Original Cardiovascular

Follow-Up and Outcome after Coronary Bypass Surgery Preceded by Coronary Stent Implantation

Marwan Hamiko[1,*]   Nicole Konrad[1,*]   Doreen Lagemann[1]   Christopher Gestrich[1]   Franz Masseli[2]
Mehmet Oezkur[2]   Markus Velten[3]   Hendrik Treede[2]   Georg Daniel Duerr[2]

[1] Department of Cardiac Surgery, Universitätsklinikum Bonn, Bonn, Nordrhein-Westfalen, Germany
[2] Department of Cardiovascular Surgery, Universitätsmedizin der Johannes Gutenberg-Universität Mainz, Mainz, Rheinland-Pfalz, Germany
[3] Department of Anesthesiology and Intensive Care Medicine, Universitätsklinikum Bonn, Bonn, Nordrhein-Westfalen, Germany

Thorac Cardiovasc Surg

Address for correspondence Georg Daniel Duerr, Department of Cardiovascular Surgery, Universitätsmedizin der Johannes Gutenberg-Universität Mainz, Mainz, Rheinland-Pfalz, Germany (e-mail: daniel.duerr@unimedizin-mainz.de; g.daniel.duerr@googlemail.com).

Abstract

Background Guidelines on myocardial revascularization define recommendations for percutaneous coronary intervention (PCI) or coronary artery bypass graft (CABG) surgery. Only little information exists on long-term follow-up and quality of life (QoL) after CABG preceded by PCI. The aim of our study was to evaluate the impact of prior PCI on outcome and QoL in patients with stable coronary artery disease who underwent CABG.

Methods In our retrospective study, CABG patients were divided in: CABG preceded by PCI: PCI-first (PCF), and CABG-only (CO) groups. The PCF group was further divided in guideline-conform (GCO) and guideline nonconform (GNC) subgroups, according to the SYNTAX score (2014 European Society of Cardiology [ESC]/European Association for Cardio-Thoracic Surgery [EACTS] guidelines). Thirty days mortality, major adverse cardiac events, and QoL using the European Quality-of-Life–5 Dimensions were evaluated.

Results A total of 997 patients were analyzed, of which 784 underwent CABG without (CO), and 213 individuals with prior PCI (PCF). The latter group consisted of 67 patients being treated in accordance (GCO), and 24 in discordance (GNC) to the 2014 ESC/EACTS guidelines. Reinfarction (PCF: 3.8% vs. CO: 1.0%; $p = 0.024$), re-angiography (PCF: 17.6% vs. CO: 9.0%; $p = 0.004$), and re-PCI (PCF: 10.4% vs. CO: 3.0%; $p < 0.001$) were observed more frequently in PCF patients. Also, patients reported better health status in the CO compared to PCF group (CO: 72.48 ± 19.31 vs. PCF: 68.20 ± 17.86; $p = 0.01$). Patients from the guideline nonconform subgroup reported poorer health status compared to the guideline-conform group (GNC: 64.23 ± 14.56 vs. GCO:

Keywords
► coronary artery bypass graft surgery
► percutaneous coronary intervention
► quality of life

*These authors contributed equally to this article.

73.42 ± 17.66; $p = 0.041$) and were more likely to require re-PCI (GNC: 18.8% vs. GCO: 2.4%; $p = 0.03$). Also, GNC patients were more likely to have left main stenosis (GCO: 19.7% vs. GNC: 37.5%; $p < 0.001$) and showed higher preinterventional SYNTAX score (GCO: 18.63 ± 9.81 vs. GNC: 26.67 ± 5.07; $p < 0.001$).

Conclusion   PCI preceding CABG is associated with poorer outcomes such as reinfarction, re-angiography, and re-PCI, but also worse health status and higher rehospitalization. Nevertheless, results were better when PCI was guideline-conformant. This data should impact the Heart Team decision.

Introduction

Among cardiovascular diseases, coronary artery disease (CAD) is one of the most relevant causes for mortality and morbidity in all countries.[1–3] Standard therapy is revascularization, associated with hospitalization, high treatment costs, and often restricted long-term outcome.[1,2] The concept of early revascularization led to improved long-term outcome in patients with CAD. The European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS) developed guidelines on myocardial revascularization: According to the guidelines, different strategies are recommended, for example, percutaneous coronary intervention (PCI), or coronary artery bypass graft surgery (CABG).[4,5] Over the last years, the SYNTAX score (SYNergy between PCI with TAXus and Cardiac Surgery) has become an important instrument for decision-making with respect to therapeutic regime.[3–11] During the last decades, primary PCI was established as the predominant therapy, and CABG is reserved for extensive disease and high complexity of coronary anatomy.[5] Nevertheless, due to extensive research on stent material as well as comparable 5-year results of PCI and CABG in complex coronary anatomy, indications were increasingly made in favor of PCI.[12–15] Recently, multivessel PCI is getting more and more popular, not just in low-risk, but also in high-risk patients affected by complex CAD, including left main (LM) stenosis, or patients with diabetes mellitus.[16] For the CABG option, this results in an increasing number of patients with previous PCI and rising complexity of coronary lesions, making CABG more difficult.[17,18] Of note, 10 to 30% of patients presenting for CABG underwent previous PCI.[19,20]

Therefore, we hypothesize that this patient cohort is at risk, as repeated PCI procedures might postpone complete revascularization, thus leading to rehospitalization.[21] Importantly, previous PCI is recognized as a perioperative risk factor for CABG.[18,19] Several studies attempted to analyze early and late outcomes in this patient population, but the prognostic impact of prior PCI in patients requiring CABG remains elusive.[22] Therefore, the aim of our study was to evaluate the outcome of CABG patients with or without preceded PCI, especially in the light of ESC/EACTS guideline conform and guideline nonconform PCI.

Material and Methods

Patients

In this retrospective study, we evaluated data of 997 consecutive patients who underwent isolated CABG in a major heart center in Germany. A signed patient permission form was obtained from every patient. CABG surgery and postoperative treatment was performed as described before.[23] According to preceded PCI and stent therapy we classified patients in two groups: PCI-first (PCF) patients with previous PCI within 3 years before CABG ($n = 213$) and CABG-only (CO) patients without previous PCI ($n = 784$). The PCF group was further divided in patients where PCI was in accordance to the ESC/EACTS guidelines (guideline compliant [GCO], $n = 67$) and patients that received guideline nonconform PCI (GNC, $n = 24$); subgroup analysis for GCO and GNC groups was performed in only 91 of the total 213 patients from the PCF population due to incomplete data transfer from hospitals where PCI was performed. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses diagrams in ►**Figs. 1** and **2** summarize the design and patient number in the present study. According to the 2014 ESC/EACTS guidelines, PCI is recommended in one-vessel CAD; Patients with stable one- or two- vessel CAD with proximal left descending artery (LAD) stenosis or with/without a LM stenosis and a SYNTAX score < 22 could undergo CABG or PCI. Patients with stable three-vessel CAD and a SYNTAX score < 22 without diabetes mellitus are recommended for PCI or CABG. All patients including LM stenosis, diabetes mellitus, and a SYNTAX score > 22 should be treated with CABG.[5,24]

Due to the complexity of the study design, patients with non-ST-segment elevation myocardial infarction (MI) as well as ST-elevation MI were excluded from the study.

