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Revascularisation of patients with end-stage renal disease on chronic haemodialysis: bypass surgery versus PCI—analysis of routine statutory health insurance data

Martin Möckel,[1] Julia Searle,[1] Henning Thomas Baberg,[2] Peter Dirschedl,[3] Benny Levenson,[4] Jürgen Malzahn,[5] Thomas Mansky,[6] Christian Günster,[7] Elke Jeschke[7]

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For numbered affiliations see end of article.

Correspondence to
Professor Martin Möckel;
martin.moeckel@charite.de

ABSTRACT

Objectives: We aimed to analyse the short-term and long-term outcome of patients with end-stage renal disease (ESRD) undergoing percutaneous intervention (PCI) as compared to coronary artery bypass surgery (CABG) to evaluate the optimal coronary revascularisation strategy.

Design: Retrospective analysis of routine statutory health insurance data between 2010 and 2012.

Main outcome measures: Primary outcome was adjusted all-cause mortality after 30 days and major adverse cardiovascular and cerebrovascular events at 1 year. Secondary outcomes were repeat revascularisation at 30 days and 1 year and bleeding events within 7 days.

Results: The total number of cases was n=4123 (PCI; n=3417), median age was 71 (IQR 62–77), 30.4% were women. The adjusted OR for death within 30 days was 0.59 (95% CI 0.43 to 0.81) for patients undergoing PCI versus CABG. At 1 year, the adjusted OR for major adverse cardiac and cerebrovascular events (MACCE) was 1.58 (1.32 to 1.89) for PCI versus CABG and 1.47 (1.23 to 1.75) for all-cause death. In the subgroup of patients with acute myocardial infarction (AMI), adjusted all-cause mortality at 30 days did not differ significantly between both groups (OR 0.75 (0.47 to 1.20)), whereas in patients without AMI the OR for 30-day mortality was 0.44 (0.28 to 0.68) for PCI versus CABG. At 1 year, the adjusted OR for MACCE in patients with AMI was 1.40 (1.06 to 1.85) for PCI versus CABG and 1.47 (1.08 to 1.99) for mortality.

Conclusions: In this cohort of unselected patients with ESRD undergoing revascularisation, the 1-year outcome was better for CABG in patients with and without AMI. The 30-day mortality was higher in non-AMI patients with CABG reflecting an early hazard with surgery. In cases where the patient's characteristics and risk profile make it difficult to decide on a revascularisation strategy, CABG could be the preferred option.

KEY QUESTIONS

What is already known about this subject?

- Current evidence on the optimal coronary revascularisation strategy in patients with end-stage renal disease (ESRD) is largely derived from large, US-based registries. There are no randomised controlled trials on this topic. A total of five systematic review articles with meta-analyses have been published. They too, are mainly based on the registry data from the USA and a few small observational studies are mainly from Asia. Only one very small study from a European country is included in any of these review articles and no European study has been published in the past 10 years. Additionally, there is a lack of data on revascularisation in patients with ESRD with acute myocardial infarction (AMI), as these patients were either excluded or not analysed separately. So far, the majority of studies report a reduced risk for short-term mortality for patients with ESRD treated with percutaneous intervention (PCI) but a reduced risk for long-term mortality when treated with coronary artery bypass grafting (CABG).

What does this study add?

- This study is the first to report large-scale data from a European country. Additionally, this is one of the two studies (and again the only European study) reporting data for patients with ESRD with AMI.

How might this impact clinical practice?

- Despite the lack of prospective randomised trials, there is good evidence that CABG should be the preferred revascularisation strategy in patients with ESRD with stable coronary artery disease. In patients with AMI, patients might benefit from an early revascularisation of an occluded culprit vessel with PCI. Elective CABG surgery could be considered, to reduce the long-term mortality in this patient group.

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INTRODUCTION

Patients with end-stage renal disease (ESRD) requiring haemodialysis have a high risk of coronary artery disease (CAD). Coronary revascularisation of this vulnerable patient group is challenging due to the high cardiovascular morbidity and mortality even after therapy.[1] The current 2014 European Society of Cardiology (ESC)/European Association for Cardio-Thoracic Surgery (EACTS) Guidelines on myocardial revascularisation[2] recommend the use of coronary artery bypass grafting (CABG) over percutaneous intervention (PCI) in patients with moderate or severe kidney disease and multivessel CAD on the basis of a large US registry.[3] Nevertheless, the outcome in this cohort was poor with unadjusted 5-year survival rates of only 22–25% for both strategies.[3] Recent data from patients on the transplant waiting list highlight the need for additional research specifically for patients on haemodialysis, as PCI did not show a large benefit over conservative strategies in this small observational study.[4] Systematic reviews of studies comparing CABG and PCI in patients with ESRD showed that CABG was mostly associated with a lower relative risk of long-term mortality, acute myocardial infarction (AMI) and repeat revascularisation, but with a higher relative risk of short-term mortality when compared to PCI.[5–9]

All systematic reviews are largely based on the same studies, which predominantly present data from the USA and Canada and from a few very small studies from Asia. Additionally, a large part of the studies included in the reviews date back into the 1990s. Of the studies performed since 2000, none originated from a European country.

