






**ORIGINAL RESEARCH**

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# Coronary Artery Bypass Graft Surgery in Patients With Acute Coronary Syndromes After Primary Percutaneous Coronary Intervention: A Current Report From the North-Rhine Westphalia Surgical Myocardial Infarction Registry

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**BACKGROUND:** Coronary artery bypass grafting has remained an important treatment option for acute coronary syndromes, particularly in patients (1) with ongoing ischemia and large areas of jeopardized myocardium, if percutaneous coronary intervention (PCI) cannot be performed; (2) following successful PCI of the culprit lesion with further indication for coronary artery bypass grafting; and (3) where PCI is incomplete, not sufficient, or failed.

**METHODS AND RESULTS:** We aimed to analyze coronary artery bypass grafting outcome following prior PCI in acute coronary syndromes from the North-Rhine-Westphalia surgical myocardial infarction registry comprising 2616 patients. Primary end points were in-hospital all-cause mortality and major adverse cardio-cerebral event. Patients were 68±11 years of age, had 3-vessel and left main-stem disease in 80.4% and 45.3%, presenting a logistic EuroSCORE of 15.1% in unstable angina, 20.3% in non-ST-segment-elevation myocardial infarction, and 23.5% in ST-segment-elevation myocardial infarction. A history of PCI was present in 36.2% and PCI was performed within 24 hours before surgery in 5.2% in unstable angina, 5.9% in non-ST-segment-elevation myocardial infarction, and 16.1% in ST-segment-elevation myocardial infarction. PCI failed in 5.3% in unstable angina, 6.8% in non-ST-segment-elevation myocardial infarction and 17.2% in ST-segment-elevation myocardial infarction, and 28.8% of patients presented with cardiogenic shock. In-hospital mortality without PCI was 7.4%, but increased to 8.7% with prior PCI >24 hours, 14.5% with prior PCI <24 hours, and 14.1% with failed PCI ( $P<0.003$ ). The in-hospital major adverse cardio-cerebral event rate was 16.4% without PCI, but 17.4% with prior PCI >24 hours, 25.6% with prior PCI <24 hours, and 41.3% with failed PCI ( $P=0.014$ ). Multivariable logistic regression analysis showed prior PCI ( $P=0.039$ ), as well as failed PCI ( $P=0.001$ ) to be predictors for in-hospital all-cause mortality and major adverse cardio-cerebral event.

**CONCLUSIONS:** In the current PCI era, immediately prior or failed PCI before coronary artery bypass grafting in acute coronary syndromes is associated with high perioperative risk, cardiogenic shock, and increased morbidity and mortality.

**Key Words:** acute coronary syndrome ■ coronary artery bypass grafting ■ outcomes ■ percutaneous coronary intervention ■ registry

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## CLINICAL PERSPECTIVE

### What Is New?

- This prospective multicenter surgical myocardial infarction registry demonstrates that there are a considerable number of patients with acute coronary syndrome (ACS) who, for various reasons and indications, have primarily undergone percutaneous coronary intervention (PCI) and are subsequently referred for coronary artery bypass (CABG) surgery.
- Different clinical scenarios and patient groups can be distinguished, including the following: (1) patients who have ACS with ongoing ischemia and/or large areas of jeopardized myocardium of the infarct-related artery and who are unsuitable for PCI; (2) patients with ACS referred for emergent/urgent CABG surgery after initial successful primary PCI (of the infarct-related artery or culprit lesion) because of a pre-existing indication, such as severe triple-vessel or left main coronary artery disease; and (3) patients with ACS in whom PCI was incomplete, insufficient, or even unsuccessful.

### What Are the Clinical Implications?

- The current North-Rhine-Westphalia Surgical Myocardial Infarction registry analysis showed that emergency CABG remains an important treatment option in the contemporary PCI era.
- In patients with ACS, PCI immediately preceding CABG and a failed PCI before CABG are associated with high perioperative risk, cardiogenic shock, and increased morbidity and mortality.
- Patients with ST-segment–elevation myocardial infarction and failed PCI who are referred to emergency CABG in cardiogenic shock represent the highest-risk category.

### Nonstandard Abbreviations and Acronyms

<b>CS</b>	cardiogenic shock
<b>IHM</b>	in-hospital mortality
<b>MACCE</b>	major adverse cardiac and cerebrovascular event
<b>UA</b>	unstable angina

**P**ercutaneous coronary intervention (PCI) is the primary reperfusion therapy in patients with acute coronary syndromes (ACS), including patients with ST-segment–elevation myocardial infarction (STEMI) and non–ST-segment–elevation myocardial infarction (NSTEMI) ACS or unstable angina (UA).<sup>1–3</sup> While surgical-based revascularization of ACS has

largely been replaced by acute PCI as the primary revascularization strategy,<sup>4</sup> coronary artery bypass grafting (CABG) continues to play an important role in daily routine treatment for specific indications and is in addition faced with a considerable number of patients who, for various reasons and indications, have primarily undergone PCI and are subsequently referred for emergent coronary artery bypass surgery.

