Původní sdělení | Original research article

Predictors of major adverse cardiovascular events in patients with coronary artery perforation treated with covered stents

Umeyir Savur, Aysel Akhundova, Başak Çatalbaş, İbrahim Oguz Karaca

Department of Cardiology, Medipol Mega University Hospital, Faculty of Medicine, Istanbul, Turkey

ARTICLE INFO

Article history:
Submitted: 14. 11. 2023
Revised: 29. 12. 2023
Accepted: 3. 1. 2024
Available online: 27. 5. 2024

Klíčová slova:
Krytý stent
Perforace koronární tepny
Perkutánní koronární intervence
Stenty potažené polytetrafluorethylenem (PTFE)

SOUHRN

Kontext: Perforace koronární tepny (coronary artery perforation, CAP) je vzácnou, život ohrožující komplikací perkutánní koronární intervence (PCI). Vysoce úspěšnou a život zachraňující metodou léčby CAP je implantace stentů potažených polytetrafluorethylenem (PTFE). Incidence trombózy a restenózy při použití stentů potažených PTFE je vyšší než při implantaci standardních stentů. Cílem této studie bylo zhodnotit klinické výsledky použití stentů potažených PTFE při řešení CAP.
Materiály a metody: Analyzovali jsme údaje celkem 38 pacientů s implantací stentů potažených PTFE po CAP provedenou v období mezi lednem 2012 a lednem 2022 na jednom pracovišti s vysokým objemem těchto výkonů (Medipol University Hospital v tureckém Istanbulu). Primárním sledovaným parametrem byl souhrn závažných nežádoucích kardiovaskulárních příhod (major adverse cardiovascular event, MACE).
Výsledky: Hodnotili jsme jednoroční výsledky pacientů s implantací stentů potažených PTFE po CAP. Do studie bylo zařazeno celkem 38 pacientů; 22 (58 %) mužů a 16 (42 %) žen průměrného věku 69,7 ± 11,4 roku. Během sledování došlo ke vzniku MACE u 37 % daného souboru (14 pacientů). Do jednoho roku byla revaskularizace cílové tepny (target vessel revascularization, TVR) provedena u 36,8 % (14 pacientů) a revaskularizace cílové léze (target lesion revascularization, TLR) u 21 % (8 pacientů), incidence úmrtí dosáhla 10,5 % (4 pacienti) a infarktu myokardu 21,1 % (8 pacientů).
Závěry: I když se dnes většina případů perforace koronární tepny úspěšně řeší zavedením stentů potažených PTFE, je jednoroční incidence MACE u pacientů s implantací takových stentů vysoká. Naše výsledky tak prokázaly, že uvedené pacienty je nutno důsledně sledovat.

Keywords:
Coronary artery perforation
Covered stent
Percutaneous coronary intervention
Polytetrafluoroethylene (PTFE)-coated stents

ABSTRACT

Background: Coronary artery perforation (CAP) is a rare, life-threatening complication of percutaneous coronary intervention (PCI). PTFE-coated stents are highly successful and lifesaving in the treatment of coronary perforation. The incidence of thrombosis and restenosis in the PTFE-covered stent is higher than in standard stents. The aim of this study was to evaluate the clinical outcomes of PTFE-covered stents for CAP.
Materials and methods: We evaluated a total of 38 patients who were treated with PTFE-coated stents for coronary perforation from January 2012 to January 2022 at a single high-volume center, Medipol University Hospital in Turkey. The primary endpoint was the composite of major adverse cardiovascular events (MACEs).
Results: The one-year outcomes of the patients who had PTFE-coated stents implanted after CAP were investigated. A total of 38 patients, 22 (58%) males and 16 (42%) females, were included. The mean age was 69.7±11.4 years. MACE developed in 37% of the population (14 patients) in the follow-up. The target vessel revascularization (TVR) rate at one year was 36.8% (14 patients), the target lesion revascularization (TLR) rate at one year was 21% (8 patients), the incidence of death was 10.5% (4 patients), of myocardial infarction 21.1% (8 patients).
Conclusions: Today, although the majority of coronary perforation cases are successfully treated with PTFE-coated stents, the one-year outcome of MACE in CS implanted patients is high. These results showed that such patients should be closely monitored.

