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ON-PUMP VERSUS OFF-PUMP COMPLETE ARTERIAL REVASCULARIZATION USING BILATERAL INTERNAL MAMMARY ARTERIES IN T-GRAFT TECHNIQUE: CLINICAL AND ANGIOGRAPHIC RESULTS IN 3445 PATIENTS UP TO 13 YEARS

Dissertation

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Dedicated to Lisa and my family

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On-Pump versus Off-Pump Complete Arterial Revascularization Using Bilateral Internal Mammary Arteries and the T-Graft Technique: Clinical and Angiographic Results for 3,445 Patients in 13 Years of Follow-Up

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Key Words
Complete arterial coronary revascularization, off-pump, on-pump · Internal mammary arteries · Coronary angiography

Abstract
Background: This is an investigation of complete arterial coronary artery bypass grafting (CACABG) using bilateral internal mammary arteries (IMA) and the T-graft technique either on- or off-pump as a routine approach to treat coronary artery disease. ***Methods:*** Between January 2000 and December 2012, 3,445 patients underwent on-pump (n = 2,216) or off-pump (n = 1,229) CACABG. A 30-day follow-up was performed prospectively, a long-term follow-up by a questionnaire, and coronary angiography in selected patients. ***Results:*** End points at 30 days were death, myocardial infarction, stroke, repeat revascularization, renal replacement, reoperation, sternal wound infection and atrial fibrillation. FitzGibbon A patency rates were 89.8 vs. 91.4% (p = 0.464) with consecutive percutaneous coronary intervention in the grafted area of 1.8 vs. 1.1% (p = 0.693) on- vs. off-pump, and no reoperation in the grafted area in both groups. ***Conclusion:*** CACABG by use of skeletonized bilateral IMA with the T-graft technique performed either on- or off-pump is a safe and effective approach.

Introduction

Complete arterial coronary artery bypass grafting (CACABG) using bilateral internal mammary arteries (IMA) has been found to result in improved long-term survival [1–3], superior graft patency [2–4] and long-term freedom from cardiac events and reoperation. On the other hand, increased perioperative mortality, a higher incidence of reoperation for bleeding and other complications have been reported using bilateral IMA-grafting [5, 6].

Additionally, off-pump coronary artery bypass (OPCAB) techniques have been established in cardiac

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Table 1. Baseline characteristics of the patients

Variable	On-pump (n = 2,216)	Off-pump (n = 1,229)	p value[a]
Male sex	1,815 (81.9)	970 (78.9)	0.033
Age, years	66.7±9.7	68.3±9.7	<0.001
BMI, kg/m^2	27.6±4.0	27.2±4.1	0.014
Insulin-dependent diabetes	190 (8.6)	82 (6.7)	0.047
	203 (9.2)	112 (9.1)	0.963
Current smoker	894 (40.3)	450 (36.6)	0.032
Previous stroke	173 (7.8)	93 (7.6)	0.801
Calcified ascending aorta	57 (2.6)	78 (6.3)	<0.001
Peripheral vascular disease	221 (10.0)	120 (9.8)	0.844
History of malignant tumor	140 (6.3)	103 (8.4)	0.023
LVEF			
>50%	1,532 (69.4)	960 (78.4)	<0.001
30–50%	421 (19.1)	187 (15.2)	0.005
<30%	219 (9.9)	65 (5.3)	<0.001
Extent of CAD			
1-vessel disease	5 (0.2)	26 (2.1)	<0.001
2-vessel disease	702 (31.7)	654 (53.2)	<0.001
3-vessel disease	1,509 (68.1)	549 (44.7)	<0.001
Creatinine level			
≤1.4 mg/dl	1,960 (88.4)	1,083 (88.1)	0.774
>1.4 mg/dl	249 (11.2)	140 (11.4)	0.891
Renal replacement therapy	7 (0.3)	6 (0.5)	0.429

Values are mean ± SD or n (%), unless otherwise indicated.
[a] χ^2 or Student's t test.

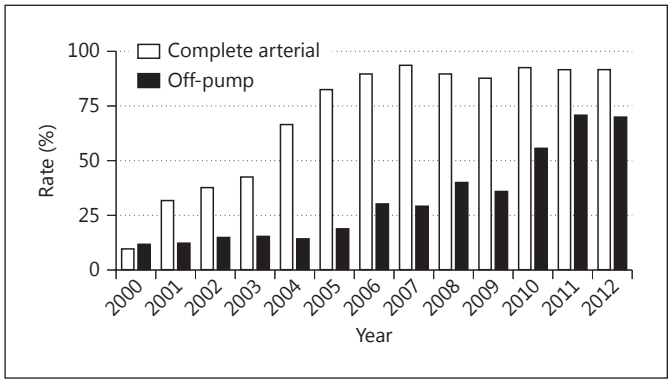

Fig. 1. Rate of complete arterial revascularization and off-pump procedures over the years.

surgery with early and mid-term results comparable to conventional CABG using cardiopulmonary bypass (CPB) [7–9]. Avoidance of CPB resulted in less myocardial injury, less transfusion requirement and a shorter hospital stay [10–12].

We investigated if CACABG, using bilateral IMA and the T-graft technique, is suitable to treat patients with coronary artery disease (CAD) on the basis of a routine approach. Moreover, we studied if use of the on-pump versus the off-pump technique resulted in different clinical and angiographic early and long-term outcomes.

Materials and Methods

In this retrospective study, we analyzed the data of 3,445 non-selected, consecutive patients who underwent primary CACABG with the use of bilateral skeletonized IMA and the T-graft technique at our institution between January 2000 and December 2012. Patients were treated by means of either on-pump (n = 2,216) or off-pump surgery (n = 1,229). Demographic data are shown in table 1. During the study period, the rate of CACABG increased from about 10% in 2000 to >90% in 2012 (fig. 1). Insulin-dependent diabetes, chronic obstructive pulmonary disease (COPD) and obesity were not contraindications for the CACABG approach. However, the decision to perform CACABG was influenced by the experience of the 6 different surgeons and the concomitant diseases of the patients, at least in the early study period.

Surgical Technique

All operations were performed via median sternotomy and exclusively by means of bilateral IMA harvested in a skeletonized technique with low cautery and hemoclips. The left IMA was used to bypass the left anterior descending branch/diagonal branches and the right IMA was implanted into the left IMA as a T-graft [13] to revascularize the obtuse marginal branches, the circumflex artery and the vessels of the right coronary artery (RCA) by sequential anastomoses. The T-anastomosis between the left and right IMA was created prior to the distal coronary anastomosis and in an on-pump procedure prior to the start of CPB. In the on-pump procedures, a membrane oxygenator and modified Calafiori solution was used. All off-pump cases were performed by an 'aortic non-touch technique' using the ESTECH stabilizing arm, together with a self-made platform (Geister) and air-cushioned silicon loops for local stabilization and temporary occlusion of the coronary vessel. Intracoronary shunts were only used in the case of ST-elevation or arrhythmias. Alternatively, the Medtronic Octopus stabilizer was used, together with intracoronary shunts. Deep pericardial traction sutures and table tilting were used to help position the heart. Opening of the right pleural cavity was used to reduce hemodynamic impairment.

