Background: Coronary artery perforation is a rare but life-threatening complication of percutaneous coronary intervention. We report our experience of incidence, management, and clinical outcomes of procedure-related coronary artery perforation in 13,888 consecutive patients.

Methods and Results: 13,888 patients underwent PCI for coronary artery disease from October 1992 to December 2006. During this period, 21 (0.15%) patients developed coronary artery perforation during PCI. Four patients with Ellis type I coronary artery perforation were treated successfully, including conservative treatment in 2 and device therapy in 2. Out of eight patients with Ellis type II coronary artery perforation, 2 patients received conservative treatment, 5 received device therapy and 1 received surgical ligation. One patient receiving device therapy had late cardiac tamponade and she expired due to aspiration pneumonia resulting from emergent endotracheal intubation. Among the seven patients with Ellis type III coronary artery perforation, 5 received device therapy and 2 received emergent surgical repairs. Additionally, four of them needed emergent pericardiocentesis for immediate cardiac tamponade. One of the 2 patients with Ellis type IV coronary artery perforation was treated with balloon inflation, but he expired due to concomitant pneumonia. The other patient received surgical repair.

Conclusion: Management of coronary artery perforation can be tailored according to the classification of coronary artery perforation and the hemodynamic status. Most patients can be treated successfully with non-surgical therapies. However, surgical intervention should be provided promptly if non-surgical therapies fail. Furthermore, late cardiac tamponade might occur even in less advanced types of coronary artery perforation.

Key Words: Coronary artery perforation • Percutaneous coronary intervention • Stent • Surgical intervention

INTRODUCTION

Coronary artery perforation is a rare but life-threatening complication of percutaneous coronary intervention (PCI), and its incidence is between 0.2% and 0.8%.

1-6 Procedure-related coronary artery perforation may result in the development of cardiac tamponade, acute myocardial infarction (AMI) and mortality. The non-surgical managements of coronary artery perforation include reversal of heparin with protamine sulphate, prolonged balloon inflation, perfusion balloon inflation, conventional or covered stent implantation and coil or thrombus embolization.² ³ We report our experience of incidence, management and clinical outcomes of procedure-related coronary artery perforation in 13,888 consecutive patients.
METHODS

From October 1992 to December 2006, 13,888 patients underwent PCI for coronary artery disease (CAD) in this institution. All patients received the percutaneous transfemoral or transradial approach via an angiography sheath, and standard angioplasty technique was used in these patients.\(^7\)\(^8\) Each patient was pretreated with intravenous heparin (100 units/kg) at the beginning of the procedure. If necessary, an additional bolus of heparin was administered to maintain activated clotting time > 300 sec. Angiographic stenosis was defined as a diameter stenosis of ≥ 50%. The stenotic morphology of coronary arteries was based on the American College of Cardiology/American Heart Association (ACC/AHA) lesion classification system.\(^2\)\(^9\) Procedure-related coronary artery perforation was classified according to the Ellis classification: Type 1, extraluminal crater without extravasation; type II, pericardial or myocardial blush without contrast jet extravasation; type III, continuous jet-like dye extravasation resulting in hypotension and tamponade; and Type IV, extravasation of contrast dye into an anatomic cavity chamber.\(^2\)\(^9\) Successful management of coronary artery perforation was defined as no more or minimal dye extravasation and/or no further clinical hemodynamic instability. Late cardiac tamponade was defined as cardiac tamponade developed within 24 hours after the patient left the cardiac catheterization room or operating room.\(^2\)

RESULTS

Patient characteristics

Totally 21 patients had procedure-related coronary artery perforation, an incidence of 0.15%. Table 1 shows