A comprehensive data set of pre-, intra-, and postoperative parameters was generated by review of the patient charts and information technology-based data sets. Clinical and demographic data, medical history, including cardiovascular risk factors, former cerebrovascular disease, and preoperative risk score systems like the Society of Thoracic Surgeons (STS) score, European System for Cardiac Operative Risk Evaluation II (EUROScore II), and the SYNTAX score were recorded.
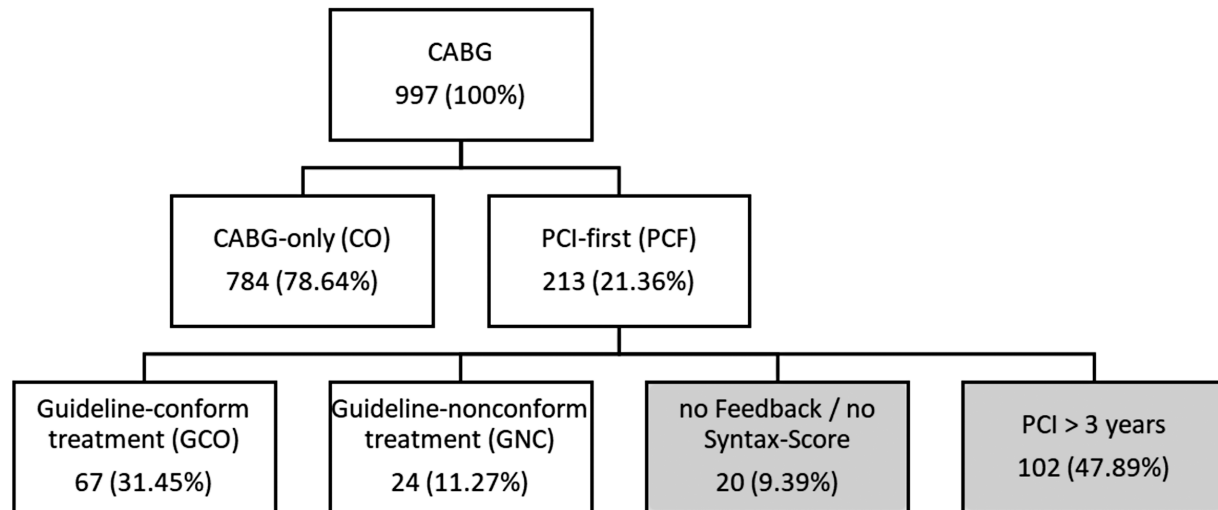
Fig. 1 This Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram summarizes the design and patient number in the present retrospective study.
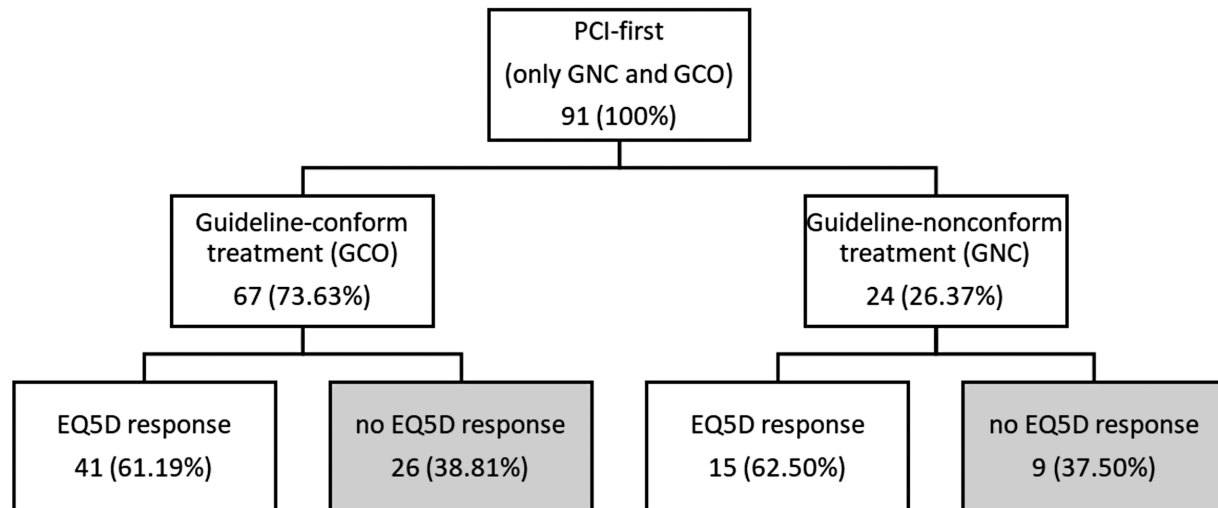

Fig. 2 The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram provides data on the feedback from patients in the different study subgroups.

Preoperative Patient Characteristics

Demographic characteristics and preexisting medical conditions (e.g., diabetes mellitus, cerebral artery disease, history of stroke, arterial hypertension, hyperlipidemia) were collected directly from the patient or indirectly from the hospital information system (ORBIS), and clinical predictive scores (EUROScore II and STS score) were calculated. The SYNTAX score was calculated using the available software (*www.syntaxscore.com*) and the respective coronary angiogram.[9–11] Clinical presentation was documented using the New York Heart Association and the Canadian Cardiovascular Society classification.

Postoperative Outcome

Outcome data included: renal failure with need for continuous venovenous hemofiltration (CVVH) or dialysis, ventilation time, length of intensive care unit (ICU) and hospital stay, nurse workload score (Therapeutic Intervention Scoring System [TISS]-10) and monitoring of the Simplified Acute Physiology Score II (SAPS-II), as well as 30-day mortality.

Follow-Up Data

Follow-up data was collected via telephone or mail. The standard European Quality-of-Life–5 Dimensions (EQ-5D) and 3 Levels health questionnaire was used for evaluation of quality of life. Accordingly, a scale from 0 to 100 represented the state of health, zero points indicating worst, and 100 points best health status. The need for care was queried via the care levels (1–5) applicable in Germany. We further evaluated the need for postoperative re-angiograms as well as re-PCI or re-CABG.

Statistical Analysis

Statistical analysis was performed using the IBM SPSS statistics version 25 (SPSS Inc., Chicago, Illinois, United States). Continuous variables were expressed as mean ± standard deviation

and categorical variables were given as absolute values and percentages. Data were tested for normal distribution using Kolmogorov–Smirnov and Shapiro–Wilk tests. Normally distributed data were analyzed using the two-tailed Student's *t*-test or Mann–Whitney *U* test where appropriate. For categorical variables, Pearson's chi-square test was used. A *p*-value of < 0.05 was considered statistically significant. For graphical display of EQ-5D, evaluation results were created using the "EQ-5D" software (*https://github.com/fragla/eq5d*).

Results

Preoperative Patients' Characteristics and Preoperative Risk Stratification

Patients' baseline characteristics are displayed in ►Tables 1 and 2: No differences were observed with respect to demographic data, prevalence of preexisting disease, surgery risk stratification, as well as SYNTAX score in the PCF and CO groups.