Clinical Follow-Up and Data Collection

Early postoperative data were collected prospectively. Late follow-up was performed retrospectively with a questionnaire which was sent to all eligible patients in February 2012. Any reports of coronary interventions performed after bypass surgery were collected. Furthermore, the referring doctors were called in the case of open questions. Data were collected between July 2012 and July 2013.

The primary end points were: death, myocardial infarction, stroke, repeat revascularization, new renal-replacement therapy, delirium, reoperation for bleeding, deep sternal wound infection

Table 2. Perioperative variables and use of resources

	On-pump (n = 2,216)	Off-pump (n = 1,229)	p value[a]
Variables			
Operative time, min	250±53	229±48	<0.001
CPB time, min	83±26	–	–
Aortic cross-clamp time, min	68±23	–	–
Mean number of bypass grafts	3.56±0.85	3.04±0.85	<0.001
1-vessel disease	1.80±0.45	2.08±0.48	0.246
2-vessel disease	2.99±0.77	2.61±0.69	<0.001
3-vessel disease	3.83±0.73	3.60±0.67	<0.001
Pattern of arrangement of conduits			
Left anterior descending artery	2,169 (97.9)	1,207 (98.2)	0.507
Diagonal branch I	958 (43.2)	465 (37.8)	0.002
Diagonal branch II	87 (3.9)	46 (3.7)	0.789
Obtuse marginal branch I	1,424 (64.3)	696 (56.6)	<0.001
Obtuse marginal branch II	431 (19.4)	122 (9.9)	<0.001
Obtuse marginal branch III	38 (1.7)	13 (1.1)	0.126
Circumflex artery	1,002 (45.2)	444 (36.1)	<0.001
RCA	25 (1.1)	9 (0.7)	0.260
Posterolateral branch of RCA	407 (18.4)	129 (10.5)	<0.001
Posterior descending artery of RCA	1,333 (60.2)	583 (47.4)	<0.001
Right marginal branch of RCA	18 (0.8)	18 (1.5)	0.071
Use of resources in ICU			
Allogenic blood transfusion	598 (27.0)	197 (16.0)	<0.001
Mean number of blood units	0.61	0.32	<0.001
Median	0	0	
Duration of mechanical ventilation, h			
Mean	11.90	9.82	0.001
Median	9	8	
Length of postoperative stay, days			
Mean	3.05	2.81	0.010
Median	2	2	

Values are mean ± SD or n (%), unless otherwise indicated.
[a] χ^2 or Student's t test.

and atrial fibrillation at 30 days. Secondary end points were the occurrence of the abovementioned events beyond 30 days.

Postoperative angiography was performed in patients with chest pain and myocardial infarction. Graft performance was graded according to the FitzGibbon ABO classification: A (excellent/widely patent), B (fair/flow-limiting) and O (occluded) [14].

Statistical Analysis

All data were expressed as mean ± SD. $p < 0.05$ was considered statistically significant and p values for baseline characteristics and perioperative variables were calculated with the use of the χ^2 test or Student's t test. Continuous data are presented as median and standard deviation. Dichotomous data are described as number (%). Comparison of postoperative results was performed with logistic regression to reduce the impact of nonrandomization. Hazard or odds ratios were adjusted for the most relevant and reasonable baseline characteristics as well as time of follow-up. All statistical analysis was performed with the use of SPSS software v20.0.0 (IBM).

Results

Patient Demographics and Risk Factors

Table 1 shows the demographic characteristics of the study population. In a considerable number of patients, the indication for the off-pump approach was influenced by frailty or the presence of concomitant diseases. Thus, patients in the off-pump group were statistically significantly older (66.7 ± 9.7 vs. 68.3 ± 9.7 years; $p < 0.001$), showed a higher frequency of calcified ascending aorta (2.6 vs. 6.3%; $p < 0.001$) or had more frequently a history of a malignant tumor (6.3 vs. 8.4%; $p = 0.023$) compared to the on-pump group.

Table 3. Trial end points at 30 days, adjusted

End point	On-Pump (n = 2,216)	Off-Pump (n = 1,229)	p value	HR (95% CI)
Death	23 (1.0)	3 (0.2)	0.006	0.17 (0.05–0.60)
Myocardial infarction	10 (0.5)	2 (0.2)	0.199	0.37 (0.08–1.69)
Stroke	16 (0.7)	6 (0.5)	0.198	0.53 (0.20–1.39)
Repeat revascularization	4 (0.2)	2 (0.2)	0.901	0.90 (0.17–4.93)
New renal-replacement therapy[a]	45 (2.0)	22 (1.8)	0.922	0.97 (0.57–1.67)
Delirium	207 (9.3)	109 (8.9)	0.657	0.94 (0.73–1.22)
Reoperation for bleeding	46 (2.1)	13 (1.1)	0.027	0.49 (0.26–0.92)
Deep sternal wound infection				
Total	37 (1.7)	7 (0.6)	0.010	0.35 (0.15–0.78)
≤30 days	29 (1.3)	6 (0.5)	0.031	0.38 (0.16–0.91)
>30 days	8 (0.4)	1 (0.1)	0.170	0.23 (0.03–1.87)
Mean number of days after surgery[b]	25.0±17.1	18.1±13.5	0.263	–
Atrial fibrillation	752 (33.9)	364 (29.6)	0.007	0.80 (0.68–0.94)

Values are n (%), unless otherwise indicated. HRs were determined with logistic regression to reduce the impact of nonrandomization; hazards were adjusted for the most relevant and reasonable baseline characteristics.
[a] Thirteen patients with prior chronic renal-replacement therapy were excluded.
[b] Deep sternal wound infections occurred between postoperative days 4 and 81.

Perioperative Variables and Use of Resources

The duration of operation was longer (250 ± 53 vs. 229 ± 48 min; p < 0.001) and mean number of bypass grafts was higher (3.56 ± 0.85 vs. 3.04 ± 0.85; p < 0.001) in patients undergoing on-pump surgery than in off-pump patients. On the other hand, the frequency of 3-vessel disease was higher in the on-pump group (68.1 vs. 44.7%; p < 0.001). Patterns of the arrangement of conduits are shown in table 2. The allogenic blood transfusion rate during the entire hospital stay was statistically significantly lower in patients undergoing off-pump revascularization (27.0 vs. 16.0%; p < 0.001), and the duration of mechanical ventilation (11.90 vs. 9.82 h; p = 0.001) and stay in ICU (3.05 vs. 2.81 days; p = 0.010) was significantly shorter in the off-pump group.

Study End Points at 30 Days

The study end points at 30 days for on-pump versus off-pump surgery are shown in table 3. Patients undergoing off-pump surgery had a significantly lower mortality rate (1.0 vs. 0.2%; p = 0.006). Risk factors for 30-day mortality were LVEF ≤50% (p < 0.001; HR 9.86; 95% CI 3.66–26.58), calcified aorta (p < 0.001; HR 10.76; 95% CI 4.01–28.85) and advanced age (p = 0.013; HR 1.07; 95% CI 1.01–1.13) (table 6).

