Cohort Study

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The prevalence, angiographic profile and clinical features, management, and outcomes of coronary artery perforation secondary to percutaneous coronary interventions in Pakistan: a retrospective cohort study

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Introduction: Coronary artery perforation (CAP) is a rare entity that is often fatal. The mortality rates reported as high as up to 21% hence prompt diagnosis, intervention, and treatment are paramount to survival for such patients. Several factors may predispose a patient to coronary artery intervention including chronic total occlusion, severe calcification and tortuosity, aggressive use of oversized balloons and stents, and use of athero-ablative devices. Therefore, it is significant to have an insight related to it as despite being rare, it is one of the most feared complications of percutaneous coronary intervention (PCI).

Method: We conducted a retrospective study of the patients who have undergone PCI at our institution from January 2015 to December 2021. During this duration, all the patients who had developed CAP based on angiographic review during the PCI were selected. The demographic, clinical, angiographic, procedure-related features, management of the CAP, and in-hospital and follow-up outcomes were gathered.

Result: Thirty-five thousand fifty-nine patients underwent PCI among which, only 93 (0.26%) patients were complicated with (CAP. Fifty-eight (62.4%) patients were in the 50–70 years age range. The most common vessel involved was the left anterior descending (36.5%) followed by the right coronary artery (32.3%). The angiographic calcification was present in 51.6% of patients, significant tortuosity greater than 90° was seen in 48.4% of patients, chronic total occlusion was observed in 42% of patients and In-stent restenosis was found in 8.6% patients. The highest mortality of four patients was seen in the CAP involving the right coronary artery.

Conclusion: Mostly the CAP involves large vessel perforations however both, the distal and large vessel perforations are related to the increased incidence of adverse clinical results which indicates the significance of the prevention and early identification and treatment of the perforation.

Keywords: cardiology, coronary artery perforation, percutaneous coronary intervention

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HIGHLIGHTS

- Coronary artery perforation (CAP) is one of the most feared complications of percutaneous coronary interventions.
- 0.26% patients suffered from CAP.
- angiographic calcification is quite a significant predictor of CAP.

Introduction

Coronary artery perforation (CAP) is quite infrequent, however, fatal and it is the most feared complication of percutaneous coronary interventions[1,2]. The incidence of coronary artery perforation during percutaneous coronary intervention (PCI) is quite rare and reportedly ranges from 0.1 to 3%[1–3]. Another study published in 2017 cited 85 patients with the occurrence of CAP out of a total of 2097 who underwent percutaneous

coronary intervention[4]. The mortality rates reported as high as up to 21% hence prompt diagnosis, intervention, and treatment are paramount to survival for such patients[5].

Several factors may predispose a patient to coronary artery intervention including chronic total occlusion, severe calcification and tortuosity, aggressive use of oversized balloons and stents, and use of athero-ablative devices. Non-modifiable factors predicting the occurrence of CAP in patients include advancing age, female gender, renal failure, history of coronary artery bypass grafting (CABG), and history of non-ST-elevation myocardial infarction[3,6,7].

The clinical sequelae are highly dependent upon the extent of damage done and the size of the artery that has been perforated. The severity of perforations is determined using the Ellis classification[2,3,6,8] which lists three grades of PCI, of which grade III may cause cardiac tamponade and other clinical complications that ultimately lead to death[3]. CAP is also classified based on location as large vessel perforation, distal vessel perforation, and collateral perforation[2,6]. According to a case report, even benign coronary artery perforations can often cause massive damage due to their unpredictable courses[9].

However, the impact of the type of perforation on the management and treatment of CAP remains insignificant. Current short-term management for the stabilization of the condition includes surgical repair to seal the perforation, prolonged balloon inflation to prevent cardiac tamponade, and fat embolization[4]. The overall data, evidence, and literature available on the topic are very limited due to a lack of follow-ups, a small sample size, and a lack of analysis of the relationship between the outcomes and patients. No such study has been reported from Pakistan[4,10].

