Total arterial revascularization coronary artery bypass surgery in patients with atrial fibrillation

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ABSTRACT

Background: Atrial fibrillation (AF) is a relatively common comorbidity among patients referred for coronary artery bypass grafting (CABG) and is associated with poorer prognosis. However, little is known about how surgical technique influences survival in this population.

Aim: The current analysis aimed to determine whether total arterial revascularization (TAR) is associated with improved long-term outcomes in patients with preoperative AF.

Methods: We analyzed patients' data from the HEIST (HEart surgery In atrial fibrillation and Supraventricular Tachycardia) registry. The registry, to date, involves five tertiary high-volume centers in Poland. Between 2006 and 2019, 4746 patients presented with preoperative AF and multivessel coronary artery disease and underwent CABG. We identified cases of TAR and used propensity score matching to determine non-TAR controls. Median follow-up was 4.1 years (interquartile range [IQR], 1.9–6.8 years).

Results: Propensity matching resulted in 295 pairs of TAR vs. non-TAR. The mean (standard deviation [SD]) number of distal anastomoses was 2.5 (0.6) vs. 2.5 (0.6) ($P = 0.94$), respectively. Operative and 30-day mortality was not different between TAR and non-TAR patients (hazard ratio [HR] and 95% confidence intervals [CIs], 0.17 (0.02–1.38); $P = 0.12$ and 0.74 [0.40–1.35]; $P = 0.33$, respectively). By contrast, TAR was associated with nearly 30% improved late survival: HR, 0.72 (0.55–0.93); $P = 0.01$. This benefit was sustained in subgroup analyses, yet most pronounced in low-risk patients (<70 years old; EuroSCORE II <2; no diabetes) and when off-pump CABG was performed.

Conclusions: TAR in patients with preoperative AF is safe and associated with improved survival, with particular survival benefits in younger low-risk patients undergoing off-pump CABG.

Key words: arterial grafts, atrial fibrillation, CABG, survival, total arterial revascularization

WHAT'S NEW?

Recent studies showed that preoperative atrial fibrillation (AF) is associated with worse short and long-term prognosis after coronary artery bypass grafting (CABG). Consequently, surgeons are less inclined to perform more advanced techniques that prolong operative time, such as total arterial revascularization (TAR). In our propensity-matched study of 590 patients with AF and multivessel coronary artery disease, TAR was associated with a nearly 30% survival benefit. Despite their high-risk profile, patients with preoperative AF may benefit from TAR. A more courageous approach should be considered.

INTRODUCTION

International guidelines on coronary artery bypass grafting (CABG) and myocardial revascularization provide a strong recommendation in single-vessel coronary artery disease (CAD) to supply the left anterior descending (LAD) coronary artery with the left internal mammary artery (LIMA) [1, 2]. In the case of multivessel CAD, complete surgical revascularization should be attempted [2]. However, the guideline recommendations are scarce about the choice of a second or third conduit during CABG surgery. Over the last years, arterial conduits including the right internal mammary artery (RIMA) and radial artery (RA) became more often chosen, constantly extending the concept of total arterial revascularization (TAR). The 2016 Society of Thoracic Surgeons position paper states that arterial graft should be considered as a second conduit in appropriate patients (class of recommendation IIA) [3]. Given the superior long-term patency of arterial conduits, lower rates of myocardial infarction (MI) and repeat revascularizations, TAR may also translate to improved long-term survival, as compared to traditional saphenous vein grafts (SVG) [4, 5]. Previous observational studies suggested the association of a greater number of arterial grafts with superior long-term survival benefits [6–8]. However, the Arterial Revascularization Trial (ART), the first randomized study to compare patients receiving one vs. two arterial grafts, found no significant difference in terms of 10-year survival [9]. A large crossover ratio could substantially affect the results of the analysis performed "per-protocol" as opposed to "intention to treat"; indeed, recent *post-hoc* analysis of the ART trial suggests a slight advantage of TAR over venous revascularization [10]. Total arterial revascularization was further shown to be beneficial in several comorbidities, including diabetes and dyslipidemia [11]. While preoperative atrial fibrillation (AF) remains an independent risk factor for increased post-CABG mortality [12], no single study has yet assessed the impact of TAR in this population. Because of the lack of consensus on the choice of arterial conduits in this higher-risk setting, the current study aimed to assess long-term prognosis of TAR vs. non-TAR in patients with preoperative atrial fibrillation.

METHODS

Study population, definitions, and endpoints

Due to the retrospective nature of the study, the ethics committee approval was waived (PCN/CBN/0052/KB/118/22). Long-term survival data are derived from the Ministry of Health through individual files of the KROK registry (Krajowy Rejestr Operacji Kardiochirurgicznych). Our investigation was part of the HEIST (Heart Surgery In atrial fibrillation and Supraventricular tachycardia) study (NCT04860882). We included all consecutive AF patients, over 18 years old, admitted to 5 tertiary centers in Poland between January 2006 and December 2019 who had isolated CABG with or without concomitant ablation performed. The current analysis was restricted to patients with AF undergoing CABG for multivessel coronary artery disease (MV-CAD). (Supplementary material, *Figure S1*). We excluded from the analyses: (1) patients who had no diagnosis of AF; (2) patients with single-vessel CAD; (3) patients in whom the number of distal anastomoses and/or type of graft material used could not be determined; or (4) patients for whom complete revascularization (revascularization of all angiographically significant lesions) was not obtained,.