Most interestingly, no statistically significant differences were observed in patients who experienced postoperative myocardial infarction, stroke, repeat revascularization, new renal-replacement therapy and delirium. All 4 patients of the on-pump group undergoing repeat revascularization in the grafted vessels were treated interventionally. All IMA bypass anastomoses were FitzGibbon A. In 1 patient in the off-pump group, an occluded, but not bypassed, D1 was stented. A second patient had to be reoperated because of kinked LIMA graft proximal to the T-anastomosis. The pericardium was opened and the graft was fixed with fibrin glue. Reoperation for bleeding was observed more frequently in on-pump patients (2.1 vs. 1.1%; p = 0.027).

Deep sternal wound infection was observed statistically significantly more often in patients treated with the use of CPB in comparison to patients operated with the off-pump approach (1.7 vs. 0.6%; p = 0.010). Insulin-dependent diabetes was identified as a further risk factor for postoperative sternal wound infection (n = 44; p = 0.020; HR 2.52; 95% CI 1.16–5.48). Deep sternal wound infections occurred in 36/3,173 nondiabetic patients (1.1%) compared to in 8/272 diabetic patients (2.9%). The respective numbers were 1.5% (31/2,026) to 3.2% (6/190) in the on-pump group and 0.4% (5/1,147) to 2.4% (2/82) in the off-pump group.

Atrial fibrillation occurred more frequently in patients undergoing the on-pump approach (33.9 vs. 29.6%; p = 0.007). Risk factors for postoperative new renal failure

Table 4. Late postoperative results from a questionnaire, adjusted

	On-pump (n = 2,216)	Off-pump (n = 1,229)	p value	OR (95% CI)
Follow-up, years	5.71±2.26	4.00±2.45	<0.001	–
Questionnaire feedback	1,354 (61.1)	911 (74.1)	<0.001	1.72 (1.45–2.05)
Complete data set, n/total	1,135/1,354 (83.8)	814/911 (89.4)	0.380	1.17 (0.83–1.65)
Death[a]	170/1,354 (12.6)	72/911 (7.9)	0.535	0.87 (0.57–1.34)
Cardiac	16/1,354 (1.2)	7/911 (0.8)	0.890	1.11 (0.25–4.85)
Noncardiac	49/1,354 (3.6)	23/911 (2.5)	0.940	0.98 (0.50–1.91)
Unknown	105/1,354 (7.8)	42/911 (4.6)	0.426	0.80 (0.45–1.40)
Deaths per year	29.8 (2.2)	18.0 (2.0)		
	(n = 1,135)	(n = 814)		
Satisfied with operative result	1,111 (98.9)	784 (97.6)	0.062	0.46 (0.20–1.04)
Free of complaints	888 (80.0)	631 (78.9)	0.548	0.93 (0.75–1.17)
Condition better than preoperatively	946 (85.1)	638 (80.2)	0.103	0.80 (0.61–1.05)
NYHA classification				
Class I	799 (74.7)	582 (75.1)	0.834	1.03 (0.80–1.31)
Class II	142 (13.3)	103 (13.3)	0.861	1.03 (0.76–1.40)
Class III	114 (10.7)	69 (8.9)	0.204	0.79 (0.55–1.14)
Class IV	14 (1.3)	21 (2.7)	0.145	1.81 (0.82–3.99)
Time to recovery, weeks	13.1±14.4	12.9±16.1	0.853	–
Short of breath	210 (19.2)	151 (18.9)	0.755	0.96 (0.73–1.25)
Angina	116 (10.6)	96 (12.0)	0.397	1.15 (0.83–1.59)
Anxiety/worry	75 (6.8)	41 (5.1)	0.239	0.77 (0.50–1.19)
Stress ECG since operation	929 (85.1)	681 (86.0)	0.111	1.28 (0.95–1.73)
Cardiac reoperation	6 (0.5)	3 (0.4)	0.455	0.59 (0.15–2.38)
Valve reoperation	5 (0.4)	1 (0.1)	0.171	0.22 (0.03–1.92)
CABG	1 (0.1)	0 (0.0)	–	–
Myocardial infarction since operation	17 (1.5)	11 (1.4)	0.485	1.33 (0.60–2.98)
Stroke since operation	65 (5.8)	38 (4.7)	0.943	0.98 (0.63–1.54)
Arrhythmia/pacemaker	198 (19.6)	116 (15.5)	0.506	0.91 (0.68–1.21)
Anticoagulation	1,095 (98.1)	780 (98.9)	0.212	1.73 (0.73–4.06)
Phenprocoumon	148 (13.3)	78 (9.9)	0.235	0.82 (0.58–1.14)
Aspirin	936 (83.9)	698 (88.5)	0.183	1.23 (0.91–1.67)
Clopidogrel	62 (5.6)	47 (6.0)	0.425	1.19 (0.78–1.82)
New-onset diabetes[b]	64 (7.5)	30 (4.7)	0.587	0.87 (0.54–1.42)

Values are n (%) or mean ± SD. ORs were determined with logistic regression to reduce the impact of nonrandomization; odds were adjusted for the most relevant and reasonable baseline characteristics as well as years of follow-up.

[a] Including early mortality (≤30 days).

[b] Patients with diabetes prior to surgery were excluded (on-pump: n = 849; off-pump: n = 635).

(n = 67) were preoperative renal insufficiency (p < 0.001; HR 9.68; 95% CI 5.66–16.56), insulin-dependent diabetes (p = 0.038; HR 2.07; 95% CI 1.04–4.12) and LVEF ≤50% (p < 0.001; HR 3.23; 95% CI 1.91–5.47).

Late Clinical Outcome

Late postoperative and adjusted results of the questionnaire are presented in table 4. Odds ratios were determined with logistic regression to reduce the impact of nonrandomization. No statistically significant differences were found except length of follow-up, which was longer in the on-pump group (5.71 ± 2.26 vs. 4.00 ± 2.45 years; p < 0.001), and questionnaire feedback, which was higher in the off-pump group (61.1 vs. 74.1%; p < 0.001). In table 7 significant risk factors of late postoperative outcome are shown.

Angiographic Results and Reintervention Rate

A total number of 316 patients underwent angiography over the follow-up period of up to 13 years. Patency rates

Table 5. Angiography results

	On-pump (n = 2,216)	Off-pump (n = 1,229)	p value
Coronary angiography	228 (10.3)	88 (7.2)	0.002
Mean time from operation till angiography, years	3.43±2.44	2.88±2.12	0.050
Total number of anastomoses	774	244	
FitzGibbon A patency[a]			
All bypass anastomoses	695/774 (89.8)	223/244 (91.4)	0.464
Left anterior descending artery	205/219 (93.6)	80/83 (96.4)	0.350
Diagonal branch I	86/89 (96.6)	31/31 (100)	0.301
Diagonal branch II	10/12 (83.3)	3/3 (100)	0.448
Obtuse marginal branch I	143/156 (91.7)	48/50 (96.0)	0.305
Obtuse marginal branch II	51/58 (87.9)	11/13 (84.6)	0.745
Circumflex artery	72/85 (84.7)	20/24 (83.3)	0.870
Posterolateral branch of RCA	32/37 (86.5)	11/11 (100)	0.198
Posterior descending branch of RCA	96/118 (81.4)	19/29 (65.5)	0.064
PCI in grafted area	4/228 (1.8)	1/88 (1.1)	0.693
Reoperation in grafted area	0/228 (0.0)	0/88 (0.0)	–

Values are n (%), unless otherwise indicated.
[a] FitzGibbon ABO class determines the patency rates of bypass grafts.

of bypass grafts are shown in table 5. Reintervention rate by percutaneous coronary intervention (PCI) or reoperation was very low. Thus, only 4/228 (1.8%) patients undergoing reangiography in the on-pump group and 1/88 (1.1%) in the off-pump group were treated by PCI in the grafted area (p = 0.693). No patient had to be reoperated.