Table 1 Preoperative patient characteristics for PCI-first vs. CABG-only patients

	PCI-first (PCF; *n* = 213)	CABG-only (CO; *n* = 784)	*p*-Value
Age (y)	66.92 ± 9.23	67.91 ± 9.21	0.124[b]
Gender			
Female	40/213 (18.8%)	146/783 (18.6%)	0.965[c]
Male	173/213 (81.2%)	637/783 (81.4%)	0.965[c]
Arterial hypertension	162/213 (76.1%)	598/783 (76.4%)	0.923[c]
Diabetes mellitus	72/160 (45.0%)	235/594 (39.6%)	0.459[c]
PAOD	41/211 (19.4%)	126/783 (16.1%)	0.250[c]
CAD	38/211 (18.0%)	137/783 (17.5%)	0.862[c]
Hyperlipidemia	136/213 (63.8%)	482/783 (61.6%)	0.541[c]
Smoker	62/213 (29.1%)	231/783 (29.5%)	0.911[c]
Former stroke	26/213 (12.2%)	96/783 (12.3%)	0.983[c]
NYHA classification			0.674[c]
I	15/213 (7.0%)	47/782 (6.0%)	
II	71/213 (33.3%)	232/782 (29.7%)	
III	103/213 (48.4%)	406/782 (51.9%)	
IV	24/213 (11.3%)	94/782 (12.0%)	
CCS classification			0.774[c]
0	33/213 (15.5%)	97/782 (12.4%)	
I	28/213 (13.1%)	100/782 (12.8%)	
II	80/213 (37.6%)	316/782 (40.4%)	
III	47/213 (22.1%)	183/782 (23.4%)	
IV	25/213(11.7%)	86/782 (11.0%)	
EUROScore II	4.57 ± 2.89 (/198 patients)	4.89 ± 3.41 (/748 patients)	0.309[b]
STS Mortality	1.82 ± 3.18 (/198 patients)	1.94 ± 3.11 (/746 patients)	0.180[b]
STS Morbidity	13.74 ± 10.41 (/198 patients)	14.40 ± 10.48 (/745 patients)	0.254[b]
SYNTAX score before CABG	22.71 ± 8.01 (/197 patients)	25.59 ± 7.98 (/743 patients)	0.843[a]

Abbreviations: CABG, coronary artery bypass graft; CAD, cerebral arterial disease; CCS, Canadian Cardiovascular Society classification system; EUROScore II, European System for Cardiac Operative Risk Evaluation II; LAD, left anterior descending artery; LM, left main coronary artery; NYHA, New York Heart Association classification system; PAOD, peripheral arterial occlusive disease; PCI, percutaneous coronary intervention; STS, Society of Thoracic Surgeons - Scoring System for Mortality and Morbidity; SYNTAX, SYNergy between PCI with TAXus and Cardiac Surgery.
Note: Preoperative patient characteristics for PCI-first vs. CABG-only patients indicate no significant differences in baseline demographic data. Values are expressed as mean ± standard deviation, or as number and percentage (in bracket). *p* < 0.05 was considered statistically significant, and significant changes are displayed in italics.
[a]*t*-Test.
[b]Mann–Whitney *U*.
[c]Chi-square test.

Table 2 Preoperative patient characteristics from guideline-conform (GCO) vs. nonconform (GNC) PCI treatment groups

	Guideline-conform treatment (GCO; $n = 67$)	Guideline-nonconform treatment (GNC; $n = 24$)	p-Value
Age (y)	64.61 ± 9.34	66.96 ± 10.08	0.449[b]
Gender			
Female	16/67 (23.9%)	4/24 (16.7%)	0.464[c]
Male	51/67 (76.1%)	20/24 (83.3%)	0.464[c]
Arterial hypertension	51/67 (76.1%)	15/24 (62.5%)	0.200[c]
Diabetes mellitus	21/50 (42.0%)	8/19 (42.1%)	0.821[c]
PAOD	14/65 (21.5%)	2/24 (8.3%)	0.150[c]
CAD	9/65 (13.8%)	5/24 (20.8%)	0.422[c]
Hyperlipidemia	40/67 (59.7%)	10/24 (41.7%)	0.128[c]
Smoker	17/67 (25.4%)	8/24 (33.3%)	0.453[c]
Former stroke	5/67 (7.5%)	3/24(12.5%)	0.455[c]
NYHA-classification			0.812[c]
I	6 (9.0%)	1 (4.2%)	
II	21 (31.3%)	9 (37.5%)	
III	32 (47.8%)	12 (50.0%)	
IV	8 (11.9%)	2 (8.3%)	
CCS classification			0.498[c]
0	11 (16.4%)	2 (8.3%)	
I	8 (11.9%)	5 (20.8%)	"
II	29 (43.3%)	8 (33.3%)	"
III	12 (17.9%)	7 (29.2%)	"
IV	7 (10.4%)	2 (8.3%)	"
EUROScore II	4.63 ± 2.72 (/59 patients)	5.00 ± 3.45 (/22 patients)	0.897[b]
STS Mortality	1.82 ± 3.20 (/59 patients)	3.20 ± 7.17 (/22 patients)	0.924[b]
STS Morbidity	13.70 ± 12.50 (/59 patients)	16.31 ± 16.33 (/22 patients)	0.824[b]
SYNTAX score before PCI (arithmetic mean)	18.63 ± 9.81 (/66 patients)	26.67 ± 5.07	*0.005[a]*
SYNTAX score before CABG	21.26 ± 7.21 (/58 patients)	21.43 ± 9.26 (/22 patients)	0.201[a]
LM stenosis	13/66 (19.7%)	9/24 (37.5%)	*<0.001[c]*
Proximal LAD stenosis	41/66 (62.1%)	20/24 (83.3%)	0.057[c]

Abbreviations: CABG, coronary artery bypass graft; CAD, cerebral arterial disease; CCS, Canadian Cardiovascular Society classification system; EUROScore II, European System for Cardiac Operative Risk Evaluation II; LAD, left anterior descending artery; LM, left main coronary artery; NYHA, New York Heart Association classification system; PAOD, peripheral arterial occlusive disease; PCI, percutaneous coronary intervention; STS, Society of Thoracic Surgeons - Scoring System for Mortality and Morbidity; SYNTAX, SYNergy between PCI with TAXus and Cardiac Surgery.

Note: This table reveals significantly higher SYNTAX score as well as incidence for left main (LM) stenosis in GNC patients. Values are expressed as mean ± standard deviation, or as number and percentage (in bracket). $p < 0.05$ was considered statistically significant, and significant changes are displayed in italics.

[a]*t*-Test.
[b]Mann–Whitney *U*.
[c]Chi-square test.

Out of the PCF patients, 67 were treated according to the 2014 ESC/EACTS guidelines for myocardial revascularization[5] (GCO: 73.6%), while in 24 patients that received a PCI prior to CABG guidelines would have recommended primary CABG and were therefore not treated according to the current guidelines (GNC: 26.4%). In the latter, LM stenosis occurred more often (GNC: 37.5% vs. GCO: 19.7%; $p < 0.001$), as shown in ►**Table 2**. Also, more than 80% of the GNC group demonstrated with a proximal LAD stenosis (83.3% vs. GCO: 62.1%; $p = 0.057$). While the SYNTAX score before PCI was higher in the GNC group (26.7 vs. GCO: 18.6; $p < 0.001$), the SYNTAX score before subsequent CABG was comparable between the groups (GNC: 21.4 vs. GCO: 21.3; $p < 0.201$).

