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MULTIPLE ARTERIAL REVASCULARIZATION IN CABG SURGERY — INVESTIGATION OF LONG-TERM BENEFIT IN A COHORT OF 3129 CONSECUTIVE PATIENTS

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Objective: *Lacking utilization of accompanying arterial grafts to a left internal thoracic artery (LITA) in CABG surgery appear to be based on the lack of conviction regarding any long-term benefit.*

Aim of our study was to investigate whether multiple arterial revascularization (MAR) has an impact on survival after CABG.

Methods: *A consecutive series of 3129 patients undergoing first, isolated, non-emergent multivessel CABG procedure from 2001 to 2010 was investigated. MAR was performed in 1068 patients (34.1%) using radial artery in 791 patients (25.3%) and a second ITA graft in 344 patients (11%). The remaining 2061 patients received single ITA and concomitant SVG (conCABG group). Proportional hazard model was performed to estimate independent predictors for long-term survival.*

Results: *Median follow up was 56.9 months in the MAR group and 44.5 months in the conCABG group ($p<0.001$). Baseline characteristics were different regarding age, gender, smoking, cerebro- and peripheral vascular (all <0.001), and pulmonary disease ($p=0.04$). Actuarial survival at 1, 3, 5, and 8 years was 98.3%, 97.7%, 96.5% and 94.3% in the MAR group compared to 97.1%, 93,1%, 92.1%, and 86.9% in the conCABG group.*

MAR remained a strong independent predictor for long-term survival (Hazard Ratio HR: 0.65; 0.45-0.95; $p=0.02$). Additionally cerebro-vascular events (HR: 2.1; 1.3-3.5; $p=0.003$) and peripheral arterial disease (HR: 2.5; 1.9-3.5; $p<0.001$) revealed significant factors for survival beside age (3.2% increase/year; 1.01-1.05; $p<0.001$). Multivariate analysis revealed an absolute mortality reduction by MAR of 2.5% and 4% at 5 and 8 years after CABG.

Conclusions: *The result of our study implies that MAR should be the standard-of-care as the survival benefits seem to widen over time.*

Key words: *Cardiac Surgery, multiple arterial revascularization, predictors of long-term outcomes, arterial graft.*

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МНОЖИННА АРТЕРІАЛЬНА РЕВАСКУЛЯРИЗАЦІЯ ПРИ АОРТОКОРОНАРНОМУ ШУНТУВАННІ: ДОСЛІДЖЕННЯ ДОВГОТЕРМІНОВИХ ПЕРЕВАГ У КОГОРТІ З 3129 ПАЦІЄНТІВ

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Недостатньо широке використання супутньої імплантації лівої внутрішньої грудної артерії при аортокоронарному шунтуванні викликане відсутністю впевненості щодо довготермінових переваг такого методу.

***Мета** нашого дослідження – перевірити чи множинна артеріальна реваскуляризація (МАР) впливає на тривалість життя після аортокоронарного шунтування.*

***Методи.** Дослідження охоплює 3129 пацієнтів, які проходили первинне ізольоване планове багатосудинне аортокоронарне шунтування з 2001 по 2010 рр.. МАР застосували у 1068 (34,1%) випадках, при цьому променева артерія використовувалася у 791 (25,3%) пацієнта, а дві імплантації внутрішньої грудної артерії – у 344 (11%) пацієнтів. Решта 2061 пацієнт пройшли одну імплантацію внутрішньої грудної артерії та супутнього трансплантату із підшкірної вени (група звичайного аортокоронарного шунтування). Для оцінки незалежних прогнозів щодо тривалого виживання використано модель пропорційних ризиків.*

***Результати**. Середній період спостереження становив 56,9 місяця у групі МАР та 44,5 місяця у групі звичайного аортокоронарного шунтування ($p<0,001$). Вихідні характеристики, такі як вік, стать, куріння, цереброваскулярні захворювання, захворювання периферійних судин (усі $<0,001$) та легеневі захворювання ($p=0,04$), були різними. Актуарне виживання у 1, 3, 5 і 8 років становило 98,3%, 97,7%, 96,5% та 94,3% в групі МАР в порівнянні із 97,1%, 93,1%, 92,1%, та 86,9% у групі звичайного аортокоронарного шунтування.*

