prompt percutaneous coronary intervention (PCI) for individuals presenting with unstable angina. individuals with ST-segment elevation myocardial infarction (STEMI) and high-risk individuals with non-ST-segment elevation myocardial infarction (NCI) are the ideal candidates for perfusion during acute coronary syndrome (ACS). Additionally, patient risk factors and the intricacy of the lesion determine whether PCI is necessary for left main disease or multivessel disease. Patients with symptoms, signs of myocardial ischemia, and viable myocardium may be candidates for percutaneous coronary intervention (PCI) for chronic total occlusions (CTOs) (4).

Additionally, percutaneous coronary intervention (PCI) may be used to restore normal blood flow in situations when stenosis develops after coronary artery bypass grafting (CABG). Left ventricular dysfunction, microvascular angina, symptomatic CTOs, and ischemia-driven revascularization in high-risk situations are some of the new indications for percutaneous coronary intervention (PCI) that are now the subject of ongoing study. When it comes to managing coronary artery disease (CAD), percutaneous coronary intervention (PCI) plays a crucial role in improving patient outcomes and treating a wide range of clinical manifestations (5).

Considerations for PCI patient selection

A thorough assessment of the patient's clinical features, coronary architecture, and procedural risk is necessary for PCI patient selection. A thorough assessment of the patient's symptoms, hemodynamic stability, co-morbidities, and risk stratification is necessary before deciding to continue with percutaneous coronary intervention (PCI). Polycystic ovary syndrome (PCI) is an option for symptomatic people whose CAD is severe enough to impair their daily lives. In order to determine the risk of procedures and to direct treatment choices, comorbidities such as old age, renal impairment, heart failure, and other similar conditions are assessed. Revascularization is necessary and PCI or CABG is chosen based on the structural complexity of the coronary lesions, which includes elements like significant calcification, bifurcation disease, left main disease, and multivessel disease. In order to determine the risk-benefit ratio, procedural risk assessment takes into account both patient variables and procedure concerns. Risk assessments, including the SYNTAX Score and Euro SCORE, help evaluate the potential risks of procedures and forecast the results of percutaneous coronary intervention (PCI) (6).

Revascularization protocols for the coronary arteries

Myocardial insufficiency is a hallmark of the arrhythmias that make up acute coronary syndrome (ACS). For patients with ST-elevation myocardial infarction (STEMI), initial percutaneous coronary intervention (PCI) within 12 hours of symptom onset or later if evidence of persistent ischemia is present is the optimum revascularization strategy, according to both the 2021 ACC/AHA/SCAI and 2018 ESC recommendations. In terms of intravenous thrombolysis (IVUS) usage, antithrombotic medication selection and duration, and revascularization timing and extent, however, the two recommendations are at odds with one another. Patients with multivessel disease who are hemodynamically stable should have full revascularization either during initial PCI or within 45 days after STEMI, according to the ACC/AHA/SCAI guideline. Contrarily, according to the ESC guideline, primary PCI should only include full revascularization for certain patients with cardiogenic shock or persistent ischemia. Patients with hemodynamically stable disease should be considered for staged revascularization within 72 hours after STEMI (7).

The ACC/AHA/SCAI recommendations and the ESC guidelines both call for 12-month dual antiplatelet treatment (DAPT) after percutaneous coronary intervention (PCI) after an acute coronary syndrome (ACS), however the ACC/AHA/SCAI recommends ticagrelor or prasugrel instead of clopidogrel in most patients because of their superior effectiveness. Patients at high risk for diabetes mellitus or recurrent ischemic episodes should only be given ticagrelor instead of clopidogrel, according to the ESC recommendation. If the patient develops problems with drug toxicity or is at high risk of bleeding, it gives them the opportunity to move from ticagrelor/prasugrel to clopidogrel within 12 months following PCI (7).

Another case in point is intravenous venous angiography (IVI) during percutaneous coronary intervention (PCI). Both recommendations recommend this technique for optimizing stent insertion, most often with the use of optical coherence tomography (OCT) or intravascular ultrasound (IVUS). There is stronger evidence that sonography-guided revascularization improves outcomes compared to angiography-guided revascularization, which is why the ACC/AHA/SCAI guideline supports sonography-guided PCI over tomography-guided PCI. According to Truesdell Alexander et al. (8), the ESC guideline does not provide a preferred method over OCT or IVUS, and both methods may be utilized interchangeably based on availability and operator choice.

