Application of endovascular pure electrocoagulation in the management of coronary artery perforation during percutaneous coronary intervention

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Coronary artery perforation (CAP) during percutaneous coronary intervention (PCI) is a serious complication associated with significant morbidity and mortality. Its incidence in the general PCI population has been reported to range from 0.50% to 0.58%. Meanwhile, in chronic total occlusion (CTO) PCI procedure, the incidence increased to 1.4%−4.4%.[1] Currently, most of CAPs are distally located and related to guidewire, especially hydrophilic guidewire manipulations.[2] To avoid urgent or emergency cardiac surgery, some commonly used techniques include balloon inflations, covered stents, and coil embolization stand as representative options in the treatment of CAP.[3] Despite the availability of treatment approaches, there is still a lack of a standard consensus about the optimal management of this challenging complication. Endovascular pure electrocoagulation is a new approach that has been reported in the management of small vessel hemorrhage disease in cerebrovascular intervention, it can also provide promising results in CAP management. Herein, we would like to present a case of coronary perforation during CTO PCI procedure, which successfully managed by endovascular pure electrocoagulation.

A 72-year-old man with a past medical history of hypertension and type-two diabetes presented with complaints of recurrent chest tightness, progressively worse fatigue, and limitation of daily activit-

ies for the last year. Within two days after his symptoms worsened, he was admitted to Huashan Hospital (Shanghai, China). His cardiac biomarkers were normal and the EKG revealed no acute ischemic changes. The coronary angiography revealed 90% stenosis in the left circumflex artery (LCX) and a CTO in the middle-left anterior descending (LAD) artery. The distal vessel of the LAD was filled retrogradely from the LCX. No significant stenosis occurred in the right coronary artery (Figure 1A & B). Based on these angiographic findings, an attempt to recanalize the LAD CTO was made.

