Impact of Hemodynamic Support on Outcome in Patients Undergoing High-Risk Percutaneous Coronary Intervention

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The use of left-ventricular (LV) hemodynamic support might facilitate high-risk percutaneous coronary interventions (PCI) in patients with complex coronary artery disease. The impact on outcome is a matter of ongoing debate. We assessed the outcome of high-risk patients who underwent protected PCI in comparison to patients who underwent unprotected high-risk PCI. One hundred and thirty nine patients underwent nonemergent high-risk PCI; 24 (17%) patients underwent protected PCI. To address selection bias, we performed a propensity score matched subanalysis. The primary end point was the occurrence of a major adverse cardiac event during the first year. Patients with protected PCI had a higher logistic EuroSCORE (logES) (protected PCI: 19% vs unprotected PCI: 12%; p = 0.01), a higher SYNTAX score (45 vs 36, p = 0.07), and significantly more often reduced LV function (40% vs 55%; p < 0.001). In protected PCI patients, complete revascularization was more often achieved (87% vs 58%, p = 0.007) without the occurrence of death at 30 days of follow-up (0% vs 4%, p = 0.31). After propensity score matching, patients who underwent protected PCI had a similar 1-year major adverse cardiac event rate compared with patients who underwent unprotected PCI (21% vs 17%, p = 0.67), despite significantly higher procedural complexity for example, more often complex left main bifurcation lesions (71% vs 29%; p = 0.004). In conclusion, 1-year outcome of patients who underwent protected PCI was not different from that in patients with less complex procedures without hemodynamic support, despite more complex coronary anatomy, a higher comorbidity burden, and more often reduced LV function. **(Am J Cardiol 2019;124:20−30)**

Patients with unprotected left main or advanced multivessel coronary artery disease (CAD), impaired left-ventricular (LV) function, and severe co-morbidities often cannot undergo surgical revascularization due to the very high periprocedural risk.[1,2] Percutaneous coronary intervention (PCI) is a viable treatment option for many of these challenging patients, but also has a certain risk.[2−4] To maintain systemic perfusion during high-risk PCI, LV assist devices such as the Impella 2.5 are used in these individuals as part of a so-called "protected PCI."[5,6] According to the 2011 American College of Cardiology/American Heart Association/Society for Cardiovascular Angiography and Interventions Guidelines for PCI, the use of hemodynamic support devices during PCI in carefully selected high-risk patients has a class IIb indication.[7] We assessed the clinical outcome of high-risk patients who underwent protected PCI under LV hemodynamic support with the Impella device in comparison to patients who underwent conventional high-risk PCI without support.

Methods

Between February 2014 and December 2017, a total of 139 patients with unprotected left main and complex CAD who were turned down for coronary artery bypass grafting after heart team discussion underwent high-risk PCI at the Heart Center Bonn.

Patients with significant distal left main coronary artery stenosis (diameter stenosis ≥50%) or left main coronary artery equivalent (ostial left anterior descending or left circumflex stenosis ≥70%) undergoing elective, nonemergent PCI were included. Patients with ST-segment elevation myocardial infarction (MI), cardiogenic shock, or hemodynamic instability before intervention were excluded. Additionally, contraindications for the use of the Impella device such as ventricular thrombus etc. have been considered.[8] No other inclusion or exclusion criteria were defined.

Out of 139 patients, 24 (17.3%) were treated with hemodynamic support due to very complex coronary anatomy in combination with impaired LV function and/or concomitant co-morbidities. We compared baseline, procedural, and outcome data between patients who underwent protected PCI in comparison with patients who underwent nonprotected

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high-risk PCI. To address selection and therapy bias in our study, we performed a subanalysis with 24 nonprotected PCI patients matched for LV ejection fraction (LVEF), logistic EuroSCORE (logES), and SYNTAX score (SS).

The LV assisted devices Impella 2.5 (75.0%) and Impella CP (25.0%) (Abiomed Inc, Danvers, Massachusetts) were used for hemodynamic support. Both devices are axial flow, rotary blood pumps generating up to 2.5 to 4.0 L/min of nonpulsatile forward flow. The Impella is inserted through the femoral artery retrogradely across the aortic valve into the left ventricle to pull blood from the ventricle into the ascending aorta. This pump increases the cardiac output, ensures stable mean arterial pressure, coronary- and end organ perfusion, as well as reduces wall stress and myocardial oxygen consumption during the procedure.[8–10] No other hemodynamic support device such as the intra-aortic balloon pump was used during the study period. In all high-risk PCI cases, it was at the discretion of the operator (GN, NW, JMS) to use an Impella device if temporary support was thought to be necessary or to go for a "minimalist" approach without additional support.

In all 24 cases the Impella device was placed through the femoral artery under fluoroscopic guidance in the cardiac catheterization laboratory. All PCIs were performed by 1 of 3 experienced interventional cardiologists (GN, NW, JMS) trained in complex PCI procedures and the implantation of