МАР залишилася сильним незалежним прогностичним фактором довготермінового виживання (Співвідношення ризиків (СР): 0,65; 0,45-0,95; $p=0,02$). Крім того, цереброваскулярні порушення (СР: 2,1; 1,3-3,5; $p=0,003$) та захворювання периферійних артерій (СР: 2,5; 1,9-3,5; $p<0,001$) виявилися важливими факторами виживання поруч із віком (3,2% зростання/рік; 1,01-1,05; $p<0,001$). Комплексний аналіз виявив абсолютне зниження смертності при МАР у 2,5% та 4% через 5 та 8 років після аортокоронарного шунтування.

***Висновки.** Результати нашого дослідження вказують на те, що МАР повинна стати стандартом лікування, оскільки її переваги для виживання збільшуються з часом.*

***Ключові слова:** кардіохірургія, множинна артеріальна реваскуляризація, прогностичні предиктори пізніх ускладнень, артеріальний імплантант.*

INTRODUCTION

Lacking utilization of accompanying arterial grafts to a left internal thoracic artery (LITA) in CABG surgery appear to be based on the lack of conviction regarding any long-term benefit (ElBardissi AW, Aranki SF, Sheng S, O´Brian SM, Greenberg CC, Gammie JS., 2012). Nevertheless, although survival advantages are well documented for those patients receiving a LITA compared to saphenous vein grafts (SVG) only, multiple arterial revascularization (MAR) has not yet become the standard-of-care in CABG surgery (Mastrobuoni S, Gawad N, Price J, Chan V, Ruel M, Mesana TG, et al, 2012). The increased risk for sternal complications especially in patients with diabetes and obesity has prevented a more common use of a second internal thoracic artery, therefore the radial and gastroepiploic artery have been introduced as alternative. However, the 1 year results of the ART trial (Arterial Revascularization Trial) has found an increased, but non-significant higher risk of sternal dehiscence at the same safety level compared to conventional CABG using single ITA (Taggart DP, Altman DG, Gray AM, Lees B, Nugara F, Yu LM, et al, 2010).

However, in a recently published study we could demonstrate that the radial artery was not a similar alternative to a second ITA graft in terms of cardiac-event free survival (Ruttmann E, Fischler N, Sakic A, Chevtchik O, Alber H, Schistek R, et al, 2011).

The benefit of additional arterial grafts is still a matter of debate and concerns about the relative merits of RA as a bypass conduit have been raised recently (Goldman S, Sethi GK, Holman W, Thai H, McFalls E, Ward HB, et al, 2011; Khot UN, Friedman DT, Petterson G, Smedira NG, Li J, Ellis SG., 2004). Contrarily, other observational studies have demonstrated significanty improved survival in patients receiving an additional RA (Zacharias A, Habib RH, Schwann TA, Riordan CJ, Durham SJ, Shah A., 2004; Tranbaugh RF, Dimitrova KR, Friedmann P, Geller CM, Harris LJ, Stelzer P, et al, 2010.).

The choice of an additional arterial graft might be more dependent on concomitant comorbid conditions rather than age, therefore the benefit of MAR has to be critically evaluated.

Aim of our current study was to investigate whether multiple arterial revascularization (MAR) has an influence on long-term survival after CABG and to investigate independent predictors for long-term outcome after CABG. Second, we wanted to quantify (if any exists after multivariate adjustment) the benefit of MAR in terms of mortality reduction at 5 and 8 years.

PATIENTS AND METHODS

Patients. Inclusion criteria for this study were first, non-emergent isolated coronary CABG for multi-vessel coronary artery disease performed by a median sternotomy access and cardiopulmonary bypass. Patients suffering a prior myocardial infarction within one

week before CABG procedure and patients receiving SVGs only were excluded. Patients receiving a totally endoscopic coronary artery bypass graft procedure (TECAB) assisted by the Da Vinci telemanipulation device for multivessel disease (either 2-vessel disease or as a hybrid procedure with concomitant PCI) were excluded from the study (n=45 patients). Additionally, patients undergoing conversion from minimally invasive CABG to median sternotomy access and patients undergoing CABG for single vessel disease (n=264 patients) were excluded from this current investigation.