The left main artery was engaged with a 6-Fr 3.5 EBU (Medtronic Vascular, Danvers, MA, USA), guided catheter through the left radial artery. However, the occlusion in the middle portion of the LAD was not possible to traverse through by using a Field XT guidewire (Asahi, Nagoya, Japan). Instead, the guidewire traversed into the distal diagonal branch frequently. Subsequently, we placed a Runthrough NS guide wire (Terumo, Tokyo, Japan) in the diagonal branch, supported by a microcatheter (Finecross, Terumo, Tokyo, Japan). A Progress 40 wire (Abbott Vascular, CA, USA) successfully passed the blocked vessel and was later exchanged with a Runthrough NS wire (Figure 1C). After predilation with a 1.5 × 15 mm and 2.0 × 15 mm Ryujin balloon (Terumo, Tokyo, Japan), a 2.5 × 33 mm Excel drug-eluting stent (JW Medical Systems, Shandong, China) was successfully deployed in the
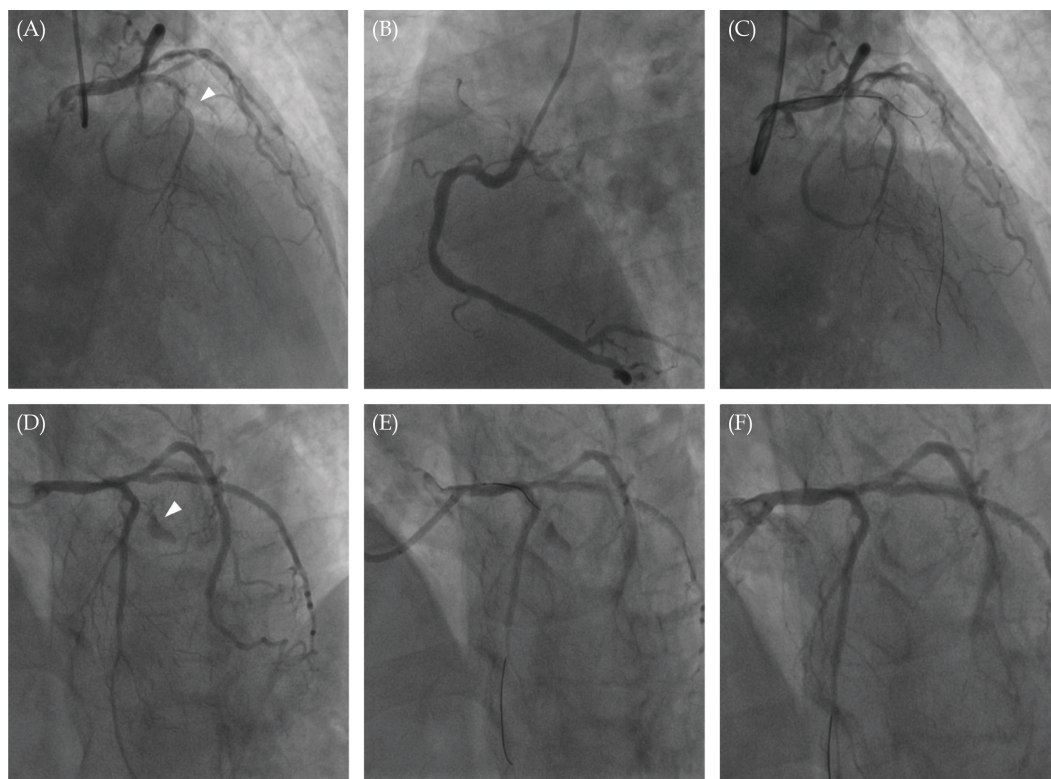
Figure 1   Angiography obtained during the procedure. (A): The LCA angiography demonstrates a CTO in the middle of the LAD; white arrow indicates CTO; (B): The RCA angiography shows no significant stenosis; (C): the procedure of PCI: run through NS guide wire was placed in the diagonal branch, supported by a microcatheter, a progress 40 wire successfully passed the blocked vessel and was later exchanged with a run through NS wire; (D): the LCA angiography demonstrates perforation of the distal diagonal branch (white arrow); (E) the procedure of electrocoagulation: a special guide wire (Traxcess-14) was put into the opening of the diagonal branch and was connected with the Solitaire stent detachment system; and (F) final angiography shows the perforation was sealed and successfully managed. CTO: chronic total occlusion; LAD: left anterior descending; LCA: left coronary artery; RCA: right coronary artery.

middle portion of the LAD. However, angiography demonstrated perforation of the distal diagonal branch and extravasation of contrast material clearing into the cardiac chamber (Figure 1D and Figure 2A & B). Recognizing the occurrence of this unfortunate complication, a 2.5 × 10 mm balloon was inflated at the opening of the diagonal branch for 30 s. After extraction, there was no apparent extravasation of contrast agent and PCI of the LCX was performed successfully. Confirmatory re-angiography however revealed that the contrast medium was visible in the cardiac chamber and was increasing. An alarming gradual drop in the systolic blood pressure was noted as it dropped from 140 mmHg to 78 mmHg. Immediate administration of fluids and dopamine to raise the blood pressure and correct the hypotension was done. To minimize bleeding into the pericardium and decrease the risk for tamponade, a balloon was inflated at the site of per-

foration. Unfortunately, fluoroscopic assessment of the cardiac silhouette revealed the presence of an increasing pericardial effusion. Pericardiocentesis was quickly performed yielding 350 mL of blood from the pericardial effusion.