The primary efficacy endpoint was long-term mortality following CABG with TAR versus CABG without TAR. Follow-up regarding mortality was obtained from National Health Fund — a nationwide obligatory public insurance institution in Poland. Total arterial revascularization was defined as using exclusively arterial grafts to achieve complete revascularization. Conversely, non-TAR was defined as complete revascularization using at least one venous graft. Analyses of early postoperative (<24 hours) mortality rates together with in-hospital complications and lengths of stays in the intensive care unit (ICU) and hospital (HLoS) are reported. Baseline clinical characteristics are reported following the pertinent definitions in the EuroSCORE II calculator.

Statistical analysis

Continuous variables were summarized as mean (SD) if normally distributed; non-normal distributions were summarized as median and interquartile range (IQR) and compared with the Mann-Whitney U test or Student's t-test as appropriate. Categorical variables (number [%]) were compared with Fisher's exact test. Propensity score (PS) matching was performed to limit selection bias by identifying a set of TAR/non-TAR pairs matched for numerous risk factors. A PS was generated for each patient from a non-parsimonious multivariable logistic regression model that was based on baseline characteristics (age, sex, number of vessels diseased [occlusion greater than >50% on coronary angiography], previous MI, smoking, diabetes, hypertension, hyperlipidemia, chronic kidney disease, EuroSCORE II, left ventricle ejection fraction [LVEF], Canadian Cardiovascular Society and New York Heart Association [NYHA] scores) and procedural covariates (number of distal anastomoses and type of surgery [Off-Pump, On-Pump], surgical ablation, procedure urgency) as independent variables with treatment type (TAR vs. non-TAR) as a binary dependent variable. A greedy match using a nearest-neighbor method was used and a one-to-one ratio, without re-placement, within a specific caliper width of 0.2 SD of the LOGIT of the estimated propensity score. A one-to-one ratio was chosen to reduce potential bias occurring in numerically unbalanced comparisons [13]. Standardized mean differences (SMDs) were computed to verify the balance between the TAR versus non-TAR groups after matching. Risk ratios (RRs) were used for in-hospital outcomes, whereas Cox proportional-hazards models were used to determine factors related to event-free survival at long-term follow-up. Hazard ratios (HRs) point estimates and 95% confidence intervals (95% CIs) were calculated with ensuing statistical models. Mortality was assessed with Kaplan-Meier survival curves fitted after PS matching.

As a further sensitivity analysis, defined subgroup analyses stratified on age, use of cardiopulmonary bypass, CAD extent, diabetes, LVEF, previous MI, and EuroSCORE II were performed to assess mortality in different scenarios. STATA MP v13.0 software (StataCorp, College Station, TX, US) was used for computations.

RESULTS

During the 13-year study period, 4746 AF patients were admitted for isolated CABG because of MV-CAD. The subjects were then divided into the TAR (295 patients, 6.2%) and non-TAR (4451 patients, 93.8%) groups. Baseline characteristics of the TAR and non-TAR groups are presented in Supplementary material, *Table S1*. Each patient in the TAR group was matched with a non-TAR patient and thus 295 pairs were obtained with similar baseline and operative characteristics (Tables 1 and 2). Analyses of standardized mean differences of a wide spectrum of baseline and procedural variables (not all included in the PS model) before and after PS matching suggested a covariate balance across the groups (Supplementary material, *Figure S2*).