A total of 3129 consecutive patients undergoing CABG fulfilled the inclusion criteria of our observational follow-up study. Patients were divided into 2 groups according to the number of arterial grafts used. Multiple arterial revascularization (MAR group) was performed in 1068 patients (34.1%) using a concomitant radial artery (RA) in 791 patients (25.3%) and a second ITA graft in 344 patients in addition to a left internal thoracic artery (LITA) (11%)%), 67 patients (6.3%) received both ITAs and a RA graft. The remaining 2061 patients (65.9%) received conventional CABG utilizing a single ITA grafting and concomitant saphenous vein grafts (SVG) as necessary (conCABG group).

Surgical technique and grafting strategy did not change over the last 10 years, except for the switching to skeletonization of ITA grafts in 2006.

The choice of bypass conduits and target area was left to the operating surgeon.

Peri-operative myocardial infarction was defined according to the Joint ESC/ACCF/AHA/WHF Tasc Force for the Redefinition of Myocardial Infarction (Thygesen, Alpert JS, White HD, 2007). Peri-operative neurologic events were defined as postoperative new onset neurologic deficit lasting for more than 72 hours after the appearance of symptoms.

Patient data were prospectively collected in full accordance to the standards of the Quality Control Working Group of the Austrian Society of Cardiothoracic Surgery. The data acquisition included a telephone interview by a trained study nurse 1 month after patient discharge to obtain 30-day mortality and morbidity. Late death was obtained from routine anniversary follow-up supplemented with the Social Security Death Index (Statistics Austria database). Permission for this study was obtained by the local Institutional Review Board.

Statistical Analysis. This current study was aimed to identify independent predictors for long term survival after CABG and to investigate whether MAR is an independent predictor for long term survival after adjusting for relevant comorbidity, gender and age. To test for univariate differences in categorical variables, Pearson´s chi-square test or Fisher´s exact test (when appropriate) were applied. Continuous variables were tested by use of Student´s t-test or Mann-Whitney U test (if assumption of a Gaussian distribution was not fulfilled). Kaplan-Meier survival analysis together with log-rank testing was applied to identify possible parameters influencing long term survival after CABG. In

a second step, proportional hazards method (Cox) was performed to obtain the Hazards Ratios (HR) and corresponding 95% Confidence Intervals (95% CI).

Thereby, the selection of variables was based on univariate comparisons (entry criteria $p<0.05$) and clinical relevance. P-values less than 0.05 were considered to indicate statistical significance.

RESULTS

Detailed patient characteristics are displayed in table 1.

Table 1

Patient characteristics of all consecutive, non-emergent primary multi-vessel CABG patients 2001 – 2010