Considering the above-mentioned clinical scenario, a decision to embolize the diagonal branch with the endovascular pure electrocoagulation technique was made. Supported by a microcatheter (Echelon-10, Covidien, Irvine, CA, USA), a special guide wire called "electric coagulation godet" (Traxcess-14, MicroVention, Tustin, CA, USA) was put into the opening of diagonal branch (Figure 1E). It was then connected it to the Solitaire stent detachment system (ev3, Irvine, CA, USA) at 4.0 V and 1.0 mA electronic current and detached it for 12 min (2 min × 6 times continuously). After completion of the procedure, the angiogram confirmed that the perforation had been sealed off without any extra-
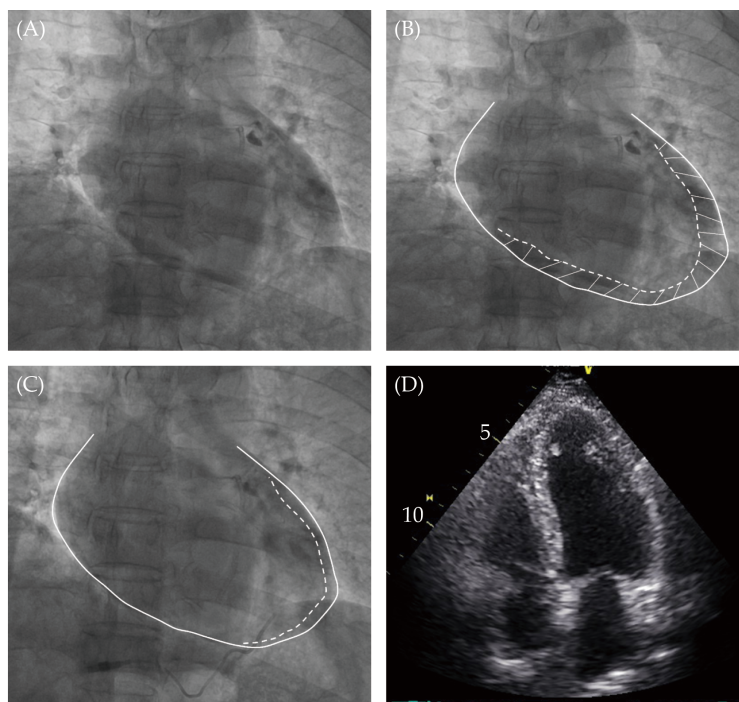
Figure 2   **Angiography and transthoracic echocardiogram demonstrate successful closure of the perforation.** (A and B): Angiography shows a large amount of contrast material and blood extravasation into the cardiac lumen; (C) angiography exhibits that the pericardial effusion decreases significantly with the use of pericardiocentesis and the endovascular pure electrocoagulation technique; and (D) transthoracic echocardiography shows there is no pericardial effusion in the pericardial cavity after two days of electrocoagulation.

vasation (Figure 1F & Figure 2C) of the contrast and the patient remained hemodynamically stable and asymptomatic. To ensure the safety of the patient, the pericardial drainage tube was kept for two days after the procedure. Within two days, only 50 mL of blood were withdrawn from the drainage tube. Prior to the patient's discharge, a transthoracic echocardiography was done and it confirmed the complete resolution and lack of pericardial effusion (Figure 2D). The patient was safely discharged after five days of admission with no further complications or symptoms.

CAP is an uncommon but potentially devastating complication of PCI, especially during a procedure involving a CTO. CAPs are now increasingly recognized and reported as complications of guidewire manipulation, especially hydrophilic wires.[4] Previous studies have shown that 50%–60% of CAPs are related to guidewire manipulations and that the vast majority of them (estimated at approximately 90%) are associated with the use of hydrophilic guidewires.[5,6] However, some of them require immediate attention and expedited management as they are associated with cardiac tamponade and high mortality.[7] Based on the Ellis classification, which is the most commonly used system, CAPs can be divided into three types: type I: presence of extraluminal crater without extravasation; type II: presence of pericardial or myocardial blush without contrast jet extravasation; type III: presence of contrast jet extravasation through frank perforation (≥ 1 mm); and type III (cavity spilling): presence of contrast jet extravasation into cavities like the cardiac chamber or coronary sinus.[8]

The CAPs' management depends on multiple factors including the Ellis type, clinical scenario, and the perforation site. CAPs with Ellis type I and II are generally conservatively managed. However, CAPs of Ellis type III are more severe and associated with higher mortality rates as they often result in pericardial effusion and cardiac tamponade. In such setting, general treatment approaches, such as adequate blood pressure support and urgent pericardiocentesis, are required and can be life-saving. Based on previous researches, the recommended specific treatment modalities for CAPs include bal-

loon inflations, covered stents, embolization with fat, coil, microspheres, thrombin, etc.[9] Proximal CAPs always occur in large vessels that facilitate the treatment with covered stents. However, distal CAPs always affect small vessels and embolization techniques with various types of embolic agents and delivery techniques can be used.[2] As previously mentioned, there is still no updated recent consensus about the optimal management of this challenging complication.