Postoperative Outcome

In ►**Tables 3** and **4**, postoperative patients' data are displayed: no significant differences are observed with respect to the length of ICU or total hospital stay, ventilation time, ICU risk and nurse workload index scores (SAPS-II and TISS-10), postoperative complication with the need for CVVH, mechanical circulatory support (extracorporeal membrane oxygenation [ECMO] or intra-aortic balloon pump [IABP]), perioperative blood transfusions, delirium, and wound healing disorder. Also, the 30-day mortality as well as long-term survival were comparable in both compared scenarios, CO versus PCF and PCF subgroups GCO versus GNC (►**Fig. 3A** and **B**). In the PCF group, outcome between one- or two-vessel CAD versus three-vessel CAD was examined: ►**Supplementary Table S1** (available in the online version) shows longer ventilation time in one-/two-vessel disease, but higher need for platelet transfusions in three-vessel disease.

Follow-Up and EQ-5D
Postoperative follow-up period was between 1 and 4.5 years. Sixty-nine percent of the patients could be contacted, and 63.3% answered to the EQ-5D questionnaire. The EQ-5D score for evaluation of the state of health after CABG was significantly higher in patients without previous PCI/stent implantation (PCF: 68.20 vs. CO: 72.48; $p = 0.01$; ►**Table 5**). Compared to the CO group, the PCF group had a higher incidence of postoperative MIs (PCF: 3.8% vs. CO: 1.0%; $p = 0.024$). Accordingly, the rate of coronary re-angiography (PCF: 17.6% vs. CO: 9%; $p = 0.004$) and the need of repeated stent implantation (10.4% vs. 3%; $p < 0.001$) were significantly higher in this group. The latter was also true for patients of GNC compared to GCO group (GCO: 2.4% vs. GNC: 18.8%; $p = 0.03$; ►**Table 6**). Also, the postoperative state of health in GNC patients was significantly lower than in the GCO group (GCO: 73.42 vs. GNC: 64.23; $p = 0.041$; ►**Table 6**). The radar diagram in ►**Fig. 4A** reflects the data from the EQ-5D questionnaire and indicates that patients in the PCF group more often reported reduced mobility, anxiety/depression, and pain/discomfort compared to the CO group. The same was seen in GNC compared to the GCO group (►**Fig. 4B**). On the other hand, GCO patients reported better ability with respect to usual activities of self-care.

So that our data can be evaluated against current standards with respect to the 2018 ESC/EACTS guidelines,[4] we ran the same analysis based on these current guidelines (►**Supplementary Tables S2** to **S4**, available in the online version), confirming that re-angiography was significantly more frequent in the GNC compared to GCO group.

Table 3 Postoperative outcome for PCI-first (PCF) vs. CABG-only (CO) patients

	PCI-first (PCF; $n = 213$)	CABG-only (CO; $n = 784$)	*p*-Value
Mobilization on the first postoperative day	82/196 (41.8%)	272/741 (36.7%)	0.082[c]
Wound healing disorder	23/194 (11.7%)	80/733 (10.7%)	0.884[c]
Delirium	17/185 (9.2%)	88/680 (12.9%)	0.166[c]
CVVH	10/209 (4.8%)	41/781 (5.2%)	0.787[c]
IABP	1/197 (0.5%)	21/746 (2.8%)	0.056[c]
ECMO	1/197 (0.5%)	13/747 (1.7%)	0.203[c]
Duration of ventilation (h)	41.68 ± 112.51 (/195 patients)	53.20 ± 155.87 (/730 patients)	0.959[b]
ICU stay (d)	3.78 ± 5.46 (/212 patients)	4.40 ± 8.09 (/779 patients)	0.392[b]
Length of hospital stay (d)	17.98 ± 10.37 (/196 patients)	18.09 ± 13.10 (of 743 patients)	0.265[b]
RBC (U)	2.10 ± 3.14 (/197 patients)	1.98 ± 4.40 (/740 patients)	0.086[b]
Platelet transfusion (U)	0.31 ± 0.86 (/197 patients)	0.33 ± 1.36 (/741 patients)	0.320[b]
FFP (U)	0.94 ± 2.30 (/197 patients)	1.03 ± 3.23 (/740 patients)	0.798[b]
SAPS-II 24 h	30.38 ± 10.32 (/138 patients)	30.28 ± 9.40 (/515 patients)	0.911[b]
TISS-10 24 h	24.01 ± 6.14 (/138 patients)	23.63 ± 6.99 (/516 patients)	0.755[b]
30-day mortality	3/154 (1.95%)	27/594 (4.55%)	0.312[c]
Death	11/154 (7.1%)	62/594 (10.4%)	0.220[c]

Abbreviations: CABG, coronary artery bypass graft; CVVH, continuous venovenous hemofiltration; ECMO, extracorporeal membrane oxygenation; FFP, fresh frozen plasma; IABP, intra-aortic balloon pump; ICU, intensive care unit; PCI, percutaneous coronary intervention; RBC, red blood cell; SAPS II, Simplified Acute Physiology Score II; TISS-10, Therapeutic Intervention Scoring System.
Note: This table reveals no significant differences with respect to postoperative outcome between the two groups. Values are expressed as mean ± standard deviation, or as number and percentage (in bracket). $p < 0.05$ was considered statistically significant, and significant changes are displayed in italics.
[a]*t*-Test.
[b]Mann–Whitney *U*.
[c]Chi-square test.

Table 4 Postoperative outcome for guideline-conform (GCO) vs. nonconform (GNC) treatment

	Guideline-conform treatment (GCO; $n=67$)	Guideline-nonconform treatment (GNC; $n=24$)	p-Value
Mobilization on the first postoperative day	21/59 (35.6%)	9/22 (40.9%)	0.659[c]
Wound healing disorder	8/59 (13.6%)	2/20 (9.1%)	0.771[c]
Delirium	5/53 (9.4%)	0/21 (0.0%)	0.145[c]
CVVH	6/66 (9.1%)	1/23 (4.3%)	0.467[c]
IABP	0/58 (0.0%)	1/22 (4.5%)	0.102[c]
ECMO	1/58 (1.7%)	0/22 (0.0%)	0.535[c]
Duration of ventilation (h)	50.56 ± 114.76 (/57 patients)	20.82 ± 7.06 (/22 patients)	0.100[b]
ICU time (d)	4.12 ± 4.33	3.25 ± 3.54	0.386[b]
Length of hospital stay (d)	17.93 ± 10.35 (/58 patients)	16.77 ± 7.78 (/22 patients)	0.974[b]
RBC (U)	2.97 ± 4.25 (/59 patients)	1.27 ± 1.86 (/22 patients)	0.080[b]
Platelet transfusion (U)	0.49 ± 1.27 (/59 patients)	0.32 ± 0.65 (/22 patients)	0.899[b]
FFP (U)	1.29 ± 3.06 (/59 patients)	1.09 ± 2.11 (/22 patients)	0.971[b]
SAPS-II 24 h	31.82 ± 11.35 (/44 patients)	33.88 ± 14.35 (/16 patients)	0.487[b]
TISS-10 24 h	24.57 ± 6.69 (/44 patients)	23.56 ± 3.83 (/16 patients)	0.698[b]
30-day mortality	2/49 (4.1%)	1/18 (5.6%)	0.361[c]
Total death	4/49 (8.2%)	1/18 (5.6%)	0.719[c]

Abbreviations: CVVH, continuous venovenous hemofiltration; ECMO, extracorporeal membrane oxygenation; FFP, fresh frozen plasma; IABP, intra-aortic balloon pump; ICU, intensive care unit; RBC, red blood cell; SAPS II, Simplified Acute Physiology Score II; TISS-10, Therapeutic Intervention Scoring System.

