ORIGINAL ARTICLE

Percutaneous coronary intervention and coronary artery bypass grafting in myocardial infarction complicated by cardiogenic shock

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ABSTRACT

Background: Cardiogenic shock (CS) remains the leading cause of poor prognosis in patients with acute myocardial infarction (AMI), sustaining a high mortality rate of 40 to 50% within 30 days.

Aims: In this unique analysis of two national all-comers, real-life registries including patients with AMI complicated by CS, for whom early revascularization was planned, we aimed to compare the effect of percutaneous coronary revascularization (PCI) and coronary artery bypass grafting (CABG) on 30-day and 1-year all-cause mortality.

Material and methods: The study included consecutive patients with AMI complicated by CS included in the Polish Registry of Acute Coronary Syndromes (PL-ACS) and the Polish National Registry of Cardiac Surgical Procedures (KROK), treated with PCI and CABG, respectively. A layered analysis and Kaplan–Meier curves were used in the propensity score matched (PSM) groups.

Results: Between 2006 and 2022, a total of 1970 patients with AMI complicated by CS, with known coronary anatomy were included in PL-ACS and KROK registries. 1376 (69.8%) had PCI and 594 (30.2%) had CABG. Following a 1:1 PSM, a total of 822 patients were finally included in the analysis. The mortality rates were 48.2% in the PCI group compared with 38.6% in the CABG group at 30 days (*P* <0.001) and 53.5% compared with 41.1%, respectively, at 1 year (*P* <0.001).

Conclusions: Among patients with AMI affected by CS, those qualified to be treated with CABG had a higher survival rate at 30 days and one year as compared to those treated with PCI.

Key words: acute myocardial infarction, CABG, cardiogenic shock, PCI, prognosis

INTRODUCTION

Acute myocardial infarction (AMI) is the most common cause of cardiogenic shock (CS) [1]. AMI-related CS (AMICS) results in a deficiency of end-organ perfusion that is often characterized by a vicious circle of pathophysiological interactions in the course of a sudden loss of cardiac systolic function as a cause of acute coronary ischemia [2, 3]. The incidence of AMICS is 7%–10% and despite ongoing intensified efforts, including broad implementation of coronary revascularization and technological and logistic progress, the prognosis associated with AMICS remains poor, with 30-day mortality approximating unacceptable 40% to 50% [4–7].

In a subanalysis of the SHOCK (Should We Emergently Revascularize Occluded Coronaries for Cardiogenic Shock) trial and in a recently published study, coronary artery bypass grafting (CABG) had comparable mortality rates to PCI, even though more complex coronary artery disease (CAD) was revascularized surgically [8, 9]. Therefore, according to current practice guidelines, CABG in AMICS should be still considered as a valuable treatment option, especially in the presence of the complexity of CAD not amenable for or after failed PCI [10, 11]. However, the broader referral of AMICS patients to CABG is not observed [12], mainly due to a lack of robust clinical data coming from randomized clinical trials (RCT) and/or real-life, all-comer registries.

Taking the above into consideration, this study aimed to assess which strategy, PCI or CABG, is superior in the context of the reduction of all-cause mortality in patients with AMICS, based on the data from two national all-comer, real-world registries: the Polish Registry of Acute Coronary Syndromes (PL-ACS Registry) and the Polish National Registry of Cardiac Surgical Procedures (KROK Registry).

METHODS

Ethical review and approval were waived for this study because of retrospective analysis of the prospective PL-ACS and KROK registry.

Design of the registries

The PL-ACS is a national, multicenter, ongoing, prospective observational registry that includes data on patients hospitalized with acute coronary syndromes in Poland. It is a joint project of the Silesian Center of Heart Diseases in Zabrze and the Polish Ministry of Health, in cooperation with the National Health Fund [13]. The registry was founded in October 2003, and in May 2004, it was harmonized with the European Cardiology Audit and Registration Data Standards [13]. Participation in the registry is mandatory for every hospital treating patients with ACS in Poland. Full details on the rationale and methods of the PL-ACS have been previously described [13].