The development of DES, which are small coils of metal mesh that are inserted into narrowed or blocked coronary or peripheral arteries and kept open to increase blood flow, is a significant step forward in percutaneous coronary intervention (PCI) technology. The medication-coated surface of DES, in contrast to BMS, is slowly released, avoiding blood clots and scar tissue formation—both of which may cause arterial constriction, a disease known as restenosis—as a result. In the years 2002–2003, DES was granted regulatory clearance by both the European and American authorities. In the time after, other clinical studies shown their superiority over BMS in lowering restenosis rates across all lesion types and clinical syndromes. According to Lee and de la Torre Hernandez (9), DES makes use of a number of medicines, including paclitaxel, sirolimus, everolimus, and zotarolimus.

According to research, DES significantly lowers the risk of restenosis when compared to other options. Real-world studies without randomization and with an acceptable possibility of selection bias and residual confounding similarly linked DES use to a decreased likelihood of MI and associated death. According to Abubakar et al. (2), the use of DES results in a significant decrease in target vessel revascularization when compared to BMS.

You should know that the outcomes might be different depending on the patient's features, the length of time they were followed, and the kind of stents utilized. It is also difficult to draw direct comparisons since various outcomes were used in the research. While one research found that DES was associated with better results than BMS, the results were not definitive (10).

Cardiovascular imaging techniques

There have been significant advancements in percutaneous coronary intervention (PCI) methods made possible by intravascular ultrasound (IVUS) and optical contrast angiography (OCT). According to Sonoda et al. (11), these imaging methods provide detailed information on coronary lesions, which helps in optimizing stents after DES placement and identifying the cause of PCI problems.

• How IVUS and OCT compare in different contexts

With the use of new tissue recognition technologies, intravascular ultrasound (IVUS) can now provide grayscale, cross-sectional images of the arterial wall. The most typical applications include cardiac interventional procedures, where it is used to define the lesion shape, assess the burden of atherosclerosis, guide the size of the stent, evaluate its expansion, offer information on the precision of its deployment, and detect any issues that may arise during the treatment. In contrast, optical coherence tomography (OCT) provides high-quality pictures of the coronary arteries, which enables precise evaluations of stent positioning and expansion (12).

It improves the imaging of tissue covering and stent apposition by providing higher-resolution pictures. These techniques lessen the likelihood of problems and increase the success rate of procedures. OCT offers a number of benefits, including better image quality, faster pullback, angiography co-registration, a number of automated measurements, and a user-friendly interface. While there is a dearth of data, there is mounting evidence that OCT-guided PCI enhances imaging and clinical results. Among the countries that have been slow to adopt

OCT recommendations for PCI, Japan ranks highest because to the high expense and lack of assurance around reimbursement (13).

• The possibility of pharmacological medicines in reducing post-PCI problems

To reduce the risk of ischemia-related events during percutaneous coronary intervention (PCI) and stent thrombotic complications, pharmacological medicines such as anticoagulant and antiplatelet treatments are essential (14).

Contrast-antiplatelet treatment

Patients with an ACS diagnosis or who have had a percutaneous coronary intervention (PCI) may benefit from a treatment regimen called dual antiplatelet therapy (DAPT), which combines aspirin with a P2Y12 receptor blocker to reduce the risk of thrombotic events. Decreasing the dosage of DAPT in order to reduce the risk of bleeding problems without sacrificing effectiveness has gained more and more attention in recent years. Determining the optimal DAPT length and combination is a topic of ongoing study. A research was carried out to assess the effectiveness and safety of various regimens. A research was carried out to compare the use of shorter durations of DAPT (less than three months) versus longer durations (more than three months) in patients having percutaneous coronary intervention (PCI) with DES. There was no increase in ischemia-related events, and the risk of large bleeding and unfavorable clinical outcomes was significantly decreased with extremely brief DAPT. Tsigkas et al. (15) found that using a very brief DAPT following a percutaneous coronary intervention (PCI) with DES was both possible and acceptable.