In the absence of European studies and the absence of prospective randomised trials we analysed a large set of unselected statutory health insurance data to compare the 30 days and 1-year mortality and proportion of major adverse cardiac and cerebrovascular events (MACCE) in patients with ESRD who underwent either coronary revascularisation by PCI or by CABG in Germany. The analysis includes patients under current state-of-the-art interventional drug-eluting stents (DESs) and surgical standards. In a subgroup analyses, we aimed to assess differences in outcomes between patients with and without myocardial infarction (MI).

METHODS

This is a retrospective analysis of anonymised data of the German healthcare insurance 'Allgemeine Ortskrankenkasse' (AOK). AOK is the largest provider of nationwide statutory healthcare insurance in Germany (~30% of the German population). Every person is allowed to enrol in the AOK regardless of age, comorbidity, income or type of employment.[10] The data were derived from the billing data for inpatient and outpatient treatment. They comprise a unique identification number, age, sex, main diagnosis and comorbidities, procedures, length of hospital stays, patient survival and insurance status. Diagnoses were coded according to the 10th revision of the International Classification of Diseases (ICD-10).[11] Procedures were documented using the German version of the International Classification of Procedures in Medicine (ICPM), the 'Operationen- und Prozeduren Schlüssel' (OPS) for inpatients and the Doctors' Fee Scale within the Statutory Health Insurance Scheme 'Einheitlicher Bewertungsmaßstab' (EBM) for outpatients.[12]

The present study is based on anonymised data provided by hospitals and outpatient physicians for health insurance accounting. The recommendations for good practice in secondary data analysis developed by the German Working Group on the Collection and Use of Secondary Data were applied in full. Therefore no formal ethical committee approval was needed.

Study population

All in-hospital patients with ESRD were included in the study who underwent coronary revascularisation between January 2010 and December 2012 (admission date). The hospitalisation associated with the initial revascularisation procedure is referred to as 'index hospitalisation'. Patients with ESRD were defined as having had inpatient or outpatient dialysis at least once in the year prior to admission. Dialyses were identified as OPS codes '8-853.X to 8-858.X' for inpatients and as EBM codes '40800 to 40808' for outpatients. Coronary revascularisation was defined either by CABG or PCI, defined as OPS codes '5-361.X, 5-362.X' for CABG and '8-837.X' for PCI. We excluded patients receiving both CABG and PCI during the index hospitalisation. Patients with renal transplantation were defined as OPS codes '5-555.X', any type of cardiac surgery were defined as OPS codes '5-35X, 5-36X' and PCI in the year preceding admission were also excluded.

Patient involvement

Owing to the applied method, that is, ex post analysis of anonymous administrative data, patients and caregivers were not involved in either recruitment or conduct of this study, nor were they involved in the development of the design and outcome measurements of this study.

Outcomes

The primary outcome was all-cause mortality at 30 days and 1 year from the date of admission.

AOK gets notified of a member's death, and the membership is cancelled. The insurance companies receive information on the date of death, but not on the cause of death. Secondary outcomes were MACCE, repeat revascularisation procedures (CABG or PCI) and coronary angiography within 1 year. MACCE was defined as death, AMI, stroke or transient ischaemic attack (TIA). AMI was defined as ICD-10 diagnosis I21, including ST-elevation myocardial infarction (STEMI) and non-STEMI (NSTEMI). Stroke was defined as diagnoses

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I63 and TIA as diagnoses G45. An AMI occurring during the index hospitalisation was not considered an outcome, since it may have occurred prior to the revascularisation.

Statistics

Descriptive statistics such as medians and IQRs and proportions were used to describe differences in baseline characteristics. The two-tailed χ^2 test and the Kruskal-Wallis test were used to analyse group differences. Subgroup analyses were performed for patients with AMI at index hospitalisation. ORs were calculated for each outcome. To assess the association between the strategy for revascularisation and outcomes, multivariable logistic regression models were conducted using stepwise backward selection based on the likelihood ratio statistics. Adjusted OR and 95% CIs were calculated. Adjustment was made for sex, age and comorbidities according to Elixhauser definition,[13] AMI, cardiogenic shock, the New York Heart Association (NYHA) class (I vs II, III or IV), left main disease, multivessel disease (two or three vessels) at index hospitalisation and AMI in the year preceding admission. The Elixhauser measure was developed in 1998 to predict mortality from administrative data. The definition includes 31 acute and chronic comorbidities: congestive heart failure, cardiac arrhythmias, valvular disease, pulmonary circulation disorders, peripheral vascular disease, hypertension uncomplicated, hypertension complicated, diabetes uncomplicated, diabetes complicated (ie, coma, ketoacidosis, vascular disease), renal failure, liver disease, coagulopathy, blood loss anaemia, deficiency anaemia, hypothyroidism, peptic ulcer disease excluding bleeding, chronic obstructive pulmonary disease (COPD), obesity (body mass index $\geq$30 kg/m^2), weight loss, solid tumour without metastasis, metastatic cancer, lymphoma, fluid and electrolyte disorders, rheumatoid arthritis/collagen vascular diseases, paralysis, other neurological disorders, alcohol abuse, drug abuse, psychoses, depression and AIDS/HIV. Comorbidities were identified using the coding algorithm by Quan *et al*[14] based on the ICD-10 coding. AMI, cardiogenic shock, NYHA class (I vs II, III or IV), left main disease and multivessel disease (two or three vessels), which are not included in the Elixhauser measure, were also analysed because they are potential risk factors and differ between the PCI and the CABG groups (p<0.005).