The KROK Registry, is a national, multicenter, ongoing, prospective observational registry of patients undergoing cardiac surgery, a joint initiative of the Polish Society of Cardiothoracic Surgeons and the Polish Ministry of Health. Details regarding the KROK Registry and the collection of follow-up data have been previously described [14].

Before enrollment, informed writing consent was given by all participants. Institutional review board approval was obtained for all participants. The authors declare that all supporting data are available within the article. No other cardiovascular endpoints (e.g. cardiovascular mortality and nonfatal myocardial infarction and stroke) are available in the registry. The primary outcome was death from any cause at 30 days.

Data on long-term all-cause mortality, including the exact date of death, were obtained from the National

WHAT'S NEW?

In this analysis of patients with acute myocardial infarction complicated by cardiogenic shock, we included consecutive patients enrolled in the Polish Registry of Acute Coronary Syndromes and the Polish National Registry of Cardiac Surgical Procedures, treated with percutaneous coronary revascularization (PCI) and coronary artery bypass grafting (CABG). The mortality rates as a primary endpoint were 48.2% in the PCI group compared with 38.6% in the CABG group at 30 days (*P* <0.001) and 53.5% compared with 41.1%, respectively, at 1 year (*P* <0.001).Among patients with acute myocardial infarction affected by cardiogenic shock, those treated with CABG had a higher survival rate at 30 days and one year as compared to treated with PCI.

Health Fund by December 2022. Follow-up time was censored at one year or the end of follow-up time (whichever came first).

Study patient population and definitions

Consecutive patients with AMICS included in the PL-ACS Registry and KROK Registry were included in the analysis. Patients with AMI were stratified by the presence of CS before revascularization. The selection of revascularization procedures was individualized for each patient at the discretion of site physicians.

The AMI was defined according to the Fourth Universal Definition of Myocardial Infarction [15]. CS was defined as 1) systolic blood pressure <90 mm Hg (in the absence of hypovolemia and after proper fluid resuscitation) for at least 30 min or the need for pharmacological support to maintain systolic blood pressure above 90 mm Hg; and 2) signs and symptoms of end-organ hypoperfusion. Patients with mechanical complications and/or who required surgical procedures other than CABG, were excluded from the analysis.

Statistical analysis

The normality of the distribution of quantitative variables was assessed using the Shapiro–Wilk test. Depending on the results, variables were presented as means with standard deviations or medians with interquartile ranges. Groups were compared using Student's t-test for variables with normal distributions or the Mann–Whitney U test for those that did not meet the normality assumption. Categorical variables were shown as percentages and groups were compared using the χ^2 test. The study patients were matched to achieve similar age, sex, history of hypertension, diabetes, myocardial infarction, percutaneous coronary intervention, coronary artery bypass grafting, peripheral arterial disease, current smoking habits, atrial fibrillation, left main disease, and multivessel coronary disease.

Data were matched using the Mahalanobis distance within propensity score calipers. The caliper radius was set to 0.2*sigma [16, 17]. Finally, the propensity score–matched groups included 411 individuals each. The standardized mean differences for groups after PSM were calculated. The matched cohorts were considered well-balanced for a given variable if the absolute standardized mean difference between the cohorts was ≤0.1.

A layered analysis was performed to further investigate the impact of the intervention on specific subgroups. Relative risks (RRs) were determined for the total sample and within each stratum. Moderation analyses were conducted using logistic regression models with interaction terms to determine whether sex, age over 65, diabetes, renal failure, PVD, and left main (LM) moderated the effect of procedure type on 30-day mortality.

Kaplan–Meier curves after PSM were drawn to show the cumulative survival in a 30-day and one-year observation period. Survival between the groups before and after PSM was compared using the log-rank test. Observation time was median: 0.2 years (IQR 0.005–3.7), 0.04 years (IQR 0.001–1.7), and 1.6 years (IQR 0.01–1.7) for the entire group, PCI and CABG respectively.

Statistical significance was defined as a 2-sided $P < 0.05$. All statistical analyses were performed using TIBCO Statistica software (TIBCO Statistica, v. 13.3; TIBCO Software Inc, Palo Alto, CA, US).