Address: Aysel Akhundova, MD, Cardiology Department, Medipol Mega University Hospital, Faculty of Medicine, Istanbul, Turkey, e-mail: akhundova.aysel@yahoo.com
DOI: 10.33678/cor.2024.002

Please cite this article as: Savur U, Akhundova A, Çatalbaş B, Karaca İO. Predictors of major adverse events in patients with coronary artery perforation treated with covered stents. Cor Vasa 2024;66:307–311.

Introduction

Coronary artery perforation (CAP), is a rare (0.2–0.5%), life-threatening complication of percutaneous coronary intervention (PCI).[1,2] The frequency of CAP increases according to the increasing number of complex PCI.[3,4] Ellis Type III has a high mortality risk and results in tamponade and cardiac arrest if early emergency intervention is not performed. The coronary perforation mortality risk is as high as 5.9–7% in studies.[5] PTFE-coated stents are highly successful and lifesaving in the threat of coronary perforation, especially in the proximal and mid-segment perforations of the vessel. However, its use is limited in tortuous, calcified vessels or distal perforation due to difficulty in advance and low flexibility. Unfortunately, potentially lifesaving covered stents have a thrombogenic problem and are associated with a relatively high restenosis rate of 31.6% at 6-month follow-up.[6,7] Long-time outcome data for CS is limited. We aimed to evaluate the one-year clinical outcomes of a PTFE-covered stent for coronary artery perforation.

Materials and methods

We evaluated a total of 38 patients who were treated with PTFE-coated stents for coronary perforation from January 2012 to January 2022 at a single high-volume center in Turkey. Out of the 45,000 patients who underwent PCI, 70 patients experienced coronary perforation. We identified 38 patients with coronary artery perforation and treated them with a PTFE-coated GRAFMASTER stent (Abbott Vascular). The primary endpoint was the composite of major adverse cardiovascular events (MACEs). MACEs were defined as death in any case, myocardial infarction, target vessel revascularization, target lesion revascularization, and the requirement for surgical repair. The diagnosis of MI was defined according to the fourth universal diagnostic criteria of MI as abnormal cardiac biomarkers in the setting of evidence of acute myocardial ischemia. Target-vessel revascularization (TVR) was defined as any repeat PCI or CABG due to stenosis in another segment of the vessels treated with CS. Target-lesion revascularization (TLR) was defined as any revascularization (PCI/CABG) of the target lesion due to restenosis or reocclusion within the stent or within 5 mm of the distal or proximal segment of the stent.[8] Patients with both type 1 and type 2 diabetes mellitus were included. Angiographic views of the coronary arteries of patients with perforation were classified according to the Ellis classification into I, II and III types. Patients with pericardial effusion and tamponade were detected on transthoracic echocardiography; clinical manifestations of tamponade – hypotension and tachycardia – were also evaluated, and patients who had undergone surgical procedures were screened. Data were collected from outpatient controls or phone calls. Patients receiving dual antiplatelet therapy after covered stent (CS) implantation – aspirin and clopidogrel or aspirin and prasugrel, or aspirin and ticagrelor – were screened. It was evaluated whether there was a relationship between MACE and choice of antiplatelet treatment. Total MACE, each component of MACE – death, myocardial infarction, target vessel revascularization, target lesion revascularization, and requirement for surgical repair – were also evaluated. The investigation complied with the Declaration of Helsinki.

Statistical analyses

Statistical analyses were conducted using SPSS (version 26.0; SPSS, Chicago, Illinois). Data were expressed as percentages (%) for categorical variables and means ± SD for continuous variables. The data were tested by conducting the Shapiro–Wilk test to determine for distribution of the data. The student *t*-test was used for comparing continuous variables that showed a normal distribution. Non-normally distributed samples were compared with a Mann–Whitney *U* test based on MACE. A Chi-square test was used to test the associations between the categorical variables in each group. Statistical significance was defined as a *p*-value <0.05 for all comparisons. Univariate and multivariate logistic regression analyses were performed to define the independent predictors of MACE after coronary perforation. Statistically significant (p <0.05) variables in the univariate model were entered in the multivariate analysis. Female gender, clinical presentation (ACS vs. CCS), previous PCI, coronary perforation type (Ellis type I–II vs. type III), and stent diameter were the independent variables, whereas the development of adverse events (MACE) was the dependent variable of the model. The results of the regression analyses were expressed as the *p*-value and hazard ratio (HR) with a 95% CI and presented in **Table 1**.