Thus, the following different clinical scenarios and patient groups can be distinguished: (1) patients with ACS with ongoing ischemia and large areas of jeopardized myocardium of the infarct-related artery being unsuitable for PCI; (2) patients with ACS referred for emergent or urgent CABG surgery after initial successful primary PCI of infarct-related artery or culprit lesion because of a pre-existing indication such as a severe triple-vessel disease or left main stem stenosis; and (3) ultimately at highest risk, patients with ACS in whom PCI was incomplete, insufficient, or even unsuccessful and had failed.

The purpose of the present analysis was therefore to stratify surgical risk and to evaluate current state-of-the-art surgical treatment and outcomes of CABG surgery following prior PCI among all subtypes of patients with ACS, including unstable angina, NSTEMI, or STEMI.

## METHODS

All data that support the findings from the North-Rhine-Westphalia surgical myocardial infarction registry are available from the corresponding author upon reasonable request.

### Study Population

The present multicentric, all-comers registry, called The Surgical Myocardial Infarction Registry of the Federal State of North-Rhine Westphalia, was physician-initiated in 2009 by 4 academic, high-volume cardiac surgery centers in Germany's most populous federal state, North-Rhine Westphalia, as recently described.<sup>5,6</sup> All consecutive adult patients with ACS with the intention to undergo a surgical-based revascularization therapy were included. Patients with ACS who were successfully treated by primary PCI or medical therapy and thus were not referred to CABG surgery were not entered. Patients were excluded if they were younger than 18 years of age or the preoperative intention was to perform concomitant cardiac surgery in addition to coronary revascularization. The study protocol was approved by the Ethics committee of the University of Duisburg-Essen (15-6553-BO).

The registry prospectively and anonymously collected a comprehensive list of relevant perioperative clinical variables in prespecified data sheets. Over 120

data items per patient, including relevant demographics, and operative and outcome data, were uniformly recorded in the participating centers. As another important part of the North-Rhine-Westphalia Surgical Myocardial Infarction Registry, especially for the present analysis, was the prespecified and detailed query regarding a prior PCI, a prior PCI before and within 24 hours before CABG surgery, as well as the query of a possible unsuccessful or failed PCI. The type of ACS as key inclusion criterion was defined by the local investigators in compliance with current guidelines for UA, NSTEMI, or STEMI.<sup>1,3</sup>

Between January 2010 and December 2017, a total of 2616 adult patients with ACS were enrolled in the registry's database. After validation and data cleansing, only complete data sets with clear identification of the type of ACS and completeness regarding the primary and key secondary end point were included in the final analysis. The overall completeness of the data was 90.4%, and 2432 patients entered the final analysis.

## Outcome Measures and Definitions

All of the outcome measures used in this analysis were prespecified. Given the subjective nature of many clinical outcomes, we only prespecified all-cause in-hospital mortality (IHM) after CABG as the primary study end point. The prespecified secondary end point was the rate of major adverse cardiac and cerebrovascular events (MACCE) as described previously.<sup>5</sup> Indication, timing of surgery, and surgical strategy were left to the discretion of the participating centers. This also included anesthesia, technique of CABG surgery (choice of conduits, off- or on-pump CABG), type of cardioplegia, and postoperative treatment.

## Statistical Analysis

Statistical analysis of all prospectively collected data sheets was performed using the statistical SAS software (SAS Version 9.4, Cary, NC). Descriptive statistics are summarized for categorical variables as frequencies (percentages) and compared between groups with Pearson's  $\chi^2$  test or a 2-sided Cochran-Armitage trend test. Continuous variables are expressed as mean $\pm$ SD and compared between groups with Student's *t* test. Univariate and multivariate logistic regressions were performed to identify preoperative independent predictors for cardiogenic shock (CS) as well as IHM/MACCE in the overall ACS study cohort. Those variables identified by univariate regression analysis with a probability value  $\leq 0.05$  for at least 1 study end point were added to the multivariate logistic-regression model. Results are presented as odds ratios (OR) with corresponding 95% CI. All reported *P* values are 2-sided and *P* $< 0.05$  were considered statistically significant.

## RESULTS

### Preoperative Characteristics of the ACS Population

Demographic data and preoperative characteristics of the 2432 included patients with ACS who underwent CABG surgery with or without prior PCI and are summarized in Table 1. Of all the patients with ACS admitted to CABG surgery, 25% of them presented with UA, 50% with NSTEMI, and 25% with STEMI. Patients were 68 $\pm$ 11 years of age, 78% male, presenting a logistic EuroSCORE I of 15.1% in UA, 20.3% in NSTEMI, and 23.5% in patients with STEMI.