RESULTS

Between 2006 and 2022, a total of 1970 patients with AMI complicated by CS, with known coronary anatomy were included in the PL-ACS and KROK registries. A total of 1376 individuals (69.8%) underwent PCI and 594 (30.2%) underwent CABG. After 1:1 PSM, a total of 822 patients were finally included in the analysis (Figure 1). The baseline clinical and angiographic characteristics before and after PSM are presented in Table 1. Before propensity score matching the higher prevalence of many comorbidities and much more complex CAD with left main disease were observed. After PSM, the groups were well-balanced in terms of baseline characteristics. The in-hospital outcomes are presented in Table 2. The mortality rate was 48.2% in the PCI group compared with 38.6% in the CABG group at 30 days ($P < 0.001$) and 53.5% compared with 41.1%, respectively, at one year ($P < 0.001$) (Table 2, Figures 2 and 3). Prespecified analyses showed results across all subgroups that were consistent with those in the primary analysis with significant interactions for diabetes and LM subgroups of patients (Figure 4), suggesting a relative benefit of CABG in these conditions, notwithstanding the in-hospital rate of stroke being significantly higher in the CABG group than in the PCI group (6.6% vs. 0.24%; $P < 0.001$).

DISCUSSION

Approximately one in ten patients develops CS in the setting of AMI, resulting from acute, sudden, and severe coronary ischemia/thrombosis. This leads to a cascade of deleterious effects, including end-organ hypoperfusion, compensatory vasoconstriction, raised ventricular diastolic pressures with refractory coronary ischemia, pulmonary congestion, increased biventricular afterload, lactic acidosis, systemic inflammatory response, and ultimately, death [18].

To date, coronary reperfusion limited to the culprit infarct artery is the only therapy proven effective for prognosis in AMICS patients. Therefore, early intervention and restoration of perfusion to the infarct-related artery (IRA) is of paramount importance for patients with AMICS. However, since the landmark Should We Revascularize Occluded Arteries in Cardiogenic Shock (SHOCK) trial was published in 1999, despite significant efforts, AMICS continues to be linked with unacceptably high rates of morbidity and mortality risks reaching up to 40%–50% in the current RCT, and has not changed much over the last decade [5–7, 19, 20]. One of the valuable explanations for these suboptimal