Table 1
Baseline characteristics—all patients

Variable	All patients (n = 139)	Protected percutaneous coronary intervention (n = 24)	Unprotected percutaneous coronary intervention (n = 115)	p Value
Men	101 (73%)	20 (83%)	81 (70%)	0.2
Age (years)	78 ± 9	78 ± 9	78 ± 9	0.96
Body mass index (kg/m^2)	26 ± 5	25 ± 5	27 ± 5	0.67
NYHA class				0.006
I	25 (19%)	1 (4%)	24 (22%)	
II	27 (21%)	1 (4%)	26 (24%)	
III	49 (38%)	10 (45%)	39 (36%)	
IV	27 (21%)	10 (45%)	17 (16%)	
CCS class				0.65
I	27 (21%)	5 (23%)	22 (21%)	
II	21 (17%)	5 (23%)	16 (15%)	
III	28 (22%)	3 (14%)	25 (24%)	
IV	46 (36%)	9 (41%)	37 (36%)	
Aortic aneurysm	13(9%)	4 (17%)	9 (8%)	0.18
Coronary artery disease	108 (78%)	20 (83%)	88 (76%)	0.47
Chronic obstructive pulmonary disease	25 (18%)	2 (8%)	23 (20%)	0.18
Dementia	12 (9%)	2 (8%)	10 (7%)	0.95
Diabetes				0.25
Insulin dependent	18 (13%)	5 (21%)	13 (11%)	
Noninsulin dependent	21 (15%)	5 (21%)	16 (14%)	
Smoker	50 (36%)	10 (42%)	40 (29%)	0.89
Hypercholesterolemia	62 (45%)	10 (42%)	52 (45%)	0.75
Extracardiac arteriopathy	51 (37%)	8 (33%)	43 (37%)	0.7
Hypertension	116 (83%)	18 (75%)	98 (85%)	0.22
Prior pacemaker	20 (14%)	6 (25%)	14 (12%)	0.002
Peripheral artery disease	38 (27%)	5 (21%)	33 (29%)	0.43
Prior myocardial infarction	26 (19%)	7 (29%)	19 (16%)	0.15
Previous stroke	24 (17%)	5 (21%)	19 (16%)	0.61
Pulmonary hypertension	39 (28%)	9 (37%)	30 (26%)	0.26
Renal failure	54 (39%)	10 (42%)	44 (38%)	0.76
Dialysis	5 (4%)	0 (0%)	5 (4%)	0.29
Prior bypass grafting,	4 (3%)	1 (4%)	3 (3%)	0.68
Previous valve surgery	3 (2%)	0 (0%)	3 (3%)	0.42
Logistic EuroSCORE	12 (6/23)	19 (11/33)	12 (5/20)	0.011
EuroSCORE II	4 (2/7)	7 (4/18)	4 (2/6)	<0.001
SYNTAX Score	36 (24/45)	45 (25/52)	36 (24/43)	0.07
Residual SYNTAX Score	7 (2/15)	10 (2/19)	7 (2/15)	0.08
SYNTAX Score II	49 (39/58)	54 (45/64)	48 (38/57)	0.02
STS PROM	3 (1/5)	5 (3/9)	2 (1/4)	<0.001
Left ventricular ejection fraction (%)	55 (40/60)	40 (28/49)	55 (45/62)	<0.001
eGFR (ml/min)	57 ± 16	51 ± 18	58 ± 16	0.46
Leukocytes	7 (6/9)	8 (6/10)	7 (6/9)	0.25
Troponin	0.5 (0.04/2.4)	2.7 (0.6/11)	0.3 (0.03/1.8)	0.012

Hypercholesterolemia is defined as the daily intake of statins; Hypertension is defined as the daily intake of at least one antihypertensive drug. Coronary artery disease occurs if a coronary artery stenosis with a diameter stenosis of ≥50% is already known.

Values are mean ± SD, or median with interquartile range (quartile 1 to quartile 3).

the Impella device. Percutaneous revascularization was aimed at coronary stenosis of left main ≥50% or stenosis of proximal vessels ≥70% in all patients. Furthermore, coronary lesions with a diameter stenosis ≥70% have been treated in side branches with a diameter ≥2.5 mm. Interventional strategies including access site, stent type, adjunctive medication as well as additional therapies such as rotational atherectomy or access site preclosure techniques were left to the discretion of the treating operator.

The SS was used to quantify CAD severity and complexity. Additionally, bifurcation lesions were classified according to the DKCRUSH-V randomized trial into complex bifurcation lesions (lesion length ≥10 mm and diameter stenosis ≥70%) and simple lesions (lesion length <10 mm and diameter stenosis <70%).[11] In case of a staged procedure to continue revascularization in the nonprotected PCI group, we used the final angiography to assess the achievement of a "complete revascularization."

The primary end point of our study was the occurrence of a major adverse cardiac event (MACE)−−a composite of death from cardiovascular cause, nonfatal MI, and target lesion failure−−during the first year.

After discharge of the patient, clinical follow-up data were prospectively collected during scheduled outpatient clinic visits or direct telephone interviews of referring cardiologists, general practitioners, and patients. Examination

