Surgical Treatment for Ellis Type 3 Coronary Perforation During Percutaneous Catheter Intervention

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Background: Coronary perforation (CP) is a rare, but sometimes lethal, complication of percutaneous catheter intervention (PCI). We reviewed surgically-treated cases of type 3 CP during PCI.

Methods and Results: From 2007 to 2010, 5 patients underwent surgical repair for type 3 CP (3 men, 2 women; mean age, 74 years). The mean number of diseased coronary branches was 2.6 and the mean SYNTAX score was 45. The target lesions were the left anterior descending artery in 4 cases and the right coronary artery in 1 case. Types of American Heart Association/American College of Cardiology classification were type B2 in only one case and type C in 4 cases. The causes of perforation were balloon inflation in 4 patients and rotational atherectomy in 1 patient. The in-hospital mortality rate was 20%. In the cases of CP associated with balloon inflation, coronary lacerations were so severe that re-bleeding occurred even if the covered stent could temporarily achieve hemostasis, and percutaneous cardiopulmonary support and emergency surgery were required.

Conclusions: CP induced by balloon inflation tends to result in a serious condition compared with rotator-induced CP. Surgery should be immediately performed even after covered stent implantation if there is any possibility of re-bleeding in the case of balloon-induced type 3 CP. (*Circ J* 2012; **76**: 377–381)

Key Words: Coronary perforation; Ellis classification; Percutaneous catheter intervention; Surgical treatment

Percutaneous catheter intervention (PCI) is now undoubtedly an indispensable option for the treatment of ischemic heart disease. Although the optimal strategy of revascularization for multivessel coronary artery disease has been controversial for a long time,^{1,2} many interventional cardiologists today use drug-eluting stents to treat complicated coronary lesions because of the low re-stenosis rate. Current advances in stenting technique have allowed interventional cardiologists to bail out most complications; however, coronary perforation (CP) is still a lethal complication of PCI. Ellis type 3 rupture³ is especially associated with high morbidity and mortality;⁴ adequate treatment is essential to rescue such severe cases. We found several studies of CP from the viewpoint of interventional cardiologists,^{5–9} but there were few regarding severe CP requiring surgical repair, with the exception of some technical reports.^{10–12} We review 5 cases of surgically-treated type 3 CP and present some lessons learned from our experience.

Methods

Between January 2007 and December 2010, 5 patients under-

went surgical intervention for PCI-induced Ellis type 3 CP. Ellis classification is as follows: type 1 CP is defined by the development of an extraluminal crater without extravasation, type 2 CP by a pericardial or myocardial blush without contrast jet extravasation, and type 3 CP by extravasation through a frank (≥ 1 mm) perforation or cavity spilling into an anatomic cavity (right ventricle, coronary sinus, etc).³ Only one patient was referred to us after intensive care in another hospital; 4 cases of CP occurred in The Sakakibara Heart Institute of Okayama. Patients' demographic characteristics are summarized in **Table 1**. There were 3 men and 2 women, with a mean age of 74 years (range, 55–82 years). The mean ejection fraction of the left ventricle was 62% (range, 45–71%); the mean number of diseased coronary branches was 2.6 vessels, and the mean SYNTAX score¹³ was 45 (range, 27–55). All patients had undergone elective PCI for ischemic heart disease; there was no case of acute coronary syndrome (ACS). Only one patient was on dialysis and other co-morbidities were atherosclerosis obliterans in 3 patients and moderate aortic stenosis in 1 patient.

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Table 1. Patients' Demographic Characteristics

	n	%
Age, years (range)*	74±11 (55–82)	
Male/female	3/2	
Coronary risk factor		
Diabetes mellitus	3	60
Hypertension	5	100
Dyslipidemia	4	80
Smoking history	3	60
Hemodialysis	1	20
Acute coronary syndrome	0	0
SYNTAX score*	45±12 (27–55)	
Intermediate SYNTAX score (23–32)	1	20
High SYNTAX score (>33)	4	80
Ejection fraction (%)*	62±10 (45–70)	
Diseased coronary arteries		
2-vessel disease	2	40
3-vessel disease	3	60
Comorbidity		
Atherosclerosis obliterans	3	60
Aortic stenosis (moderate)	1	20

*Mean±standard deviation (range).