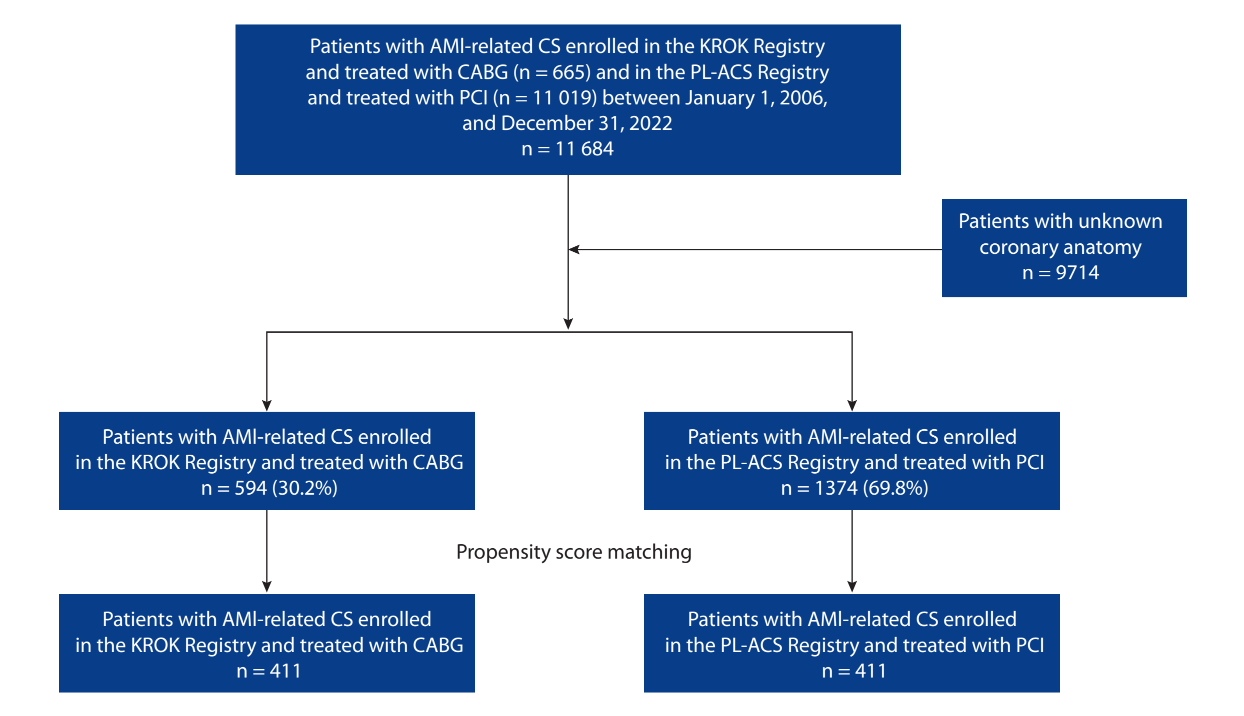


Figure 1. Study flowchart. Graphical presentation of the patients included in the analysis

Abbreviations: AMI, acute myocardial infarction; CABG, coronary artery bypass grafting; CS, cardiogenic shock; KROK, Polish National Registry of Cardiac Surgical Procedure; PCI, percutaneous coronary intervention; PL-ACS, Polish Registry of Acute Coronary Syndromes

Table 1. Baseline patient characteristics by study groups

Variable	Before matching			After matching		
	CABG n = 594	PCI n = 1376	*P*-value	CABG n = 411	PCI n = 411	*P*-value
Sex (female), n (%)	177 (29.8)	493 (35.8)	0.01	137 (33.3)	114 (27.7)	0.1
Age, years (mean, SD)	67.6 (9.4)	69.4 (11.8)	0.001	67.9 (9.4)	69.2 (11.2)	0.07
Current smoker, n (%)	154 (25.9)	368 (26.7)	0.7	106 (25.8)	108 (26.3)	0.9
Hypertension, n (%)	493 (83)	825 (60)	<0.001	316 (76.9)	321 (78.1)	0.74
Hyperlipidemia, n (%)	330 (56)	516 (37)	<0.001	203 (49.4)	206 (50)	0.89
Diabetes, n (%)	192 (32.3)	424 (31.1)	0.6	142 (34.5)	129 (31)	0.4
Body mass index[a] (mean, SD)	27.7 (4.4)	27.9 (5)	0.4	27.6 (4.3)	27.7 (4.9)	0.8
Previous PCI, n (%)	168 (28.3)	224 (16.3)	<0.001	103 (25.1)	104 (25.3)	1.0
Previous CABG, n (%)	7 (1.2)	58 (4.2)	<0.001	7 (1.7)	11 (2.7)	0.5
Atrial fibrillation, n (%)	58 (9.8)	270 (19.6)	0.001	49 (11.9)	46 (11.2)	0.8
Previous stroke, n (%)	32 (5.4)	108 (8.7)	0.02	24 (5.8)	24 (5.8)	0.8
Chronic kidney disease, n (%)	115 (19.4)	170 (13.7)	0.002	71 (17.3)	72 (17.5)	1.0
Peripheral artery disease, n (%)	117 (19.7)	133 (10.7)	<0.001	63 (15.3)	56 (13.6)	0.5
COPD, n (%)	57 (9.6)	64 (5.2)	0.001	35 (8.5)	33 (8.03)	0.9
1VD, n (%)	31 (5.2)	317 (23.0)	<0.001	28 (6.8)	28 (6.8)	0.9
2VD, n (%)	63 (10.6)	329 (23.9)	<0.001	57 (13.9)	57 (13.9)	0.9
3VD, n (%)	139 (23.4)	302 (21.9)	0.5	117 (28.5)	117 (28.5)	0.9
Left main+1VD, n (%)	86 (14.5)	180 (13.1)	0.44	74 (18)	74 (18)	0.9
Left main + 2/3VD, n (%)	275 (46.3)	248 (18)	<0.001	135 (32.8)	135 (32.8)	0.9
No. of vein grafts (mean, SD)	0.6 (0.6)	–		0.7 (0.6)	–	
No. of arterial grafts (mean, SD)	1.7 (0.9)	–		1.7 (0.9)	–	
No. of all grafts (mean, SD)	2.4 (0.9)	–		2.4 (0.9)	–	
No. of vessels treated with PCI (mean, SD)	–	1.4 (0.7)		–	1.6 (0.8)	
No. of stents used (mean, SD)	–	1.6 (1.1)		–	1.7 (1.2)	