Discussion

The main result of this study is that CACABG using skeletonized bilateral IMA and the T-graft technique could be used as a routine approach in CAD patients, with excellent clinical and angiographic results for up to 13 years. It was not our intention to investigate the difference between arterial versus venous grafts.

Early mortality at 30 days was statistically significant lower in patients undergoing the off-pump approach (1.0 vs. 0.2%; p = 0.006). Furthermore, postoperative rethoracotomy for bleeding (2.1 vs. 1.1%; p = 0.027) and deep sternal wound infection (1.7 vs. 0.6%; p = 0.010) occurred statistically significantly less often in patients in the off-pump group. These findings are in agreement with a meta-analysis that included more observational studies than randomized controlled trials [15]. Other authors, however, in controlled randomized studies, found no difference between off-and on-pump CABG with respect to 30-day mortality, stroke, myocardial infarction or new renal failure [10, 16–18].

Moreover, the duration of mechanical ventilation and stay in ICU were statistically significantly shorter in the off-pump group than in the on-pump group (p = 0.001 and p = 0.010) (table 2). These results might suggest that avoiding CPB is a less traumatic procedure with a lower perioperative risk, leading to faster recovery of patients because of lower doses of heparin during the operation and also avoiding the side-effects of cardiopulmonary bypass such as a loss off coagulation factors, platelet count, and platelet function, even though off-pump patients were statistically significantly older (66.7 ± 9.7 vs. 68.3 ± 9.7 years; p < 0.001), showed calcification of the ascending aorta more often (2.6 vs. 6.3%; p < 0.001) and had a history of malignant tumor (6.3 vs. 8.4%; p = 0.023).

On the other hand, with the more frequent off-pump procedure, the operative time was significantly shorter (250 ± 53 vs. 229 ± 48 min; p < 0.001) and the rate of blood transfusion was lower (27.0 vs. 16.0%; p < 0.001) than in patients undergoing coronary revascularization with the use of CPB.

The reasons for prolonged operative time in the on-pump group might be the higher number of bypass anastomoses, higher doses of heparin, the loss of thrombocyte count and function and the loss of coagulation factors due to CPB resulting in a longer time for hemostasis and sig-

Table 6. Significant risk factors of 30-day end points

End point: risk factors	HR	p value	95% CI
Death (n = 26):			
On-pump/off-pump	0.17	0.006	0.05–0.60
LVEF ≤50%	9.86	<0.001	3.66–26.58
Calcified aorta	10.76	<0.001	4.01–28.85
Age (per year)	1.07	0.013	1.01–1.13
Myocardial infarction (n = 12):			
None			
Stroke (n = 22):			
Age (per year)	1.09	0.002	1.03–1.16
Previous stroke	2.90	0.040	1.05–8.03
Repeat revascularization (n = 6):			
None			
New renal-replacement therapy[a] (n = 67):			
Renal insufficiency	9.68	<0.001	5.66–16.56
Diabetes mellitus[c]	2.07	0.038	1.04–4.12
LVEF ≤50%	3.23	0.001	1.91–5.47
Delirium (n = 316):			
Male	1.49	0.016	1.08–2.07
COPD	1.58	0.010	1.12–2.24
LVEF ≤50%	1.38	0.012	1.07–1.78
Reoperation for bleeding (n = 59):			
On-pump/off-pump	0.49	0.027	0.26–0.92
Deep sternal wound infection[b] (n = 44):			
Diabetes mellitus[c]	2.52	0.020	1.16–5.48
Atrial fibrillation (n = 1,116):			
On-pump/off-pump	0.80	0.007	0.68–0.94
LVEF ≤50%	1.45	<0.001	1.23–1.70
Age (per year)	1.06	<0.001	1.05–1.06
BMI (per point)	1.02	0.030	1.00–1.04

HRs were determined with logistic regression to reduce the impact of nonrandomization; hazards were adjusted for the most relevant and reasonable baseline characteristics. [a] Thirteen patients with prior renal replacement therapy were excluded. [b] Deep sternal wound infections occurred between days 4 and 81. [c] Insulin-dependent diabetes.

nificantly more foreign blood transfusions (table 2). This corresponds with the finding that the rate of rethoracotomy due to bleeding complications was statistically significantly higher in on-pump patients than in off-pump patients (2.1 vs. 1.1%; p = 0.027) [15–17].

In on-pump patients, BMI was statistically significantly higher (27.6 ± 4.0 vs. 27.2 ± 4.1; p = 0.014), as were the rates of insulin-dependent diabetes (8.6 vs. 6.7%; p = 0.047), current smoking (40.3 vs. 36.6%; p = 0.032) and LVEF <30% (9.9 vs. 5.3%; p < 0.001). These demographic parameters may have contributed to the significantly higher postoperative mortality and higher rate of deep sternal wound infection observed in patients undergoing on-pump operation.

The significantly higher rate of 3-vessel disease in the on-pump group (68.1 vs. 44.7%; p < 0.001) probably contributed to the significantly longer operative time, and is at least one explanation for the higher number of bypass grafts (3.56 ± 0.85 vs. 3.04 ± 0.85; p < 0.001) found in the on-pump group than in the off-pump group, even when comparing the corresponding 2-vessel- and 3-vessel-disease groups (table 2) [16]. However, this did not result in a worse clinical outcome.

Atrial fibrillation was statistically significantly more frequently observed in patients undergoing on-pump surgery (33.9 vs. 29.6%, p = 0.007). However, in the on-pump group, more patients suffered from impaired left ventricular function (LVEF ≤50%), which was found to be a predictor for postoperative cardiac arrhythmias or pacemaker implantation in the long-term follow-up (p < 0.001; HR 1.61; 95% CI 1.21–2.14).

Most interestingly, no difference was found in the rate of postoperative stroke, in contrast to the results of the meta-analysis by Reston et al. [15], who found a lower rate of stroke with the off-pump approach, and also in agreement with controlled randomized studies [16–18]. However, in these studies, many patients received vein grafts to the ascending aorta; in contrast, in our study, all off-pump patients were operated without any manipulation to the ascending aorta. These patients showed statistically significantly greater calcification of the ascending aorta (2.6 vs. 6.3%; p < 0.001). Thus, these patients probably benefitted from the 'off-pump aortic non-touch' approach in avoiding cerebrovascular events. Due to the complete arterial approach in our on-pump patients, no side clamp of the ascending aorta was performed, which probably contributed to preventing neurological events. With respect to the stroke rate, it is important to emphasize that patients in whom calcification of the ascending aorta was detected intraoperatively were excluded in some controlled randomized trials [18].