Age was entered as a continuous variable. Other variables were entered as separate dichotomous variables. Data were censored in the analyses in case of death and AOK membership termination (2.74%/n=113). Hospitals are legally bound (§ 301 SGB V) to transmit complete data sets to the health insurance companies for all inpatients. For this reason, there are no missing data. All analyses were performed using STATA V.11.2 (StataCorp, College Station, Texas, USA).

RESULTS

We included n=4123 cases corresponding to n=3961 patients. All double interventions except one were PCIs. Compared to CABG, the frequency of PCI was higher with 82.88% over the 3 years period (2010: 81.17%; 2011: 83.13%; 2012: 84.20%). Figure 1 shows the included cases with respect to the reperfusion strategy and the diagnosis of AMI.

Table 1 shows the characteristics of the patients. The patients in the CABG group were slightly younger (69 vs 72 years) and there were less women.

Table 2 shows event proportions for the defined outcomes. The 30 days mortality was significantly higher in the CABG group (p=0.002). After 1 year, the mortality was nearly identical but the MACCE rate was higher for

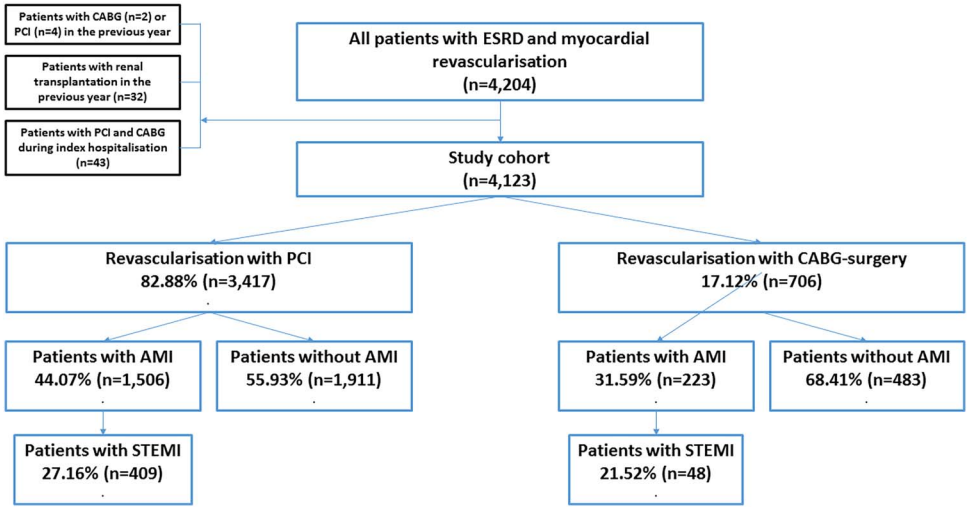

Figure 1 Flow chart indicating the cohort of patients included in the analysis. Patients were included if their index hospitalisation occurred during the predefined study period (January 2010–December 2012). The inclusion and exclusion criteria are outlined in the methods section.

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PCI driven by significantly more MI (p<0.001). The bleeding rate was similar in both groups.

Table 3 shows the OR for both revascularisation strategies. Mortality within 30 days was significantly lower in the PCI group with an adjusted OR of 0.59 (0.43 to 0.81) compared to CABG. One-year outcome is better in the CABG group, with an adjusted OR for MACCE within 1 year of 1.58 (1.32 to 1.89). The frequency for both, CABG and PCI treatments within 1 year after the index revascularisation, is significantly higher in the PCI group. The same is true for bleeding events within 7 days after the index intervention.

Tables 4 and 5 show the subanalysis of patients with and without AMI. For patients with AMI (table 4) there was no difference in 30 days mortality between PCI and CABG, but there was a non-significant trend towards more patients with STEMI in the PCI group (27.16% vs. 21.52%, p=0.06). Patients with STEMI had a higher risk of death within 30 days (OR=2.16 (1.56 to 2.98) and therefore a potential negative influence on survival in the PCI group and is therefore included in the variables for adjustment. After 1 year, the CABG group had better survival and less repeat interventions compared to the PCI group. This is independent of the diagnosis of STEMI in the index hospital stay.