Results

Our study is a single-center, retrospective study. The one-year outcomes of the patients who had PTFE-coated stents implanted after CAP were investigated. All patients were successfully treated with covered stent implantation and followed for one year. A total of 38 patients, 22 (58%) males and 16 (42%) females, were included. The mean age was 69.0±10 years. The baseline characteristics of study patients are shown in **Table 1**, and lesion and procedural characteristics are shown in Table 2. The most common perforated artery was left anterior descending (LAD), in 28 patients (73.7 %). Type III perforation was observed in the most of the patients in our study (22 patients, 58%). Coronary perforation was observed more frequently after stent deployment (12 patients, 31.6%) and balloon post-dilation after stent implantation (12 patients, 31.6%). Pericardial effusion was observed in 18 patients (47.3%), tamponade developed in 8 patients (21%), and pericardiocentesis was performed. Cardiogenic shock was observed in 4 patients, and mechanical circulatory support was required, two patients underwent surgical operations (5%). The 16 patients (42%) had a history of previous percutaneous coronary intervention (PCI). The 32 patients (84.2%) presented with acute coronary syndromes, and 6 patients (15.8%) had chronic coronary syndromes. There was not any periprocedural death or death after emergency cardiac surgery. MACE developed

Table 1 – Baseline characteristics of study patients

Clinical features	Overall (n = 38)	MACE (–) n = 24	MACE (+) n = 14	*p*-value
Age (years)	70.5±10	71.4±8.8	65.9±14.3	0.147
Sex (female), n (%)	16 (16/38)	8 (8%)	8 (57%)	0.048
Hypertension, n (%)	34 (89%)	20 (83%)	14 (100%)	0.106
Diabetes, n (%)	14 (36%)	6 (25%)	8 (57%)	0.048
Hyperlipidemia, n (%)	38 (100%)	18 (75%)	10 (71%)	0.809
Smoker, n (%)	34 (89%)	16 (67%)	8 (57%)	0.557
Previous MI, n (%)	10 (26%)	8 (33%)	2 (14%)	0.198
Previous CABG, n (%)	12 (32%)	8 (33%)	4 (29%)	0.761
Previous PCI, n (%)	16 (42%)	6 (25%)	10 (71%)	0.023
LVEF (%)	49±11	48.3±11.5	50.7±9.8	0.520
Clinical presentation				
ACS	32 (84%)	22 (92%)	10 (71%)	0.036
CCS	6 (16%)	2 (8%)	4 (29%)	0.036

Table 2 – Lesion and procedual characteristics

	MACE (–) n = 24	MACE (+) n = 14	*p*-value
Lesion-related artery, n (%)			0.102
LAD	14 (58%)	4 (29%)	
Cx	2 (8%)	0 (0%)	
RCA	6 (25%)	8 (57%)	
Ao-Cx SVG	2 (8%)	0 (0%)	
Ao-RCA SVG	0 (0%)	2 (14%)	
Perforation type, n (%)			0.032
Ellis I/II	14 (58%)	2 (14%)	
Ellis III	10 (42%)	12 (86%)	
Main vessel, n (%)	22 (92%)	12 (86%)	0.564
Cause of perforation, n (%)			0.080
Wire	4 (17%)	4 (29%)	
Predilatation	4 (17%)	4 (29%)	
Stent	6 (25%)	6 (43%)	
Postdilatation	10 (42%)	2 (14%)	
DAPT choice, n (%)			0.441
ASA + clop.	18 (75%)	12 (86%)	
ASA + pras./ticag.	6 (25%)	2 (14%)	
Pericardial effusion, n (%)	12 (50%)	6 (43%)	0.671
Pericardiosynthesis, n (%)	6 (25%)	2 (14%)	0.435
Cardiogenic shock, n (%)	4 (17%)	0 (0%)	0.106
Surgery, n (%)	2 (8%)	0 (0%)	0.267
Number of covered stents	1.2±0.3	1.4±0.7	0.147
Stent length (mm)	26.2±8.7	29.9±13.3	0.308
Stent diameter (mm²)	3.34±0.65	2.73±0.28	0.002