	MAR n=1068 patients	conCABG n=2061 patients	p-value
Male gender (%)	931 (87.2%)	1580 (76.7%)	**<0.001**
Age (years)	58.8 ± 8.7	67.3 ± 9.3	**<0.001**
BMI (kg/m2) Obesity (BMI ≥ 30 kg/m2)	27.6 ± 3.9 250 (23.4%)	26.9 ± 4.0 463 (22.5%)	0.11 0.55
COPD Mild Moderate Severe	255 (23.9%) 182 (17.0%) 66 (6.2%) 7 (0.7%)	563 (27.3%) 397 (19.3%) 142 (6.9%) 24 (1.2%)	**0.038** 0.15
Arterial hypertension (%)	846 (79.2%)	1607 (78.0%)	0.83
Dyslipidemia (%)	880 (82.4%)	1648 (80.0%)	0.10
Diabetes Oral Insuline-dependent	246 (23.0%) 107 (10.0%) 14 (1.3%)	520 (25.2%) 126 (6.1%) 51 (2.5%)	0.18 **0.03**
Smoking (%) Current smoking (%)	436 (40.8%) 167 (16.2%)	656 (31.8%) 213 (10.3%)	**<0.001** **<0.001**
Cerebro-vascular disease Previous cerebrovascular event	53 (5.0%) 26 (2.4%)	24 (1.2%) 97 (4.7%)	**<0.001** **0.002**
Peripheral vascular disease (%)	120 (11.2%)	311 (15.1%)	**0.003**
Creatinine levels at timepoint of CABG Normal (<1.17 mg/dl) Slightly elevated (1.18 - <2 mg/dl) Elevated (≥ 2 mg/dl)	1.11± 0.85 863 (80.8%) 1867.4%) 19 (1.8%)	1.06 ± 0.71 1650 (80.1%) 360 (17.5%) 51 (2.5%)	0.11 0.46
Number of diseased coronary vessels Two-vessel disease Three-vessel disease Left main stenosis (%) Previous PCI	 533 (50.0%) 534 (50.0%) 248 (12.0%) 158 (14.8%)	 1073 (52.1%) 987 (47.9%) 142 (13.9%) 298 (14.5%)	 0.26 0.15 0.80
Impaired left ventricular function (LVEF<48%) Mean ejection fraction (%)	239 (22.4%) 52.7 ± 11.9	487 (23.6%) 52.2 ± 12.5	0.43 0.37
Preoperative arrhythmia (%)	104 (9.8%)	228 (11.1%)	0.18
EuroSCORE	2.7 ± 3.0	4.7 ± 5.0	**<0.001**
Median follow-up time (months)	56.9	44.5	**<0.001**

BMI, Body mass index; COPD, Chronic obstructive pulmonary disease; LVEF, left ventricular ejection fraction

Baseline characteristics were different regarding age, gender, smoking, cerebro- and peripheral vascular (all <0.001), and pulmonary disease (p=0.04). Patients undergoing MAR were significantly younger and more likely to be male (87.2% vs. 76.7%, p<0.001).

Table 2

Intraoperative characteristics of patients undergoing either multiple arterial revascularization (MAR) or conventional CABG (conCABG)

	MAR n=1068 patients	conCABG n=2061 patients	p-value
Mean number of bypass grafts	3.2 ± 0.87	2.9 ± 1.0	**<0.001**
ECC time (min)	116.9 ± 40	103.9 ± 42	**<0.001**
Aortic cross-clamp time (min)	66.8 ± 27.0	58.8 ± 26.0	**<0.001**
Procedure time (min)	259.5 ± 144	231.2 ± 156	**0.001**
Bypass conduits used Bilateral ITA grafts (%) Radial artery (%) Saphenous vein grafts (%)	344 (11%) 791 (25.3%) 812 (76%)	2061 (100%)	**<0.001**
Intraaortic ballon pump required (%)	25 (2.3%)	59 (2.9%)	0.39
Perioperative MACCE events Myocardial infarction (%) Stroke (%) Cardiac-related death	24 (2.3%) 19 (1.8%) 9 (0.8%)	39 (1.9%) 33 (1.6%) 32 (1.5%)	0.50 0.71 0.09
Sternal dehiscence (%)	39 (3.6%)	51 (2.5%)	0.06

Table 2 shows the intra-operative patterns of the study population. Patients undergoing MAR received significantly more bypass grafts than patients in the conCABG group (3.2 ± 0.87 vs. 2.9 ± 1.0, p<0.001). Furthermore, extracorporeal circulation time (ECC) as well as aortic cross-clamp time were significantly longer in the MAR group (all<0.001).