### Preoperative Characteristics of Patients With Prior PCI in the ACS Population

A history of prior PCI was present in 36.2% (n=878) out of all patients with ACS (n=2432). In those patients with prior PCI, 245 (27.9%) presented with unstable angina, 373 (42.5%) with NSTEMI, and 260 (29.6%) with STEMI (Table 1). According to the patients' preoperative risk profile, those patients with prior PCI more frequently had arterial hypertension (89.2% versus 83.2%; *P* $< 0.001$ ) and hyperlipidemia (65.3% versus 53.0%; *P* $< 0.001$ ) compared with those without PCI. Patients with PCI more often had a single-vessel disease (4.4% versus 2.5%; *P*=0.013) and conversely, less often a triple-vessel (77.4% versus 82.2%; *P* $< 0.005$ ) or left main disease (42.3% versus 47.1%; *P*=0.02). Not surprisingly, patients with prior PCI had a significantly higher number of prior myocardial infarction (36.2% versus 21.6%; *P* $< 0.001$ ), but did not differ in their preoperative left ventricular ejection fraction. Regarding preoperative medication, 95% of all patients had aspirin, but patients with PCI had significantly more clopidogrel (55.0% versus 47.4%; *P* $< 0.001$ ) and dual antiplatelet therapy before surgery (56.4% versus 48.1%; *P* $< 0.001$ ). Of note, preoperative risk stratification by logistic EuroSCORE I was slightly lower in patients with prior PCI (17.3% versus 19.2%; *P*=0.015), but the STS score was higher (6.7% versus 5.6%; *P* $< 0.04$ ). Preoperative myocardial biomarker levels in patients with prior PCI showed lower troponin I (2.2 $\pm$ 7.3 versus 3.6 $\pm$ 10.1 ng/mL; *P*=0.013), but higher troponin T levels (1.1 $\pm$ 2.2 versus 0.9 $\pm$ 1.8 ng/mL; *P*=0.023) before surgery. Patients with PCI more often presented with a status after cardiopulmonary resuscitation (10.4% versus 7.4%; *P*=0.011) before CABG surgery. Some of the patients (26.6%) who initially underwent PCI because of ACS and immediately thereafter (within 24 hours) had to undergo a subsequent CABG surgery presented with unstable angina in 5.9%, NSTEMI in 7.0%, and STEMI in 18.4%. A total of 17.6% of the patients had a history of PCI

**Table 1. Baseline Characteristics in All Patients With ACS, in Patients With ACS Without Versus With Prior PCI**

	All ACS (n=2432)	No PCI (n=1545)	PCI (n=878)	P value*
ACS subtypes				
UA	24.5 (596/2432)	22.6 (349/596)	27.9 (245/596)	
NSTEMI	50.0 (1218/2432)	54.4 (841/1218)	42.5 (373/1218)	<0.001
STEMI	25.4 (618/2432)	23.0 (355/618)	29.6 (260/618)	
Demographics				
Age, y	67.8±10.6	68.1±10.8	67.1±10.3	0.020
Male sex	77.6 (1887/2432)	78.5 (1212/1545)	76.3 (670/878)	0.244
BMI, kg/m <sup>2</sup>	28.0±4.8	27.9±4.7	28.1±4.9	0.504
Risk factors and comorbidities				
Diabetes	32.1 (772/2405)	31.3 (482/1539)	33.3 (286/860)	0.329
Hypertension	85.5 (1797/2103)	83.2 (1099/1321)	89.2 (691/775)	<0.001
Hyperlipidemia	57.6 (1211/2102)	53.0 (700/1321)	65.3 (506/775)	<0.001
PVD	14.8 (357/2416)	13.4 (207/1540)	17.2 (149/869)	0.013
COPD	12.7 (308/2422)	11.7 (180/1542)	14.6 (127/873)	0.041
Prior stroke	10.0 (243/2421)	10.2 (158/1544)	9.7 (84/869)	0.656
Renal failure	17.5 (423/2424)	16.9 (260/1540)	18.2 (160/877)	0.395
Cardiac history				
Triple-vessel disease	80.5 (1956/2431)	82.2 (1269/1544)	77.5 (680/878)	0.004
Left mainstem disease	45.4 (1098/2421)	47.1 (727/1542)	42.3 (369/873)	0.020
Prior myocardial infarction	27.1 (656/2424)	21.6 (333/1543)	36.2 (316/873)	<0.001
LVEF, %	50.3±14.6	50.5±14.7	49.9±14.5	0.380
Prior cardiac surgery	2.2 (44/1968)	1.3 (16/1214)	3.7 (28/748)	<0.001
Risk-scores				
Log EuroSCORE, %	18.5±18.1	19.2±18.5	17.3±17.3	0.015
STS score, %	6.0±9.4	5.6±9.2	6.7±9.7	0.044
PCI and lysis history				
Prior thrombolysis, % (n)	1.0 (19/1923)	0.8 (9/1191)	1.4 (10/729)	0.185
Prior PCI	36.2 (878/2423)	0.0 (0/1545)	100.0 (878/878)	<0.001
PCI <24 h	12.1 (234/1928)	0.0 (0/1190)	31.8 (234/735)	<0.001
Failed PCI	9.2 (177/1922)	0.0 (0/1191)	24.3 (177/728)	<0.001
Preoperative status				
CPR	8.5 (205/2426)	7.4 (114/1543)	10.4 (91/878)	0.011
IABP support	6.5 (158/2421)	6.4 (99/1544)	6.6 (58/873)	0.824
ECLS support	0.1 (2/2420)	0.1 (1/1543)	0.1 (1/873)	0.683
Cardiogenic shock	13.2 (321/2424)	12.8 (197/1541)	13.9 (122/877)	0.353
Killip class IV, % (n)	12.1 (288/2379)	11.8 (181/1533)	12.5 (105/841)	0.627