Table 2
Baseline characteristics—propensity score matched analysis

	All patients (n = 48)	Protected percutaneous coronary intervention (n = 24)	Unprotected percutaneous coronary intervention (n = 24)	p Value
Men	39 (81%)	20 (83%)	19 (79%)	0.71
Age (years)	79 ± 7	78 ± 9	81 ± 6	0.32
Body mass index (kg/m^2)	26 ± 5	25 ± 5	27 ± 5	0.36
NYHA class				0.24
I	4 (8%)	1 (4%)	3 (13%)	
II	6 (13%)	1 (4%)	5 (21%)	
III	19 (40%)	10 (46%)	9 (38%)	
IV	17 (35%)	10 (46%)	7 (29%)	
CCS class				0.67
I	10 (2%)	5 (23%)	5 (23%)	
II	7 (15%)	5 (23%)	2 (10%)	
III	6 (13%)	3 (14%)	3 (14%)	
IV	19 (40%)	9 (41%)	10 (48%)	
Aortic aneurysm	6 (13%)	4 (17%)	2 (8%)	0.38
Coronary artery disease	37 (77%)	20 (83%)	17 (71%)	0.30
Chronic obstructive pulmonary disease	7 (15%)	2 (8%)	5 (21%)	0.22
Dementia	5 (10%)	2 (8%)	3 (13%)	0.64
Diabetes				0.73
Insulin dependent	10 (21%)	5 (21%)	5 (21%)	
Noninsulin dependent	8 (17%)	5 (21%)	3 (13%)	
Smoker	16 (33%)	10 (42%)	6 (25%)	0.026
Hypercholesterolemia	20 (42%)	10 (42%)	10 (42%)	1.0
Extracardiac arteriopathie	18 (38%)	8 (33%)	10 (42%)	0.55
Hypertension	37 (77%)	18 (75%)	19 (79%)	0.73
Prior pacemaker	9 (19%)	6 (25%)	3 (13%)	0.22
Peripheral artery disease	14 (29%)	5 (21%)	9 (38%)	0.2
Prior myocardial infarction	8 (17%)	7 (29%)	1 (4%)	0.02
Previous stroke	9 (19%)	5 (21%)	4 (17%)	0.7
Pulmonary hypertension	17 (35%)	9 (38%)	8 (33%)	0.76
Renal failure	25 (52%)	10 (42%)	15 (63%)	0.15
Dialysis	3 (6%)	0 (0%)	3 (13%)	0.07
Prior bypass grafting	2 (4%)	1 (4%)	1 (4%)	1.0
Previous valve surgery	0 (0%)	0 (0%)	0 (0%)	1.0
Logistic EuroSCORE	23 (12/34)	19 (11/33)	19 (12/35)	0.65
EuroSCORE II	7 (4/15)	7 (4/18)	6 (4/12)	0.42
SYNTAX Score	41 (32/48)	45 (25/52)	40 (32/47)	0.69
Residual SYNTAX Score	11 (2/20)	10 (2/20)	11 (3/19)	0.4
SYNTAX Score II	56 (47/64)	54 (45/64)	58 (48/67)	0.56
STS PROM	4 (3/8)	5 (3/9)	4 (2/8)	0.33
LVEF *(%)*	40 (29/49)	40 (29/49)	38 (28/50)	0.88
eGFR (ml/min)	50 (35/67)	61 (34/66)	44 (35/71)	0.81
Leukocytes	8 (6/10)	8 (6/10)	8 (6/10)	0.68
Troponin	1 (0.2/4)	3 (0.6/11)	0.6 (0.1/3)	0.12

Hypercholesterolemia is defined as the daily intake of statins; Hypertension is defined as the daily intake of at least one antihypertensive drug. Coronary artery disease occurs if a coronary artery stenosis with a diameter stenosis of ≥50% is already known.

Values are mean ± SD, or median with interquartile range (quartile 1 to quartile 3).

of autopsy reports, hospital records, and medical files of the referring general practitioner and cardiologists determined causes of death. No patient was lost to follow-up.

Data are presented as mean ± standard deviation if normally distributed or as median and interquartile range (IQR) (quartile 1/quartile 3) if not normally distributed. Continuous variables were tested for normal distribution with the use of the Kolmogorov-Smirnov test. Categorical variables are given as frequencies and percentages. For continuous variables, Student's *t* Test or a Mann-Whitney *U* test, as appropriate, was performed for comparison between 2 groups. When comparing more than 2 groups, ANOVA or the Kruskal-Wallis test was used. Spearman's correlation coefficients were used to establish associations. The chi-square test was used for analysis of categorical variables.

Survival according to the use of an Impella device was determined with use of the Kaplan-Meier method. The log-rank test was used to determine statistical differences in terms of survival. To address the selection/therapy bias in our analysis, we performed a propensity score matching

Table 3
Procedural characteristics—all patients

	All patients (n = 139)	Protected percutaneous coronary intervention (n = 24)	Unprotected percutaneous coronary intervention (n = 115)	p Value
Coronary artery disease				0.22
-3-vessel-disease	90 (65%)	19 (79%)	71 (62%)	
-2-vessel-disease	44 (32%)	4 (17%)	40 (35%)	
-1-vessel-disease	5 (4%)	1 (4%)	4 (5%)	
-Chronic total occlusion	32 (23%)	11 (46%)	21 (18%)	0.004
-Left main	115 (83%)	19 (79%)	96 (84%)	0.61
-Distal left main	106 (76%)	18 (75%)	88 (77%)	0.76
-Right coronary	94 (68%)	19 (79%)	75 (65%)	0.18
-Left circumflex	106 (76%)	20 (83%)	86 (75%)	0.37
-Left anterior descending	126 (91%)	22 (92%)	104 (90%)	0.85
True bifurcation	54 (39%)	15 (63%)	39 (34%)	0.009
Complex bifurcation	54 (39%)	17 (71%)	37 (27%)	<0.001
Two-stent strategy	45 (32%)	15 (63%)	30 (22%)	0.001
Complete revascularization	88 (63%)	21 (88%)	67 (58%)	0.007
Last remaining	9 (7%)	3 (13%)	6 (5%)	0.19
Number of chronic total occlusions				0.014
-1 vessel	24 (17%)	8 (33%)	16 (14%)	
-2 vessels	8 (6%)	3 (13%)	5 (4%)	
Chronic total occlusions treated	6 (4%)	1 (4%)	5 (4%)	0.95
Access site				0.53
-Transfemoral	116 (84%)	19 (79%)	97 (84%)	
-Radial	23 (17%)	5 (21%)	18 (16%)	
Anaesthesia				0.003
-Analgosedation	15 (11%)	4 (17%)	11 (10%)	
-Mechanical ventilation	8 (6%)	5 (21%)	3 (3%)	
-Local anesthesia	115 (83%)	15 (63%)	100 (87%)	
-None	1 (1%)	0 (0%)	1 (1%)	
Procedure time (minutes)	81 ± 50	147 ± 60	67 ± 34	<0.001
Fluoroscopy time (minutes)	24 ± 16	38 ± 21	21 ± 13	0.006
Contrast media (millilitres)	152 (111/210)	195 (144/271)	148 (110/198)	0.009
Conversion to surgery	0 (0%)	-	-	
Rotablation	4 (3%)	4 (17%)	0 (0%)	<0.001
Number of stents	2 ± 1	3 ± 1	2 (1%)	0.039
Total stent length (millimetre)	44 ± 24	56 ± 28	41 ± 23	0.33
Type of stents				0.89
-Drug eluting stent	136 (98%)	24 (100%)	112 (97%)	
-Bare metal stent	1 (1%)	0 (0%)	1 (1%)	
-Bioresorbable vascular scaffold	1 (1%)	0 (0%)	1 (1%)	
Number of vessels treated				0.90
-1	16 (12%)	3 (13%)	13 (11%)	
-2	114 (82%)	19 (79%)	95 (83%)	
-3	9 (7%)	2 (8%)	7 (6%)	
Vessel treated				
-Left main	118 (85%)	20 (83%)	98 (85%)	0.81
-Left anterior descending	121 (87%)	23 (96%)	98 (85%)	0.16
-Ramus circumflexus	77 (55%)	18 (75%)	59 (51%)	0.03
-Ramus intermedius	10 (7%)	3 (13%)	7 (6%)	0.27
-Right coronary artery	9 (7%)	2 (8%)	7 (6%)	0.68