[a]The body mass index is the weight in kilograms divided by the square of the height in meters

Abbreviations: CABG, coronary artery bypass grafting; COPD, chronic obstructive pulmonary disease; PCI, percutaneous coronary intervention; SD, standard deviation; VD, vessel disease

Table 2. In-hospital outcomes: 30-day and 12-month mortality

Variable	Before matching			After matching		
	CABG n = 594	PCI n = 1376	*P*-value	CABG n = 411	PCI n = 411	*P*-value
Stroke, n (%)	40 (6.7)	8 (0.6)	<0.001	27 (6.6)	1 (0.24)	<0.001
IABP, n (%)	342 (57.6)	125 (9.1)	<0.001	228 (55.5)	31 (7.5)	<0.001
ECMO, n (%)	5 (0.8)	2 (0.07)	0.03	3 (0.7)	0 (0)	0.27
Pacemaker placement, n (%)	1 (0.2)	11 (0.8)	0.14	1 (0.2)	2 (0.5)	0.9
In-hospital stay, days median (IQR)	10.6 (7.1–15.6)	6.8 (3.1–11.0)	<0.001	10.6 (7.1–15.0)	6.7 (3.8–9.9)	<0.001
In-hospital stay, days median (IQR)[b]	2.7 (0.5–8.8)	0.4 (0.1–2.2)	<0.001	2.7 (0.5–10.2)	0.3 (0.1–3.0)	<0.001
In-hospital death from any cause, n (%)	190 (32)	593 (43.1)	<0.001	130 (31.6)	169 (41.1)	0.006
30-day death from any cause, n (%)	198 (33.3)	683 (49.6)	<0.001	138 (33.6)	198 (48.2)	<0.001
12-month death from any cause, n	250 (42.1)	788 (57.3)	<0.001	169 (41.1)	220 (53.5)	<0.001

[a]Patients who survived and were discharged. [b]Patients who died during index hospitalization

Abbreviations: ECMO, extracorporeal membrane oxygenation; IABP, intra-aortic balloon pump; IQR, interquartile range; other — see Table 1

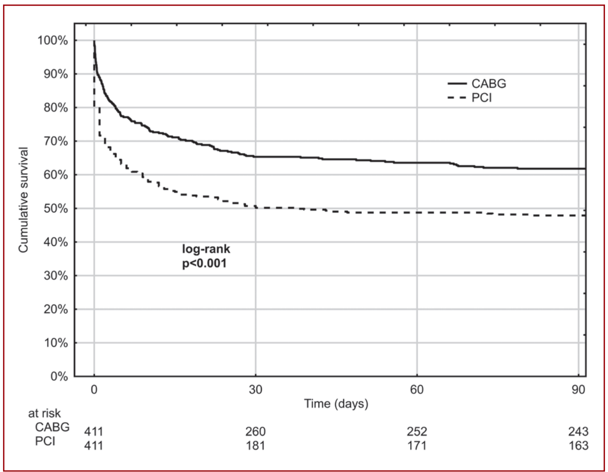


Figure 2. Kaplan–Meier estimates for all-cause 30-day survival. Free from all-cause mortality at 30 days