In this case, the perforation of a distal diagonal branch was caused by the improper operation of a hydrophilic guidewire. Although the rate of bleeding was slow, a delayed tamponade still occurred half an hour after the PCI procedure. During that time, the initial management strategy focused on treating hypotension and pericardiocentesis were performed immediately to manage the cardiac tamponade. Balloon inflation also failed to achieve adequate sealing of the perforation. The final management technique of endovascular pure electrocoagulation successfully treated this serious perforation (Figure 3). Electrocoagulation was a rapid and effective method of embolization by the use of electrical energy. Previous studies have demonstrated that when sufficient electricity was passed through biological tissue, heat was produced causing proteins to be denatured and a substance, called coagulum, was formed. Coagulum can lead to vessel occlusion and hemostasis.[10]

To the best of our knowledge, this is the first description or case report of the successful management of coronary artery perforation during CTO PCI using the endovascular pure electrocoagulation. In cerebrovascular intervention, it is also a new approach to treat small vessel hemorrhage disease when microcatheters cannot be navigated into the aneurysms.[11] Electrocoagulation therapy includes two microscopic processes: thrombosis and thrombus organization. Studies have shown that a certain range of constant DC electricity can attract negative factors in the blood and induce thrombosis. The electric heating effect generated by the current can accelerate the formation of the thrombus by further promoting its degeneration and organization and transforming an unstable thrombus into a stable thrombus.[12] The main basis of the treatment mechanism is to cause the formation of a lumen thrombus as soon as possible and to maintain long-term stability. In this case, the perforation of the distal diagonal branch was successfully blocked by the thrombus produced by the guide wire of Traxcess-14 with a constant DC electricity of 4.0 V and 1.0 mA lasting 12 min. However, it is still important to acknowledge that this technique may certainly have limitations. Affected by the use of antithrombotic drugs and under the effect of the human body's own fibrinolytic mechanism, the stability of endovascular pure electrocoagulation therapy should be further clarified in larger sample size studies with longer follow-up. Furthermore, the optimal conditions of voltage and current intensity during electrocoagulation therapy should also be determined.
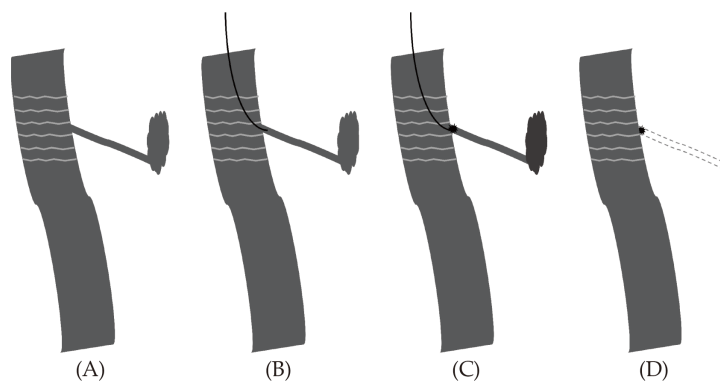

Figure 3　Endovascular pure electrocoagulation technique for sealing a small vessel perforation (diagonal branch). (A): Distal diagonal branch perforation caused by guidewire; (B): an electric coagulation godet (Traxcess-14) put into the opening of the diagonal branch and connected with a Solitaire stent detachment system; (C): after twelve minutes of electrocoagulation with 4.0 V and 1.0 mA electronic current, a thrombus formed at the tip of the guidewire; and (D) the perforated diagonal branch was successfully embolized by the thrombus after evacuating the guidewire.

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