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LETTER TO THE EDITOR
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The balloon occlusion and thrombus aspiration catheter mediated-distal coronary perfusion technique (BI-RESCUE) for treatment of coronary artery perforation

Yong-Tai GONG*, Song ZHANG*, Ding-Yu WANG, Dang-Hui SUN, Li SHENG, Yue LI✉

Cardiovascular Department, the First Affiliated Hospital of Harbin Medical University, Harbin, China
*The authors contributed equally to this manuscript
✉ Correspondence to: ly99ly@vip.163.com
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Coronary artery perforation (CAP) remains an infrequent but potentially life-threatening complication during percutaneous coronary intervention (PCI). Although the prevalence of CAP is about 0.2%–0.9% in relatively low risk PCI, the incidence could up to 9% in complex clinical scenarios such as severe coronary calcification, chronic total occlusions and rotational atherectomy.[1] Despite the new techniques and equipment had lower morbidity and mortality, up to 17% of acute CAP cases would evolve to tamponade and subsequent death.[2] Ellis, *et al*.[3] classified coronary perforation into three types: Type I, extraluminal crater without extravasation; Type II, pericardial or myocardial blushing; and Type III, perforation ≥ 1 mm diameter with contrast streaming or cavity spilling. In terms of Ellis type I and II CAPs, it is generally considered as a benign condition; however, Ellis type III CAP is usually more severe, with respect to need for urgent pericardiocentesis, emergent cardiac surgery and with higher mortality as compared with type I and II CAPs. Generally accepted treatments for CAP include prolonged balloon inflation, reversal of anticoagulation, covered stents and embolization.[4] For Ellis type III CAP specifically, occurring in large coronaries involving proximal and mid segments, prolonged balloon inflation is a initially treatment, but it often causes myocardial ischemia.[5] A perfusion balloon catheter is useful when performing prolonged balloon inflation to minimize ischemia.[6,7] However, this equipment is not available in many countries, and even if available, it is difficult to stock the full range of sizes in individual hospitals. In the current case study, we report for the first time one case of successful closure of Ellis type III CAP with balloon occlusion and thrombus aspiration catheter mediated-distal coronary perfusion technique, which allows prolonged balloon inflation without causing myocardial ischemia and provides a novel method for management of lager and proximal CAP.

Written informed consent was obtained from patient for this case study. A 65-year-old man was admitted to the First Affiliated Hospital of Harbin Medical University with a ten days history of paroxysmal chest pain. An electrocardiogram revealed T wave inversion in the anterior chest leads, and high-sensitivity troponin I increased to 106.5 ng/mL (reference range: ≤ 0.034 ng/mL). Coronary angiography via radial approach showed long and critical stenosis in the ostial and middle segment of the left anterior descending artery (LAD) with significant ostial stenosis of the second diagonal artery (D2) (Figure 1A & 1B). There are middle stenosis in the distal segment of the left circumflex artery (LCX) (Figure 1A & 1B) and a severe stenosis in the proximal segment of posterior descending artery (Figure 1C).

A 7Fr BL3.5 guiding catheter (Terumo, Tokyo, Japan) was engaged in the left coronary artery via right femoral access. Three workhorse guidewires (Sion, Asahi, Tokyo, Japan) were positioned in the LAD, LCX and D2 arteries respectively. After predilation

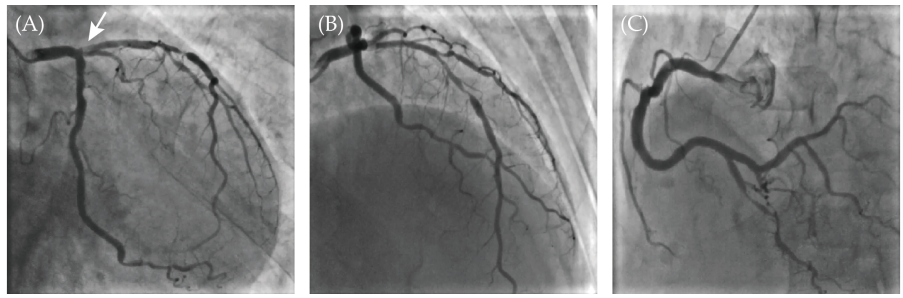

Figure 1 Coronary angiography results. Coronary angiography showed long and critical stenosis in the ostial (A, arrow) and middle segment of the left anterior descending artery with significant ostial stenosis of the second diagonal artery (B). There are middle stenosis in the distal segment of left circumflex (A & B) and a severe stenosis in the proximal segment of posterior descending artery (C).