Note: Comparable outcomes are observed with respect to death, adverse events, risk and nurse workload scores, and length of hospital stay. Values are expressed as mean ± standard deviation, or as number and percentage (in bracket). $p < 0.05$ was considered statistically significant, and significant changes are displayed in italics.

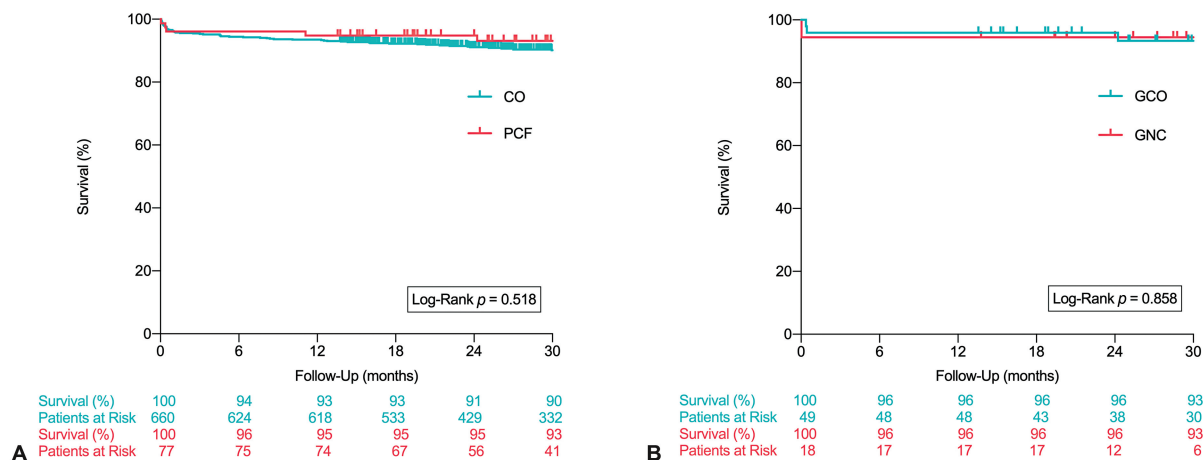[a]t-Test.
[b]Mann–Whitney U.
[c]Chi-square test.

Fig. 3 The Kaplan–Meier curves demonstrate similar survival between (**A**) coronary artery bypass graft (CABG)-only (CO) and percutaneous coronary intervention (PCI)-first (PCF) as well as PCF subgroups (**B**) guideline-conform (GCO) and nonconform (GNC) patients.

Discussion

Several studies compared the efficacy of PCI and CABG with respect to the outcome.[25,26] Comparable 5 years' results between PCI and CABG in multivessel coronary lesions have inaugurated the PCI therapy as an equal therapy over the last decades.[6] Therefore, PCI gained acceptance for the treatment of CAD also with complex lesions. As a consequence, PCI leads to less CABG, but was also associated with higher morbidity and mortality.[5,17,18]

Therefore, the SYNTAX score has been established to predict the postprocedural risk associated with PCI or CABG. The SYNTAX score is an angiographic tool that determines the complexity of CAD, taking into account the

Table 5 Follow-up data for PCI-first (PCF) vs. CABG-only (CO) patients

	PCI-first (PCF; $n = 213$)	CABG-only (CO; $n = 784$)	*p*-Value
State of health (0–100)	68.20 ± 17.86 (/116 patients)	72.48 ± 19.31 (/446 patients)	*0.010*[b]
Degree of care			0.404[c]
None	119/132 (90.2%)	452/491 (92.1%)	
1	2/132 (1.5%)	12/491 (2.4%)	
2	7/132 (5.3%)	14/491 (2.9%)	
3	2/132 (1.5%)	8/491 (1.6%)	
4	0/132 (0.0%)	3/491 (0.6%)	
5	2/132 (1.5%)	2/491 (0.4%)	
Re-angiography	24/136 (17.6%)	45/501 (9.0%)	*0.004*[c]
Stent implantation	14/134 (10.4%)	15/498 (3.0%)	*<0.001*[c]
Stroke	5/133 (3.8%)	13/502 (2.6%)	0.470[c]
MI	5/133 (3.8%)	5/499 (1.0%)	*0.024*[c]
Pacemaker	1/131 (0.8%)	11/501 (2.2%)	0.285[c]
ACB	0/132 (0.0%)	1/499 (0.2%)	0.607[c]

Abbreviations: ACB, aortocoronary bypass surgery; CABG, coronary artery bypass graft; MI, myocardial infarction; PCI, percutaneous coronary intervention.
Note: This table shows significant higher incidence of myocardial infarction (MI), angiography, and stent implantation in PCF. Interestingly, state of health is significantly better in CO patients. Values are expressed as mean ± standard deviation, or as number and percentage (in bracket). $p < 0.05$ was considered statistically significant, and significant changes are displayed in italics.
[a]*t*-Test.
[b]Mann–Whitney *U*.
[c]Chi-square test.

Table 6 Follow-up data for guideline-conform (GCO) vs. nonconform (GNC) treatment

	Guideline-conform treatment (GCO; $n = 67$)	Guideline-nonconform treatment (GNC; $n = 24$)	*p*-Value
State of health (0–100)	73.42 ± 17.66 (/38 patients)	64.23 ± 14.56 (/13 of patients)	*0.041*[b]
Degree of care			0.280[c]
None	38/41 (92.7%)	14/15 (93.3%)	
1	0/41 (0.0%)	1/15 (6.7%)	
2	2/41 (4.9%)	0/15 (0.0%)	
3	1/41 (2.4%)	0/15 (0.0%)	
4	0/41 (0.0%)	0/15 (0.0%)	
5	0/41 (0.0%)	0/15 (0.0%)	
Re-angiography	5/43 (11.6%)	5/17 (29.4%)	0.096[c]
Stent implantation	1/41 (2.4%)	3/16 (18.8%)	*0.030*[c]
Stroke	1/40 (2.5%)	1/15 (6.7%)	0.462[c]
MI	1/41 (2.4%)	2/16 (12.5%)	0.126[c]
Pacemaker	0/41 (0.0%)	0/15 (0.0%)	–
ACB	0/41 (0.0%)	0/15 (0.0%)	–