In our study cohort, in agreement with some controlled randomized studies, there was no significant difference in postoperative myocardial infarction, indicating that coronary anastomoses could be performed with comparable success (table 3) [17, 18]. Other authors found similar good/even better results in the off-pump patients compared to the on-pump group [15] and also pointed out the role of surgical expertise and local stabilizers [19].

Harvesting both IMAs in the pedicle technique, particularly in diabetic patients, is associated with an increased incidence of sternal wound infections [4, 5, 20]. In our study, in the population undergoing bilateral IMA,

Table 7. Significant risk factors of late postoperative outcome

Variable: risk factors	OR	p value	95% CI
Death (n = 242)[a]:			
LVEF ≤50%	2.48	<0.001	1.69–3.65
Renal insufficiency	1.72	0.026	1.07–2.78
PAOD	2.11	0.003	1.28–3.48
COPD	2.60	<0.001	1.59–4.24
Age (per year)	1.07	<0.001	1.04–1.09
Years since surgery	1.31	<0.001	1.21–1.42
Satisfied with operative result (n = 1,895):			
Previous stroke	0.32	0.020	0.13–0.84
History of malignant tumor	0.35	0.044	0.13–0.97
PAOD	0.34	0.023	0.14–0.86
Free of complaints (n = 1,519):			
Male/female	0.54	<0.001	0.41–0.71
COPD	0.55	0.002	0.38–0.80
BMI (per point)	0.96	0.005	0.93–0.99
Shortness of breath (n = 361):			
Male/female	1.72	<0.001	1.29–2.29
COPD	2.71	<0.001	1.87–3.93
Age (per year)	1.02	0.025	1.00–1.03
BMI (per point)	1.06	<0.001	1.03–1.09
Angina (n = 212):			
Male/female	1.68	0.003	1.19–2.36
COPD	2.00	0.003	1.26–3.19
Diabetes mellitus[c]	1.84	0.023	1.09–3.11
Anxiety/worry (n = 116):			
Male/female	1.94	0.004	1.24–3.04
Age (per year)	0.95	<0.001	0.93–0.97
Cardiac reoperation (n = 9):			
Age (per year)	1.10	0.040	1.00–1.21
Myocardial infarction since operation (n = 28):			
Diabetes mellitus[c]	4.33	0.005	1.58-11.89
Age (per year)	1.24	0.006	1.06–1.45
Stroke since operation (n = 103):			
LVEF ≤50%	1.76	0.013	1.13–2.75
Previous stroke	1.88	0.048	1.01–3.51
Age (per year)	1.04	0.004	1.01–1.07
Years since surgery	1.13	0.005	1.04–1.23
Arrhythmia/pacemaker (n = 314):			
LVEF ≤50%	1.61	<0.001	1.21–2.14
COPD	2.24	<0.001	1.49–3.38
Renal insufficiency	1.61	0.022	1.07–2.42
Age (per year)	1.04	<0.001	1.02–1.06
Years since surgery	1.14	<0.001	1.08–1.21
Phenprocoumon (n = 226):			
LVEF ≤50%	2.67	<0.001	1.94–3.65
Active smoker	0.71	0.044	0.51–0.99
Renal insufficiency	1.89	0.003	1.24–2.90
Diabetes mellitus[c]	1.77	0.043	1.02–3.06
Age (per year)	1.08	<0.001	1.05–1.10
Aspirin (n = 1,634):			
Previous stroke	0.50	0.003	0.32–0.79
LVEF ≤50%	0.46	<0.001	0.34–0.79
Renal insufficiency	0.60	0.015	0.40–0.91
Age (per year)	0.95	<0.001	0.93–0.97
Years since surgery	0.89	<0.001	0.84–0.95
New diabetes (n = 94)[b]:			
Male/female	2.54	<0.001	1.55–4.16
BMI (per point)	1.16	<0.001	1.10–1.22
Years since surgery	1.31	<0.001	1.19–1.44

ORs were determined with logistic regression to reduce the impact of nonrandomization; odds were adjusted for the most relevant and reasonable baseline characteristics as well as years of follow-up. PAOD = Peripheral artery occlusive disease. [a] Including early mortality (≤30 days). [b] Patients with diabetes prior to surgery are excluded. [c] Insulin-dependent diabetes mellitus.

we observed a rate of sternal wound infection of 1.7% in the on-pump group and of 0.6% in the off-pump group, respectively (p = 0.010), despite bilateral IMA being used without restriction, even in patients with insulin-dependent diabetes (table 1). This is in agreement with the meta-analysis of Reston et al. [15] who found a highly significant lower rate of wound infections with the off-pump approach. The relatively low rate of sternal wound infection in both groups might have been due to that, during skeletonized preparation, low cautery energy and hemoclips were used, together with stable osteosynthesis of the sternum with at least 8 wires in combination with sternal steel bands. Most importantly, skeletonized harvesting of IMAs preserves venous backflow and arterial collaterals. This is in agreement with other studies that found reduced sternal wound infection in diabetic patients [19, 21] and a reduced time for pulmonary recovery [22] with IMA skeletonization versus the pedicle technique. The significantly lower rate of sternal wound infection in the off-pump group might have been due to the significantly lower rate of insulin-dependent diabetes and the lower BMI, significantly fewer blood transfusions and rethoracotomies, significantly shorter duration of surgery and mechanical ventilation and the avoidance of CPB. More-

over, in the off-pump group, significantly fewer patients were current smokers and the stay in ICU was shorter. All these parameters were detected as independent risk factors for deep sternal wound infection in patients undergoing CABG [23]. On the other hand, further risk factors for sternal wound infection described in the literature, i.e. advanced age and female sex, were found significantly more often in the off-pump group of our study.

In the insulin-dependent diabetic patients, the incidence of deep sternal wound infection increased from 1.5 to 3.2% in the on-pump group and from 0.4 to 2.4% in the off-pump group, in comparison to nondiabetic patients; this is in agreement with other studies [5, 6, 15, 20].

As our preoperative data indicate, the on-pump procedure was carried out more often for patients with 3-vessel disease. On-pump surgery was also used more often at the beginning of our study period. Hence, the duration of follow-up and the extent of CAD are most likely to result in further repeat revascularisation. Nevertheless, due to the small number of repeat revascularisations, the logistic regression analysis could not find significant risk factors.

Systematic coronary angiography of all patients who undergo CACABG is hardly justifiable due to the good results of CACABG and the potential risk of coronary angiography. Therefore, only in the case of chest pain, recurrent angina or myocardial infarction, were patients referred for diagnostic coronary angiography, i.e. 316 patients. Overall patency of FitzGibbon A in all the bypass grafts in these 'symptomatic patients' was 89.8% in the on-pump and 91.4% in the off-pump group, and the re-intervention rate was very low. Thus, during the 30-day follow-up, only 4 on-pump patients and 2 off-pump patients needed repeat revascularization of the previously treated vessels (table 3). Only 4 on-pump patients and 1 off-pump patient were treated by PCI during the entire 13-year follow-up. Not one single patient was treated by a coronary-artery reoperation (table 5). This is in contrast to other studies that found a significantly higher repeat intervention rate with the off-pump approach [15, 17, 24]. In the questionnaire, only one single coronary reoperation was reported in the on-pump group and there were none in the off-pump group (table 4). Possibly, even better late patency results could be expected for the 'asymptomatic' study cohort [25].