Abbreviations: see Figure 1

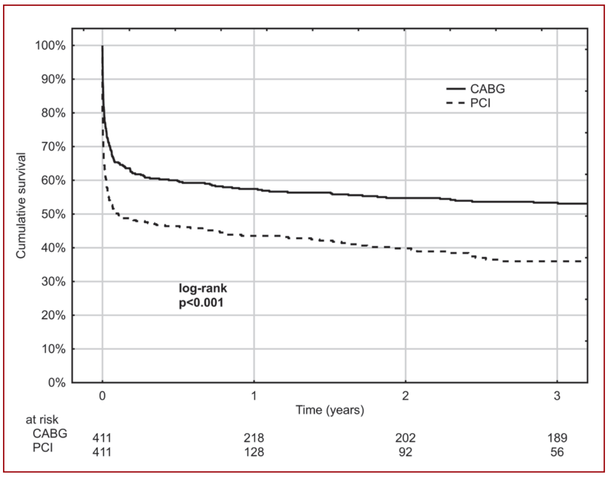


Figure 3. Kaplan–Meier estimates for all-cause one-year survival. Free from all-cause mortality at one year

Abbreviations: see Figure 1

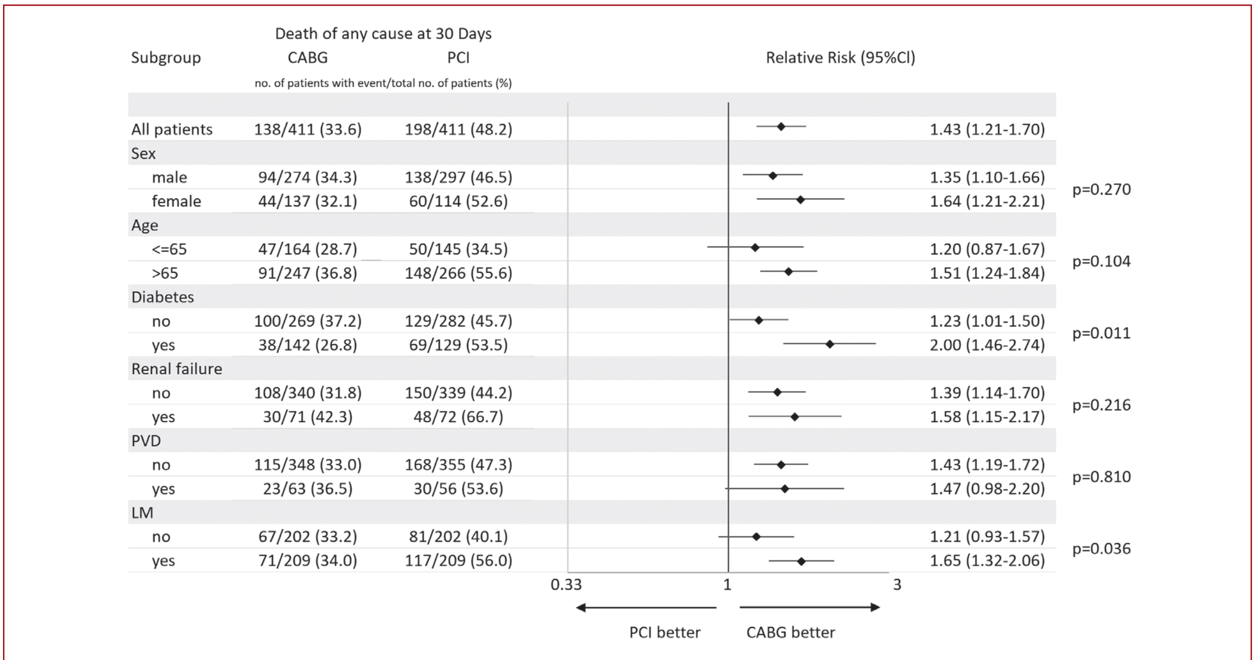
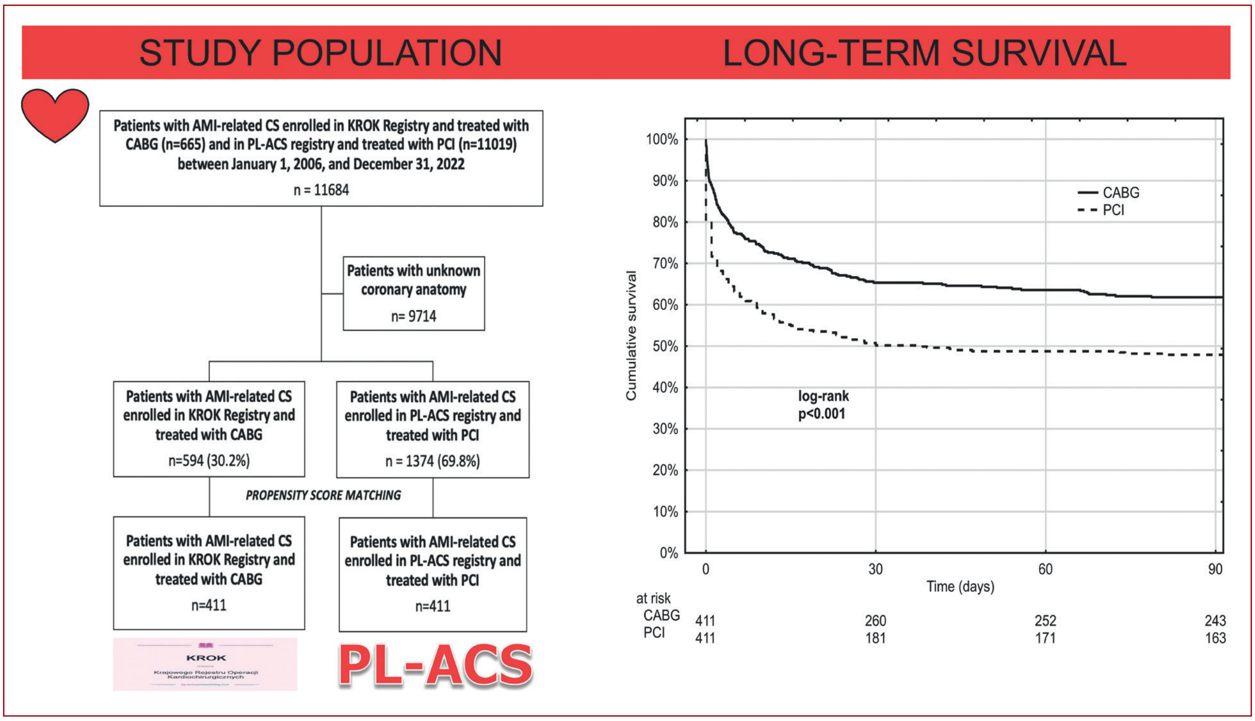