Table 3

Multivariate statistical analysis of independent predictors for long-term survival after CABG

	Wald	Hazard Ratio (95% CI)	p-value
Multiple arterial revascularization	**5.1**	**0.65 (0.45 – 0.95)**	**0.024**
Gender	0.68	0.87 (0.63 – 1.21)	0.41
Age (per year)	**1.0**	**1.032 (1.014 – 1.051)**	**<0.001**
Diabetes	0.54	1.3 (0.66 – 2.5)	0.46
Previous cerebro-vascular event	**9.1**	**2.1 (1.31 – 3.48)**	**0.003**
Cerebro-vascular disease	1.1	0.99 (0.66 – 1.51)	0.98
Chronic obstructive pulmonary disease	2.9	1.4 (0.96 – 1.92)	0.087
Peripheral arterial disease	**34.1**	**2.5 (1.90 – 4.47)**	**0.001**
Impaired left ventricular function (LVEF <48%)	2.9	1.7 (0.92 – 3.2)	0.09

Mean total procedure time was 28 minutes longer in the MAR group compared to conCABG (p=0.001).

Actuarial unadjusted survival at 1, 3, 5, and 8 years was 98.3%, 97.7%, 96.5% and

94.3% in the MAR group compared to 97.1%, 93,1%, 92.1%, and 86.9% in the conCABG group ($p<0.001$, see figure 1).

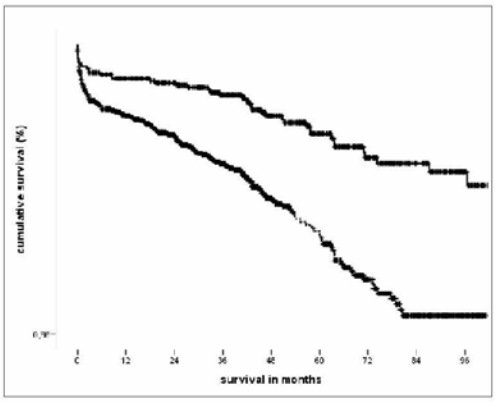

Fig. 1. Unadjusted Kaplan-Meier survival cures among patients with multivessel coronary artery disease undergoing coronary artery bypass grafting (CABG) receiving either multiple arterial revascularization (MAR, solid line) or conventional CABG (conCABG, dashed line). Unadjusted survival at 1, 3, 5, and 8 years after conCABG: 96.6%, 94.3%, 90.8%, and 86.9%; unadjusted survival at 1, 3, 5, and 8 years after MAR: 98.4%, 97.6%, 95.7%, and 94.3%), log-rank: $p<0.001$.

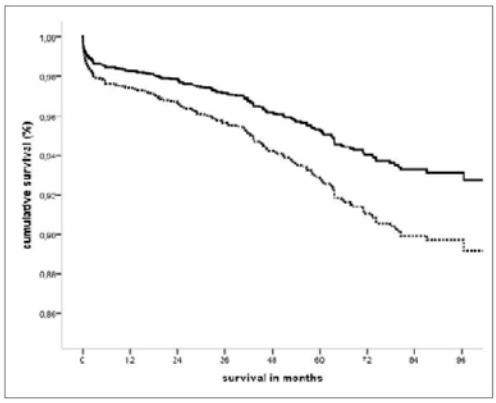

Fig. 2. Adjusted survival curves among patients with multivessel coronary artery disease undergoing coronary artery bypass grafting (CABG) receiving either multiple arterial revascularization (MAR, solid line) or conventional CABG (conCABG, dashed line); Adjustment has been performed for age and gender and relevant comorbidities such as diabetes, hypertension, cerebro-vascular disease and event, chronic obstructive pulmonary disease, peripheral arterial disease, impaired left ventricular function and impaired renal function; Adjusted survival at 1, 3, and 5 years after MAR: 98.3%, 97.0% and 95.2%, adjusted survival at 1, 3, and 5 years after conCABG: 97.5%, 95.7%, and 92.7%; Hazards Ratio for MAR: HR: 0.65 (95% CI: 0.45 – 0.95; p=0.02).

Predictors for long-term survival after CABG

Kaplan-Meier analysis was performed to identify parameters influencing long term (all cause) mortality. Parameters being significant at univariate analysis by Kaplan-Meier

(log-rank testing) were included into a proportional hazards model according to clinical relevance and statistical significance (entry $p<0.05$).

Table 3 displays the results of the multivariate statistical analysis.