with a 2.0 mm × 15 mm balloon (Boston Scientific, Massachusetts, USA), intravascular ultrasound (IVUS) was performed and diffuse fibrous plaque accumulation with calcification was observed. Therefore, a 3.0 mm × 10 mm cutting balloon (Boston Scientific, Massachusetts, USA) was inflated to 10−12 atm in the LAD to get plaque modification. With application of jailed semi-inflated balloon technique, the 3.5 mm × 33 mm and 4.0 mm × 33 mm drug eluting stents (Nano, Lepumedical, Beijing, China) were sequentially implanted from the LAD to the left main (LM). After rewiring to the LCX, proximal optimization technique was performed in the LM with a 4.5 mm × 10 mm non-compliant balloon (Hiryu, Terumo, Tokyo, Japan) and followed by kissing balloon dilatation with a 2.5 mm × 10 mm and a 4.0 mm × 10 mm non-compliant balloons (Hiryu, Terumo, Tokyo, Japan) in the LCX and LAD respectively. After post-dilatation with a 3.5 mm × 10 mm non-compliant balloon (Hiryu, Terumo, Tokyo, Japan) in the middle portion of the LAD, angiography and IVUS showed underexpansion at the distal segment of the stent (Figure 2A & 2B). Then, another Sion guidewire was inserted into the distal part of the LAD, a 3.5 mm × 10 mm non-compliant balloon (Hiryu, Terumo, Tokyo, Japan) was used to post-dilatation (16 atm, three times) again for achieving optimal stent expansion (Figure 2C). However, repeated angiography revealed an Ellis type III perforation of this site with extravasation of contrast into the pericardial space and the balloon was immediately positioned proximally to the site of perforation and inflated to 10 atm to prevent continued bleeding (Figure 2D). However, the patient developed severe chest pain due to prolonged balloon inflation, the blocking balloon had to be transiently and frequently deflated (the angiogram revealed leakage of contrast agent at the perforation site when we deflated the balloon and gently injected some contrast dye, Figure 3A), which lead to tamponade with blood pressure (BP) decreased from 150/90 mm Hg to 90/60 mm Hg. Therefore, the pericardiocentesis was performed immediately. Meanwhile, the protamine was injected (10 mg, two times) via a peripheral venous and the activated clotting time was decreased to 162 s. To allow pro-

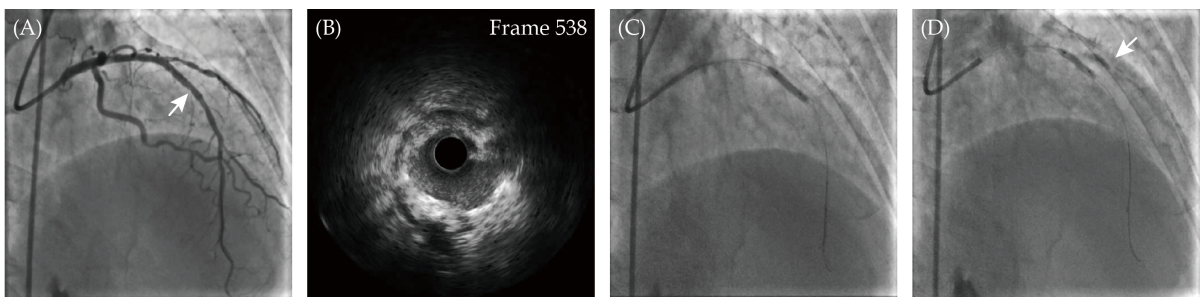

Figure 2 The perforation occurred after post-dilatation. Angiography (A, arrow) and intravascular ultrasound (B) showed underexpansion at the distal segment of the stent; post-dilatation with a parallel wire was performed (C); repeated angiography revealed an Ellis type III perforation of this site and the balloon was positioned proximally to the site and inflated to prevent bleeding (D, arrow indicates the extravasation of contrast).