Baseline characteristics of the ACS patient cohort and in patients with no PCI (n=1545) vs with PCI (n=878) before surgical revascularization. Values are expressed as mean (SD) or percentages (counts). ACS indicates acute coronary syndrome; BMI, body mass index; COPD, chronic obstructive pulmonary disease; CPR, cardiopulmonary resuscitation; ECLS, extracorporeal life support; IABP, intra-aortic balloon pump; LVEF, left ventricular ejection fraction; NSTEMI, non-ST-segment-elevation myocardial infarction; PCI, percutaneous coronary intervention; PVD, peripheral vascular disease; STEMI, ST-segment-elevation myocardial infarction; and UA, unstable angina.

\*P value between No PCI vs PCI group.

within 6 hours before CABG surgery and presented with unstable angina in 3.7%, NSTEMI in 3.4%, and STEMI in 14.7%. Of note, a total of 20.2% of the patients underwent CABG surgery after failed PCI and 30.5% of them presented with CS or Killip class 4. To confirm the associated risk of prior PCI before CABG surgery, a multivariable logistic regression analysis revealed failed PCI, and PCI within 24 hours before

CABG surgery, to be an independent predictor for CS ( $P<0.01$ ).

### Impact on Outcomes of Prior PCI Procedures in the ACS Population

According to intraoperative and postoperative results (Tables 2 and 3), patients with prior PCI had a

significantly lower number of bypass grafts ( $2.5\pm 0.8$  versus  $2.6\pm 0.7$ ;  $P<0.001$ ) in total, a reduced use of arterial grafts ( $1.1\pm 0.4$  versus  $1.2\pm 0.7$ ;  $P<0.001$ ), and a reduced use of left internal thoracic artery grafts (90.0% versus 94.8%;  $P<0.001$ ). Postoperatively, there was a significantly higher rate of re-thoracotomy in patients with prior PCI (5.7% versus 8.7%;  $P=0.003$ ).

Overall IHM and MACCE of patients with ACS undergoing CABG surgery were 7.4% and 16.4% without PCI, 8.7% and 17.4% with PCI >24 hours, but significantly increased to 14.5% and 25.6% with PCI <24 hours and 14.1% and 41.3% with failed PCI (Figure 1). In patients without prior PCI, IHM and MACCE occurred in 3.2% and 6.6% in UA, 7.4% and 16.1% in NSTEMI, and 11.8% and 26.8% in STEMI (Figure 2), but rose significantly with PCI >24 hours before CABG surgery to 5.2% and 7.6% in UA, 9.4% and 18.1% in NSTEMI, and 12.3% and 30.1% in STEMI ( $P<0.001$ ). In patients with PCI <24 hours before CABG surgery, the IHM and MACCE rate tended to be higher with 5.7% and 11.4% in UA, but interestingly in patients with NSTEMI, IHM was significantly lower with 4.7% but the MACCE rate remained unchanged with 16.5%. However, in the STEMI group, again the IHM and MACCE rate were significantly increased to 15.8% and 38.8% ( $P<0.01$ ; Figure 2).

### Impact on Outcomes of Failed PCI in the ACS Population

The incidence of unsuccessful or failed PCI in the cohort of all patients with ACS was 7.3%, while the incidence in ACS subgroups was 5.4% for patients with UA, 4.5% for patients with NSTEMI, and rose to 14.6% in patients with STEMI. In the subset of patients with a status after PCI, the incidence of failed PCI was as high as 20.2%.

Patients with failed PCI before CABG surgery had a significantly lower number of bypass grafts ( $2.3\pm 0.8$  versus  $2.6\pm 0.7$ ;  $P<0.001$ ), and also a reduced use of left internal thoracic artery and right internal thoracic artery grafts (84% and 5% versus 93% and 7%;  $P<0.001$ ). Cardiopulmonary bypass time was shorter ( $89\pm 44$  minutes versus  $100\pm 42$  minutes;  $P<0.001$ ), but the use rate of postoperative intra-aortic balloon pump and

extracorporeal life support was significantly higher (31% and 4% versus 15% and 2%;  $P<0.001$ ), and the rate of postoperative bleeding with a significantly higher rate of transfusion >5 times red blood cells was significantly higher in these patients (29% versus 19%;  $P<0.012$ ).