In patients without AMI, the 30 days mortality was significantly lower with PCI, but after 1 year survival was better with CABG and repeat interventions and MI occurred less often in the CABG group (table 5).

DISCUSSION

Our study is the first to analyse a large European routine data set, using health insurance data from 4123

Table 1 Patient characteristics, for all patients and for the subgroups of patients with PCI and CABG

Variable	Total (n (%)) 4123 (100%)	PCI (n (%)) 3417 (100%)	CABG (n (%)) 706 (100%)	p Value
Age in years (median (IQR))	71 (62–77)	72 (63–77)	69 (60–74)	<0.001
Female patients	1252 (30.37%)	1087 (31.81%)	165 (23.37%)	<0.001
Diagnoses at the index hospital stay*				
Cardiovascular diseases				
AMI	1729 (41.94%)	1506 (44.07%)	223 (31.59%)	<0.001
Prior MI	499 (12.10%)	383 (11.21%)	116 (16.43%)	<0.001
Stroke	78 (1.89%)	47 (1.38%)	31 (4.39%)	<0.001
TIA	14 (0.34%)	12 (0.35%)	2 (0.28%)	0.778
Intracerebral bleeding	6 (0.15%)	4 (0.12%)	2 (0.28%)	0.292
Congestive heart failure	2059 (47.10%)	1649 (48.26%)	410 (58.07%)	<0.001
NYHA-stage >1	1685 (40.87%)	1323 (38.72%)	362 (51.27%)	<0.001
Coronary 2-vessel disease	1020 (24.74%)	884 (25.87%)	136 (19.26%)	<0.001
Coronary 3-vessel disease	2236 (54.23%)	1678 (49.11%)	558 (79.04%)	<0.001
Left main disease	435 (10.55%)	220 (6.44%)	215 (30.45%)	<0.001
Shock	248 (6.02%)	189 (5.53%)	59 (8.36%)	0.004
Hypertension	3211 (77.88%)	2595 (75.94%)	616 (87.25%)	<0.001
Cardiac arrhythmia	1814 (44.00%)	1408 (41.21%)	406 (57.51%)	<0.001
Valvular disease	1026 (24.88%)	727 (21.28%)	299 (42.35%)	<0.001
Peripheral vascular disorders	1455 (35.29%)	1121 (32.81%)	334 (47.31%)	<0.001
Other concomitant diseases				
Diabetes mellitus	2263 (54.89%)	1864 (54.55%)	399 (56.52%)	0.340
Chronic obstructive pulmonary disease	549 (13.32%)	420 (12.29%)	129 (18.27%)	<0.001
Coagulopathy	486 (11.79%)	224 (6.56%)	262 (37.11%)	<0.001
Hypothyroidism	449 (10.89%)	366 (10.71%)	83 (11.76%)	0.417
Obesity (BMI ≥30 kg/m^2)	442 (10.72%)	310 (9.07%)	132 (18.70%)	<0.001
Interventions at index hospital stay (%)				
BMS	1460 (35.41%)	1460 (42.73%)	–	–
DES	1519 (36.84%)	1519 (44.45%)	–	–
PCI >1 coronary artery†	464 (11.25%)	464 (13.58%)	–	–
Pacemaker implantation	90 (2.18%)	67 (1.96%)	23 (3.26%)	0.032
ICD implantation	35 (0.85%)	34 (1.00%)	1 (0.14%)	0.024

The p value was calculated using Kruskal-Wallis test for age and two-tailed χ^2 test all other variables.
*Other analysed comorbidities according to Elixhauser *et al* with frequency <5% are not shown (pulmonary circulation disorders, liver disease, blood loss anaemia, deficiency anaemia, peptic ulcer disease excluding bleeding, weight loss, solid tumour without metastasis, metastatic cancer, lymphoma, fluid and electrolyte disorders, rheumatoid arthritis/collagen vascular diseases, paralysis, other neurological disorders, alcohol abuse, drug abuse, psychoses, depression and AIDS/HIV).
†At least two stents in one or more coronary arteries during the index hospitalisation.
AMI, acute myocardial infarction; BMS, bare metal stent; CABG, coronary artery bypass graft; DES, drug-eluting stent; ICD, implantable cardioverter defibrillator; NYHA, New York Heart Association; PCI, percutaneous coronary intervention; TIA, transient ischaemic attack.

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Table 2 Event proportions for patients undergoing PCI or CABG

Outcome	PCI (n (%)) 3417 (100%)	CABG (n (%)) 706 (100%)
Mortality within 30 days	318 (9.31)	93 (13.17)
MACCE within 1 year	1287 (38.68)	249 (36.46)
Mortality	1044 (31.41)	216 (31.49)
Myocardial infarction	281 (11.81)	24 (5.11)
Stroke	63 (2.75)	10 (2.12)
TIA	28 (1.23)	3 (0.64)
CABG up to 1 year after index hospital stay	60 (2.62)	1 (0.21)
Within 30 days	8 (0.28)	0 (0.00)
31 days until 365 days	52 (2.27)	1 (0.21)
PCI up to 1 year after index hospital stay	739 (26.39)	31 (6.60)
Within 90 days	341 (12.27)	9 (1.71)
91 days until 365 days	298 (12.31)	22 (4.86)
Coronary angiography up to 1 year after index hospital stay	969 (38.93)	52 (10.95)
Bleeding during hospital stay or transfusion within 7 days after the intervention/operation	524 (15.34)	94 (13.31)

CABG, coronary artery bypass graft; MACCE, major cardiovascular or cerebrovascular event; PCI, percutaneous coronary intervention; TIA, transient ischaemic attack.