Figure 4. Subgroup analysis of the primary outcome. The forest plot illustrates the relative risk of death from any cause at 30 days (the primary outcome) in prespecified subgroups

Abbreviations: LM, left main; PVD, peripheral artery disease; other — see Figure 1



Graphical abstract. Among patients with AMI affected by CS, those treated with CABG had a higher survival rate at 30 days and one year as compared to those treated with PCI. Graphical presentation of the major findings coming from the presented study

Abbreviations: AMI, acute myocardial infarction; CABG, coronary artery bypass grafting; CS, cardiogenic shock; KROK, Polish National Registry of Cardiac Surgical Procedure; PCI, percutaneous coronary intervention; PL-ACS, Polish Registry of Acute Coronary Syndromes

outcomes may be the fact that clinical gaps in knowledge regarding optimal revascularization strategies are present.

Currently, immediate coronary angiography and PCI of the IRA are recommended in this population regardless of time delay. Emergency CABG is recommended if PCI of the IRA is not possible and/or failed [21, 22]. However, bearing in mind that over 70% of patients with AMICS have a complex form of CAD, involving the LM multivessel, which is a strong and independent predictor of mortality, and given the very high mortality of patients with unsuccessful PCI, CABG should still be viewed as a valuable option of complete revascularization in patients with AMICS [23]. This is in line with the subanalysis of the SHOCK trial, published nearly two decades ago, in which White et al. [8] revealed that CABG vs. PCI in AMICS patients showed comparable survival rates. However, those patients allocated for CABG had much a more complex coronary anatomy, higher prevalence of diabetes, and a longer time to revascularization (0.9 hours for PCI vs. 2.7 hours for CABG). The authors concluded that the next "logical step" needs to be to design and perform RCTs comparing PCI and CABG in patients with AMICS [8]. To the best of our knowledge, no such RCT has yet been conducted. Moreover, the utility of CABG in the setting of AMI complicated by CS remains rare. In the Intra-aortic Balloon Pump in Cardiogenic Shock (IABP-Shock II) trial and registry, for example, where 52% of patients had a three-vessel disease and the left main was the IRA in approximately 9%, only 3.5 % of patients had immediate CABG [5].