Values are mean ± SD, or median with interquartile range (quartile 1 to quartile 3).

considering the confounding variables LVEF, logES, and SS, so that we could perform a subanalysis comparing procedural and outcome data between 24 protected and 24 non-protected PCI patients.

Statistical significance was assumed when the null hypothesis could be rejected at $p < 0.05$. Statistical analyses were conducted with PASW Statistics version 22.0.0.0 (IBM Corporation, Somer, New York) and MedCalc version 11.6.1.0 (MedCalc Software, Mariakerke, Belgium). The investigators initiated the study, had full access to the data, and wrote the manuscript. All authors vouch for the data and analysis.

Results

The mean age of our study patients was 78 ± 9 years and 101 of 139 patients (73%) were of male gender. The mean logES was 12% (IQR 6/23) and the mean SS was 36 (IQR 24/45). Sixty-five patients (47%) had a non-ST elevation MI at the time of presentation, 12 patients (9%) had unstable angina pectoris, 59 (42%) patients presented with stable angina pectoris and 3 patients (2%) had no specific symptoms.

Of 139 patients undergoing high-risk PCI, 24 (17%) were treated with hemodynamic support. In 18 patients

Table 4
Procedural characteristics—propensity score matched analysis

	All patients (n = 48)	Protected percutaneous coronary intervention (n = 24)	Unprotected percutaneous coronary intervention (n = 24)	p Value
Coronary artery disease				0.38
-3-vessel-disease	36 (75%)	19 (79%)	17 (71%)	
-2-vessel-disease	11 (23%)	4 (17%)	7 (29%)	
-1-vessel-disease	1 (2%)	1 (4%)	0 (0%)	
-Chronic total occlusion	19 (40%)	11 (46%)	8 (33%)	0.67
-Left main	42 (87%)	19 (79%)	23 (96%)	0.81
-Distal left main	39 (81%)	18 (75%)	21 (87%)	0.47
-Right coronary	36 (75%)	19 (79%)	17 (71%)	0.50
-Left circumflex	41 (85%)	20 (83%)	21 (87%)	0.68
-Left anterior descending	45 (94%)	22 (92%)	23 (96%)	0.55
Complex bifurcation	24 (50%)	17 (71%)	7 (29%)	0.004
Two-stent strategy	25 (52%)	15 (62%)	10 (42%)	0.15
Complete revascularization	40 (83%)	21 (87%)	19 (79%)	0.44
Last remaining,	5 (10%)	3 (12%)	2 (8%)	0.64
Number of chronic total occlusions				0.67
-1 vessel	14 (29%)	8 (33%)	6 (25%)	
-2 vessels	5 (10%)	3 (12%)	2 (8%)	
Chronic total occlusion treated	3 (6%)	1 (4%)	2 (8%)	0.55
Access site				0.44
-Transfemoral	40 (83%)	19 (79%)	21 (87%)	
-Radial	8 (17%)	5 (21%)	3 (12%)	
Anesthesia				0.03
-Analgosedation	6 (12%)	4 (17%)	2 (8%)	
-Mechanical ventilation	5 (10%)	5 (21%)	0 (0%)	
-Local anesthesia	37 (77%)	15 (62%)	22 (92%)	
-None	0 (0%)	0 (0%)	0 (0%)	
Procedure time (minutes)	110 ± 61	147 ± 60	73 ± 35	0.004
Fluoroscopy time (minutes)	32 ± 20	38 ± 21	25 ± 18	0.43
Contrast media (millilitres)	180 (123/239)	195 (144/271)	162 (110/196)	0.078
Conversion to surgery	0 (0%)	-	-	
Rotablation	4 (8%)	4 (17%)	0 (0%)	0.037
Number of stents	2 ± 1	2 ± 1	2 ± 0.7	0.083
Total stent length (millimetre)	46 ± 24	56 ± 28	36 ± 16	0.09
Type of stents				1.0
-Drug eluting stent	48 (100%)	24 (100%)	24 (100%)	
-Bare metal stent	0 (0%)	0 (0%)	0 (0%)	
Number of vessels treated				0.16
-1	3 6%	3 (12%)	0 (0%)	
-2	42 87%	19 (79%)	23 (96%)	
-3	3 6%	2 (8%)	1 (4%)	
Vessel treated				
-Left main	44 92%	20 (83%)	24 (100%)	0.37
-Left anterior descending	43 90%	23 (96%)	20 (83%)	0.16
-Ramus circumflexus	33 69%	18 (75%)	15 (62%)	0.35
-Ramus intermedius	3 6%	3 (12%)	0 (0%)	0.74
-Right coronary artery	3 6%	2 (8%)	1 (4%)	0.55

Values are mean ± SD, or median with interquartile range (quartile 1 to quartile 3)

(75%) the Impella 2.5, and in 6 patients (25%) the Impella CP was used for LV support. The indications for hemodynamic support included complex coronary anatomy (96%), reduced LVEF (75%), major co-morbidities and frailty (37%), and/or personal preference of the treating operator based on the clinical presentation of the individual patient (37%). Immediately after PCI, 21 patients could be weaned from hemodynamic support in the cath lab, 3 patients could be weaned in the intensive care unit on the same day of the intervention. Closure of the access site was achieved by use of 2 ProGlides or Prostar (Abbott Vascular, Santa Clara, California) in 6 patients (25%) and 13 (54%) patients, respectively, in 5 case (21%) by manual compression.