Abbreviations: ACB, aortocoronary bypass surgery; MI, myocardial infarction.
Note: This table shows significant higher incidence of stent implantation in GNC compared to GCO patients. In the latter, also, state of health is significantly better. Values are expressed as mean ± standard deviation, or as number and percentage (in bracket). $p < 0.05$ was considered statistically significant, and significant changes are displayed in italics.
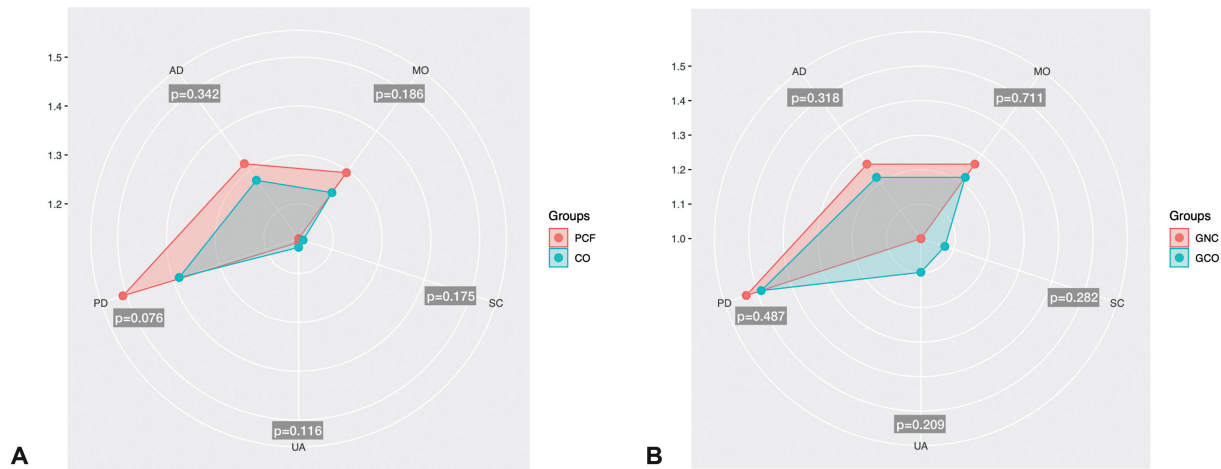[a]*t*-Test.
[b]Mann–Whitney *U*.
[c]Chi-square test.

Fig. 4 These radar diagrams demonstrates the European Quality-of-Life–5 Dimensions (EQ-5D) items AD (Anxiety/Depression), MO (Mobility), PD (Pain/Discomfort), SC (Self-Care), and UA (Usual Activities), and graphically represent the distribution of the groups with respect to the dimensions in (**A**) percutaneous coronary intervention (PCI)-first (PCF) vs. coronary artery bypass graft (CABG)-only (CO) and (**B**) guideline-conform (GCO) vs. nonconform (GNC) patients. The radar diagrams were created using the "EQ-5D" software (https://github.com/fragla/eq5d).

number of diseased vessels. It was derived from preexisting risk assessment classifications from numerous studies and expert consensus; Medical cardiovascular and cardiothoracic societies such as the ESC/EACTS adopted it and further propagated it as a decision-making tool in order to facilitate the decision in favor of PCI or CABG.[4,5]

Nevertheless, as PCI is recognized as a less invasive therapy for revascularization of CAD by many interventionalists, PCI is favored over CABG irrespective of the SYNTAX score, sometimes also engaging three-vessel CAD. For this reason, interventionalists sometimes do not adhere to the existing guidelines, which is underlined by the fact that up to 30% of ad hoc PCI patients would have been candidates for CABG due to their coronary findings.[27]

In return, as PCI has become commonly available, the profile of patients subjected to CABG also changed: As a result, CABG patients now present with more comorbidities, are older, and many of them underwent prior PCI, resulting in anatomically more complex lesions for CABG surgery.[17,18] For this reason, cardiac surgeons often face patients referred to CABG with prior PCI therapy. The number of patients with prior PCI is reported to be about 10 to 30%.[20] In our study, 21% of the patients who presented for CABG had a history for preceding PCI.

Guidelines such as the ESC/EACTS guideline on myocardial revascularization make a recommendation for the therapeutic strategy for patients with CAD according to their coronary anatomy and complexity of lesions, for example, PCI or CABG.[5] One of the aims of our study was to evaluate patients' outcome after undergoing different strategies for revascularization.

Different studies analyzed the long-term morbidity and mortality for this group, revealing prior PCI as an independent risk factor for in-hospital mortality after CABG, irrespective of which vessels were used as bypass grafts.[15,19] Also, previous multiple PCIs were associated with higher in-hospital mortality and major adverse cardiac and cerebrovascular events after CABG.[14,28] In contrast, our work could

show that CABG preceded by PCI within 3 years did not influence survival. Other studies confirmed our findings.[29–32] Recently, a retrospective single-center study including 11,332 CABG patients showed that prior PCI had no impact on 5-, 10-, and 15-year survival when comparing them to CABG patients without prior PCI.[33] A prospective multicenter registry investigated the prognostic impact of multiple prior PCIs in CABG patients and showed an adjusted 30-day mortality rate of 1.3 to 3.1%, depending on the number of vessels that were intervened before CABG.[34] Of note, our data showed no differences in mortality and outcome with respect to the number of bypass grafts implanted in patients with prior PCI.

However, Mehta et al showed that PCI patients had higher incidence of postoperative adverse events, longer hospitalization time, and higher readmission rates after CABG.[29] Our data could not show any difference with respect to the incidence of renal failure with need for CVVH, need for left ventricular assist (ECMO, IABP), transfusion of blood products, and wound healing disorder or delirium. Also, ICU-related risk score SAPS-II and nurse workload index TISS-10 were similar.

On the other hand, we could demonstrate that PCI resulted in a significantly higher incidence for MI, re-PCI, and re-angiography after CABG. When the current 2018 ESC/EACTS guidelines were applied, re-angiography was also significantly more frequent in the GNC compared to GCO group. Although the incidence for MI and re-PCI were not significantly different under these circumstances, the time of patient inclusion to this study has to be considered. This data is in accordance with previous studies, which confirms negative influence of PCI in cardiovascular readmission rate at 5-year follow-up after CABG.[22] In this regard, it is important to point out that preoperative risk assessment scores, EUROScore II and the STS score, have been comparable in patients of all examined groups in our study, for example, CO, PCF, and even subgroups, for example, guideline-conformant PCI (GCO) and guideline-nonconformant (GNC) groups.

Of note, it has been reported that the aforementioned scoring systems are not accurate to predict early mortality in PCI patients admitted for CABG.[35] As described above, a sensitive scoring system to predict the postprocedural risk associated with PCI or CABG is the SYNTAX scoring system. It describes the complexity of the coronary anatomy and medical societies such as the ESC/EACTS take advantage of it for their recommendation for treatment of CAD. Our data reveals comparable SYNTAX score before CABG in both, patients undergoing CABG with (PCF) and without (CO) prior PCI. In contrast, we could demonstrate significantly enhanced preinterventional SYNTAX score in patients that were treated with PCI, in disagreement with the above-mentioned guidelines (GNC group). Not surprisingly, these patients also showed a significantly higher incidence of LM stenosis compared to those treated with CABG in accordance with the guidelines (GCO group). Of note, according to the ESC/EACTS guidelines, CABG should be performed in patients with multivessel disease, LM stenosis, and complex CAD.[4,5] Furthermore, not guideline-conformant PCI was associated with significantly higher incidence of subsequent stent implantation after CABG.