Table 3 – Clinical outcomes of study patients

Duration	1-year
Myocardial infarction (%)	21
Target-vessel revascularization (%)	36.8
Target-lesion revascularization (%)	21
All-cause mortality (%)	10.5

Table 4 – Predictors of adverse events

Variable	Univariate analysis		
	Hazard ratio	95% confidence interval	*p*-value
Female gender	2.654	0.802–5.316	0.023
Clinical status	2.326	1.511–3.716	0.212
Previous PCI	2.011	1.268–2.754	0.039
Type-III perforation	0.767	0.327–1.798	0.541
Stent diameter	1.103	1.007–1.208	0.045
	Multivariate analysis		
	Hazard ratio	95% confidence interval	*p*-value
Female gender	1.252	1.012–1.492	0.036
Previous PCI	2.245	1.145–4.387	0.042
Stent diameter	0.960	0.936–0.994	0.135

in 37% of the population (14 patients) in the follow-up. The TVR rate at one year was 36.8% (14 patients), the TLR rate at one year was 21% (8 patients), the incidence of death was 10.5% (4 patients), and the myocardial infarction was 21% (8 patients). Two patients (5%) experienced emergent surgical repair after CP.

Table 3 shows clinical outcomes of study patients. The results of the logistic regression analysis are shown in **Table 4**. The univariate analysis revealed that female gender, previous PCI history, and stent diameter were correlated with major adverse cardiovascular events. On multivariate analysis, female gender and previous PCI history were independent predictors of major adverse cardiovascular events.

Discussion

We presented a one-year outcome after treatment of coronary artery perforation with PTFE-coated stents. In previous studies, the total MACE rate was found to be high in patients with CS implantation. Perforation is mostly seen in elderly patients; vascular structure is more fragile in elderly patients; and coronary artery disease is progressive over time. The covered stent consists of a polytetrafluoroethylene layer between two stainless steel sections, the endothelialization is difficult and the restenosis risk is higher than with conventional stents. In trials, the risk of thrombosis and restenosis was found to be higher in cover stents compared to other stents. Neoendothelialization is slower, and metal components are more common in cover stents than in other drug-eluting stents.[9] Optical coherence tomography (OCT) studies revealed that delay in endothelialization after covered stent implantation is an important factor in thrombosis.[10] The studies showed that the frequency of coronary perforation increases over time. This is related to the development of invasive cardiology and the increase in complex PCI procedures.[11] Most of the patients included in our study were male, and most patients had a history of hypertension (HT), hyperlipidemia (HL), and smoking. In this study, the MACE rate was higher in females than in males. In other studies, patients of advanced age, female sex, and with renal impairment were found to have a higher risk of coronary perforation. Female sex was a predictor of adverse outcomes after PCI in studies. The small vessel diameters, reduced vessel compliance due to a stiffer vessel[12] in women, and the predisposition of cover stents to thrombosis support the high MACE result in women. This may also be due to the atypical course of the complaint of coronary syndrome in women, its confusion with anxiety, and the delay in admission to the hospital as observed in other studies.[13]

CP was observed more frequently in patients treated with acute coronary syndrome than in patients treated with chronic coronary syndrome in this study. However, MACE was significantly higher in patients with PTFE-coated stent implantation for chronic coronary syndrome than in acute coronary syndrome. As in our or other studies, this result was correlated to the more complex and diffuse lesions, complex PCI, or higher pressure balloon inflation in chronic coronary disease than acute coronary disease.[13] MACE was found to be higher in patients with a previous history of PCI. Stent thrombosis is not only due to the CS itself. MACE was also found to be high in patients with previous stents in other trials.[14] This is due to stent under expansion, strut malapposition, and edge dissections where cover stents overlap with previous stents. Post-procedure imaging with intravascular imaging with intravascular ultrasound (IVUS) or optical coherence tomography (OCT) can predict these situations.