With most of the data on the impact, prevalence, management, and outcomes of coronary artery perforation existing in small healthcare setups, this study aims to analyze the epidemiology, mechanisms, and management of CAP secondary to PCI in the largest tertiary healthcare setup in Pakistan.

Methods

We conducted a retrospective study of the patients who have undergone PCI at our institution from January 2015 to December 2021. During this duration, all the patients who had developed coronary artery perforation (CAP) based on angiographic review during the PCI were selected. The demographic, clinical, angiographic, procedure-related features, management of the CAP, and in-hospital and follow-up outcomes were gathered. The perforation was classified with the help of both Ellis classification [types I, type II, type III, and type III CS (cavity spilling)] and modified Ellis classification by the EuroPCR team (types I, type II, type III, type IV, and type V)[11,12]. The perforation of the coronary artery was categorized into a large vessel and a distal/small vessel. The perforation in the major epicardial coronary artery or branch greater than or equal to 2 mm in size was classified as a large vessel and in a branch less than 2 mm in diameter, it was classified as a small or distal vessel.

Based on the ACC/AHA classifications, the lesion type was categorized and along with that, the angiographic features of the lesions were also entered which include tortuosity, calcification, lesion length, and chronic total occlusion[13]. The data relating to in-hospital outcomes such as reinfarction, side-branch occlusion, acute stent thrombosis, and death were also collected[14,15]. All of these patients were followed in outpatient departmental visits for 6 months. Those patients who manifest features suggestive of moderate or severe ischaemia based on non-invasive tests had to go for another angiographic evaluation. The long-term outcomes of the CAP patients were also gathered which include unstable angina [Canadian Cardiovascular Society grading (CCS) IV], stable angina (CCS I-III), asymptomatic (CCS 0), myocardial infarction, Stent thrombosis, target lesion revascularization, Target vessel revascularization, need for CABG and deaths due to any cause. The Statistical Package for Social Sciences software version 21.0 (IBMCorp., Armonk) was used for the descriptive statistics, frequency, and percentages of categorical and continuous variables that have been reported.

Our study was approved by the ethical review board committee of the respective hospital and it adheres to the guidelines of the Declaration of Helsinki. The work has been reported in line with the STROCSS criteria[16], Supplemental Digital Content 1, http://links.lww.com/MS9/A80. A complete STROCSS 2021 checklist has been provided as a Supplementary file, Supplemental Digital Content 1, http://links.lww.com/MS9/A80. Our study has been registered on Research Registry with the following UIN: researchregistry8626 https://www.researchregistry.com/browse-the-registry#home/.

Result

During the period of our study, 35 059 patients underwent PCI among which, only 93 (0.26%) patients were complicated with (CAP. Table 1 shows the baseline clinical characteristics of the CAP patients, 58 (62.4%) patients were in the 50–70 years age range and the majority of the patients were male (77.4%), 7 (7.5%) patients had prior CABG, 67 (72%) patients had a BMI greater than 25, and 60 (64.5%) were smokers. Diabetes mellitus (58%) was found to be the most common cardiovascular risk factor present among the patients, 18.3% of patients had a family history of coronary artery disease and 4.3% had renal dysfunction. The mean ejection fraction was 57 ± 7. ST-elevation myocardial infarction was the major indication of PCI among 44% of CAP patients. Forty-six (49.5%) patients had a history of multivessel disease. The majority of the patients were given Clopidogrel (86%), Aspirin (95.7%), and Heparin (83.9%). The mean stent diameter (mm) was 3.6 ± 0.3 and the mean stent length (mm) was 36 ± 19.

Table 2 shows the angiographic procedural characteristics of the patients who are complicated with CAP. The most common vessel involved was the left anterior descending (36.5%) followed by the right coronary artery (32.3%). The treated lesions were classed as B2 and C in 34.4% and 52.7% of patients respectively. The angiographic calcification was present in 51.6% of patients, significant tortuosity greater than 90° was seen in 48.4% of patients, chronic total occlusion (CTO) was observed in 42% of patients and In-stent restenosis was found in 8.6% patients. Among the 93 cases of angiographically recognized CAP, most CAPs were classified as Ellis type II (43%) and type III (37.6%).

