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Research Article

Review of Management of Coronary Artery Perforation

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Abstract

Percutaneous coronary angioplasty can be associated with a number of complications. The most dangerous and fatal for patients is coronary artery perforation. In most cases, this damage is caused by direct damage to the vessel shear with the instruments used, such as balloons, stents, or guidewires. Treatment can be difficult, especially when standard methods are inadequate. This review presents the most important techniques used in the treatment of coronary artery perforations.

Introduction

Coronary Artery Perforation (CAP) is a rare (0.2% - 0.6%), but potentially fatal complication of Percutaneous Coronary Intervention (PCI). It is characterized by a rupture of the arterial lumen and blood extravasation into the myocardium or pericardium. CAP can be a life-threatening complication resulting in cardiac tamponade and hemodynamic instability [1]. Mortality rates can be as high as 21.2% [2].

Diagnosis and classification

If sudden and very severe chest pain occurs during percutaneous coronary angioplasty, always keep in mind the possibility of coronary artery perforation. In this situation, the balloon should be left in the guiding catheter until verification by angiography. Once this complication is confirmed, the balloon should be inflated immediately at the perforation site. Coronary angiography is still the gold standard for the diagnosis of CAP. The modified Ellis classification is used to stratify coronary perforations (Figure 1).

Type I CAP is characterized by an extraluminal crater with no linear contrast extravasation that suggests dissection. Type II CAP is characterized by myocardial or pericardial blushing. Type III CAP is characterized by frank contrast medium

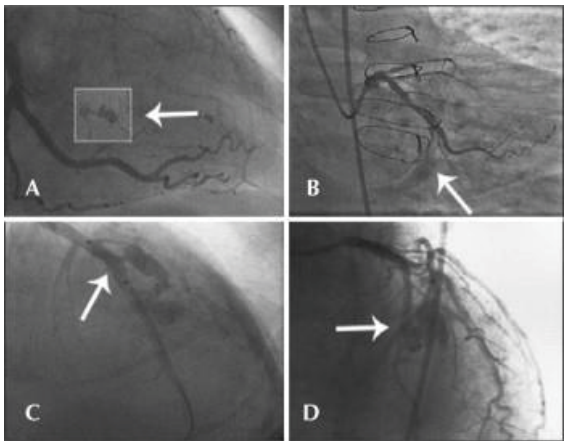

Figure 1: A- Type I in Ellis classification, B- Type II in Ellis classification, C- Type III in Ellis classification, D-[8] Type IV in Ellis classification [1].

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extravasation into the pericardium. Type IV cap is characterized by perforation with contrast extravasation directly into the left ventricle, to the coronary sinus or other vascular [3].

Etiology of coronary artery perforation

Several observational studies have found a higher risk of perforation in old age, female gender [3], history of previous Coronary Artery Bypass Graft (CABG), hypertension [4], peripheral artery disease, congestive heart failure [5], lower body mass index and lower creatinine clearance [6]

The main role in the formation of perforation is played by anatomical factors (treatment of lesions type B or C, chronic total occlusion, and the presence of coronary calcification) and the type of tools used (catheters, balloon caterers, cutting balloons, rotational atherectomy, stents). Most perforations occur during balloon or stent expansion, which is related to their size mismatch with the vessel [4].

Distal Coronary Vessel Perforation (DCVP) presents another mechanism of damage usually caused by a guidewire placed in a small peripheral side branch or terminated with a loop shape in a narrow distal segment of the coronary vessel.

Management

The general guidelines when treating coronary artery perforations are hemodynamic stabilization and sealing of the perforation site. Closure of type I coronary artery perforations in the Elissa classification can occur without intervention or after Prolonged Balloon Inflation (PBI) using low pressure (2 to 4 atm) at the site of the vessel injury. Balloon deflation should be performed after 5 - 10 min to verify the effectiveness of hemostasis. When the bleeding has stopped, the effectiveness of hemostasis should be confirmed angiographically after the same amount of time. When bleeding persists, consider re-inflation of the balloon and administering protamine sulfate to reverse the anticoagulant effect of heparin. For pharmacological treatment, transfusion of platelet cell concentrate can be considered to offset the effect of GP-IIB/IIIa receptor antagonists used previously.

For severe type II-IV vessel lesions according to the Elissa classification, balloon inflation alone may not be sufficient and may require more advanced techniques. If the aforementioned fail, implantation of stentgrafts should be considered.

We occasionally observe another mechanism of perforation, ie, Distal Coronary Vessel Perforation (DCVP). This damage occurs during deep penetration of the guidewire, which is often terminated with a loop shape into the small peripheral side branch. This type of perforation can cause diagnostic difficulties, as most often the extravasation of blood into the pericardial sac is asymptomatic, and the patient is often already outside the catheterization laboratory. In untreated cases, we may observe subacute pericardial tamponade. Regularly performed ECHO may allow for the diagnosis of late development of pericardial effusion and tamponade, especially in patients treated conservatively. A life-saving procedure, in hemodynamically unstable patients, may be to perform a pericardial puncture during cardiac tamponade. If heart failure and hypotonia are present, left ventricular assist techniques (Impella CP, IVAC) may be necessary.

Examples of more advanced coronary artery embolization techniques include the use of coils, spongostan, glue, autologous fat particles or blood clots, and thrombin injection [5].

Coils are made of metallic agents like stainless steel or platinum with wired structures made of PTFE or synthetic wool, which have thrombogenic properties. They are delivered through microcatheters and the choice of coil size is important to ensure compatibility with the inner diameter of the delivery catheter, firstly to be able to deliver and secondly to prevent the coil from being stuck and damaged. These are commonly used for distal coronary artery perforations. The size of these coils needs to be larger than the size of the vessel involved [6].

