Contemporary Management of Coronary Artery Perforation

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While coronary artery perforation remains an uncommon complication of percutaneous coronary intervention, appropriate recognition, early stabilisation and definitive treatment are essential. The immediate goals are to prevent progressive haemodynamic deterioration complicating cardiac tamponade, avoid the need for surgical intervention and limit accompanying mortality. Understanding the role and utility of newer devices that may influence procedural planning and improve procedural results when these complications occur is essential to minimise morbidity and mortality.

Keywords   Coronary perforation • Percutaneous coronary intervention

Background

While coronary artery perforation remains an uncommon complication of percutaneous coronary intervention, appropriate recognition, early stabilisation and definitive treatment are essential. The immediate goals are to prevent progressive haemodynamic deterioration complicating cardiac tamponade, avoid the need for surgical intervention and limit accompanying mortality [1].

With the development of newer technologies, treatment of coronary perforation can be simplified when compared to previous iterations of devices used to treat this complication. In particular, the availability of more deliverable covered stents and microcatheters can more effectively treat this complication.

The incidence of coronary artery perforation is reported to be between 0.3% and 0.6% [2,3], with incidence paralleling procedural complexity [1,4]. Certain procedural characteristics are recognised to carry an increased risk of perforation, including the presence of calcification, female gender, use of rotablation and chronic total occlusion interventions [2,5].

Coronary perforations can be divided into two broad groups: vessel perforation with extravasation at the site of intervention (Ellis type III – see Figure 1 and Video 1), or perforation in a smaller, distal vessel, typically complicating unrecognised migration of hydrophilic guidewires, most commonly in chronic total occlusion interventions (Ellis type I and II) [6–8]. Treatment principles are similar, noting the need to treat smaller, distal vessels may involve methods to occlude proximal flow, as opposed to direct treatment at the site of vessel perforation.

General Principles

Once recognised, several important steps should be undertaken to prevent progressive extravasation and allow institution of measures to definitively treat the perforation. Obtaining additional staff to assist is desirable. Inflation of a compliant balloon placed proximal to the site of perforation at low pressure will limit extravasation and allow for techniques designed to definitively treat the perforation site. Chronic total occlusion intervention is associated with a higher incidence of coronary perforation [9], with distinct challenges; the presence of collateral vessels which may feed the distal vessel and provide an ongoing source of haemorrhage require recognition and treatment. With approaches evolving using septal and ipsilateral collateral branches [10], awareness of the unique complications associated with these approaches is increasingly important.

Urgent echocardiography can exclude cardiac tamponade, however if echocardiography is not immediately available, fluoroscopic assessment of the cardiac silhouette may provide early evidence of tamponade physiology with reduced excursion suggestive of early pericardial effusion [11]. Peri-

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Figure 1 Example of an underdeployed stent in a left anterior descending artery requiring aggressive postdilation with a non-compliant balloon, resulting in coronary perforation seen in Video 1.

cardial aspiration relieves cardiac tamponade and central venous access (typically using femoral venous sheath) may allow auto-transfusion in order to alleviate progressive hypovolaemia. One caveat is in the setting of septal branch perforation in the retrograde treatment of chronic total occlusions. In this case, the presence of an expanding interventricular septal haematoma may prevent ventricular filling with this ''dry'' tamponade potentially causing ventricular arrhythmia, ventricular septal rupture and hypotension [12]. It requires definitive treatment similar to other perforations discussed below in order to limit ongoing extravasation into the myocardium.

Once extravasation is limited by balloon inflation, definitive treatment can be performed. Prolonged balloon inflation may allow small perforations to seal without additional intervention. Reversal of heparin in this setting should be avoided if possible as it may predispose to stent thrombosis and predispose to thrombus formation within the auto-transfusion circuit.

In the event of ongoing perforation, treatment options will depend on procedural and vessel characteristics.

Procedural Examples in Managing Vessel Perforation

Large calibre vessels may be treated with implantation of a covered stent, while smaller, distal vessels may require occlusion, using microcatheters to deliver various occlusion devices.