Table 3 ORs for the interventional treatment (PCI) (reference: CABG)

Outcome	Adjusted OR (95% CI)*	Crude OR (95% CI)
Mortality within 30 days	0.59 (0.43 to 0.81)	0.68 (0.52 to 0.89)
MACCE within 1 year	1.58 (1.32 to 1.89)	1.09 (0.92 to 1.31)
Mortality	1.47 (1.23 to 1.75)	1.00 (0.84 to 1.18)
Myocardial infarction	2.30 (1.49 to 3.53)	2.49 (1.67 to 3.71)
Stroke	1.46 (0.78 to 2.72)	1.30 (0.73 to 2.33)
TIA	3.55 (1.06 to 11.89)	1.94 (0.59 to 6.31)
PCI up to 1 year after index hospital stay	5.69 (3.81 to 8.50)	5.08 (3.46 to 7.44)
Within 90 days	8.94 (4.49 to 17.81)	8.02 (4.05 to 15.87)
91 days until 365 days	3.84 (2.42 to 6.01)	2.86 (1.80 to 4.54)
Coronary angiography up to 1 year after index hospital stay	6.14 (4.39 to 8.58)	5.19 (3.73 to 7.20)
Bleeding during hospital stay or transfusion within 7 days after the intervention/operation	1.58 (1.09 to 2.29)	1.18 (0.93 to 1.49)

*Risk adjustment: age, sex, comorbidities according to Elixhauser, myocardial infarction/STEMI, Shock, NYHA-stadium >1, 2-rsp. 3-coronary vessel disease, left main disease during index hospital stay or myocardial infarction in the year before. CABG surgery during the one-year follow-up period after the index event only occurred once in the CABG group and did not occur in the PCI group.
CABG, coronary artery bypass graft; MACCE, major cardiovascular or cerebrovascular event; PCI, percutaneous coronary intervention; TIA, transient ischaemic attack.

patients with ESRD on dialysis who underwent myocardial revascularisation during a 3-year period. Importantly, our study is one of the two studies published in the past 10 years which included and specifically reported results for patients with AMI during the index hospitalisation.

Our analysis shows that, even though patients with ESRD with PCI had a lower short-term mortality, 1-year results regarding mortality, AMI and combined MACCE as well as bleeding events and repeat revascularisation were significantly less frequent in patients undergoing bypass surgery. In the subgroup of patients who were admitted with AMI, the 30-day outcome did not significantly differ between the PCI and CABG groups whereas, again, the 1-year outcome was better in the CABG group regarding all outcomes, except for recurrent AMI. Given the lack of European data and of prospective randomised trials and the resulting lack of clear evidence-based guideline recommendations on the optimal therapeutic strategy, our large-scale and unselected data provide important support that surgical therapy should be favoured, where possible.

Current evidence

Our analysis largely confirms the results of systematic reviews and meta-analyses on this topic. Zheng *et al*[9] evaluated 16 retrospective, observational trials (1990 until 2010) with a total number of 32 350 patients with ESRD with CAD and a minimal follow-up time of 12 months, where patients with CABG had a lower long-term

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Table 4 ORs for the interventional treatment (PCI) of patients with acute myocardial infarction (reference: CABG)

	Adjusted OR (95% CI)* for patients with AMI	Crude OR (95% CI) for patients with AMI
Mortality within 30 days	0.75 (0.47 to 1.20)	0.74 (0.42 to 1.30)
MACCE within 1 year	1.40 (1.06 to 1.85)	1.04 (0.80 to 1.34)
Mortality	1.47 (1.08 to 1.99)	1.02 (0.77 to 1.36)
Myocardial infarction	1.67 (0.99 to 2.80)	1.76 (1.08 to 2.86)
Stroke	1.16 (0.36 to 3.80)	1.47 (0.47 to 4.61)
TIA	4.05 (0.42 to 39.11)	1.93 (0.25 to 14.74)
PCI up to 1 year after index hospital stay	5.43 (2.96 to 9.96)	4.30 (2.36 to 7.85)
Within 90 days	4.39 (2.02 to 9.54)	4.08 (1.89 to 8.81)
91 days until 365 days	4.36 (1.95 to 9.72)	3.30 (1.44 to 7.55)
Coronary angiography up to 1 year after index hospital stay	5.38 (3.20 to 9.06)	4.54 (2.73 to 7.53)
Bleeding during hospital stay or transfusion within 7 days after the intervention/operation	1.96 (1.18 to 3.24)	1.43 (0.89 to 2.31)

*Risk adjustment: age, sex, comorbidities according to Elixhauser, myocardial infarction/STEMI, Shock, NYHA-Stadium >1, 2-rsp. 3-coronary vessel disease, left main disease during index hospital stay or myocardial infarction in the year before.
CABG, coronary artery bypass graft; MACCE, major cardiovascular or cerebrovascular event; PCI, percutaneous coronary intervention; TIA, transient ischaemic attack.