Table 2. Lesion Morphology

	n	%
Target lesion		
Left anterior descending artery	4	80
Right coronary artery	1	20
Total occlusion	0	0
Small vessel (<2.5 mm)	0	0
Ostial lesion	0	0
Angulation		
Moderate (45–90°)	1	20
Severe (>90°)	1	20
Bifurcation	3	60
Calcification		
Moderate	1	20
Severe	2	40
Diffuse lesion (>20 mm)	4	80
AHA/ACC classification		
Type B2	1	20
Type C	4	80

AHA/ACC, American Heart Association/American College of Cardiology.

Figure 1. Coronary angiography of each case of type 3 coronary perforation (arrows). Case 1 was induced by postdilatation ballooning for segment 7. Case 2 was caused by balloon inflation for stenting at segment 7. Case 3 was the only case of rotatable-induced type 3 rupture. Case 4 was caused by balloon inflation for stenting at segment 6. In Case 5, debulking with a rotatable for the first diagonal branch prior to catheter intervention for the left anterior descending artery led to type 2 bleeding; subsequent balloon inflation for hemostasis resulted in a type 3 rupture.

Table 3. Details of Coronary Perforation

Case	Perforation site	Cause of perforation	Device	ACT (s)	Cardiac tamponade
1	#7	Balloon (postdilatation)	Cypher 2.5×28 mm, unknown balloon (14 atm)	200	+
2	#7	Stenting	Driver 3.5×24 mm (unknown pressure)	269	+
3	#2	Rotablator	1.5-mm burr	219	–
4	#6	Stenting	Endeavor 3.5×18 mm (20 atm)	205	+
5	#9	Rotablator, balloon	1.5-mm burr, Lacrosse 2.0×10 mm (1 atm)	187	+

ACT, activated coagulation time.

Table 4. Rotablator vs. Balloon

	Rotablator (n=1)	Balloon (n=4)
PCPS	0	4
Covered stent	0	3
Pericardiocentesis	0	3
Hemostasis	1	3
Re-bleeding	0	3/3
Emergency surgery	0	4

PCPS, percutaneous cardiopulmonary support.

Results

Incidence of Perforation

The number of PCI performed in the referral hospital during the same period was 4,189; the rate of type 3 CP requiring surgical intervention was 0.1%. We have had 17 cases (0.4%) of CP, which were successfully treated by bail-out catheter procedures during the study period. Non-surgical cases of CP were all Ellis type 2; 15 perforations were induced by a guidewire, one by rotational atherectomy, and only one was caused by balloon angioplasty (1.3×10 mm monorail balloon, 2 atm, 12 s) for chronic total occlusion (CTO).

Coronary Lesion Morphology

Coronary lesion morphology is summarized in [Table 2](#). Target lesion was in the left anterior descending (LAD) artery in 4 cases (80%) and the right coronary artery in 1 case (20%). Diffuse lesions (>20 mm) were detected in 4 cases (80%); the mean length of the coronary lesions was 31 mm (range, 12–50 mm). Calcified lesions occurred in 3 cases (60%); CTO, small vessel lesion (<2.5 mm) and ostial lesions were not found. The American Heart Association/American College of

Cardiology (AHA/ACC) classifications were type B2 in only one case (20%) and type C in 4 cases (80%).