The CAP was observed mainly in the large vessels. The most common mechanism of the CAP in the large vessel was compliant balloon (30%) and stent (27.4%) while in the distal vessel, the most common mechanism of CAP was guidewire (67.7%) as shown in Table 3. 13 (20.9%) patients with CAP involving the large vessel and 6 (2%) with CAP involving the distal vessel was conservatively managed. Prolonged balloon inflation was

Table 1

The demographic and clinical characteristics of the CAP patients

Variables	Categories	Results, $n = 93$ (%)
Age (years)	< 50	10 (10.7)
	50–70	58 (62.4)
	> 70	25 (26.9)
Sex	Male	72 (77.4)
	Female	21 (22.6)
Known IHD	Prior myocardial infarction	4 (4.3)
	Prior CABG	7 (7.5)
	Prior PCI	3 (3.2)
BMI	> 25	67 (72)
	< 25	26 (28)
Current smoker	Yes	60 (64.5)
Cardiovascular risk factors	Diabetes mellitus	54 (58)
	Hypertension	49 (52.7)
	Dyslipidemia	44 (47.3)
Family history of coronary artery disease	Yes	17 (18.3)
Renal dysfunction (creatinine > 200umol/l)	Yes	4 (4.3)
Ejection fraction (mean)		57 ± 7
Indication for PCI	STEMI	41 (44)
	NSTEMI	32 (34.4)
	Stable angina	12 (13)
	Ischaemic heart failure	6 (6.5)
Thrombolysis within 24 h	—	23 (24.7)
Urgent/emergency procedure	—	16 (17.2)
Multivessel coronary disease	—	46 (49.5)
Mean Stent diameter, mm	—	3.6 ± 0.3
Mean Stent length, mm	—	36 ± 19
Procedural medications	Clopidogrel	80 (86)
	Prasugrel	13 (14)
	Ticagrelor	11 (12)
	Glycoprotein IIB/IIIA inhibitor	6 (6.5)
	Aspirin	89 (95.7)
	Heparin	78 (83.9)
	Bivalirudin	31 (33.3)

CABG, coronary artery bypass graft; CAP, coronary artery perforation; IHD, ischaemic heart disease; NSTEMI, non-ST-elevation myocardial infarction; PCI, percutaneous coronary intervention; STEMI, ST-elevation myocardial infarction.

performed at low pressures of 4–6 atm for an average of 10 min duration in 54.8% of the patients with large vessels and 61.3% of patients involving the distal vessel. Overall in 44.9% of patients, covered stent implantation was utilized. Overall, 11.8% of patients were referred for emergency surgery. The rate of in-hospital mortality involving large vessels was 9.7% and for the distal vessel, it was 6.4%. The highest mortality of 4 patients was seen in the CAP involving the right coronary artery as shown in Table 4. It also shows that the highest number of successful cases of CAP were with the left anterior descending artery (29 patients) Fig. 1.

Discussion

Our study demonstrates the life-threatening condition of CAP complicating routine PCI. We evaluated the incidence and the demographic and angiographic features, treatment given, management, and outcomes of a life-threatening condition known as CAP. To the best of our knowledge, it is the first study from Pakistan to

Table 2

The angiographic characteristics of the CAP patients

Variables	Categories	Results ($n = 93$), n (%)
Treated vessel	Left main artery	1 (1)
	LAD artery	34 (36.5)
	Diagonal artery	10 (10.8)
	Ramus artery	3 (3.2)
	Circumflex artery	13 (14)
	RCA	30 (32.3)
	Saphenous vein graft	2 (2.2)
Lesion complexity and vessel morphology	A	5 (5.4)
	B1	7 (7.5)
	B2	32 (34.4)
	C	49 (52.7)
Lesion length > 20 mm	—	52 (56)
Moderate/severe calcification	—	48 (51.6)
Significant tortuosity > 90°	—	45 (48.4)
Chronic total occlusion	—	39 (42)
In-stent restenosis	—	8 (8.6)
Radial access		52 (56)
Ellis classification	I	14 (15)
	II	40 (43)
	III	35 (37.6)
	III CS	4 (4.3)
EuroPCR classification	I	12 (13)
	II	37 (39.7)
	III	36 (38.7)
	IV	3 (3.2)
	V	5 (5.4%)

CAP, coronary artery perforation; LAD, left anterior descending; RCA, right coronary artery.