Table 5 ORs for the interventional treatment (PCI) of patients without acute myocardial infarction (reference: CABG)

	Adjusted OR (95% CI)* for patients without AMI	Crude OR (95% CI) for patients without AMI
Mortality within 30 days	0.44 (0.28 to 0.68)	0.35 (0.24 to 0.51)
MACCE within 1 year	1.82 (1.44 to 2.31)	1.90 (1.47 to 2.45)
Mortality	1.45 (1.16 to 1.83)	1.67 (1.29 to 2.16)
Myocardial infarction	3.44 (1.63 to 7.25)	2.89 (1.39 to 6.03)
Stroke	0.95 (0.46 to 1.97)	1.82 (0.45 to 7.39)
TIA	2.66 (0.72 to 9.76)	6.37 (0.90 to 45.10)
PCI up to 1 year after index hospital stay	7.09 (4.30 to 11.69)	5.23 (3.19 to 8.57)
Within 30 days	17.29 (5.35 to 55.90)	15.03 (4.99 to 45.29)
31 days until 365 days	2.73 (1.52 to 4.88)	2.58 (1.46 to 4.55)
Coronary angiography up to 1 year after index hospital stay	6.03 (3.99 to 9.13)	5.28 (3.52 to 7.90)
Bleeding during hospital stay or transfusion within 7 days after the intervention/operation	1.36 (0.83 to 2.22)	0.89 (0.61 to 1.32)

*Risk adjustment: age, sex, comorbidities according to Elixhauser, shock, NYHA-stadium >1, 2-rsp. 3-coronary vessel disease, left main disease during index hospital stay or myocardial infarction in the year before.
CABG, coronary artery bypass graft; MACCE, major cardiovascular or cerebrovascular event; PCI, percutaneous coronary intervention; TIA, transient ischaemic attack.

mortality and ORs for MI and repeat revascularisation, while short-term mortality was lower in the PCI group. All studies included in this meta-analysis originated from the USA, Canada, Germany (n=1, 40 patients included)[15] and Japan, including two 2 large-scale US studies, which provided the majority of the analysed patients (n=30 090 of n=32 350 in total).[16 17]

Both US studies used data from the USA Renal Data System (USRDS) database, a national registry of the ESRD Medicare population in the USA, looking at patients on dialysis who were hospitalised from 1978 to 1995[16] and 1995 to 1998.[17]

Other systematic reviews published in recent years basically evaluate the same studies with a high proportion of studies dating far back.[5–9] The only exception is a review by Deo *et al*,[8] who only included studies published since the year 2000. The review by Kannan *et al*[5] additionally includes a large study which analysed USRDS data from 1997 to 2009.[3] Interestingly, the proportion of CABG in all studies included in the study Zheng *et al* was 47%, as compared to 17% in our cohort, reflecting that most data were generated in the early 1990s when PCI was not as predominantly used as it is today. Data on the temporal development of revascularisation strategy use show consistently higher numbers of PCI as compared to CABG in recent years.[18 19]

Recently, Bangalore *et al* published a registry study with data from the New York State Coronary Reporting

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System and Cardiac Surgery Reporting system on 11 305 patients with chronic kidney disease (CKD) and multivessel coronary disease. This included a prespecified analysis of patients on dialysis with matched CABG/PCI pairs based on a propensity score (n=243 per group). Again, PCI was associated with a higher long-term risk (HR 2.02 (1.4 to 2.93)) as compared to CABG, with also a higher risk of repeat revascularisation and AMI.[20] Krishnaswami *et al* published data from Kaiser Permanente Northern California (KPNC), which is reported as a healthcare delivery system with 33 million members. Of the 1015 patients on chronic dialysis who underwent elective coronary revascularisation, n=569 patients were treated with PCI (38% bare metal stent (BMS) and 63% DES) and n=446 with CABG. The analysis showed no significant differences between CABG and PCI (unadjusted HR for 1-year mortality 0.94 (0.71 to 1.24) for CABG, adjusted 1-year mortality HR 1.16 (0.80 to 1.67)).[21]

Current recommendations

Current recommendations are provided by cardiovascular, rather than renal guidelines. The European Renal Best Practice Guideline on kidney donor and recipient evaluation and perioperative care published in 2014 recommend 'performing coronary angiography in renal transplant candidates with a positive test for cardiac ischemia. Further management should be according to the current cardiovascular guidelines'.[22]

The 2014 ESC/EACTS Guidelines on myocardial revascularisation have devoted a small section on patients with chronic renal disease.[2] For patients with severe CKD and ESRD or in haemodialysis, the guidelines base their recommendation on a more recent study using USRDS registry data.[3] The guidelines recommend that 'CABG should be considered over PCI in patients with multivessel CAD and symptoms/ischaemia whose surgical risk profile is acceptable and life expectancy is beyond 1 year' whereas 'PCI should be considered over CABG in patients with multivessel CAD and symptoms/ischaemia whose surgical risk profile is high or life expectancy is less than 1 year'.[2] Both are Class IIb, level B recommendations. In figure 2 our results are integrated into the current guideline recommendations to show an amended proposed strategy for myocardial revascularisation for patients with ESRD on haemodialysis.