longed balloon inflation without ischemia, another 6F guiding catheter (Terumo, Tokyo, Japan) (ping-pong guide catheter technique) via the left femoral approach was engaged into the left coronary artery. Through this guiding catheter, another Sion guidewire was advanced into the distal LAD beyond the perforation and a thrombus aspiration catheter (ASAP-LP, Merit Medical Systems Inc, South Jordan, USA) was delivered to the distal part of the LAD over this guidewire (Figure 3B). After inflation of the blocking balloon at the site of perforation, the blood was drawn with a 20 mL syringe from the radial artery through the radial artery sheath (also can from the first guiding catheter) and then was injected into the LAD via the aspiration catheter to prevent myocardial ischemia. The hemodynamic stability was restored with BP increased to 140/90 mm Hg. Angiography demonstrated that the perforation was closed completely after prolonged balloon inflation (about 60 minutes) and thrombus aspiration catheter mediated-distal coronary perfusion, however, the thrombus occlusion at the site of perforation was observed (Figure 3C). The thrombus was immediately removed with multiple aspirations (Figure 3D) and achieved a satisfactory angiographic result with thrombolysis in myocardial infarction flow 3 (Figure 3E). Final IVUS imaging showed adequate stent expansion and apposition and a minor dissection of the distal part of the LAD without a thrombus (Figure 3F & 3G). Serial echocardiography showed no further re-accumulation of pericardial fluid, and the pericardial drainage catheter was withdrawn after 24 h. The patient recovered successfully and was discharged from hospital four days later without pericardial effusion.

CAP is a rare but potentially fatal complication of PCI that can result in life threatening cardiac tamponade.[1] Many possible factors are predicting the occurrence of CAP, including clinical factors such as advanced age and non-ST-elevation myocardial infarction patients; angiographic factors such as coronary artery calcification, long and eccentric lesions; technique-associated factors such as atherectomy devices and high-pressure stent post-dilatation.[8] In our present case report, the patient has multiple risk factors and therefore more prone to CAP. It is reported that perforation after stenting is mainly caused by excessive overdilatation or oversized stent implantation.[9] Consistently, the CAP of

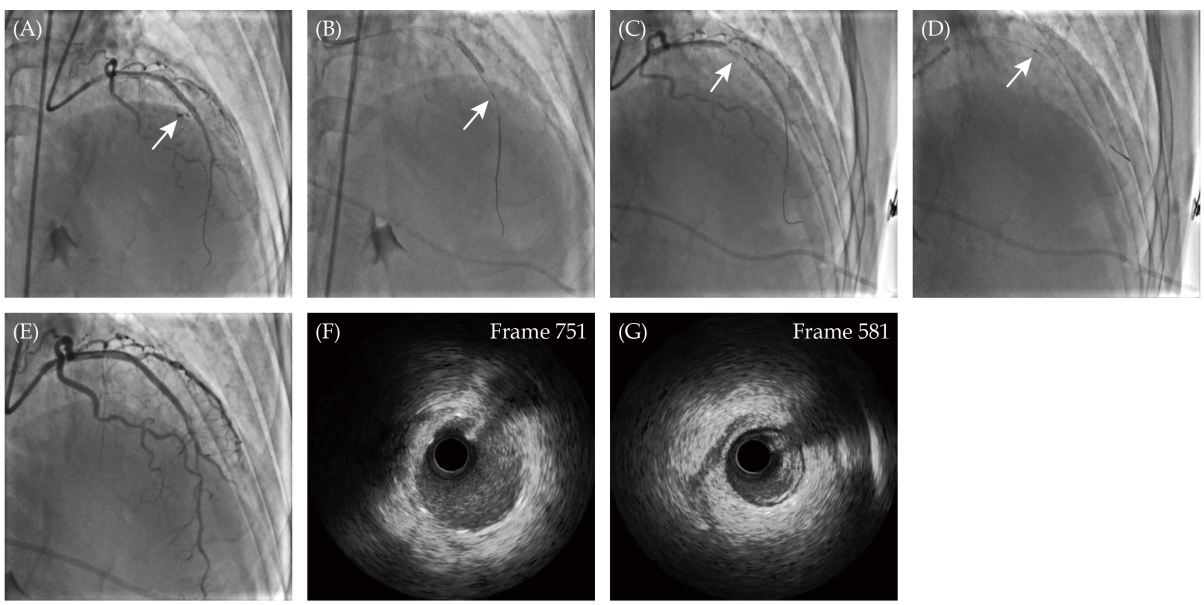

Figure 3 Successful closure of the perforation with BI-RESCUE. (A): The angiogram revealed continuous leakage of contrast (arrow); (B): the pericardiocentesis and BI-RESCUE were performed (arrow indicates the tip of the thrombus aspiration catheter); (C): angiography demonstrated that the perforation was closed but the thrombus occlusion (arrow) at the site of perforation was observed; (D): the thrombus was removed with multiple aspirations (arrow indicates the tip of the thrombus aspiration catheter); (E): a satisfactory angiographic result with thrombolysis in myocardial infarction flow 3; (F): final intravascular ultrasound imaging showed adequate stent expansion and apposition; and (G): a minor dissection of the distal left anterior descending artery without a thrombus.

this patient is mainly due to the excessive over-dilatation, especially with the cutting effect of the parallel wire during post-dilatation at the site of eccentric calcification lesion.