Follow-up data were collected for all 139 patients, with a mean follow-up duration of 530 ± 394 days (median 440; IQR 227/814; protected PCI: 369 ± 268 days, nonprotected PCI: 563 ± 408 days). Baseline characteristics are summarized in Table 1.

The 24 protected PCI patients had a higher co-morbidity burden, represented by a higher logES (protected PCI: 19% [IQR 11/33%] vs nonprotected PCI: 12% [IQR 5/20%]; p = 0.01) and a higher SS II (7 [IQR 4/18] vs 4 [IQR 2/6]; p < 0.001). The protected PCI patients had more complex coronary anatomy, as indicated by a higher baseline SS (protected PCI: 45 [IQR 25/52] vs nonprotected PCI: 36 [IQR 24/43]; p = 0.07), and significantly more often reduced LV function (40% [IQR 28/49] vs 55% [IQR 45/62]; p < 0.001). In addition, the protected PCI patients had more severe symptoms in terms of NYHA class (protected PCI: NYHA III or IV: 83% vs nonprotected PCI: 64%; p = 0.006) and a higher baseline troponin value (2.7 ng/l [IQR 0.6/11.1] vs 0.3 ng/l [IQR 0.03/1.8]; p = 0.01). Baseline characteristics of the propensity score matched patient cohort are summarized in Table 2.

Procedural characteristics for all patients are presented in Table 3. Patients did not differ significantly with regard to procedural factors such as access site, anesthesia methods, implanted stent type or the number of vessels treated. However, hemodynamic support was used in patients with more complex coronary anatomy in terms of complex bifurcation lesions (protected PCI: 71% vs nonprotected PCI: 27%; p < 0.001) requiring a 2-stent-strategy (62% vs 22%; p = 0.001). Four (17%) of 24 patients with Impella device also underwent rotational atherectomy (17% vs 0%; p < 0.001). PCI with Impella support led more often to complete revascularization (87% vs 58%, p = 0.007).

After propensity score matching, we found that use of hemodynamic support was still associated with higher rates of complex bifurcation lesions in the protected PCI group (protected PCI: 71% vs nonprotected PCI: 29%; p = 0.004) (Table 4).

Clinical outcomes for all patients are given in Table 5. A high-risk PCI with use of the Impella device was safe: mortality, MI, or target lesion failure did not occur in any of the protected PCI patients during the index hospitalization. Rates of MACE as well as the individual secondary end points 1 year after procedure did not differ significantly between the patient groups (protected PCI: 21% vs nonprotected PCI: 11%; p = 0.19) (Figures 1 & 2).

In the unmatched cohort, 30-day mortality (protected PCI: 0% vs nonprotected PCI: 4%, p = 0.31) and 1-year mortality did not differ significantly between the groups (protected PCI: 21% vs nonprotected PCI: 14%, p = 0.43).

Clinical outcome data of the propensity score matched study patients are presented in Table 6. One-year MACE rate was still similar (protected PCI: 21% vs nonprotected PCI: 17%, p = 0.67) (Figure 1). Assessing the individual secondary end points, we could not find a statistically significant difference between the groups except for a trend toward lower rates in the protected PCI group (cardiovascular death: 12% vs 22%; p = 0.4; MI: 8% vs 22%; p = 0.2) (Figure 2).

Discussion

The present study assessed the impact of hemodynamic support with the Impella device on outcome of patients

Table 5
Clinical outcomes—all patients

	All patients (n = 139)	Protected percutaneous coronary intervention (n = 24)	Unprotected percutaneous coronary intervention (n = 115)	p Value
30-day mortality	5 (4%)	0 (0%)	5 (4%)	0.31
180-day mortality	15 (11%)	3 (12%)	12 (10%)	0.77
1-year mortality	21 (15%)	5 (21%)	16 (14%)	0.43
30-day major adverse cardiac events	2 (1%)	0 (0%)	2 (2%)	0.52
1-year major adverse cardiac events	18 (13%)	5 (21%)	13 (11%)	0.19
Target lesion failure	12 (9%)	2 (8%)	10 (9%)	0.90
Unplanned revascularization	23 (17%)	4 (17%)	19 (17%)	0.93
Cardiovascular death	14 (10%)	3 (12%)	11 (10%)	0.73
Stroke	4 (3%)	0 (0%)	4 (4%)	0.34
Myocardial infarction	17 (13%)	2 (8%)	15 (14%)	0.47
In-Stent restenosis	21 (15%)	4 (17%)	17 (15%)	0.82
Bleeding	17 (13%)	2 (8%)	15 (14%)	0.65
Major bleeding	5 (4%)	1 (4%)	4 (4%)	
Minor bleeding	12 (9%)	1 (4%)	11 (10%)	
Vascular complication	8 (6%)	0 (0%)	8 (7%)	0.41
Acute kidney injury	20 (15%)	3 (12%)	17 (15%)	0.71