ESRD populations

Our analysis is the first large-scale report using data of patients who mainly have been treated according to current standard practice as patients underwent index revascularisation between 2010 and 2012. Demographics and healthcare seeking behaviour greatly differ between the German AOK and the US Medicare population. Medicare is the health insurance for all US citizens above 65 years and/or with disabilities and/or renal failure requiring chronic haemodialysis or transplantation. It covers hospital care, nursing facility care, nursing home care and hospice care, as well as ambulance services and limited outpatient care and prescription drugs. These latter services require extra monthly fees (http://www.medicare.gov). Around 16% (~50 Mio people) of the US population are covered by Medicare.[23] Of these, 209 000 people received Medicare coverage because of ESRD and another 175 000 because of age and ESRD (2007). Medicare does not cover primary care or early stage disease management for comorbidities.[24]

AOK is Germany's largest public health insurance company. Health insurance is mandatory for all German citizens and covers all healthcare costs which are considered to be effective. People can choose private healthcare instead of public health insurance, if they have a yearly income above €54 900. Compared with other public and with private insurances, AOK-insured persons

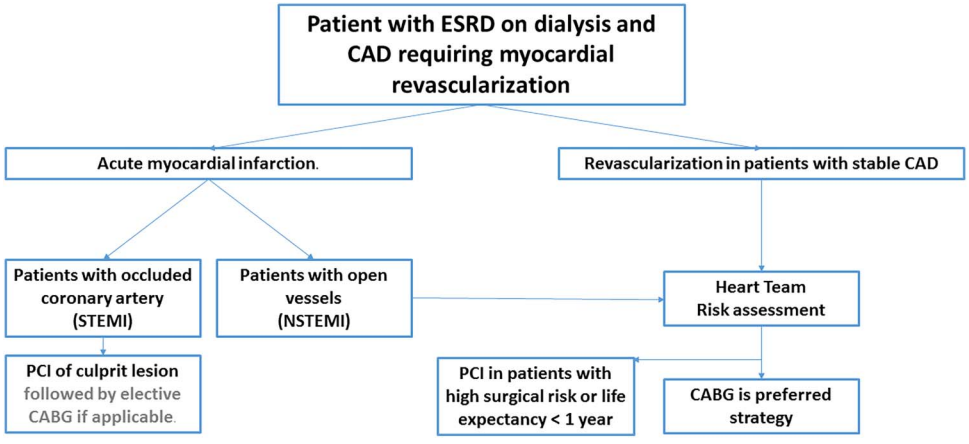

Figure 2 Proposed future revascularisation strategy in patients with ESRD based on our current results and previous guideline recommendations. AMI, acute myocardial infarction; CABG, coronary artery bypass graft; CAD, coronary artery disease; ESRD, end-stage renal disease; NSTEMI, non-ST-elevation myocardial infarction; STEMI, ST-elevation myocardial infarction.

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are more likely to be older, less likely to have a high school degree and more likely to perceive their health status as poorer than persons with private health insurance.[25] Still, when comparing patient characteristics between the Medicare population reported by Chang *et al* and our cohort, the Medicare population is considerably younger (mean age CABG 63/PCI 65 years) than our patients (median age CABG 69/PCI 72 years), with a lower rate of AMI in the index hospitalisation (Medicare cohort: CABG 23.9%/PCI 27.6%, AOK: CABG 31.6/PCI 44.1%) but with a higher prevalence of prior MI (CABG 17.5%/PCI 20% Medicare cohort, CABG 16.4/PCI 11.2% AOK). Long-term mortality was significantly higher in the Medicare cohort, but follow-up time was longer (Medicare: 70.9% CABG, 70.2% PCI vs AOK: CABG 31.5%, PCI 31.4%).

Acute MI

Very few studies provide separate analyses for patients with acute coronary syndrome (ACS) and AMI even though optimal revascularisation strategies might be different in an elective versus an acute setting, given the high morbidity of this patient cohort.

Of the studies published in the past 10 years, only one trial by Shroff *et al*[19] included and explicitly reported data on patients with AMI, the other studies either exclude patients with AMI,[20 26 27] only had elective patients in their cohort[21] or did not report separate results for the subgroup of patients with AMI,[3 28–30] although Chang *et al* provide a sensitivity analysis, showing that the presence of AMI had no influence on the result of their study.