Previous study showed that most of Ellis type I and II CAPs could be successfully managed with prolonged balloon inflation, while only 64% of Ellis type III CAP were successfully treated and the balloon inflation time was significantly longer.[5] Therefore, prolonged balloon inflation with a perfusion balloon catheter is ideal at low pressure to seal the perforation while allowing distal myocardial perfusion to prevent ischemia, especially for the large perforation occurring in large arteries involving proximal and mid segments. However, the perfusion balloon catheter is unavailable at many laboratories, which hinders the efficiency and application scenarios of this method. In this case, we did initially attempt prolonged balloon inflations in the LAD proximal to the perforation but this was unsuccessful due to the patient's intolerance of myocardial ischemia. Under this situation, the implantation of a polytetrafluoroethylene-covered stent may be an optimal method to seal the perforation.[8] However, the covered stent might lead to the occlusion of the D2 and result in a larger area of infarction, and the incidence of subacute thrombosis and restenosis in the covered stent is relatively higher than in standard stents.[8]

In this case study, we describe for the first time a novel method of sealing the large perforation in the proximal and mid segments of coronary-the balloon occlusion and thrombus aspiration catheter mediated-distal coronary perfusion technique (which we named BI-RESCUE, and as illustrated by Figure 4). The technique can maintain the distal coronary perfusion during prolonged balloon inflation and thereby avoiding myocardial ischemia, which can decrease the period of blocking balloon deflation, reducing the bleeding to pericardium and increases the chance of successful closure of the perforation. As previously reported, the use of protamine in CAP patients seems to be safe without any increase in stent thrombosis.[10] However, prolonged balloon inflation may lead to stent thrombosis as shown in this case. With using of the thrombus aspiration catheter, the thrombosis was easily and effectively removed.

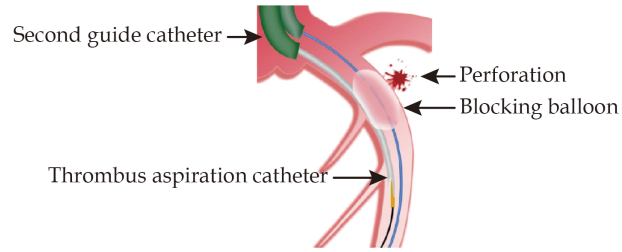

Figure 4 Illustration of the BI-RESCUE technique.

There are several tips and tricks need to be noted when this technique is used. Firstly, use of a dual catheter (ping-pong guide) technique is required to minimize bleeding into the pericardium while delivering the second guidewire along with the thrombus aspiration catheter. Secondly, the blocking balloon should be positioned at the site (not the proximal) of perforation and inflated to block the bleeding during distal coronary perfusion via the thrombus aspiration catheter, therefore, before autologous blood injection, a small amount of contrast should be injected via the thrombus aspiration catheter to confirm the bleeding point was fully sealed. If the perforation was not fully sealed by the blocking balloon, the adjustment of position or (and) pressure of the balloon is needed and, if necessary, another balloon should be advanced through the same guidewire to seal the bleeding point. Thirdly, a thrombus aspiration catheter rather than a microcatheter, which was used previously,[11] should be used to maintain the distal coronary perfusion, because the lumen of an aspiration catheter is significantly larger than that of a microcatheter. Our *in vitro* experiment demonstrated that the mean value of maximum blood flow injection velocities per minute of FineCross™ MG (Terumo, Tokyo, Japan), Corsair (CM, Asahi Intecc Co., Japan) and ASAP-LP (Merit Medical Systems Inc, South Jordan, USA) is about 8, 2 and 70 mL/minute respectively (the test was performed by one same operator and repeated three times). And another advantage of the aspiration catheter is that it can be used to remove the thrombus once the thrombosis has occurred.

In summary, we describe for the first time the balloon occlusion and thrombus aspiration catheter mediated-distal coronary perfusion technique for treatment of large and proximal CAP. This technique is effective, easy, inexpensive and widely available.

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