The use of fat, clots, or thrombin in CAP embolization is limited due to limited operator experience [7].

Spongostan is an interesting option to treat perforation, especially in a side branch. After blocking the main vessel with an expanded balloon, spongostan can be injected into the side branch by an over-the-wire balloon to produce transient embolization and even restoration of branch blood flow after several hours. Embolization with glue has a high risk of entrapment of the microcatheter in the coronary vessel.

The Cut Balloon Technique (CBT)

A new technique in embolization of distal coronary artery perforation is the Cut Balloon Technique (CBT). It involves embolization of the vessel using a clipped balloon, delivered via another balloon catheter (Figure 2). In a multicenter study we conducted between 2017 and 2023 [8], we described the efficacy and safety of the Cut Balloon Technique. Twenty-six patients participated in the study, and all patients succeeded in closing the perforation site, of which only 4 (16%) developed cardiac tamponade. Neither emergency surgery nor cardiac

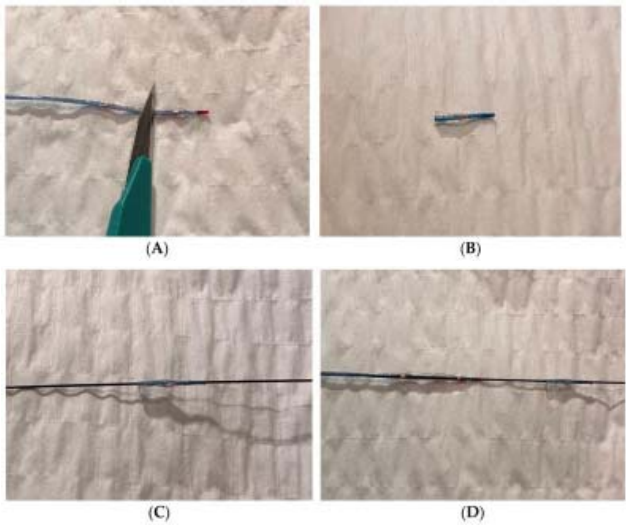

Figure 2: The cut balloon technique (CBT). (A) Semi-compliant balloon cut in the middle, (B) distal part of the balloon, (C) distal part of the balloon on the coronary wire, (D) balloon being pushed together with the distal part of the cut balloon on the coronary wire.

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death occurred. Compared to other methods, this technique is an easy, inexpensive, and effective way to treat perforations of distal coronary artery segments. It is available in every catheterization laboratory and does not require additional equipment or exceptional operator experience [9].

The condom technic

The latest extension of the above method is the so-called The Condom Technic. It was described in the article by Agostoni, et al. [10] as an effective method of sealing coronary vessels. It involves embolization of the coronary vessel using the distal portion of a balloon catheter delivered over a Drug-Eluting Stent (DES). The whole device is then inserted and implanted in front of the perforation site. This simple, cheap, and easy-to-use technique may have applications in sealing perforations of distal blood vessels.

The BI-rescue technique

A major problem in performing PBI is transient myocardial ischemia behind the site of coronary artery perforation, which can lead to hemodynamic instability. Perfusion balloon catheters, due to their special design, have been shown to reduce myocardial ischemia during prolonged balloon inflation. Unfortunately, they can only deliver 10% - 15% of coronary blood flow. Gong, et al. [11] described the BI-RESCUE method, which allows for improved perfusion in the distal parts of the coronary arteries and at the same time to perform prolonged (up to 60 min) balloon inflation. The BI-RESCUE technique is illustrated in Figure 3. Immediately after the diagnosis of severe coronary artery perforation, Prolonged Balloon Inflation should be performed. Another guiding catheter should then be inserted (ping-pong technique) through a separate peripheral puncture and a guidewire inserted into the distal region of the vessel behind the perforation site. The aspiration catheter is delivered after a quick balloon deflation to the distal part of the perorated vessel. After the re-inflation of the balloon, blood (20 ml) is drawn with a syringe from the vascular sheath and then delivered through a second guiding catheter to the site behind the balloon (the distal part of the vessel).

After the above maneuvers, hemodynamic stability was achieved in the described case despite previous hypotonia while maintaining the inflated balloon for one hour

The technique is effective, convenient, inexpensive, and widely available. The BI-RESCUE technique has the potential to become an alternative for some large vessel perforations by experienced operators.

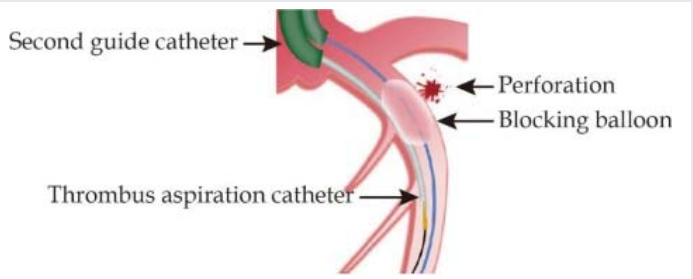

Figure 3: Illustration of the BI-RESCUE technique [11].

If tamponade develops and pericardiocentesis is ineffective, a cardiac surgeon should be consulted for surgical treatment of coronary artery perforation.

Summary

Perforation of the coronary arteries is a dangerous, fortunately rare complication of percutaneous coronary intervention. Prompt as well as correct response makes it possible to reduce CAP mortality, but unfortunately, not all patients respond positively to the applied treatment. Developing new techniques may allow CAP mortality rates to be reduced.

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