Approaches to procedures that provide better results

• Access the coronary arteries

Complete revascularization and radial artery access are two procedural tactics that have improved patient outcomes after percutaneous coronary intervention (PCI). While percutaneous coronary intervention (PCI) has traditionally been performed via the femoral artery, the radial artery has lately become more popular for a number of reasons. One major benefit of radial artery access over femoral artery access is the reduced risk of bleeding and vascular problems. The proximity of the radial artery to the skin's surface makes compression of the artery simpler, which in turn reduces bleeding (16).

In addition, patients are able to sit up and walk about sooner after the treatment, which means they heal quicker and remain in the hospital shorter. People who are overweight, have peripheral vascular disease, or have had problems with femoral access in the past may benefit more from radial artery access. While this is true, there are also some restrictions. Patients with small or curving radial arteries may have technical difficulties, which may lead to operation failure or the need to use a femoral approach, which is a big drawback. Furthermore, radial artery spasm or blockage might happen in 10–20% of individuals, making radial artery access impractical. Another thing that might be better is that radial artery access requires certain tools and personnel, which may make it hard for the approach to be used by everyone (17).

Successful revascularization with positive results

The idea of full revascularization is another major development in percutaneous coronary intervention (PCI) methods. Reopening all of the heart's clogged arteries, not just the ones that are producing symptoms, is what's known as complete revascularization. Reducing rates of severe cardiovascular events and improving long-term survival are two outcomes that improve with full revascularization, according to a research. Refinements in patient selection criteria for percutaneous coronary intervention (PCI) have been made in recent years with an eye toward optimal utilization and the reduction of complications. Optimal patient selection for coronary revascularization is based on established acceptable usage criteria that take into account variables such CAD severity and extent, symptomatic illness, and anticipated therapeutic benefits. Using the SYNTAX score is crucial for assessing the complexity of CAD, which in turn aids in therapy selection and therapeutic decision-making (18).

Pros and Cons of Percutaneous Coronary Intervention

Nowadays, percutaneous coronary intervention (PCI) is a technique with a low risk of consequences. Greater safety and better results have been achieved by the use of stronger anti-platelet drugs, improved hardware, enhanced operator skills, a better knowledge of the approach to percutaneous coronary intervention (PCI), radial access, non-ionic dye, adjunct imaging, mechanical cardiac support (MCS), and other innovations. The use of MCS, sophisticated and high-risk coronary intervention PCI, PCI with chronic complete occlusion (CTO), and more complicated procedures are all linked to an increased risk of problems. It is crucial to exchange experiences and learn from collective knowledge and literature due to the scarcity of individual operators' expertise in addressing different types of problems (19).

PACE-related issues

According to Doll et al. (19), in cases of diagnostic procedures, 0.6% of PCI vascular problems occurred; in cases of elective PCI, 2.6% happened; and in cases of complicated interventions, 6% occurred (Table 1).

Table 1: Complications of PCI (20)

Local access related complications • **Major complications: local hematoma, retroperitoneal hematoma, pseudoaneurysm, arteriovenous fistula, thrombosis, embolism, arterial dissection, rupture and infection** • **Minor complications: Minor hematoma, local pain and bruising and discoloration**
Coronary complications • **Acute –Stent thrombosis, Intra mural hematoma coronary perforation, cardiac tamponade, no flow, acute vessel closure, dissection, thrombus migration, branch vessel closure, stent loss, failure to deliver stent, under expanded stent, stent distortion, and entrapment of Rota burr** • **Chronic – ISR, LAST, Coronary aneurysm**
Arrhythmic complications: VT, VF, Asystole, bradycardia, tachycardia, SVT, AF
Non coronary complications – Renal failure, acute respiratory distress, seizures, stroke
Death

PCI: Percutaneous coronary intervention, ISR: In-stent restenosis, VT: Ventricular tachycardia, VF: Ventricular fibrillation, SVT: Supraventricular tachycardia, AF: Atrial fibrillation, LAST: Late stent thrombosis

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