Taking into consideration all facts mentioned above, the present study aimed to compare PCI and CABG regarding survival rates in patients with AMI complicated by CS. We strongly believe that conducting such an analysis using PSM could reignite a debate about the optimal revascularization methods in this highly demanding patient population. This may include expediting the process of designing and conducting dedicated RCTs or prospective registries. Additionally, this holds significant importance, particularly in light of recently published RCTs that have failed to demonstrate any benefits with regards to changes in current clinical practices. These include the routine use of intra-aortic balloon pump [5], routine immediate complete revascularization [6], and routine use of extracorporeal life support treatment [7].

The primary finding of this investigation is the significantly higher survival rates at both 30 days and one year in patients with AMI complicated by CS who underwent CABG compared to those who underwent PCI. The results of this study align with other observational data, although the inclusion of a small number of subjects [24] and limitation to in-hospital outcomes [25] should be noted. Of note, this was recorded despite of significantly higher rate of in-hospital stroke in CABG group. Although cardiopulmonary bypass was thought to be the primary cause of stroke in all cardiac surgeries, the development of off pump CABG surgery has made it possible to directly compare the risk of stroke with and without bypass, and no discernible difference has been observed [26].

Considering the latitude and potential of surgical coronary revascularization, the superiority of CABG over PCI in patients with AMICS regarding survival may be reasonably explained. This assumption may be corroborated by several findings. Firstly, CABG can accomplish one-stage complete revascularization even in the presence of chronic total occlusion or complex and calcified coronary anatomy. A propensity score-matching analysis compared a smaller set of patients who underwent PCI followed by CABG with patients who underwent PCI alone. This analysis showed no difference in mortality at 7 days (15.9% vs. 25%; $P = 0.29$) but a substantial difference favoring PCI + CABG at 30 days (20.5% vs. 40.9%; $P = 0.03$) [24]. Secondly, CABG using cardio-pulmonary bypass aids in arresting the heart with cardioplegia, cooling the myocardium, and ventricular unloading with adequate circulatory and hemodynamic support. These effects may be attributed to myocardial rest during surgery and a reduction in the myocardium's oxygen demand before revascularization, consequently preserving ischemic myocardium. Moreover, cardio-pulmonary bypass during surgery reverses global ischemia and sustains perfusion of vital organs, thus halting the cascade of events that can precipitate systemic inflammation and progressive hemodynamic deterioration in CS [27].

Study limitations

There are several limitations to our analysis that warrant acknowledgment. Firstly, this is a retrospective cohort study and we were constrained by the data available in the PL-ACS and KROK Registry, which are databases with different designs. The convergence of collected data, including the type of MI, is incomplete. Unfortunately, we did not record the timing between the onset of MI, the onset of cardiogenic shock, and the timing of coronary revascularization. Additionally, our follow-up analysis was limited to all-cause mortality. Due to the observational nature of the study and the limited number of patients, these results should be interpreted as hypothesis-generating and could be used for sample size calculation in randomized controlled trials comparing PCI with CABG in AMICS patients. Moreover, despite data adjustment in the propensity score matching, the results could still be biased by potentially important parameters that were not available in the PL-ACS and KROK registries. Finally, as this is a single-country study, its findings may not be generalizable to other populations.

However, a key strength of the present study lies in the assessment of all-cause mortality, which was conducted using a centralized, national database. This approach ensured a thorough and comprehensive capture of all deaths. Additionally, the data presented originates from a large administrative database, potentially identifying a representative cohort of patients with cardiogenic shock in terms of real-life clinical practice.

CONCLUSIONS

Our study indicates that CABG, when compared to PCI, was linked to higher 30-day and one-year survival rates in patients with AMICS. This underscores the need for further validation through multi-center, adequately powered randomized studies and/or prospective registries to conclusively evaluate the absolute benefits and risks of CABG in this patient population.

Article information

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