Our data buttresses the impression that patients with prior PCI reveal a higher incidence of complications such as MI, re-angiography, and re-PCI after CABG. This data is in accordance with previous studies.[22] Whereas survival is fortunately not affected, previous studies do not give consideration to the subjective well-being of these patients. Therefore, our study particularly evaluated quality of life of these patients using the EQ-5D questionaire.[36] We could show that higher incidence of MI, re-angiography, and stent implantation was associated with lower state of health in patients that received PCI before CABG, which was significantly better in patients who underwent CABG only.

There are multiple reasons why prior PCI might cause a deteriorated outcome after CABG. On one side, the presence of coronary stents increases the technical difficulty of surgery, including limitations with respect to the number of anastomoses and grafts to be anastomosed to more distal landing zones, possibly resulting in a worse graft patency.[37] Furthermore, stents cause a local inflammatory reaction in the coronary vessels' wall resulting in endothelial dysfunction.[4,19,28] It therefore seems logical that these changes complicate the outcome and are associated with higher need of reinterventions, as demonstrated by the 5-year results of the SYNTAX trial with a reported rate of repeat revascularization after PCI of 25.9%.[38] This was further corroborated by a large registry study.[39] Hence, these studies underpin our data, showing 17.6% of patients needing re-angiography and 10.4% re-PCI when CABG was preceded by PCI.

Furthermore, we shed light on patients where CABG was performed within 3 years after PCI, with particular attention to those patients where PCI was not according to the recommendations of the ESC/EATCS guidelines. As to these patients, the abovementioned results were even more striking: When PCI was not performed in accordance with the guidelines, the incidence for re-angiography doubled from

11.6 to 29.4% when compared to patients with guideline-conformant PCI, and went up to18.8% for re-PCI compared to 2.4%. To our knowledge, this is the first study that sheds light on an unexpressed problem of misguided therapeutic strategy for CAD treatment.

Keeping in mind the quality of life of these patients, it seems obvious that significantly enhanced incidence for re-stent implantation goes along with deteriorated subjective state of health, as revealed by the EQ-5D. Also, specific qualities of quality of life, for example, anxiety, mobility, and discomfort, are reduced while self-care and usual activities are unburdened when PCI was done in accordance with the guidelines. Being in line with this, Cohen et al compared quality of life of patients that underwent CABG or PCI: Among patients with three-vessel or LM CAD, there was greater relief from angina after CABG than after PCI after 6 and 12 months.[40] In this light, our data appears plausible as patients eligible for surgical revascularization according to the ESC/EACTS guidelines benefit from a CO strategy.

The present study emphasizes the importance of the Heart Team approach and adherence to acknowledged guidelines. This is especially true when complete interventional treatment of CAD is not feasible and/or if later treatment has to be anticipated.

Limitations

This study is a single-center retrospective study. The retrospective design increases susceptibility to selection and observational bias. Further, we used the 2014 ESC/EACTS guidelines for the evaluation of guideline compliance due to the time period during which the patients were included in this study.

With respect to statistical limitations, the originally planned regression analysis for the primary endpoints was abandoned in light of similar short-term outcomes between the PCF and CO groups as demonstrated in ►Tables 3 and 4, as well as small sample size in the GCO and GNC subgroups. Also, due to the small sample size, our study lacks direct comparison of patients without previous PCI and those with one, two, or multiple previous PCI procedures. The small sample size in PCF subgroups further foiled propensity score matching.

Finally, we have only a small number of patients from the GNC group that provided the EQ-5D questionnaires, reducing the robustness of the results. The inability to see patients again due to structural or health insurance reasons is a general restriction that applies to most retrospective studies. Therefore, our data has to be confirmed by prospective studies, registries, or meta-analysis.

Conclusion

PCI preceding CABG does not influence survival, but the outcome is more often impaired by MI, re-angiography, and re-PCI. This was further associated with worse health status revealed by the EQ-5D quality of life questionnaires. In addition, patients that have undergone guideline-conformant PCI

before CABG reported a better quality of life and could be spared additional invasive and expensive interventions. Therefore, the present study emphasizes the importance of the Heart Team approach for coronary revascularization.

Authors' Contribution

Conceptualization: G.D.D., M.H., C.G. Methodology: G.D.D., M.H., N.K., F.M., C.G. Software: M.H., N.K., D.L., C.G., F.M. Validation: N.K., M.H., F.M., C.G. Formal analysis: G.D.D., M.H., N.K. Investigation: G.D.D., M.H., N.K. Resources: G.D.D., N.K., D.L. Data curation: M.H., N.K., D.L., G.D.D. Writing – original draft preparation: M.H., N.K., G.D.D. Writing – review and editing: G.D.D., C.G., M.O., M.V., H.T. visualization: G.D.D., M.H., F.M., M.O., M.V., H.T. Supervision: G.D.D., M.H.. Project administration: G.D.D., M.H.

Conflict of Interest

None declared.

References

1 Townsend N, Nichols M, Scarborough P, Rayner M. Cardiovascular disease in Europe 2015: epidemiological update. Eur Heart J 2015;36(40):2673–2674

2 Heidenreich PA, Trogdon JG, Khavjou OA, et al; American Heart Association Advocacy Coordinating Committee Stroke Council Council on Cardiovascular Radiology and Intervention Council on Clinical Cardiology Council on Epidemiology and Prevention Council on Arteriosclerosis Thrombosis and Vascular Biology Council on Cardiopulmonary Critical Care Perioperative and Resuscitation Council on Cardiovascular Nursing Council on the Kidney in Cardiovascular Disease Council on Cardiovascular Surgery and Anesthesia, and Interdisciplinary Council on Quality of Care and Outcomes Research. Forecasting the future of cardiovascular disease in the United States: a policy statement from the American Heart Association. Circulation 2011;123(08):933–944

3 Melina G, Angeloni E, Refice S, et al. Clinical SYNTAX score predicts outcomes of patients undergoing coronary artery bypass grafting. Am Heart J 2017;188:118–126

4 Neumann FJ, Sousa-Uva M, Ahlsson A, et al; ESC Scientific Document Group. 2018 ESC/EACTS Guidelines on myocardial revascularization. Eur Heart J 2019;40(02):87–165

5 Windecker S, Kolh P, Alfonso F, et al; Authors/Task Force members. 2014 ESC/EACTS Guidelines on myocardial revascularization: the Task Force on Myocardial Revascularization of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS): developed with the special contribution of the European Association of Percutaneous Cardiovascular Interventions (EAPCI). Eur Heart J 2014;35(37):2541–2619

6 Serruys PW, Morice MC, Kappetein AP, et al; SYNTAX Investigators. Percutaneous coronary intervention versus coronary-artery bypass grafting for severe coronary artery disease. N Engl J Med 2009;360(10):961–972

7 Kundu A, Sardar P, O'Day K, Chatterjee S, Owan T, Dawn Abbott J. SYNTAX score and outcomes of coronary revascularization in diabetic patients. Curr Cardiol Rep 2018;20(05):28

8 Bundhun PK, Yanamala CM, Huang F. Percutaneous coronary intervention, coronary artery bypass surgery and the SYNTAX score: a systematic review and meta-analysis. Sci Rep 2017;7:43801

9 Serruys PW, Onuma Y, Garg S, et al. Assessment of the SYNTAX score in the Syntax study. EuroIntervention 2009;5(01):50–56