<table>
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</table>

A = aspirin; ACC/AHA class = American College of Cardiology/American Heart Association lesion classification; AMI = acute myocardial infarction; AP = angina pectoris; Bl = balloon inflation; CABG = coronary artery bypass graft; Conserv = conservative treatment; CS = conventional stent; CoS = covered stent; CTO = chronic total occlusion; D = distal; DM = diabetes mellitus; DVD = double-vessel disease; F = female; GW = guide wire; H = heparin; HT = hypertension; LAD = left anterior descending artery; LC = late cardiac tamponade; LCX = left circumflex artery; LI = dyslipidemia; M = male; Mi = middle; P = proximal; Pl = Plavix; Pr = protamine infusion; PB = perfusion balloon; PC = pericardiocentesis; RCA = right coronary artery; SL = surgical ligation; SR = surgical repair; SVD = single-vessel disease; TVD = triple-vessel disease.
clinical characteristics of the 21 patients with procedure-related coronary artery perforation. The mean age of the patients was 68 ± 8 years (range 46 to 82 years). Fourteen patients (67%) had hypertension, 7 (33%) had dyslipidemia, 5 (24%) had diabetes mellitus. Eighteen (86%) patients received PCI under the indication of angina pectoris, and the remaining 3 (14%) patients had AMI. Seventeen (81%) patients had more than one diseased vessel; 24% were double-vessel disease and 57% were triple-vessel disease. The coronary artery perforation occurred at the left anterior descending artery in 16 (76%) patients, left circumflex artery in 3 (14%) and right coronary artery in 2 (10%). Coronary artery perforation developed during PCI for chronic total occlusion in 12 (57%) patients. According to the ACC/AHA lesion classification system, 1 (5%) patient had class A, 14 (67%) had class B and 6 (29%) had class C lesion morphology. Coronary artery perforation occurred in 5 (24%) patients during guide-wire manipulation, in 13 (62%) during coronary balloon angioplasty and in 3 (14%) during coronary stenting. The perforation classification of Ellis type was type I in 4 (19%), type II in 8 (38%), type III in 7 (33%) and type IV in 2 (10%) patients.

**Managements and clinical outcomes of coronary artery perforation**

Four patients with Ellis type I coronary artery perforation were treated successfully, including conservative treatment in 2, balloon inflation in 1 and conventional stent implantation in 1. Percardiocentesis and surgical intervention were not needed in these 4 patients.

Among the eight patients with Ellis type II coronary artery perforation, 2 patients received conservative treatment, 3 were managed with prolonged balloon inflation and 2 were treated with stent implantation, including conventional stent in 1 and polytetrafluoroethylene-covered stents in 1 (Patient no. 11, Figure 1). The remaining one patient (no. 12) received surgical ligation because the coronary artery perforation could not heal after 30-minute balloon inflation. Patient no. 9 with AMI, however, who was treated with conventional stenting followed by perfusion balloon inflation, had late cardiac tamponade. She expired 20 days later due to aspiration pneumonia resulting from emergent endotracheal intubation. Patient no. 6 had postprocedural non-ST elevation AMI.

Out of the seven patients with Ellis type III coronary artery perforation, 4 patients received emergent pericardiocentesis for immediate cardiac tamponade. Three patients were treated with prolonged balloon inflation and 2 received perfusion balloon inflation. The remaining two patients received emergent surgical repairs because they did not respond to device therapy (patients no. 18 and 19). Patient no. 17 had postprocedural non-ST elevation AMI. Furthermore, patient no. 13 had late cardiac tamponade within 24 hours, and he was treated successfully with pericardiocentesis alone.

One of the 2 patients with Ellis type IV coronary artery perforation was treated successfully with balloon inflation (patient no. 20); however, he expired due to his concomitant pneumonia at 17 days after the event of coronary artery perforation. The other patient received surgical repair because she did not respond to covered
The clinical events after procedure-related coronary artery perforation are summarized in Table 2. Cardiac tamponade occurred in 6 (29%) patients with coronary artery perforation. While 4 patients with immediate cardiac tamponade had Ellis type III coronary artery perforation and needed emergent pericardiocentesis, the remaining two patients with Ellis type II and III, respectively, had late cardiac tamponade within 24 hours. Postprocedural AMI developed in 1 patient with Ellis type II and 1 with Ellis type III coronary artery perforation. Three of the 4 patients receiving emergent surgery had Ellis type III/IV coronary artery perforation. Two patients with Ellis type II and IV coronary artery perforation, respectively, had in-hospital mortality.

DISCUSSION

Coronary artery perforation during PCI is infrequent, but this complication is associated with high morbidity and mortality. The incidence of coronary artery perforation during PCI in our study was 0.15%. Previous studies showed that coronary artery perforation increased significantly in the patients receiving laser ablation, rotational and extraction atherectomies compared with those receiving balloon angioplasty alone.2,3,10-12 Coronary artery perforation most commonly occurred in patients with coronary balloon angioplasty in the present study.