Due to the risk of haemodynamic collapse once the balloon used to tamponade bleeding is deflated, using the original guidewire for either covered stent delivery or placement of a microcatheter is problematic. As such, the use of a second vascular access and guiding catheter to position a second guidewire distal to the site of balloon occlusion while temporarily deflating the occlusion balloon (dual catheter or ''ping-pong'' technique) can permit device positioning while minimising the time of extravasation [3,13,14].
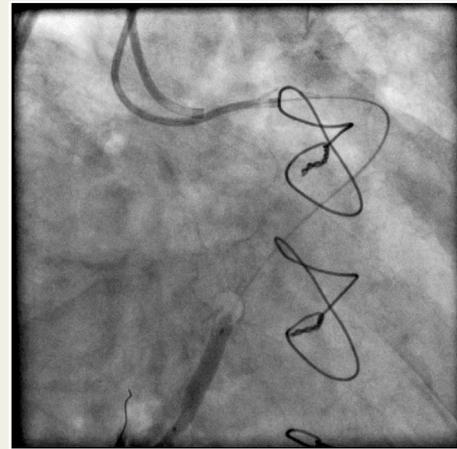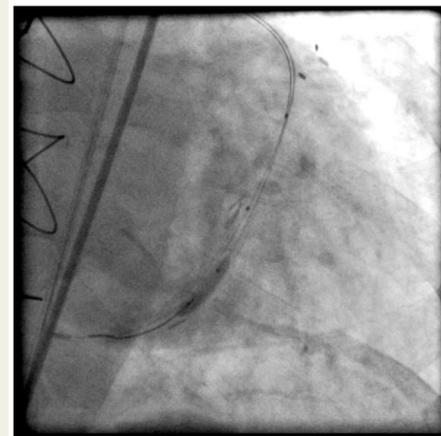
Figure 2 (a) Example of using a second guide catheter to perform a 'ping-pong' technique in order to maintain balloon occlusion while preparing to deliver a covered stent. This case is of coronary perforation of a saphenous vein graft seen in right anterior oblique (RAO) projection. (b) Parallel wiring of the saphenous vein graft allows a covered stent (above) to be prepared for delivery behind the occlusion balloon (below).

After perforation is noted (Video 2) and balloon inflation has limited further bleeding, additional arterial access is obtained and the initial guide catheter is disengaged (while guidewire remains positioned in the distal vessel) and a second guide catheter is positioned at the vessel ostium (Figure 2a). A second guidewire is then positioned in the affected vessel while the occlusion balloon is transiently deflated. At this stage it is possible to deliver a covered stent (Figure 2b) or microcatheter according to the desired occlusion technique, while again temporarily deflating the occlusion balloon. With the development of new generation covered stents, with improved deliverability, it is now possible to both perform balloon occlusion and deliver a covered stent using a single guide catheter. This obviates the need for second vascular access, with concomitant risks in an anticoagulated patient, as well as likely reducing the time to definitive treatment.

Covered stents can be used to either directly seal the site of perforation, or alternatively, occlude the vessel by placing the covered stent over the ostium of a perforated side branch. Previous generations of covered stents utilised a layer of polytetrafluoroethylene (PTFE) between two layers of stent materials (Graftmaster, Abbott Vascular, Lake Bluff, IL, USA). This resulted in a bulky device that was difficult to deliver. In contrast, newer versions use a single layer of polyurethane on a single layer of stent material (Papyrus covered stent, Biotronik, Berlin, Germany) or a micro-porous ePTFE membrane on a single layer of stent material (BeGraft stent, Bentley, Hechingen, Germany). These devices have reduced crossing profiles making them significantly more flexible, compatible with 5Fr guiding catheters and 6Fr guide catheter extension devices (GuideLiner®, Teleflex, Wayne, PA, USA - see Figure 3; Guidezilla II, Boston Scientific, Marlborough, MA, USA), all of which facilitate stent delivery. Use of these covered stents has been shown to reduce rates of pericardial effusion in coronary artery perforation [15]. An additional advantage of the Papyrus covered stent is in the event of coverage of an important side branch while sealing a coronary perforation, the side branch can be successfully recanalised using a stiff coronary guidewire (Confianza Pro 12, Asahi Intecc, Santa Clara, CA, USA) through the covered stent polyurethane cover. This permits side branch access and allows balloon dilatation and stent placement to restore flow [16]].

The use of a single guiding catheter to replace a "ping-pong" technique can be illustrated using benchtop models. We identified both a 7Fr guide (Cardinal Health-Cordis, Milpitas, CA, USA) and 7.5Fr sheathless guide (Euacath, Asahi Intecc, Aichi, Japan) are individually sufficient to deliver a Papyrus or BeGraft covered stent with a compliant balloon simultaneously positioned within the coronary artery to occlude the perforation site. Similarly, an 8Fr guide (Cordis) will allow delivery of both a non-compliant balloon and Papyrus or BeGraft covered stent (Video 3). While the majority of coronary interventions are performed using a 6Fr system, this information may encourage operators to
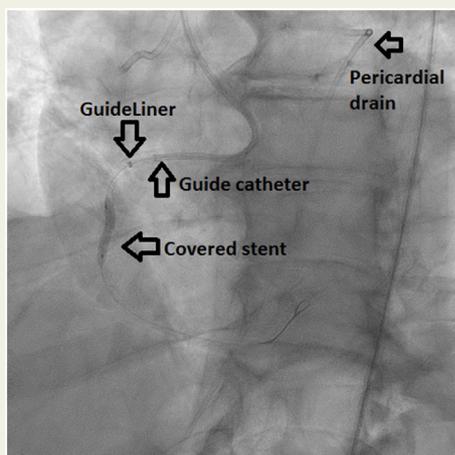