This study has limitations. It is not a randomized but a descriptive study. However, it provides mid-term data on a cohort of patients treated, at a high rate, by on-pump and off-pump CACABG. Moreover, angiographic data are not available for all patients. However, the presented angiographic result consists of a negative selection from 'symptomatic patients', so even better results could be expected in the 'asymptomatic' patients.

In conclusion, CACABG by the use of skeletonized LIMA/RIMA T-graft technique was found to be a highly effective approach for nonselected patients with excellent early and clinical results for up to 13 years of follow-up. Bypass patency rates were excellent in both groups. We conclude that CACABG using skeletonized IMA and the T-graft technique could be the 'gold standard' in the operative treatment of CAD.

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ON-PUMP VERSUS OFF-PUMP COMPLETE ARTERIAL REVASCULARIZATION USING BILATERAL INTERNAL MAMMARY ARTERY IN T-GRAFT TECHNIQUE: CLINICAL AND ANGIOGRAPHIC RESULTS IN 3445 PATIENTS UP TO 13 YEARS

Introduction, Summary and Further Thoughts

Abbreviations

LIMA	-	left internal mammary/thoracic artery
RIMA	-	right internal mammary/thoracic artery
BITA	-	bilateral internal mammary/thoracic artery
SITA	-	single internal mammary/thoracic artery
HLM	-	heart-lung-machine
CABG	-	coronary artery bypass graft
OPCAB	-	off-pump coronary artery bypass
3-V-D	-	three vessel disease
2-V-D	-	two vessel disease
LAD	-	left artery descending
CAD	-	coronary artery disease
PCI	-	percutaneous coronary intervention
DSWI	-	deep sternal wound infection
LVEF	-	left ventricular ejection fraction
PAOD	-	peripheral arterial occlusive disease
COPD	-	chronic obstructive pulmonary disease
BMI	-	body mass index

Background and Introduction

Operational techniques have been improved since the first use of aortocoronary bypass surgery in the 1960s (Elbardissi et al., 2012). Nevertheless, the introduction of percutaneous coronary intervention (PCI), and more recently drug-eluting-stents along with advanced medication for coronay artery disease (CAD) has become a decent alternative to bypass surgery.

Only recently, the guidelines of revascularisation of 2014 have reassured that coronary artery bypass grafting (CABG) needs to be done in 3-Vessel-Disease and left main disease and is superior to PCI, especially with a high Syntax score (Windecker et al., 2014). Since indications for surgery are clear, issues concerning the ideal operational procedure are still present.

Grafts

About 30 years ago, superior graft patency was found with the usage of the left internal mammary artery as opposed to saphenous vein grafts. This was histologically and biologically explained 21 days after bypass surgery of dogs (Sauvage et al., 1986). Since then various studies showed improved morbidity and mortality outcome using a complete arterial approach, including composite grafts, such as the radial artery, right internal mammary artery or gastroepiploic arteries (Collins et al., 2008; Fitzgibbon et al., 1996; Zacharias et al., 2009).

BITA or SITA

For many years now, the left internal mammary artery has become the standard graft for bypass surgery, since its anatomic position and patency rates are excellent. In 2009, 94.7% of all bypass operations in the USA used at least one mammary artery (Elbardissi et al., 2012). Surprisingly, only 4.1% were undergone with bilateral internal thoracic arteries (BITA). The most important issues that explain the hesitation of the BITA use is the concern about deep sternal wound infections (DSWI) and sternal dehiszence, since two major providing arteries for the anterior thorax become extracted. The problem of DSWI using BITA can be prevented by harvesting the grafts in a skeletonized fashion, especially regarding patients with diabetes. An adverse effect could be seen with a pedicled approach (Deo et al., 2013; Mannacio et al., 2011). A review of 2001 and 2013 with similar inclusion and exclusion criteria (Taggart, Amico, & Altman, 2001; Weiss et al., 2013) could show a significant better survival for BITA patients and therefore were in favour of BITA technique. Nevertheless these reviews were composed of non-randomised studies. The Arterial Revascularisation Trial (ART) will be the first pioneering major randomised trial comparing BITA and single internal thoracic arteries (SITA) with a

10-year outcome impatiently awaited for. The 1-year result is already present and showed no significant difference in the outcome besides a small absolute increase (1.3 %) of sternal wound reconstruction (Taggart et al., 2010).

Off-Pump Procedure

Introducing off-pump coronary artery bypass (OPCAB) in mid 1990s had mainly been initiated to reduce neurological incidents, since manipulation of the aorta may release emboli and lead to stroke (Roach et al., 1996). Furthermore cardiopulmonary bypass was believed to form microemboli and therefore trigger brain damage (Uretzky et al., 1987).

Various studies have investigated the outcome of these two procedures beyond neurological end points. The ROOBY trial (2009) has shown significant better survival, complete revascularisation and patency rate for CABG after one year, but also no significant difference regarding neurological outcome (Shroyer et al., 2009). Opposing that, the CORONARY trial (2012) illustrated no siginficant difference in the primary outcome. Apart from early revascularisation, other findings, such as re-operation for bleeding, kidney failure and lung complications were significantly in favor of OPCAB. Surprisingly no difference in neurological outcome was seen, either (Lamy et al., 2012).

The question remains, why do these two large randomised studies have such diverse results. A crucial difference seems to be the inclusion of surgeons, who had at least 20 off-pump procedures (ROOBY) against 100 (CORONARY). Several studies indicated the importance of expertise and the delicate learning curve of anyone attempting to master the off-pump procedure (Song et al., 2003; Edelman et al., 2013).

Hence, off-pump procedure carried out by experienced surgeons seems to have similar outcome compared to on-pump surgery as large randomized trials concluded. But does off-pump really not differentiate from on-pump in terms of neurological outcome?

A recent review of randomized trials stated no significant difference in the neurological outcome, especially as time goes by (Kennedy et al., 2013). Interestingly another review of randomized trials (including non-published), with a greater number of patients, observed a 30% risk reduction regarding postoperative strokes within 30 days (Afilalo et al., 2012).

A metaanalysis of Edelman and colleagues (Edelman et al., 2011) could show a reduction of stroke with the anaortic technique, providing that even side-clamping was spared. He also presumed in his review in 2013, along with other authors, that a complete anaortic procedure in the ROOBY and CORONARY study was not present, since figures about side-clamping or anoartic surgery could not be presented (Edelman et al., 2013).

Complete Revascularisation

It is not elusive to believe that a complete revascularisation of all heavily constrained coronary arteries is a good indicator for future myocardial incidents. Several studies have underlined an improved prognosis if complete revascularisation in bypass surgery was done as opposed to subtotal recascularisation (Zacharias et al., 2009; Sabik et al., 2006; Windecker et al., 2014). This is another important aspect whilst planning bypass surgery and makes an OPCAB less likely if surgeons still have backlog within the learning curve, mentioned earlier. Some parts of the heart are difficult to reach and operate on, especially with a beating heart (Edelman et al., 2013). Hence, if complete arterial revascularisation is intended, available grafts need to be carefully extracted and prepared with maximum length. Skeletonization of the internal mammary artery (IMA) vessels leads to longer grafts and makes complete revascularisation more likely.