In patients with UA, IHM and MACCE increased with failed PCI to 9.4% and 15.6%. In the NSTEMI group, however, again IHM appeared to be lower with 1.8% only, but the MACCE rate increased to 20.0%. In patients with STEMI, IHM and MACCE further increased to 21.1% and 31.1% ( $P<0.001$ ) and showed the highest rate with 28.9% and 47.4% ( $P<0.0001$ ) in patients with failed PCI and CS. In a first multivariate logistic regression model (Table 4) several patient characteristics, risk factors, and comorbidities, such as age, gender, hyperlipidemia, peripheral vascular disease, left main-stem disease, and left ventricular ejection fraction <30%, log EuroSCORE, as well as failed PCI were identified as preoperative independent predictors for CS.

In a second multivariable logistic regression model, age, sex, hyperlipidemia, peripheral vascular disease, prior cardiopulmonary resuscitation, low left ventricular ejection fraction <30%, Killip class IV, prior thrombolysis, log EuroSCORE, as well as prior PCI ( $P=0.039$ ; OR, 1.25 [95% CI, 1.01–1.56]) and failed PCI ( $P=0.001$ ; OR, 1.88 [95% CI, 1.31–2.70]) were found to be independent predictors for the combined end point of IHM and MACCE (Table 4).

## DISCUSSION

The present prospective, multicenter, all-comers registry of patients treated by surgical revascularization with CABG surgery for acute myocardial infarction with all subtypes of ACS reports the current situation and the current treatment strategies in the most populous (18 million inhabitants) Federal State of Germany, North-Rhine Westphalia. Currently, the registry consists of >2600 patients who were admitted to CABG surgery because of ACS, and an initial report of its results has been published recently.<sup>5,6</sup> In this present all-comers study of a “real-world” data set, we now focused on the risk assessment and surgical outcomes of patients

**Table 2. Operative Characteristics in All Patients With ACS, in Patients With ACS Without Versus With Prior PCI**

	All ACS (n=2432)	No PCI (n=1545)	PCI (n=878)	P value*
No. of bypass grafts	2.6±0.7	2.6±0.7	2.5±0.7	<0.001
Arterial grafts	1.2±0.6	1.3±0.5	1.2±0.6	<0.001
LITA	93.1 (2257/2424)	94.8 (1464/1544)	90.4 (790/874)	<0.001
RITA	6.9 (168/2422)	7.1 (109/1543)	6.7 (59/873)	0.776
CPB	100.4±41.9	99.8±41.6	100.9±42.5	0.547

Operative characteristics of the ACS patient cohort and in patients with no PCI (n=1545) vs with PCI (n=878) before surgical revascularization. Values are expressed as mean (SD) or percentages (counts). ACS indicates acute coronary syndrome; CPB, cardiopulmonary bypass; LITA, left internal thoracic artery; PCI, percutaneous coronary intervention; and RITA, right internal thoracic artery.

\*P value between No PCI vs PCI group.

**Table 3. Clinical Outcomes in All Patients With ACS, in Patients With ACS Without Versus With Prior PCI**

	All ACS (n=2432)	No PCI (n=1545)	PCI (n=878)	P value*
Post-CPR	4.7 (115/2432)	4.5 (69/1545)	5.1 (45/878)	0.461
Post-IABP	15.6 (378/2426)	15.7 (243/1545)	15.2 (133/875)	0.730
Post-ECLS	1.7 (42/2421)	1.8 (27/1542)	1.7 (15/873)	0.952
Transfusions >5RPC/48 h	20.0 (382/1913)	20.8 (246/1184)	18.6 (135/726)	0.246
Re-thoracotomy	6.8 (164/2419)	5.7 (87/1541)	8.7 (76/871)	0.003
ICU stay, d	5.27±6.50	5.2±6.8	5.5±6.0	0.294
Hospital stay (survivors), d	12.95±12.14	13.2±10.3	12.5±14.8	0.293
Hospital stay (nonsurvivor), d	11.28±13.73	10.2±11.9	12.0±14.2	0.365
PMI	2.33 (55/2432)	2.3 (35/1545)	2.2 (19/878)	0.192
LCOS	12.8 (311/2432)	12.4 (191/1545)	13.6 (119/878)	0.870
Stroke	2.5 (62/2432)	2.7 (41/1545)	2.4 (21/878)	0.398