Shroff *et al* included 23 033 patients with CKD stage 5 on renal replacement therapy for at least 90 days who were hospitalised for their first coronary revascularisation therapy, of these, 54.2% presented with ACS (66% AMI and 34% unstable angina pectoris (UAP)). Overall survival was lower in the ACS group. Interestingly, patients with ACS greatly profited from CABG on the long-term whereas patients without ACS had a similar long-term outcome with CABG or PCI. In patients with ACS, the HR for predicting mortality in DES and BMS versus CABG was 1.08 (1.02 to 1.15) and 1.30 (1.21 to 1.38), respectively. In-hospital mortality was highest in patients with CABG (10.4%) and lowest for DES (4.0%). In non-ACS patients the HR for predicting mortality in DES and BMS versus CABG was 1.01 (0.95 to 1.07) and was only significant for BMS with 1.13 (1.05 to 1.22).[19]

In our cohort, patients with ESRD with AMI in the index hospital stay were at higher risk for short-term and long-term adverse outcomes, as compared to patients without AMI. Patients with AMI had longer hospital stays, higher mortality at 30 days and higher ORs at 1 year. In the subgroup of patients with AMI, the 30-day mortality did not differ significantly between the revascularisation strategies, but the OR for 1-year mortality and 1-year MACCE were 1.47 (1.08 to 1.99) and 1.40 (1.06 to 1.85) in PCI versus patients with CABG, respectively. Importantly, patients with STEMI had a higher risk of death within 30 days (OR=2.16 (1.56 to 2.98)) and therefore a potential negative influence on survival in the PCI group. The shorter door-to-balloon time in PCI might have a higher impact in patients with STEMI and PCI should probably be the preferred strategy in these patients.

Limitations and external validity of health insurance data

Registries usually have to rely on complete and accurate information without being able to validate the data. Since they are especially set up for future analyses, variables which are not routinely provided can be included in the report forms. Registries provide larger and more unselected data sets than clinical trials, although here source data verification guarantees valid information of the selected group of patients who met the inclusion criteria.

Using health insurance data for large-scale outcome analyses has become increasingly popular and compared to study and registry data they hold a number of advantages. The most obvious advantage is the large sample size and the completeness of available data, thus avoiding selection and recall bias. In particular data from clinical trials exclude a large number of patients, often older and multimorbid. Health insurance data also have the great advantage of providing intersectoral data from the inpatient and outpatient healthcare system.[31]

On the other hand, health insurance data are not originally generated to analyse processes and patient outcome but are primarily needed for budgeting and reimbursement. Thus, valuable information is lacking, including data on coronary anatomy, quality of life and lifestyle-related risk factors. Also, specific budget regulations can cause particular coding behaviour. Additionally, data from one health insurance do not necessarily represent the whole population of one country.

One limitation of secondary data analyses is caused by a lack of international coding of diseases (ICD-10) codes for the clinical classification of diseases. There is no specific ICD code for patients with ESRD by which these patients can be identified. We therefore chose to select patients with ESRD on the basis of the dialysis procedure rather than ICD codes.

Patient outcome after revascularisation is dependent on the chosen revascularisation strategy, and on the quality of postrevascularisation care. This important factor is not reflected in the current analysis.

CONCLUSIONS

Our data from a large German cohort of unselected patients with ESRD on haemodialysis undergoing either PCI or CABG due to stable and unstable CAD confirm older data from US registries. The 1-year long-term outcome was significantly better in patients with surgical revascularisation, with respect to mortality and MACCE. This was especially true for patients with AMI.

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The short-term outcome was significantly better in patients undergoing PCI. This was probably driven by patients with STEMI, suggesting that PCI might be the preferred revascularisation strategy for this patient group. Our data suggest that revascularisation strategies need to differentiate between patients with and without AMI. Patients with STEMI might profit from urgent PCI with subsequent elective CABG surgery.

Generally, long-term outcome is better for patients with ESRD undergoing CABG. In cases where the patient's characteristics and risk profile make it difficult to decide on a revascularisation strategy, CABG could be the preferred option.

Author affiliations
[1]Division of Emergency Medicine and Chest Pain Units, Department of Cardiology, Campus Virchow Klinikum and Campus Charité Mitte, Charité—Universitätsmedizin Berlin, Berlin, Germany
[2]Department of Cardiology and Nephrology, Helios Klinikum, Berlin-Buch, Berlin, Germany
[3]Medical Service of the Health Funds (MDK) Baden-Württemberg, Lahr, Germany
[4]German Society of Cardiologists in Private Practise (BNK—Bundesverband niedergelassener Kardiologen), München, Germany
[5]Federal Association of the Local Health Care Funds (AOK), Berlin, Germany
[6]Faculty of Economics and Management, Division of Structural Development and Quality Management in Healthcare, Technische Universität Berlin, Berlin, Germany
[7]Research Institute of the Local Health Care Funds (WIdO), Berlin, Germany

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