Patency Rates

The ROOBY trial was able to investigate 1253 pedicled left internal mammary arteries (LIMA) to left artery descending (LAD) bypasses 1 year after surgery (Mcdonald et al., 2009). The difference of patency rate off-pump vs. on-pump was not significant (95.3% vs 96.2%, p=0.48). Though, classification after Fitz-Gibbon could favour on-pump procedure (89.0% vs 93.2%, p=0.01). Overall 4093 grafts could be analyzed, most of them were saphenous veins and therefore of no more interest regarding our own study. Veinous graphts are proven to fail earlier than arterial grafts, as mentioned earlier. Representative data to our own study in terms of patency rates were not present.

Study

Our study was designed to compare the 30-day and long-term results of patients who underwent a complete arterial coronary bypass operation with bilateral internal thoracic arteries in a T-graft technique (see Figure 2). Grafts were harvested in a skeletonized fashion. Off-pump procedure was done in aortic no-touch technique. Furthermore we compared on-pump as opposed to off-pump procedure. Within 13 years, we had a number of 3445 patients, having undergone the surgery mentioned above. Perioperative and early postoperative data were collected before enrolling rehabilitation. Late Follow-Up was gathered by a questionnaire, sent via mail. The feedback was almost 66% and was on average about 5 years after surgery. The study was non-randomized, therefore we used logistic regression for a more precise outcome.

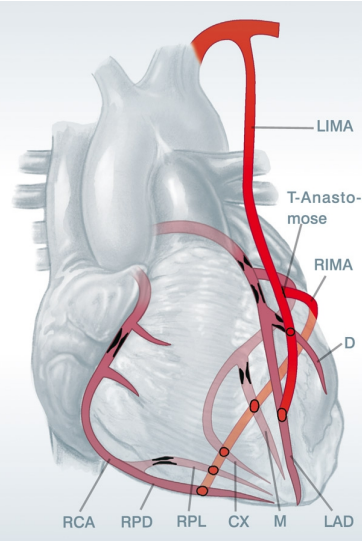

Figure 2: T-graft technique with LIMA in situ and RIMA end-to-side anastomosis. Illustration by Andreas Rieß

Results

Baseline Characteristics of the Patients

Since the usage of a heart lunge machine was influenced by the concomittant diseases of the patients and the experience of the surgeons, baseline characteristics differed.

Significant differences of operational risc factors regarding on-pump patients were the body mass index (27.6 ± 4.0 vs. 27.2 ± 4.1; p = 0.014), insulin-dependent diabetes mellitus (8.6% vs. 6.7%; p = 0.047), active smoking (40.3% vs. 36.6%; p = 0.032), chronic heart failure and the extent of coronary artery disease. On the other hand off-pump patients were burdened with age (68.3 ± 9.7 vs. 66.7 ± 9.7; p < 0.001), calcified ascending aorta (6.3% vs. 2.6%; p < 0.001) and history of malignant tumor (8.4% vs. 6.3%; p = 0.023) (see Table 1. Baseline characteristics of the patients, page 2).

Perioperative Variables and Use of Resources

Off-pump procedure was faster by 21 minutes (p < 0.001), needed less blood transfusion (16.0% vs. 27.0%; p < 0.001) and the duration of mechanical ventilation (9.82 hrs vs. 11.90 hrs; p = 0.001) as well as intensive care unit (ICU) stay was shorter (2.81 days vs. 3.05 days; p = 0.010). On the other hand, less anastomoses were performed concerning multi-vessel-diease (see Table 2. Perioperative variables and use of resources, page 3).

Trial End Points at 30 Days

Perioperative and early postoperative data were collected before enrolling rehabilitation. In the early outcome, off-pump procedure convinced due less deaths (0.2% vs. 1.0%; p = 0.006), less re-operations for bleeding (1.1% vs. 2.1%; p = 0.027), less deep sternal wound infections (0.6% vs. 1.7%; p = 0.010) as well as less atrial fibrillations (29.6% vs. 33.9%; p = 0.007) (see Table 3. Trial end points at 30 days, adjusted, page 4).

Late Postoperative Results

Late follow-up could be achieved in 65.7% of all patients, 5.09 years after surgery on average. Apart from more feedback from the off-pump group (74.1% vs. 61.1%; p < 0.001) with less time of follow up (4.00 ± 2.45 years vs. 5.71 ± 2.26 years; p < 0.001), there was no significant difference in the late clinical outcome. Both groups claimed to recover after 13 weeks on average and were equally as happy about the operational result (see Table 4. Late postoperative results from a questionnaire, adjusted, page 5).

Angiography Results

Of all 3445 patients, we are able to identify 316 coronary angiographies. Those were performed due to chest pain or myocardial infarction. Time passed since operation was longer regarding on-pump surgery (3.43 ± 2.44 years vs. 2.88 ± 2.12 years; $p = 0.050$) and more angiographies were reported (10.3% vs. 7.2%; $p = 0.002$).

All anastomoses were referred to as A (widely patent) or not (B or 0). Both groups had excellent results. Of all bypasses 89.8 % were widely patent in on-pump procedure, as opposed to 91.4 % in off-pump. 5 of them needed an intervention in the grafted area, no operation followed (see Table 5. Angiography results, page 6).

Risc Factors of 30-day end points

Age, insulin-dependent diabetes mellitus, chronic heart failure and calcified aorta were found to have a great impact of 30-day outcome, especially regarding death, stroke and renal failure (see Table 6. Significant risk factors of 30-day end points, page 7).

Risc Factors of Late Postoperative Results

The older the patients were and the more concomittant diseases they had, the worse was the late postoperative outcome. Interestingly, women seemed to suffer more from recurrent symptoms such as dyspnea, angina or anxiety (see Table 7. Significant risk factors of late postoperative outcome, page 8).

Discussion

Even though off-pump surgery is known for its delicate learning curve and a more complex procedure (Edelman et al., 2013; Song et al., 2003) , perioperative data indicated that off-pump surgery was faster (229 min ± 48 vs. 250 min ± 53, p= <.001), needed less transfusion of red blood cells and patients could be transferred earlier back to normal station. Therefore one could argue that off-pump procedure was less traumatic with faster recuperation. On the other hand, on-pump surgery could show a significant higher number of anastomoses performed. Even though our late postoperative results with 5.09 (SD 2.47) years of follow up could not show a difference in well-being or pectanginose discomfort, several studies stated the benefits of complete arterial revascularisation (Sabik et al., 2006; Windecker et al., 2014; Zacharias et al., 2009).

In the early outcome our results were in favour of off-pump procedure. We reported less deaths (0.2% vs 1.0%; p = 0.006), less re-operations for bleeding (1.1% vs 2.1%; p = 0.027), less deep sternal wound infections (0.6% vs 1.7%; p = 0.010) and less atrial fibrillations (29.6% vs 33.9%; p = 0.007). This could indicate, that cardiac surgery on a beating heart automatically implies immense caution and therefore may lower perioperative and early postoperative issues.