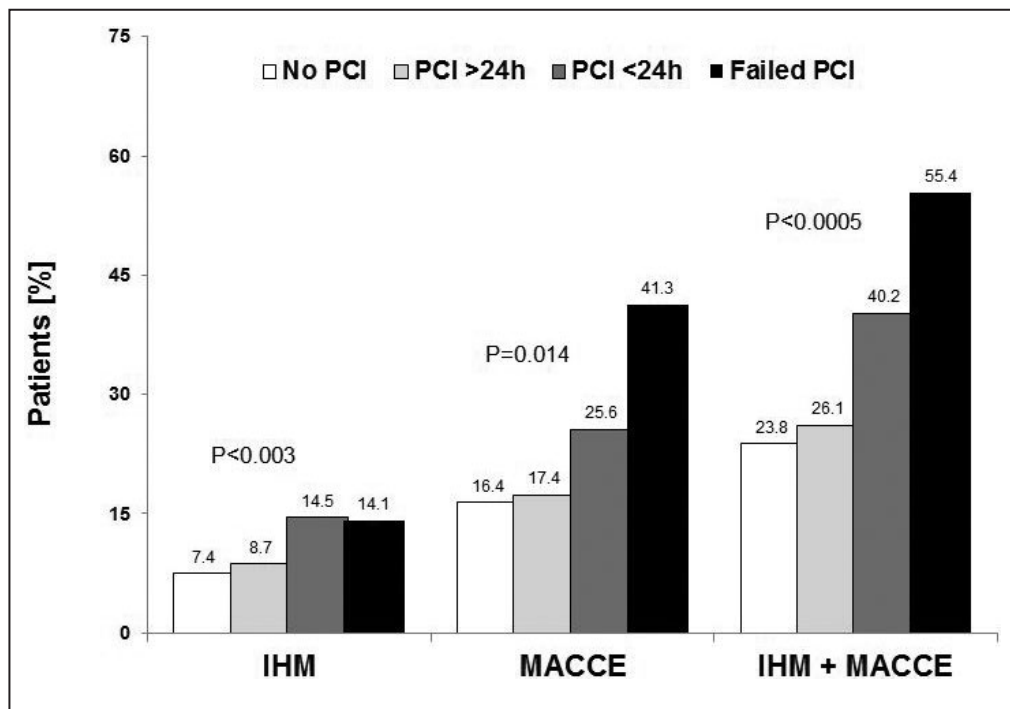
Postoperative clinical outcomes of the ACS patient cohort (n=2432) and in patients with no PCI (n=1545) vs with PCI (n=878) before surgical revascularization. Values are expressed as mean (SD) or percentages (counts). ACS indicates acute coronary syndrome; CPR, cardiopulmonary resuscitation; ECLS, extracorporeal life support; IABP, intra-aortic balloon pump; ICU, intensive care unit; PCI, percutaneous coronary intervention; and RPC, red packed cells.

\*P value between No PCI vs PCI group.

who were referred to CABG surgery after and with a prior PCI procedure, either by following a successful PCI of the culprit lesion with a further indication for CABG surgery or where PCI was incomplete, not sufficient, or had failed.

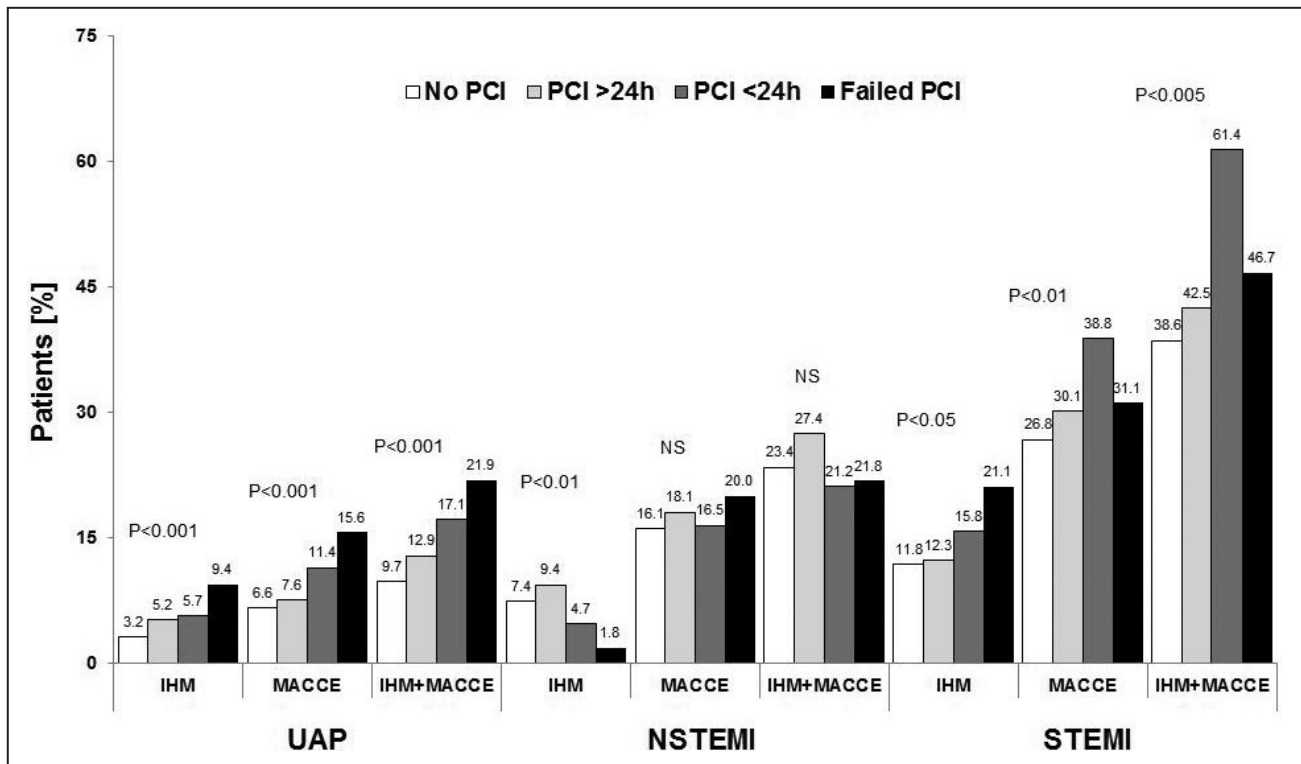
First, in the current era of PCI, “The North-Rhine-Westphalia Surgical Myocardial Infarction Registry”