Table 3

Mechanism, management, and immediate and long-term outcomes of the CAP patients

		Vessel	
Variables	Categories	Large vessel ($n = 62$), n (%)	Distal vessel ($n = 31$) , n (%)
Mechanism	Compliant balloon	19 (30)	0
	Non-compliant balloon	3 (4.8)	4 (12.9)
	Stent	17 (27.4)	2 (6.4)
	Coronary guidewire	12 (19.3)	21 (67.7)
	Microcatheter	5 (8)	1 (3.2)
	Thrombectomy catheter	3 (4.8)	2 (6.4)
	Rotational atherectomy	3 (4.8)	1 (3.2)
Management	Pericardiocentesis	21 (33.9)	13 (42)
	Prolonged balloon inflation	34 (54.8)	19 (61.3)
	Covered stent(s) implantation	25 (40.3)	16 (51.6)
	Emergency surgery	4 (6.4)	7 (22.6)
	Coil embolization	1 (1.6)	3 (9.7)
	Conservative	13 (20.9)	6 (2)
In-hospital outcomes	Reinfarction	2 (3.2)	1 (3.2)
	Side-branch occlusion	8 (13)	3 (9.7)
	Acute stent thrombosis	2 (3.2)	1 (3.2)
	Death	6 (9.7)	2 (6.4)

CAP, coronary artery perforation.

Table 4

Shows the type of perforation, treatment modalities given, and procedural outcomes of CAP regarding the vessel involved

	EURO PCR type of CAP					Treatment modality						Procedural outcome		
Vessel involved	I	II	III	IV	V	Conservative	Prolonged balloon inflation	Pericardiocentesis	Covered stent	Coiling	Emergency surgery	Successful	Abandoned	Mortality
Left main (*n* = 1)	0	0	1	0	0	0	1	0	0	0	1	0	0	1
Left anterior descending (*n* = 34)	8	8	16	1	1	5	17	12	17	1	2	29	3	1
Diagonal (*n* = 10)	0	7	2	0	1	6	4	4	1	2	1	6	4	0
Ramus (n = 3)	0	1	1	0	1	1	2	1	2	0	0	0	2	1
Circumflex (*n* = 13)	0	7	4	1	1	4	10	7	3	1	4	9	3	1
Right coronary artery (*n* = 30)	4	13	12	0	1	3	19	10	17	0	3	18	8	4
Saphenous vein graft (*n* = 2)	0	0	0	1	0	0	0	0	1	0	0	0	2	0

CAP, coronary artery perforation.

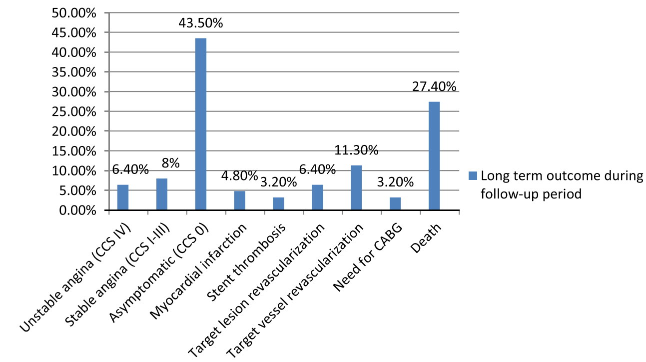

Figure 1. Shows the late outcomes found among patients in the follow-up period. Most commonly patients were asymptomatic (43.50%); however 27.4% mortality rate was noted. CABG, coronary artery bypass graft; CSS, Canadian Cardiovascular Society grading.

outline the incidence, features, and outcomes of CAP. During the entire period of the study, the incidence of CAP was found to be 0.26% and in-hospital mortality was 8.6% which is comparable with the studies by Gruberg *et al.*[17] reporting 0.29% incidence and 10% mortality, Ben-Gal *et al.*[18] reporting 0.25% incidence and 12% mortality, and Krishnegowda *et al.*[1] reporting 0.13% cases of CAP and 10% mortality.