According to our own results as well as former studies, the use of bilateral internal thoracic arteries (BITA) can be used for complete arterial revascularisation (CACABG) as a routine approach. Bilateral IMA grafts harvested in a pedicled way should only be used with hesitation, especially with diabetes involved, as deep sternal wound infections (DSWI) will appear significantly more often (Deo et al., 2013; Mannacio et al., 2011). Our grafts were exclusively extracted in a skeletonized way. Those grafts may enable venous backflow and the formation of arterial collaterals. DSWI were seen in 1.7 % (on-pump) and 0.6 % (off-pump), a total of 44 cases, this included patients with insulin dependant diabetes, who had a 2.52-fold risc of developing a DSWI (p = 0.02; HR 1.16-5.48).

Again, no difference in the neurological outcome was observed. The difference in the rate of stroke was not significant. An important aspect of this finding is the demographic data of patients treated. Due to calcified ascending aorta, more of those patients were operated in off-pump procedure in aortic non-touch technique (6.3% vs 2.6%; p < 0.001) to avoid the release of emboli. Since a complete anaortic surgery seems to be the true factor of reducing stroke rates (Edelman et al., 2011), this could explain the absent difference of our study. Since we could not justify a compulsory angiographic follow up, we collected angiographic results of any patient who had a severe indication for it, such as pectanginose discomfort or dyspnea. The patency rates of both groups were particularly good, even though some authors underlined the impact of competitive flow in case of moderate stenosis of the native vessels

(Nakajima et al., 2004; Nakajima et al., 2007; Pevni et al., 2007). After 3.43 years ± 2.44 (on-pump) and 2.88 years ± 2.12 (off-pump), the patency rate A according to FitzGibbon was 89.8% (on-pump) and 91.4% (off-pump) with no significant difference concerning the individual anastomoses. Only five of them needed an intervention, no re-operation followed. These results represented patency rates of "symptomatic" patients. An even better outcome was to be expected of asymptomatic patients.

Limitations

This study was non-randomized. Concomitant diseases, experience of the surgeons and time progression of the study period had a significant impact in the decision-making of operational procedure for each individual patient. Therefore the demographic data of both groups were different. To reduce the impact of non-randomization, we used logistic regression for the outcome of our peri- and postoperative results. Most relevant and reasonable baseline characteristics could adjust the hazard ratios and P-values, especially regarding common end points. As most mid- and long-term studies, we could not obtain a complete feedback. About 1/3 of the patients could not be contacted for the late outcome via questionnaire. Hence, missing out on unsatisfactory results or even fatal consequences was likely. Additionally, further angiographies may have been performed without our notice.

Further thoughts

This study was designed to evaluate the outcome of CACABG in T-graft technique and to investigate the differences between on-pump and off-pump surgery. Nevertheless, since women have smaller hearts, accompanied with more delicate coronary vessels, revascularisation tends to be more difficult for the female gender. Several studies tried to examine this issue and compare early and late postoperative mortality. Since 15 years ago, a higher perioperative mortality rate for women was well documented, especially for younger women with a moderate risc profile (Brandrup-Wognsen et al., 1996; Edwards et al., 1998; Vaccarino et al., 2002). Interestingly, long term survival and quality of life did not differ from men to women, providing there was no discrimination regarding operational procedures (Gansera et al., 2004; Kurlansky et al., 2002; Kurlansky et al., 2013). Therefore, natural long term survival for women was adjusted after CABG. Hence one could still argue a slight benefit for men. In our own study we used logistic regression to examine relevant risc factors of early and late postoperative outcome. We realized that various variables were in favour of men, such as late postoperative symptoms or patency of bypasses used. Further investigation of differential outcome of men and women seems appropriate. This could even be explored using the very same data.

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Conclusion

Complete arterial coronary artery bypass surgery with bilateral internal thoracic mammary arteries in T-graft technique can be performed as a routine approach, either on-pump or off-pump.
Skeletonization of both grafts enables a low rate of deep sternal wound infections, even more in off-pump procedure. Passing patients with calcified ascending aorta to off-pump surgery may balance the peri- and postoperative stroke rate. Complete arterial revacularisation could be achieved significantly more often in on-pump surgery, although this did not result in worse clinical outcome about 5 years after surgery. Early postoperative results could favor off-pump procedure in terms of death, atrial fibrillation and re-operation for bleeding. Overall morbidity and mortality was low in both groups.
About 90% of all bypasses of symptomatic patients were graded FitzGibbon A, more than 3 years after surgery.

Zusammenfassung

Die komplett arterielle Bypass-Operation mit beiden Arteriae mammariae in so genannter T-Graft Technik kann in erfahrenen Zentren auch als Standard Operation angewandt werden. Die Skelettierung der Gefäße beugt der postoperativen Wundinfektion vor, insbesondere im Off-Pump Verfahren. Stark verkalkte Aortae sollten ohne Herz-Lungen-Maschine operiert werden. Durch diese Selektionierung sahen wir letztlich keinen Unterschied im neurologischen Outcome zwischen On- und Off-Pump. Die komplett arterielle Versorgung konnte On-Pump deutlich häufiger erzielt werden, dennoch gab es klinisch keine Unterschiede circa 5 Jahre nach der Operation. Die 30-Tages Morbidität und Mortalität war sehr gering in beiden Gruppen, allerdings trat der Tod, Vorhofflimmern, und die Re-Operation aufgrund von Blutungen häufiger in der On-Pump Gruppe auf. Etwa 90% aller koronarangiographierten Bypässe symptomatischer Patienten wurden als FitzGibbon A gewertet, durchschnittlich über 3 Jahre nach der Operation.

Contribution of Participants

Stefan Heller, shared first authorship

- Assistance of designing the study
- Assistance of designing the questionnaire for the late postoperative results
- Enter all returning data into data file
- Contact all missing patients or their general practitioners up to three times
- Evaluation and interpretation of data
- Statistical analysis, including regressional analysis
- Co-author of writing manuscript and publication

Prof. Dr. Med. Friedrich-Christian Rieß, shared first authorship

- Design of the study
- Design of the questionnaire
- Evaluation and interpretation of data
- Co-author of manuscript and publication
- Leading surgeon

Eva Cramer

- Assistance of designing, managing, coordinating and submitting the study
- Help contact missing patients

Nizar Awwad, Wagma Amin, Lorenz Hansen, Claas Lehmann, Joachim Schofer, Jan Stripling, Stephan Winkel, Peter Kremer

- Assistance of contacting missing patients
- Advisory function as leading surgeons or cardiologists

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Receiving, unwrapping, sorting and storing all of the returning questionnaires was an enormous effort. All of that was done by Prof. Rieß' secretaries, especially Petra Schlizio. This made entering the data a lot easier and saved me numerous hours of extra work.

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Ich versichere ausdrücklich, dass ich die Arbeit selbständig und ohne fremde Hilfe verfasst, andere als die von mir angegebenen Quellen und Hilfsmittel nicht benutzt und die aus den benutzten Werken wörtlich oder inhaltlich entnommenen Stellen einzeln nach Ausgabe (Auflage und Jahr des Erscheinens), Band und Seite des benutzten Werkes kenntlich gemacht habe.

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