Figure 3 Newer generation covered stents have a reduced profile and can be delivered through guide catheter extension devices; in this example a Papyrus covered stent and 6Fr GuideLiner® were used.

employ a strategy of using 7Fr guide catheters in cases with coronary calcification, particularly when rotational atherectomy is considered. Use of sheathless guide catheters and the development of the 7Fr Glidesheath slender for transradial access (Terumo, Tokyo, Japan) facilitates use of large calibre guide catheter support [17]. In cases where aggressive post-dilation can be anticipated, the use of an 8Fr guide may be of value to allow delivery of covered stents after non-compliant balloon dilatation in the event of perforation.

In smaller calibre vessels where vessel occlusion is desired, this can be performed using a number of different materials, including coils, aspirated subcutaneous fat or dedicated microspheres. Delivery of coils requires positioning of a microcatheter as distally as possible to limit the extent of resulting infarction. Microcatheters can be potentially delivered through an 8Fr guide catheter alongside a standard balloon used to occlude the affected vessel, which obviates the need for a second access site and guiding catheter [18]. Once the vessel is occluded proximally, a second guidewire allows a microcatheter to be positioned in the distal vessel while transiently deflating the occlusion balloon. Familiarity with available coils and their mechanism of delivery is critical. Coils which can be pushed through a microcatheter include the Hilal and Tornado coils (Cook Medical, Bloomington, IN, USA). Once the coil is placed in the microcatheter, a guidewire is then introduced, advancing the coil to the end of the microcatheter. These "pushable" coils require a microcatheter with an internal diameter of 0.018 inches, such as the Stride (Asahi Intecc, Aichi, Japan) microcatheter (noting the 2.6Fr Stride microcatheter will accommodate coils, while the 2.2Fr Stride microcatheter will not). The Corsair and Caravel (Asahi Intecc) microcatheters are frequently utilised in chronic total occlusion intervention. The low profile limits the ability to deliver pushable coils as outlined, however, the Ultra Coils (Stryker, MI, USA) can be delivered using these devices. These coils are released by the application of an electrolytic current, rather than by directly advancing through the microcatheter. Multiple coils may be required to seal the perforation.

An alternative to coils is the use of subcutaneous fat, which may be obtained at the site of femoral access or the abdomen. After obtaining a small amount of subcutaneous fat, the tissue is then divided into smaller fat particles (0.5-1.0 mm) and then slowly injected through a microcatheter using diluted contrast [19]. It is important to remember that the density of adipose tissue is such that the syringe may need to be inverted for successful delivery (Figures 4a-e). Additional options include the delivery of microspheres, which have been traditionally used in interventional radiology, and in particular interventional oncology, with use in coronary perforation described [20]. The Embosphere™ (Merit Medical, South Jordan, UT, USA) is a pre-packaged microsphere that can be delivered through a 2.4Fr microcatheter.

A unique challenge in managing coronary perforation is in the setting of chronic stenoses or occlusions where collateral filling has developed. These cases require anticipation and recognition to avoid concealed bleeding when only unilateral supply to the perforation receives balloon tamponade. While the majority of planned cases will have upfront dual injections,

Figure 4 a-e. Local anaesthetic is used and a short incision allows removal of small amounts of subcutaneous fat (4a, 4b). Scissors and/or scalpel are used to create small fragments of adipose tissue for embolisation (4c). The adipose tissue is mixed with blood and contrast and is seen here in the hub of the microcatheter (4d). The syringe is inverted for delivery. Injection with contrast, blood and/or saline allows successful delivery for embolisation (4e). The process is repeated until haemostasis is achieved.

unplanned cases will require prompt alternative arterial access for a second guiding catheter to stem the blood flow from other feeding vessels. A confounding issue can be when the collateral filling is ipsilateral, such as a left anterior descending artery with an epicardial collateral vessel to the left circumflex artery. These cases will still require alternative arterial access and a second guiding catheter to deliver a total of two tamponade balloons as well as definitive treatment such as a covered stent or embolisation microcatheter. There is added complexity where multiple feeding vessels supply the perforated vessel, such as in patients with coronary bypass grafts.

Conclusions

Coronary artery perforation is an uncommon, however, potentially disastrous complication of percutaneous coronary intervention, particularly when undertaking complex procedures such as chronic total occlusions and rotational atherectomy. Understanding the role and utility of newer devices that may influence procedural planning and improve procedural results when these complications occur is essential to minimise morbidity and mortality.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.hlc.2019.03.008.

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