Details of Coronary Perforation

Case-oriented details of CP are shown in [Figure 1](#) and [Table 3](#). In Case 5, debulking with a rotablator for the first diagonal branch prior to catheter intervention for LAD led to type 2 bleeding; subsequent balloon inflation for hemostasis resulted in a type 3 perforation. The other causes of perforation were rotational atherectomy in 1 case, balloon inflation for postdilatation in 1 case, and stenting in 2 cases. The mean activated coagulation time was 216 s at the end of catheterization. Cardiac tamponade occurred in all 4 cases of type 3 CP associated with balloon inflation.

Rotational Atherectomy vs. Balloon Inflation

Although statistical analysis was not available because of the small number of cases, a comparison of type 3 CP induced by rotablator and those by balloons is shown in [Table 4](#). In the case of rotablator-induced CP, covered stents could not be passed through the calcified perforation site; only prolonged balloon inflation was available for hemostasis. Prolonged balloon inflation was successfully performed, avoiding emergency surgery; however, a torn guidewire was left in the right coronary artery and a pseudoaneurysm requiring surgical repair occurred. In contrast, type 3 CP associated with balloon inflation led to shock with cardiac tamponade requiring percutaneous cardiopulmonary support (PCPS) in all 4 cases. With the exception of 1 case of uncontrollable intrapericardial hemorrhage, pericardiocentesis was performed and temporary hemostasis was achieved with covered stent implantation in 3 cases. However, re-bleeding occurred in 3 cases, and all 4 patients with CP caused by balloon inflation underwent emergency surgical repair under unstable hemodynamics.

Table 5. Details of Surgery and Outcome

Case	Surgery	Waiting time	Peak CK-MB (IU/L)	Morbidity	Outcome
1	Long onlay-patch repair with SVG	7 h	1,436	LOS, brain ischemia	Death
2	CABG with SVG, felt wrapping	10 h	43	Brain ischemia	Patient transfer
3	AVR, CABG with SVG, felt wrapping, guidewire removal	7 days	33	–	Discharge
4	CABG with SVG, felt wrapping	10 h	179	–	Discharge
5	CABG with SVG, Felt wrapping	5 h	296	–	Discharge

CK-MB, creatine kinase MB; SVG, saphenous vein graft; LOS, low output syndrome; CABG, coronary artery bypass grafting; AVR, aortic valve replacement.

Figure 2. Postoperative 3-dimensional computed tomography scan (Case 2). The ruptured coronary artery and the epicardial tear was widely wrapped with 2 felt strips (arrow) and a saphenous vein graft was used as a conduit for prompt coronary perfusion (arrowheads).

Surgery and Outcome

A case-oriented summary of the surgery and outcomes are shown in [Table 5](#). Intrapericardial findings were subepicardial hematoma in the case of rotablator-induced CP and persistent arterial bleeding from an epicardial tear in the 4 cases of CP caused by balloon inflation. In the case of CP induced by rotational atherectomy, elective surgery was performed followed by hemostasis using prolonged balloon inflation. The waiting time from perforation to surgery was 7 days. All 4 patients with type 3 CP associated with balloon inflation needed emergency surgery; the mean waiting time was 8 h.

We tried long onlay-patch repair with saphenous vein graft (SVG) for the first case; however, the coronary laceration was so severe that it was difficult to achieve complete hemostasis. After this case, we chose felt wrapping with a running over-and-over suture of the epicardium and concomitant coronary artery bypass grafting (CABG) with SVG. The mortality rate was 20%. Postoperative levels of creatine kinase MB (CK-MB) were elevated in 3 cases of balloon-induced CP. In Case 1, a massive thrombosis developed at the left main trunk during prolonged balloon inflation and the patient died of low output syndrome and hole brain ischemia. In Case 2, the patient had been transferred with PCPS, but PCPS flow was insufficient because of massive intrapericardial hemorrhage. Massive cerebral infarction was discovered after emergency surgery and the patient did not regain consciousness.