Therapeutic options for procedure-related coronary artery perforation

Previous studies showed that patients with coronary artery perforation could be managed successfully with conventional stent or covered stent implantation.13,14 Briguori et al. reported that conventional stent implantation was successfully managed in only 2 of their 5 patients with Ellis type II or III coronary artery perforation.13 In the present study, out of the 3 patients treated with conventional stent implantation, 2 were successes. The remaining patient (no. 9) failed and received perfusion balloon inflation as additional treatment. However, late cardiac tamponade occurred within 24 hours in this patient. Despite perfusion balloon inflation, conventional stent implantation still carries with it a risk of late cardiac tamponade. In recent years, covered stents have become an alternative treatment when conservative approaches fail. Similar to perfusion balloons, covered stents must be implanted with caution in regions of significant side branching.

Previous studies have shown that coil or thrombus embolization could treat coronary artery perforation.4,9,19,20 Embolization can be used if the bleeding site is in a small distal branch or in the setting of chronic coronary artery occlusion.9,18

Previous reports showed that some patients needed to receive surgery when conservative treatment and device therapy could not correct hemodynamic instability.1 Kihara et al. also reported that coronary artery perforation could be managed successfully by emergent surgical intervention without cardiopulmonary bypass.15 In the present study, 4 patients receiving emergent surgery intervention had immediate excellent outcomes.

Coronary artery perforation type-specific therapy

The options for management may be chosen according to the severity of perforation and the hemodynamic status of the patients. Previous studies and the present study have shown that patients with Ellis type I and II coronary artery perforation rarely developed adverse cardiac events such as cardiac tamponade and severe...
ischemia and could be treated successfully with conservative treatment and/or device therapy in most cases.²⁻⁴ Patients with Ellis type III coronary artery perforation usually have severe cardiac complications such as cardiac tamponade, and this complication may result in the need for urgent surgical intervention and death.²⁻⁴ Fas-seas et al. and the present study have reported that all patients receiving emergent pericardiocentesis had Ellis type III coronary artery perforation.³ About half of the patients with Ellis type III coronary artery perforation in the present study needed emergent pericardiocentesis. Immediate balloon re-inflation can minimize pericardial effusion, and bedside echocardiography may facilitate pericardiocentesis if hemodynamic status allows. In addition, prompt reversal of anticoagulation with intravenous protamine is valuable. The other managements include perfusion balloon, conventional or covered stent implantation, embolization and emergent surgical repair. Patients with Ellis type IV coronary artery perforation had more favorable presentation compared to those with Ellis type III. Previous reports had shown that the vascular communication might even close spontaneously during follow-up.¹⁷ However, the present study showed that monitoring, intensive care and option of surgical repair are necessary for some patients with Ellis type IV coronary artery perforation.

Clinical outcome after initial management of coronary artery perforation

Ellis et al. reported that two (13%) of 15 instances of cardiac tamponade in their series were delayed.² In the present study, two (33%) of 6 patients with cardiac tamponade, including Ellis type II and III coronary artery perforation respectively, had late cardiac tamponade within 24 hours after dismissal from the cardiac catheterization room. Thus, the interventionist should be aware of this information after the initial management of coronary artery perforation. Patients should be monitored carefully for at least 24 hours since even less advanced types of coronary artery perforation may have late cardiac tamponade.

Among the three AMI patients in this study, coronary artery perforation was treated successfully in 2 patients, including covered stenting in patient no. 11 and prolonged balloon inflation in patient no. 20. However, patient no. 20 expired because of his concomitant pneumonia. The remaining patient (no. 9) developed late cardiac tamponade after device therapy. She expired due to development of aspiration pneumonia resulting from emergent endotracheal intubation during late cardiac tamponade. Patient no. 9 had received conventional stenting, followed by perfusion balloon inflation as additional treatment. However, she suffered from late cardiac tamponade. It is possible that more aggressive use of antiplatelet agents and anticoagulants in AMI patients have complicated the management of coronary artery perforation. Prompt reversal of anticoagulation with sufficient amount of intravenous protamine may be helpful in these patients. In addition, other alternative options for device therapy should be considered.

Study limitations

The number of the patients in the present study was small; we could not determine if the usage of antiplatelet and/or anticoagulation therapies increased the risk of coronary artery perforation. Secondly, patients were treated according to the experiences and judgments of their interventionists, so the treatment algorithms might be inconsistent.¹⁶,¹⁷

CONCLUSION

Management of coronary artery perforation can be tailored according to the classification of the coronary artery perforation and the hemodynamic status. Most patients with coronary artery perforation can be treated successfully with non-surgical management; however, surgical intervention should be provided promptly without delay if coronary artery perforation does not respond to the non-surgical therapies. Furthermore, patients should be monitored carefully because late cardiac tamponade and postprocedural AMI might occur even in less advanced types of coronary artery perforation.

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