Although the effect of stent length on MACE was not detected, stent diameter is affected by MACE. The MACE rate was found to be higher in patients with smaller PTFE-coated stents implanted than larger ones (2.73±0.28 versus 3.34±0.65, $p = 0.002$) In previous studies, stent restenosis was a major complication in patients treated with CS implantation. IVUS examination revealed more restenosis in stent edges than in the center of CS.[15]

Our study has several limitations. It was conducted with a retrospective analysis and with a small number of patients. Although dual antiplatelet therapy is planned for 12 months, drug use information is limited, and the dual antiplatelet treatment duration and bleeding complications could not be established correctly. We did not have any intravascular imaging data during or after the procedure. One-year results of cover stents were investigated, but longer results were not considered.

Conclusions

Although the majority of coronary perforation cases are successfully treated with PTFE-coated stents, the one-year

outcome in CS-implanted patients is high. For this reason, such patients should be closely monitored.

Conflict of interest
None declared.

Funding
None.

Ethical statement
The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki.

Reference

1. Shimony A, Joseph L, Mottillo S, Eisenberg MJ. Coronary artery perforation during percutaneous coronary intervention: a systematic review and meta-analysis. Can J Cardiol 2011;27:843–850.
2. Harnek J, James S, Lagerqvist B. Coronary artery perforation and tamponade incidence, risk factors, predictors and outcomes from 12 years' data of the SCAAR Registry. Circ J 2019;84:43–53.
3. Ellis SG, Ajluni S, Arnold AZ. Increased coronary perforation in the new device era. Incidence, classification, management, and outcome. Circulation 1994;90:2725–2730.
4. Stankovic G, Orlic D, Corvaja N. Incidence, predictors, in--hospital, and late outcomes of coronary artery perforations. Am J Cardiol 2004;93:213–216.
5. Shimony A, Zahger D, Van Straten M, et al. Incidence, risk factors, management and outcomes of coronary artery perforation during percutaneous coronary intervention. Am J Cardiol 2009;104:1674–1677.
6. Mohammed Al-M, Prashanth P, Kadhim S. Coronary Perforation and Covered Stents: An Update and Review. Heart Views 2011;12:63–70.
7. Takano M, Yamamoto M, Inami S, et al. Delayed Endothelialization After Polytetrafluoroethylene-Covered Stent Implantation for Coronary Aneurysm. Circ J 2009;73:190–193.
8. von Korn H, Stefan V, van Ewijk R, et al. Treatment of coronary bifurcation lesions: stent-covering of the side branch with and without PCI of the side branch: a retrospective analysis of all consecutive patients. BMC Cardiovascular Disorders 2013;13:27.
9. Nagaraja V, Schwarz K, Moss S, et al. Outcomes of patients who undergo percutaneous coronary intervention with covered stents for coronary perforation: A systematic review and pooled analysis of data. Catheter Cardiovasc Interv 2020;96:1360–1366.
10. Takano M, Yamamoto M, Inami S, et al. Delayed Endothelialization After Polytetrafluoroethylene Covered Stent Implantation for Coronary Aneurysm. Circ J 2009;73:190–193.
11. Ford TJ, Khan A, Docherty KF, et al. Sex differences in procedural and clinical outcomes following rotational atherectomy. Catheter Cardiovasc Interv 2020;95:232–241.
12. Mozos I, Maidana JP, Stoian D, Stehlik M. Gender differences of arterial stiffness and arterial age in smokers. Int J Environ Res Public Health 2017;14:565.
13. Asghari E, Gholizadeh L, Kazami L, et al. Symptom recognition and treatment-seeking behaviors in women experiencing acute coronary syndrome for the first time: a qualitative study. BMC Cardiovasc Disord 2022;22:508.
14. Wańha W, Januszek R, Kołodziejczak M, et al. Procedural and 1-year outcomes following large vessel coronary artery perforation treated by covered stents implantation: Multicentre CRACK registry. PLoS One 2021;16:e0249698.
15. Mikhail P, Howden N, Monjur M, et al. Coronary perforation incidence, outcomes and temporal trends (COPIT): a systematic review and meta-analysis. Open Heart 2022;9:e002076.