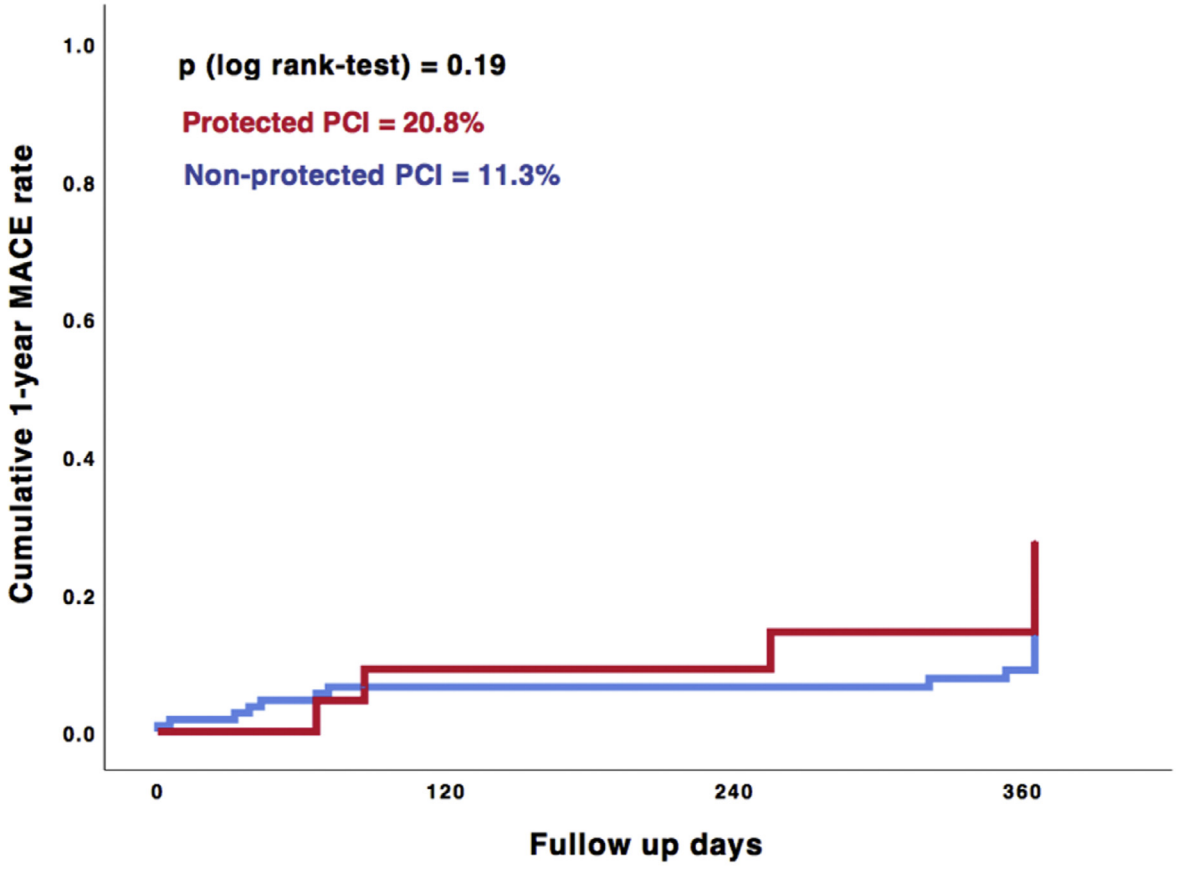
Higher mortality rates are driven by causes of death; MACE only includes cardiovascular death, mortality includes all causes of death.

undergoing high-risk PCI. The main findings of our study are as follows:

1) High-risk patients who underwent protected PCI have a higher co-morbidity burden and more complex CAD compared with patients who underwent a nonprotected high-risk PCI.
2) Impella use was safe without major vascular access complications and, despite the higher comorbidity burden, the short-term survival in patients undergoing protected PCI was not different from that in patients with less complex procedures without hemodynamic support.

Selecting the optimum revascularization strategy in elderly patients with severe co-morbidities, previous cardiac surgery and/or reduced LVEF is often challenging.[2,12–14] Many of these patients are turned down for cardiac surgery by the heart team due to high perioperative risk so that a conservative or interventional treatment strategy is often the only therapeutic option. The temporary use of LV support devices has been shown to be feasible and safe in these patients and can prevent hemodynamic instability during high-risk PCI.[15–19] The PROTECT II study, a prospective multicenter randomized trial comparing the impact of different hemodynamic support systems in high-risk patients, showed less intraprocedural cardiac power output decrease in patients treated with the Impella device, resulting in improved outcomes in the Impella 2.5 group compared with the intra-aortic balloon pump (IABP) group in a post hoc analysis after 90 days of follow-up.[16] Kovacic et al compared clinical outcomes of the TandemHeart compared with the Impella 2.5 device in patients who underwent high-risk PCI with comparable results in both groups.[17] The question