clearly showed that emergency CABG still remains an important treatment option. As a result, emergency CABG after PCI is associated with a substantial IHM and MACCE rate, but patients’ outcomes would probably be much worse in the absence of such emergency CABG treatment. Therefore, the present analysis clearly demonstrates that the requirement for



**Figure 1. IHM, MACCE, and its cumulative value (IHM+MACCE) in patients with no PCI, with prior PCI >24 hours, with prior PCI <24 hours, and with failed PCI before surgical myocardial revascularization in all patients with ACS.**

P values indicate the significance between groups with no PCI, PCI >24 hours, and PCI <24 hours before coronary artery bypass grafting calculated by a 2-sided Cochran-Armitage trend test. ACS indicates acute coronary syndrome; IHM, in-hospital mortality; MACCE, major adverse cardio-cerebral events; and PCI, percutaneous coronary intervention.



**Figure 2.** IHM, MACCE, and its cumulative end point (IHM+MACCE) in patients without PCI, with prior PCI >24 hours, with prior PCI <24 hours, and in patients with failed PCI before surgical myocardial revascularization in all ACS subtypes, UAP, NSTEMI, and STEMI.

*P* values indicate the significance between groups with no PCI, PCI >24 hours, and PCI <24 hours before coronary artery bypass grafting calculated by a 2-sided Cochran-Armitage trend test. ACS indicates acute coronary syndrome; IHM, in-hospital mortality; MACCE, major adverse cardio-cerebral events; NS, not significant; PCI, percutaneous coronary intervention; NSTEMI, non-ST-segment-elevation myocardial infarction; STEMI, ST-segment-elevation myocardial infarction; and UAP, unstable angina pectoris.

emergency CABG following PCI treatment in all types of ACS continues to be a relevant issue in the current area of interventional treatment of ACS.

Second, by differentiating PCI subgroups with regard to their subsequent urgency, we could demonstrate that acute and subsequent CABG before PCI within 24 hours, as well as a failed PCI in this scenario, is associated with a considerable perioperative risk and CS, which in turn is clearly associated with increased morbidity and mortality following CABG surgery. Interestingly, in the subgroup of patients with NSTEMI, it was shown that in the group of patients operated on within 24 hours after PCI, surprisingly a significantly lower mortality was observed with an overall relatively low event rate, but as in the UA and STEMI group, there was a tendency toward an increased MACCE rate.

Although surgical revascularization for reperfusion therapy in ACS has been largely superseded by primary PCI, and the indication for coronary bypass surgery in ACS, especially in STEMI, has also been pushed far into the background in the current ACS guidelines,<sup>1,3,7</sup> not at least this surgical infarction

registry shows that acute coronary artery bypass surgery remains an important treatment option in these different scenarios of ACS (1) with ongoing ischemia and large areas of jeopardized myocardium, if PCI cannot be performed; or (2) following successful PCI of the culprit lesion with a further indication for CABG surgery; or (3) where PCI was incomplete, not sufficient, or has even failed.

We and others clearly demonstrated that in elective CABG surgery, the patient outcome in terms of mortality and MACCE rate can be compromised by prior PCI procedures regarding short- but also long-term prognosis.<sup>8-10</sup> In this current era of PCI treatment and because 15% to 30% of PCI-treated patients with coronary artery disease will furthermore require “post-PCI” coronary revascularization<sup>2,11,12</sup> and nearly 20% of those will be referred to CABG surgery at some time after stenting, the number of “stent-loaded” patients is likewise increasing and will probably further increase. The situation in patients with ACS is on the one hand different compared with the elective coronary artery disease treatment, but on the other hand, patients with severe or even end-stage coronary artery disease with

**Table 4. Multivariable Logistic Regression Analysis Identifying Preoperative Predictors for CS, and IHM/MACCE in All Patients With ACS**