Presence of peripheral arterial disease at the time-point of CABG was the strongest independent predictor for inferior long-term survival (Wald: 34.1, HR: 2.5; 95% CI: 1.9 – 4.47; p=0.001). Furthermore, previous cerebro-vascular events prior to CABG were associated with a 2.1 fold higher mortality risk (Wald: 9.1; HR: 2.1; 95% CI: 1.31 – 3.48; p=0.003).

MAR remained a strong independent predictor for improved long-term survival (Wald: 5.1; HR: 0.65; 0.45-0.95; p=0.02) and revealed a significant predictor for survival beside age (3.2% increase/year; 1.01-1.05; $p<0.001$). Gender, presence of diabetes, cerebro-vascular disease, chronic obstructive pulmonary disease and impaired left ventricular function however were not predictive for long-term survival after multi-variate adjustment.

Estimation of survival benefit due to MAR.

Adjusted survival curves for MAR versus conCABG are shown in figure 2. Adjustment has been performed for age and gender and relevant comorbidity such as diabetes, hypertension, cerebro-vascular disease and event, chronic obstructive pulmonary disease, peripheral arterial disease, impaired left ventricular function and impaired renal function. Adjusted survival at 1, 3, 5, and 8 years after MAR was: 98.3%, 97.0% and 95.2%, 93.0%; adjusted survival at 1, 3, 5, and 8 years after conCABG was: 97.5%, 95.7%, 92.7%, and 89% respectively. These results emphasized an adjusted absolute survival benefit for MAR of 2.5% at 5 years and 4% at 8 years after CABG.

DISCUSSION

Our study implies that the use of an additional arterial graft concomitant to a LITA reduces absolute mortality about 2.5% and 4% at 5 and 8 years even after adjustment for significant comorbidity, gender and age. Presence of extra-cardiac arteriopathy was the most relevant determining predictor for inferior long-term survival after CABG. However, the effect of MAR was the third most important predictor improving long-term survival and even more relevant than other conditions such as diabetes or impaired left ventricular function indicating the importance to establish MAR as standard-of-care procedure in coronary revascularization.

The results of our study are in line with previous observational studies that all came to the conclusion that two internal thoracic arteries are better than one (Kelly R, Buth KJ, Legare JF., 2012; Taggart DP, D`Amicio R, Altman DG., 2001; Rankin JS, Tuttle RH, Wechsler AS, Teichmann TL, Glower DD, Califf RM., 2007). However, patient recruitment of most of these studies was performed during the 1980ies not considering

that since then interventional cardiologists have been steadily expanded the spectrum of percutaneous interventions (PCI) in the setting of bypass graft failure (Brilakis ES, Rao SV, Benerjee S, Goldman S, Shunk KA, Holmes DR, et al, 2011). Furthermore, the area-wide improvement of acute PCI maintenance has led to a significant reduction of cardiac morbidity and mortality in order to prevent CABG patients with bypass graft failure from ongoing congestive heart failure and cardiac-related death (Doerler J, Edlinger M, Alber HF, Altenberger J, Benzer W, Grimm G, et al, 2011).

The role of the RA is still a matter of debate and current studies provide controversial results. Several studies indicated the RA to be associated with improved survival and long-term graft patency compared to SVG (Zacharias A, Habib RH, Schwann TA, Riordan CJ, Durham SJ, Shah A., 2004; Tranbaugh RF, Dimitrova KR, Friedmann P, Geller CM, Harris LJ, Stelzer P, et al, 2010; Collins P, Webb CM, Chong CF, Moat NE, 2008). Contrarily to this, another prospective randomized clinical trial concluded that the use of a RA did not result in a greater 1-year patency compared to SVG (Goldman S, Sethi GK, Holman W, Thai H, McFalls E, Ward HB, et al, 2011).

By now, long-term survival after CABG surgery was thought to be mostly dependent from relevant comorbidity and age. Our study indicated, presence of peripheral vascular disease was the most relevant predictor indicating worse outcome after CABG in our study. Among Dutch patients, van Straten and colleagues reported that peripheral vascular disease was an independent risk factor for late mortality. However, in CABG patients without peripheral vascular disease, the long-term survival was even better compared to the age-and-gender-matched Dutch population indicating excellent life expectancy after CABG (Van Straten AHM, Firanescu C, Soliman MA, Tan ME, ter Woorst JF, Martens EJ, et al, 2010).