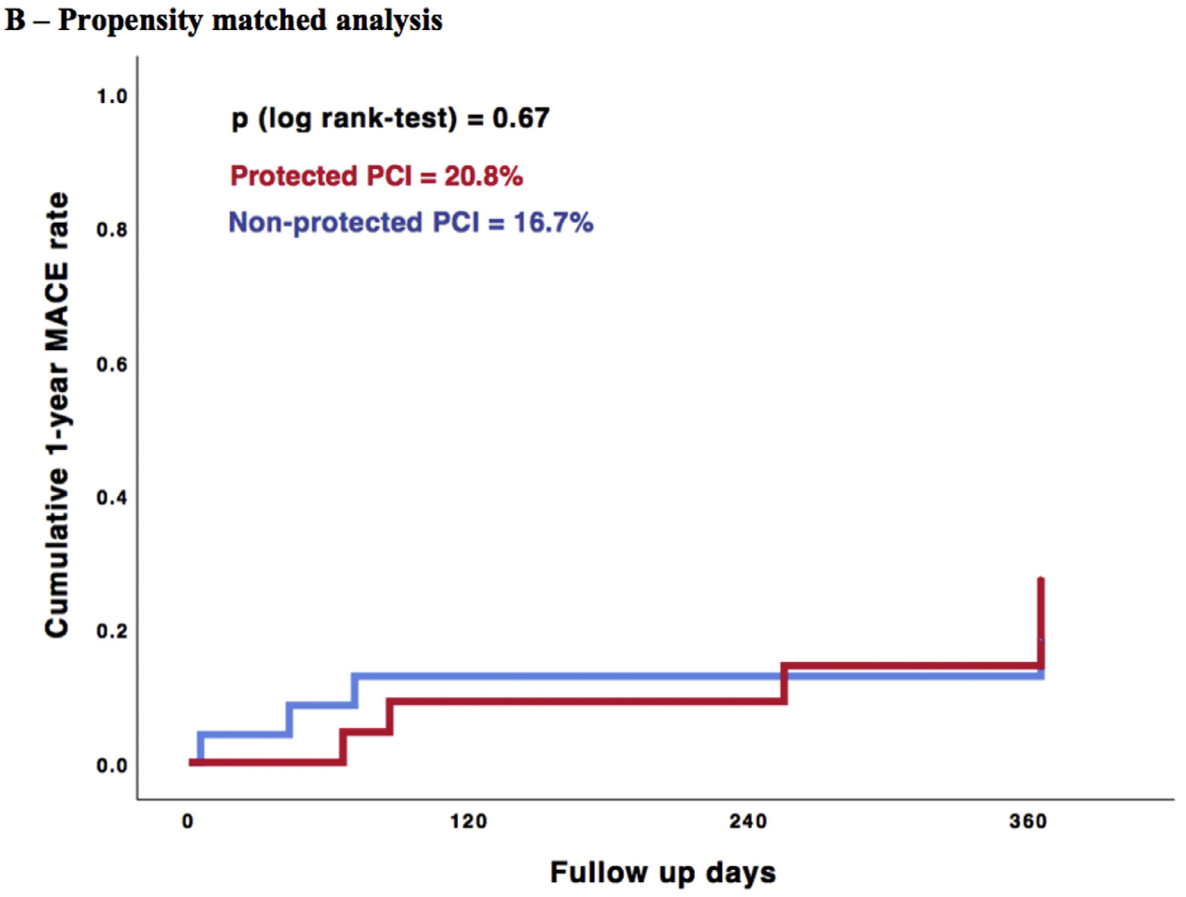
A – All patients



Number at risk

	0 Days	90 Days	180 Days	365 Days
Protected PCI	24	20	19	13
Unprotected PCI	115	96	92	73

Figure 1A. Kaplan-Meier survival analysis in patients undergoing protected versus nonprotected PCI−all patients.
MACE = major adverse cardiac event; PCI = percutaneous coronary intervention.



Number at risk

	0 Days	90 Days	180 Days	365 Days
Protected PCI	24	20	19	13
Unprotected PCI	24	19	19	16

Figure 1B. Kaplan-Meier survival analysis in patients undergoing protected versus nonprotected PCI—propensity matched analysis.
MACE = major adverse cardiac event; PCI = percutaneous coronary intervention.

of which patient group benefits most from hemodynamic support, however, remains unanswered.

Out of 139 high-risk patients in our study cohort, 24 underwent protected PCI using the Impella device. These 24 patients had a higher co-morbidity burden reflected by higher surgical risk scores. Similar findings have been described in different other studies. Baumann et al recently showed on the basis of data collected in the German Impella registry that the use of hemodynamic support was associated with high logES of 14.7% to 17.4% on average representing a high co-morbidity burden in a total of 154 high-risk patients who underwent protected PCI.[12] Alaswad et al found that patients who underwent PCI with mechanical circulatory support had a high prevalence of renal failure (25%), diabetes mellitus (45%), previous MI (30%), and previous PCI (42%).[13]

In addition to this co-morbidity burden, the protected PCI cohort in our study had a more complex coronary anatomy as indicated by a higher SS, higher rates of complex bifurcation lesions (defined as bifurcation lesions with a length ≥10 mm and a diameter stenosis ≥70%), and chronic total occlusions than the nonprotected PCI cohort. Despite this higher co-morbidity and CAD burden the patients underwent more often extensive lesion preparation and complex interventions such as rotational atherectomy and a 2-stent-strategy. This treatment strategy resulted in a higher rate of complete revascularization.

Despite the higher co-morbidity and CAD burden, 1-year MACE rate as well as 1-year all-cause mortality in patients who underwent protected PCI in our study, were not different from that in patients with less complex procedures without hemodynamic support. Similar findings have been described in a meta-analysis including 13 studies