Discussion

CP during PCI ranges from tiny guidewire-induced perforation to massive hemorrhage requiring emergency surgery; Ellis type 3 rupture is still a lethal complication. During the study period, we had 17 cases of type 2 CP and 5 cases of type 3 CP. Of the 17 cases of type 2 CP, 15 perforations were caused by a guidewire, and only one case was caused by bal-

loon angioplasty for CTO. There was no case of CTO among the cases of type 3 CP. A Guidewire or small-balloon inflation tends to become a cause of perforation in cases of CTO, and so it may rarely lead to type 3 bleeding that needs surgical repair. CP induced by a large-balloon inflation results in a serious condition compared with rotablator-induced CP. On the other hand, our study showed that type 3 CP occurred in cases of diffuse or calcified lesion. In particular, the case of rotablator-induced type 3 CP involved a calcified lesion and the cases of balloon-induced CP related to diffuse lesions (data not shown). This is logical, considering the principle of rotational atherectomy.¹⁴ In the present study, there was no case of ACS; the cause of CP was elective PCI in all cases. Considering that 80% of these cases were AHA/ACC type C and high SYNTAX score (>33), challenging PCI for complicated coronary lesions for which CABG is usually chosen would be the direct cause of CP.

Rotablator-induced CP was compared with CP caused by balloon inflation in the present study, although statistical analysis was not performed because of the small number of cases. There was a great difference in regard to hemostasis between the rotablator and balloon cases. We considered this was related to the degree of coronary laceration. We used long onlay-patch repair with SVG in Case 1, which was caused by ballooning for postdilatation. In this case, the coronary laceration was multiple, multi-directional, and severe, and we had much trouble achieving hemostasis. In contrast, we confirmed the perforation site in Case 4 (rotablator-induced CP) as a small hole measuring 2 mm in diameter in the calcified right coronary artery. In addition, there was an epicardial tear bleeding into the pericardial space in all 4 cases of balloon-induced CP, whereas rotablator-induced CP led to subepicardial hematoma at most. Balloon inflation seemed to result in not only severe coronary rupture but also epicardial tearing.

As a surgical technique for complete hemostasis, we abandoned SVG patch repair after our experience in Case 1. We now perform felt wrapping of the ruptured coronary artery with TachoComb patch and concomitant CABG with SVG ([Figure 2](#)). The basic technique is a running over-and-over suture of the epicardium with felt strips.¹⁰ A CP site is usually separate from an epicardial tear, so felt wrapping that includes the ruptured coronary artery and the epicardial tear is quite simple and effective. Recently, hemostatic patches impregnated with human fibrinogen and thrombin (TachoSil) or autologous pericardial patches are reported as an alternative for Teflon felt, and off-pump surgery is preferred.^{11,12} We used cardiopulmonary bypass (CPB) for hemodynamic stabilization and because of the massive intrapericardial bleeding in all 4 cases of balloon-induced CP. We believe that such an emergency situation permits the use of CPB. In addition, coronary stenting was performed at the perforation sites before emergency surgery in all 4 cases of CP caused by balloon inflation. Covered stents were used for hemostasis in 3 cases and a bare metal stent was deployed as a guide at the ruptured diagonal branch in Case 5. Although the covered stents could not achieve complete hemostasis, coronary stents were useful for identifying the CP point under a massive subepicardial hematoma. In the present study, in-hospital mortality of 20% was acceptable; however, emergency CABG with SVG is not associated with a long-term outcome. Interventional cardiologists should know that type 3 CP leads to low-quality revascularization even in rescue cases.

Conclusion

CP induced by balloon inflation tends to result in a more serious condition than rotablator-induced CP. Especially, the coronary laceration associated with balloon inflation is so severe that re-bleeding tends to occur even if covered stent implantation can temporarily achieve hemostasis. Surgical repair must be done without delay if there is any possibility of re-bleeding. In contrast, conservative management can achieve hemostasis in rotablator-induced type 3 CP, but additional surgical intervention would be necessary for untreated coronary lesions and for pseudoaneurysms.

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