	Cardiogenic shock		IHM/MACCE	
	OR (95% CI)	P value	OR (95% CI)	P value
Age, y	0.93 (0.91–0.95)	<0.001	1.03 (1.00–1.05)	0.018
Sex, female	...	...	1.37 (1.02–1.93)	0.031
Hyperlipidemia	1.79 (1.23–2.61)	0.002	1.81 (1.18–1.89)	0.002
Peripheral vascular disease	3.92 (2.15–7.14)	<0.001	1.72 (1.25–2.47)	0.005
Left main-stem disease	1.68 (1.16–2.44)	0.006	...	...
Prior myocardial infarction	...	...	0.98 (0.71–1.37)	0.919
Prior CPR	...	...	5.10 (3.78–6.87)	<0.001
LVEF <30%	0.98 (0.97–0.99)	<0.001	1.68 (1.52–1.87)	<0.001
Killip class IV	...	...	1.37 (1.01–1.86)	0.042
Thrombolysis	...	...	4.61 (1.85–11.43)	0.001
Log EuroSCORE	1.08 (1.07–1.09)	<0.001	1.12 (1.07–1.73)	0.035
Prior PCI	...	...	1.25 (1.01–1.56)	0.039
Failed PCI	4.11 (2.85–5.91)	<0.001	1.88 (1.31–2.70)	0.001

Multivariable logistic regression analysis identifying independent preoperative factors associated with CS and the cumulative end point of IHM and MACCE in all patients with ACS. ACS indicates acute coronary syndrome; CPR, cardiopulmonary resuscitation; CS, cardiogenic shock; IHM, in-hospital mortality; LVEF, left ventricular ejection fraction; MACCE, major adverse cardiac and cerebrovascular event; OR, odds ratio; and PCI, percutaneous coronary intervention.

acute myocardial infarction primarily treated with PCI may still have a further indication for CABG surgery.

Currently, the clinical scenarios of patients who are referred to CABG surgery with ACS can be different and various. Here and in our recent report<sup>5</sup> we demonstrated that there are still a notable number of patients in daily practice who present with ACS being directly referred to a surgical revascularization strategy after initial coronary angiography without any PCI “pre”-treatment. This is especially true for patients with severe multivessel and/or left main-stem disease in whom the decision and indication for CABG surgery has outweighed the risk of acute “high-risk” PCI. Furthermore, CABG surgery is sometimes indicated in patients with ACS in whom acute PCI of a culprit lesion has been performed successfully. However, contrary to our initial assumption before the present evaluation, the registry has uncovered and shown that the risk of subsequent surgical revascularization in patients “pretreated” with PCI of the culprit lesion is unfortunately not reduced in all subtypes, but is significantly increased in terms of mortality and MACCE in patients with unstable angina and STEMI, whereas mortality appears to be lower with PCI <24 hours and failed PCI in the NSTEMI group. Finally, there are still a substantial number of patients, also in this registry with a total 9.2% in all patients with ACS (STEMI 17.2%, NSTEMI 6.7%, and UA 5.4%), where elective or emergent PCI was unsuccessful or has failed. These patients with ACS, and especially those presenting with STEMI and CS, do have the highest perioperative risk in terms of IHM and/or MACCE for emergency CABG surgery. The present multivariable regression analysis confirmed

that various preoperative independent predictors such as age, female sex, hyperlipidemia, peripheral vascular disease, reduced left ventricular ejection fraction, prior cardiopulmonary resuscitation, prior thrombolysis, Killip class IV, and logistic EuroSCORE I,<sup>13–18</sup> in addition prior PCI, as well as failed PCI operated as independent predictors for IHM and MACCE. Therefore, emergency CABG surgery is still an important part of an optimal treatment strategy and must be considered as a complementary treatment option in selected patients with extensive coronary disease.

The finding of a significantly increased risk of emergency CABG surgery in patients after unsuccessful, failed elective, or even failed emergency PCI is of course not new and has been described and discussed many times since the introduction of catheter-based coronary revascularization strategies.<sup>19–23</sup> However, it is noteworthy that even though the incidence of failed PCI may have decreased, the number of patients who ultimately require surgical treatment is still remarkably high with a percentage of 9.2% in this current registry, especially in view of the many times higher number of patients who are primarily stented because of ACS currently. The present evaluation clearly shows that especially patients with STEMI and failed PCI, who are referred to emergency bypass surgery in cardiogenic shock, are still in the highest risk category.

### Limitations

Several limitations need to be acknowledged, which are inherent in such a multicenter all-comers registry, especially when it comes to data acquisition from acutely treated patients. First, this



physician-initiated registry was nonrandomized and had a nonpowered study design for all investigated early primary and secondary outcome measures, as well as for all subgroup analysis. Second, this registry unfortunately does not give exact information about the type and technique of PCI nor the urgency of PCI. There was also no information on whether PCI was acutely performed because of ACS or, conversely, whether elective PCI itself was the cause of ACS, especially in the case of a failed PCI. Third, although great efforts were made to collect all relevant data prospectively and at the patient's bedside in predefined data sheets, the completeness varied for many data elements, as was clearly stated here in the Methods section and explicitly reported in the present tables. Therefore, such missing data may have influenced our results and the significance of the data. Finally, although we cannot definitely rule out an institutional treatment bias in this surgical myocardial infarction registry, we strongly believe that the present large sample size and multicentric approach may have limited such a bias of individual institutional policies with regard to indication and decision-making for revascularization strategy, timing of CABG surgery, as well as all other intraoperative and adjuvant treatment strategies and clinical outcomes in this ACS cohort.

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