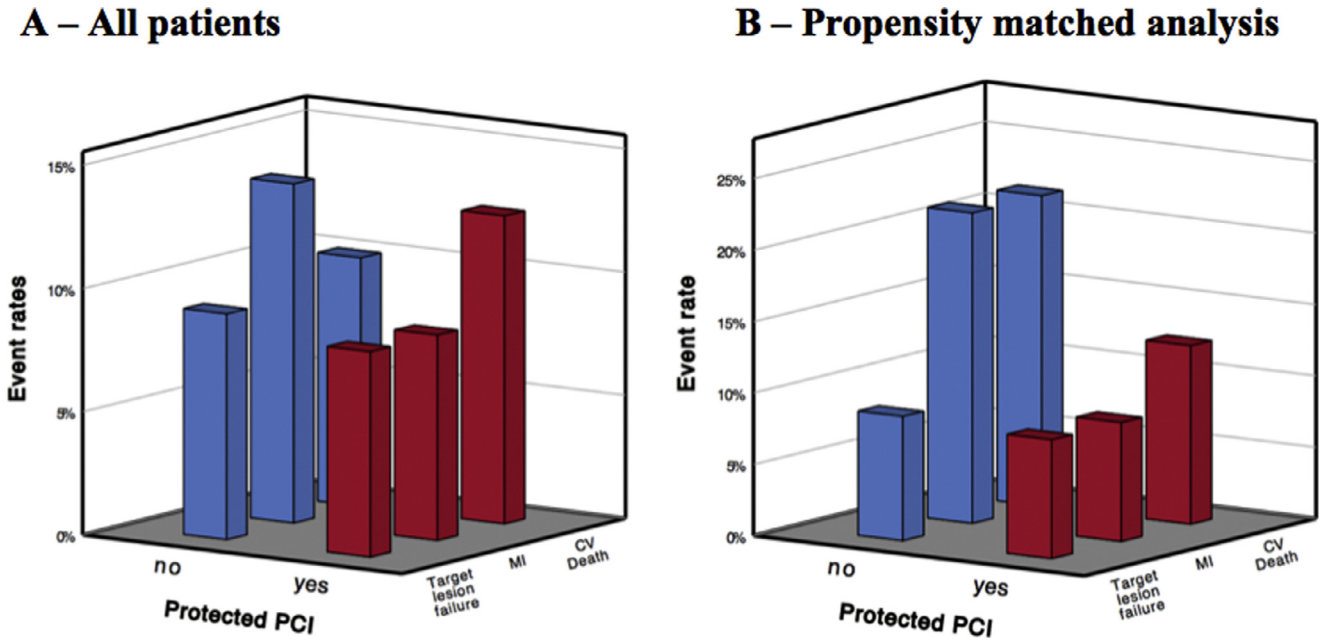


Figure 2. Bar chart. Clinical outcomes in patients undergoing protected versus nonprotected PCI.
CV death = cardiovascular death; MI = myocardial infarction; PCI = percutaneous coronary intervention.

comparing medical treatment versus IABP versus other percutaneous ventricular assist devices in high-risk PCI patients. The authors showed no benefit of routine use of IABP or percutaneous ventricular assist device in improving overall survival, compared with medical treatment alone.[20] However, one limitation of this meta-analysis is that it included heterogeneous studies with different definitions of high-risk PCI or interventional strategies. The included studies did not investigate other efficacy end points such as target vessel/lesion revascularization or the benefit of hemodynamic support devices to ensure hemodynamic stability to complete PCI in the high-risk PCI population.

In our study, we performed a subanalysis with 24 nonprotected PCI patients matched for LVEF, logES, and SS to address the selection/therapy bias. Our propensity score matched analysis showed no significant difference of 1-year MACE between the 2 treatment groups. Thus, we were able to show that hemodynamic support in high-risk patients who underwent protected PCI is safe and offers the interventionalist the possibility to perform complete revascularization with complex interventional techniques if necessary.

Taken together, prospective, randomized trials are eagerly needed to further evaluate the clinical importance of hemodynamic support in patients who underwent high-

Table 6
Clinical outcome−−propensity matched analysis

	All patients (n = 48)	Protected percutaneous coronary intervention (n = 24)	Unprotected percutaneous coronary intervention (n = 24)	p Value
30-day mortality	2 (4%)	0 (0%)	2 (8%)	0.16
180-day mortality	8 (17%)	3 (12%)	5 (21%)	0.44
1-year mortality	11 (23%)	5 (21%)	6 (25%)	0.73
30-day major cardiac adverse events	1 (2%)	0 (0%)	1 (4%)	0.32
1-year major cardiac adverse events	9 (19%)	5 (21%)	4 (17%)	0.67
Target lesion failure	4 (8%)	2 (8%)	2 (8%)	0.96
Unplanned revascularization	8 (17%)	4 (17%)	4 (17%)	0.95
Cardiovascular death	8 (17%)	3 (12%)	5 (22%)	0.40
Stroke	2 (4%)	0 (0%)	2 (9%)	0.14
Myocardial infarction	7 (15%)	2 (8%)	5 (22%)	0.20
In-Stent restenosis	8 (15%)	4 (17%)	4 (17%)	0.50
Bleeding	5 (10%)	2 (9%)	4 (17%)	0.45
Major bleeding	1 (2%)	1 (4%)	0 (0%)	
Minor bleeding	4 (8%)	1 (4%)	3 (12%)	
Vascular complication	2 (4%)	0 (0%)	2 (9%)	0.35
Acute kidney injury	8 (17%)	3 (12%)	5 (21%)	0.44

Higher mortality rates are driven by causes of death; MACE only includes cardiovascular death, mortality includes all causes of death.

risk PCI and to establish an algorithm to optimize patient identification as described in an expert consensus on the implementation of cardiovascular support devices for high-risk PCIs for daily routine.[21]

Limitations of our study are sample size and its monocentric, retrospective character. Additionally, patients were not randomly assigned to a treatment group as the choice of therapy was made by the Heart Team. Despite the propensity score matching, a certain selection/therapy bias is apparent. Further, in our study we only used the Impella device for hemodynamic support; other LV support devices have not been included. Another limitation is that the median follow-up duration of 440 days provides insights into the impact of hemodynamic support on outcome in the mid-term, yet precludes extrapolation to longer-term follow-up.

In conclusion, hemodynamic support in high-risk patients with very complex coronary anatomy and a high co-morbidity burden who were turned down for cardiac surgery led to a 1-year outcome that was not different from patients with less complex procedures without hemodynamic support. The use of a LV hemodynamic support device such as the Impella facilitates complex PCI procedures in selected high-risk patients.

Disclosures

Drs. Sinning and Werner have received speaker honoraria from Abiomed, Medtronic, Boston Scientific, and Edwards Lifesciences. The other authors report no conflicts of interest.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amjcard.2019.03.050.

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