In our study, MAR was highly predictive to improve survival after CABG and, contrarily to doctrine, was more relevant to improve survival than any coronary risk factor such as diabetes, age or left ventricular dysfunction.

Diabetes is a major risk factor for the development of coronary artery disease. Furthermore, diabetes has been shown to be associated with higher restenosis and reinterventions after PCI and has resulted in a higher rate of diabetic patients referred to CABG surgery (Hueb W, Gersh BJ, Costa F, Lopes N, Soares PR, Dutra P, et al, 2007; The BARI investigators. The bypass angioplasty revascularization investigation (BARI): Influence of diabetes on 5-year mortality in a randomized trial comparing CABG and PTCA in patients with multivessel disease. Circulation. 1997, 96, 1761-69). On the other hand, diabetes has been proposed to be a risk factor for reduced benefit of CABG in the long term (Alserius T, Hammar N, Nordqvist T, Ivert T., 2009). Furthermore, diabetes as a known risk for sternal complications has prevented a more common use of multiple arterial grafts

even in the knowledge of inferior saphenous vein graft patency in diabetic patients (Momin AU, Deshpande R, Potts J, El-Gamel A, Marrinan MT, Omigie J, et al, 2005; Lev-Ran O, Braunstein R, Nesher N, Ben Gal Y, Bolotin G, Uretzky G., 2004).

In our study among more than 3000 patients, impaired left ventricular dysfunction was not predictive for inferior long-term survival after multivariate adjustment. Left ventricular dysfunction has been advocated to indicate poor long-term survival after CABG. More recent large studies, however, could demonstrate excellent long-term survival in patients with severely impaired left ventricular function undergoing CABG and improvements in perioperative management have reduced the significance of severe left ventricular dysfunction (Galbut DL, Kurlansky PA, Traad EA, Dorman MJ, Zucker M, Ebra G., 2012; Davierwala PM, Maganti M, Yau TM., 2012). Furthermore, there is not even a single study available that has investigated whether complete surgical revascularization is able to improve left ventricular function. Contrarily to these findings, the STICH trial has proposed no difference between CABG and medical treatment alone in patients with severe left ventricular dysfunction, however, the trial had a 17% cross-over rate from medical treatment to CABG (Velazquez EJ, Williams JB, Yow E, et al, 2012).

By now, MAR is predominantly performed in patients with younger age and less comorbid conditions. Our study, however has confirmed that the use of more than 1 arterial graft improves long term survival even in "non-ideal" surgical candidates with diabetes or left ventricular dysfunction. Long term survival after CABG is strongly related to the presence of extra-cardiac arteriopathy. Moreover, the results of our study have shown that results after CABG can be improved by the use of more than 1 arterial graft even in patients with extracardiac arteriopathy, diabetes and impaired left ventricular function.

Previously, ElBardissi has shown the development of CABG surgery in the US during the past decade (ElBardissi AW, Aranki SF, Sheng S, O´Brian SM, Greenberg CC, Gammie JS., 2012). Mortality rate over this period declined from 2.4% in 2000 to 1.9% representing a relative risk reduction of 24.4%. Additionally the rate of perioperative stroke decreased significantly from 1.6% to 1.2% (relative risk reduction 26.4%) and a 32.9% risk reduction for sternal wound complications. However, even due to this tremendous improvement of surgical revascularization, the utilization of both internal thoracic arteries only rose from 3.8% to 4.1% indicating a extremely low MAR rate in the US.

Even due to the large number of cases and the extraordinary high rate of patients receiving MAR in our study there are several limitations to mention, namely the non-randomized nature of this observational study. Therefore, we cannot rule out confounding by missing covariates.

However, as the use of additional arterial grafts improved survival by one third, MAR

ought to become standard-of-care even in patients with significant comorbidity such as diabetes or left ventricular dysfunction and for patients with older age; the survival benefit divergence of MAR seems to widen over time.

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