10 Sianos G, Morel MA, Kappetein AP, et al. The SYNTAX score: an angiographic tool grading the complexity of coronary artery disease. EuroIntervention 2005;1(02):219–227

11 Farooq V, van Klaveren D, Steyerberg EW, et al. Anatomical and clinical characteristics to guide decision making between coronary artery bypass surgery and percutaneous coronary intervention for individual patients: development and validation of SYNTAX score II. Lancet 2013;381(9867):639–650

12 Ohlmeier C, Czwikla J, Enders D, et al. Percutaneous coronary interventions : Use between 2004 and 2012 in Germany [in German]. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 2016;59(06):783–788

13 Landes U, Bental T, Levi A, et al. Temporal trends in percutaneous coronary interventions thru the drug eluting stent era: Insights from 18,641 procedures performed over 12-year period. Catheter Cardiovasc Interv 2018;92(04):E262–E270

14 Thielmann M, Leyh R, Massoudy P, et al. Prognostic significance of multiple previous percutaneous coronary interventions in patients undergoing elective coronary artery bypass surgery. Circulation 2006;114(1, Suppl):I441–I447

15 Hassan A, Buth KJ, Baskett RJ, et al. The association between prior percutaneous coronary intervention and short-term outcomes after coronary artery bypass grafting. Am Heart J 2005;150(05):1026–1031

16 Farkouh ME, Domanski M, Sleeper LA, et al; FREEDOM Trial Investigators. Strategies for multivessel revascularization in patients with diabetes. N Engl J Med 2012;367(25):2375–2384

17 Head SJ, Kaul S, Mack MJ, et al. The rationale for Heart Team decision-making for patients with stable, complex coronary artery disease. Eur Heart J 2013;34(32):2510–2518

18 Frutkin AD, Lindsey JB, Mehta SK, et al; NCDR (National Cardiovascular Data Registry) Drug-eluting stents and the use of percutaneous coronary intervention among patients with class I indications for coronary artery bypass surgery undergoing index revascularization: analysis from the NCDR (National Cardiovascular Data Registry). JACC Cardiovasc Interv 2009;2(07):614–621

19 Lisboa LA, Mejia OA, Dallan LA, et al. Previous percutaneous coronary intervention as risk factor for coronary artery bypass grafting. Arq Bras Cardiol 2012;99(01):586–595

20 O'Brien SM, Feng L, He X, et al. The Society of Thoracic Surgeons 2018 adult cardiac surgery risk models: part 2-statistical methods and results. Ann Thorac Surg 2018;105(05):1419–1428

21 Filardo G, Maggioni AP, Mura G, et al. The consequences of under-use of coronary revascularization; results of a cohort study in Northern Italy. Eur Heart J 2001;22(08):654–662

22 Miguel GSV, Sousa AG, Silva GS, Colósimo FC, Stolf NAG. Does prior percutaneous coronary intervention influence the outcomes of coronary artery bypass surgery? Rev Bras Cir Cardiovasc 2020;35(01):1–8

23 Hamiko M, Slottosch I, Scherner M, et al. Timely extracorporeal membrane oxygenation assist reduces mortality after bypass surgery in patients with acute myocardial infarction. J Card Surg 2019;34(11):1243–1255

24 Dangas GD, Farkouh ME, Sleeper LA, et al; FREEDOM Investigators. Long-term outcome of PCI versus CABG in insulin and non-insulin-treated diabetic patients: results from the FREEDOM trial. J Am Coll Cardiol 2014;64(12):1189–1197

25 Spadaccio C, Benedetto U. Coronary artery bypass grafting (CABG) *vs.* percutaneous coronary intervention (PCI) in the treatment of multivessel coronary disease: quo vadis? -a review of the evidences on coronary artery disease. Ann Cardiothorac Surg 2018;7(04):506–515

26 Deb S, Wijeysundera HC, Ko DT, Tsubota H, Hill S, Fremes SE. Coronary artery bypass graft surgery vs percutaneous interventions in coronary revascularization: a systematic review. JAMA 2013;310(19):2086–2095

27 Hannan EL, Samadashvili Z, Walford G, et al. Predictors and outcomes of ad hoc versus non-ad hoc percutaneous coronary interventions. JACC Cardiovasc Interv 2009;2(04):350–356

28 Massoudy P, Thielmann M, Lehmann N, et al. Impact of prior percutaneous coronary intervention on the outcome of coronary artery bypass surgery: a multicenter analysis. J Thorac Cardiovasc Surg 2009;137(04):840–845

29 Mehta GS, LaPar DJ, Bhamidipati CM, et al. Previous percutaneous coronary intervention increases morbidity after coronary artery bypass grafting. Surgery 2012;152(01):5–11

30 Boening A, Niemann B, Wiedemann A, et al. Coronary stenting before coronary artery bypass graft surgery in diabetic patients does not increase the perioperative risk of surgery. J Thorac Cardiovasc Surg 2011;142(02):e53–e57

31 Mannacio V, Di Tommaso L, De Amicis V, et al. Previous percutaneous coronary interventions increase mortality and morbidity after coronary surgery. Ann Thorac Surg 2012;93(06):1956–1962

32 Gaszewska-Zurek E, Zurek P, Kaźmierski M, et al. Coronary artery bypass grafting in patients with relatively recent previous stent implantation: three years follow-up results. Cardiol J 2009;16 (04):312–316

33 Rai P, Taylor R, Bittar MN. Long-term survival in patients who had CABG with or without prior coronary artery stenting. Open Heart 2020;7(02):e001160

34 Biancari F, Dalén M, Ruggieri VG, et al. Prognostic impact of multiple prior percutaneous coronary interventions in patients undergoing coronary artery bypass grafting. J Am Heart Assoc 2018;7(20):e010089

35 Bonaros N, Vill D, Wiedemann D, et al. Major risk stratification models do not predict perioperative outcome after coronary artery bypass grafting in patients with previous percutaneous intervention. Eur J Cardiothorac Surg 2011;39 (06):e164–e169

36 EuroQol Group. EuroQol–a new facility for the measurement of health-related quality of life. Health Policy 1990;16(03): 199–208

37 Kamiya H, Ushijima T, Mukai K, Ikeda C, Ueyama K, Watanabe G. Late patency of the left internal thoracic artery graft in patients with and without previous successful percutaneous transluminal coronary angioplasty. Interact Cardiovasc Thorac Surg 2004;3 (01):110–113

38 Mohr FW, Morice MC, Kappetein AP, et al. Coronary artery bypass graft surgery versus percutaneous coronary intervention in patients with three-vessel disease and left main coronary disease: 5-year follow-up of the randomised, clinical SYNTAX trial. Lancet 2013;381(9867):629–638

39 Stolker JM, Cohen DJ, Kennedy KF, et al; Evaluation of Drug-Eluting Stents and Ischemic Events (EVENT) Investigators. Repeat revascularization after contemporary percutaneous coronary intervention: an evaluation of staged, target lesion, and other unplanned revascularization procedures during the first year. Circ Cardiovasc Interv 2012;5(06):772–782

40 Cohen DJ, Van Hout B, Serruys PW, et al; Synergy between PCI with Taxus and Cardiac Surgery Investigators. Quality of life after PCI with drug-eluting stents or coronary-artery bypass surgery. N Engl J Med 2011;364(11):1016–1026