Our study also demonstrates that among all the CAP, 66.7% were of large vessel perforations and 33.3% of distal vessel perforations. The findings are consistent with the findings of Arsalan *et al.* showing the prevalence of 75% CAP cases in a large vessel[2]. Although the subtle CAP can go undiagnosed, the CAPs are usually identified during coronary angiography at the time of perforation. The commonly occurring presentation involves persistent or recurrent chest pain, hypotension, new-onset tachycardia, and acute shortness of breath. Therefore in these situations, the CAP needs to be one of the differentials. Even a little amount of blood (e.g. 100 ml) within the pericardial space in acute cases can result in hemodynamic instability[19]. The early diagnosis of CAP utilizing coronary angiography is of vital importance. Serial echocardiography can assist in the delayed diagnosis of pericardial effusions and tamponade, particularly in conservatively managed patients[20]. The occurrence of CAP can further be avoided if the appropriate technique of the PCI is applied. The aggressive application of oversized balloons and stents, and the application of athero-ablative devices along with hydrophilic guidewires are the few factors associated with catheterization-related risk factors for CAP[21].

The independent predicting factors for CAP in the literature are female gender, age, CTO, angiographic complex lesions, and calcifications[22–24]. In the cohort of our study, the incidence of CAP was quite common in the male gender, complex lesion type B2, and type C, CTO interventions, and calcified vessels. The most common artery involved was the left anterior descending followed by RCA while in other studies, the RCA was the most commonly involved artery affected with CAP[23,25]. The overall most common mechanism of CAP was Coronary guidewire in our study, however, in another study, the guidewire was the second most common mechanism responsible for the CAP while post-dilation was the most common mechanism[1].

After the prolonged balloon inflation, a lot of coronary perforations can be sealed hence preventing the bleed into the

pericardium. Pericardiocentesis is conducted in cases where the patient develops tamponade. It was only required in 36.6% of the patients in our cohort. It was carried more in the distal vessel as compared to a study in which it was needed in the large vessel perforations reflecting its greater severity and hemodynamic instability[2]. It is reported that a delayed tamponade can cause a greater risk of CAP resulting in 21–32% of the perforation cases[4,21,26]. This indicates the significance of aggressive initial treatment and vigilant monitoring of the patients with coronary perforation irrespective of the initial management and the causes of it.

The findings of this study give a deep insight into the clinical and angiographic features, initial management, and further management of the CAP and the outcomes which are quite beneficial for further studies to consider these variables and manage the patients suspected to be suffering from CAP in a way to avoid the worst outcomes. The strength of this study was its long duration.

The major limitation of this study was that it includes the data from a single centre and it is retrospective in nature, the findings might not be able to be generalized for all the centres. Our study was observational therefore few unknown factors might have affected the results however we managed to include all the relevant factors. We did not compare the variables with the patients who have undergone PCI and did not suffer from the CAP to check the strength of the predicting factors. Additionally, as the condition is quite rare, our sample size was quite modest.

Conclusion

The prevalence of coronary perforation in patients undergoing PCI is quite low and in accordance with other studies. Mostly the CAP involves large vessel perforations, however, both, the distal and large vessel perforations are related to the increased incidence of adverse clinical results which indicates the significance of the prevention and early identification and treatment of the perforation.

Ethical review

Ethical approval was taken from the ethical committee Jinnah Post Graduate Medical Centre (No.F.2-81/2015-GENL/286/JPMC).

Consent

Informed consent from the patients was obtained considering Helsinki's Declaration.

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None.

Author contribution

A.K. and R.K.: study design and concept. R.A.: data analysis. K.F. and R.A.: data collection. M.A., R.A., and G.M.: manuscript writing. M.H.: manuscript writing, design, critical review, data interpretation. A.F.U.D.K.: critical review, data analysis.

Conflicts of interest disclosure

The authors report no conflicts of interest.

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