Table 1. Preoperative characteristics after propensity score-matching

	Total matched (590)	Non-TAR matched (295)	TAR matched (295)	*P*-value[a]	Non-TAR unmatched (4451)	*P*-value[b]
Baseline characteristics						
Age, years, median (IQR)	68 (63–74)	68 (63–74)	68 (62–74)	0.63	70 (63–75)	<0.001
Male sex, n (%)	459 (77.8)	231 (78.3)	228 (77.3)	0.84	3,441 (77.3)	>0.99
EuroSCORE II, median (IQR)	1.30 (0.83–2.35)	1.28 (0.83–2.37)	1.31 (0.83–2.33)	0.33	1.32 (0.87–2.32)	0.02
Diabetes, n (%)	247 (41.9)	131 (44.4)	116 (39.3)	0.24	1,853 (41.3)	0.46
Insulin ± oral hypoglycemic drugs, n (%)	103 (17.5)	51 (17.3)	52 (17.6)	>0.99	730 (16.4)	0.57
Active smoking, n (%)	400 (67.8)	205 (69.5)	195 (66.1)	>0.99	2,732 (61.4)	0.11
Hypertension, n (%)	527 (89.3)	265 (89.8)	262 (88.8)	0.79	4,037 (90.7)	0.30
Hyperlipidemia, n (%)	373 (63.2)	194 (65.8)	179 (60.7)	0.23	2,955 (66.4)	0.05
Poor mobility[c], n (%)	28 (4.7)	15 (5.1)	13 (4.4)	0.85	233 (5.2)	0.68
BMI, kg/m^2, median (IQR)	28.63 (25.80–31.46)	28.40 (25.45–31.97)	28.72 (26.26–30.58)	0.68	28.39 (25.71–31.44)	0.70
Pulmonary hypertension[d], n (%)	25 (4.2)	15 (5.1)	10 (3.4)	0.41	215 (4.8)	0.32
Severe (PA systolic >55 mm Hg), n (%)	0 (0)	0 (0)	0 (0)	>0.99	18 (0.4)	0.62
Renal impairment, n (%)	166 (28.1)	83 (28.1)	83 (28.1)	>0.99	1,318 (29.6)	0.65
Dialysis (regardless of CC), n (%)	2 (0.3)	2 (0.7)	0 (0)	0.50	26 (0.58)	0.40
Peripheral artery disease, n (%)	88 (14.9)	51 (17.3)	37 (12.5)	0.13	698 (15.7)	0.16
Cerebrovascular disease, n (%)	49 (8.3)	29 (9.8)	20 (6.8)	0.23	471 (10.6)	0.04
History of stroke, n (%)	19 (3.2)	12 (4.1)	7 (2.4)	0.35	181 (4.1)	0.17
History of TIA, n (%)	20 (3.4)	11 (3.7)	9 (3.05)	0.82	188 (4.2)	0.45
Chronic lung disease, n (%)	60 (10.2)	28 (9.5)	32 (10.9)	0.68	376 (8.5)	0.16
LVEF, %, median (IQR)[d]	50 (40–55)	48 (40–55)	50 (40–55.25)	0.08	50 (40–55)	0.10
3 vessel CAD, n (%)	249 (42.2)	125 (42.4)	124 (42.0)	>0.99	2,667 (59.9)	<0.001
LM disease, n (%)	165 (28.0)	88 (29.8)	77 (26.1)	0.36	1,400 (31.5)	0.06
Previous MI, n (%)	329 (55.8)	176 (59.7)	153 (51.9)	0.07	2,484 (55.8)	0.20
Previous PCI, n (%)	152 (25.8)	76 (25.8)	76 (25.8)	>0.99	992 (22.3)	0.17
NYHA, class IV, n (%)	15 (2.5)	8 (2.7)	7 (2.4)	>0.99	132 (3.0)	0.72
CCS 4, n (%)	60 (10.2)	35 (11.9)	25 (8.5)	0.22	549 (12.3)	0.05
ACS, n (%)	26 (4.4)	12 (4.1)	12 (4.1)	>0.99	123 (2.8)	0.10

[a]*P*-value for comparison of matched TAR vs. non TAR cohorts. [b]*P*-value for comparison of matched TAR vs. unmatched non TAR cohorts. [c]Defined according to EuroSCORE II as severe impairment of mobility secondary to musculoskeletal or neurological dysfunction. [d]Missing data

Abbreviations: ACS, acute coronary syndrome; BMI, body mass index; CAD, coronary artery disease; CC, creatinine clearance; CCS, Canadian Cardiovascular Society; IQR, interquartile range; LM, left main; LVEF, left ventricular ejection fraction; MI, myocardial infarction; NYHA, New York Heart Association; PA, pulmonary artery; PCI, percutaneous coronary intervention; TAR, total arterial revascularization; TIA, transient ischemic attack

Table 2. Operative characteristics after propensity score-matching

	Total (590)	Non-TAR (295)	TAR (295)	*P*-value
Procedural characteristics				
Redo surgery, n (%)	8 (1.4)	2 (0.7)	6 (2)	0.29
Critical preoperative state, n (%)	8 (1.4)	5 (1.7)	3 (1)	0.73
CPR, n (%)	1 (0.2)	1 (0.3)	0 (0)	>0.99
IABP, n (%)	20 (3.4)	12 (4.1)	8 (2.7)	0.50
IV inotropes, n (%)	19 (3.2)	11 (3.7)	8 (2.7)	0.64
OPCAB, n (%)	440 (74.6)	219 (74.2)	221 (74.9)	0.93
CPB, min, median (IQR)[a]	80 (58.5–100.5)	80 (60–105)	75 (58–95)	0.28
X-clamp, min[a], median (IQR)	44 (31–55)	42 (32–55)	38 (28–55.75)	0.33
Conversion to ONCAB, n (%)	8 (1.4)	4 (1.4)	4 (1.4)	>0.99
Concomitant ablation, n (%)	54 (9.2)	25 (8.5)	29 (9.8)	0.67
Concomitant LAAO, n (%)	6 (1)	3 (1)	3 (1)	>0.99
N of distal anastomoses, mean (SD)	2.5 (0.9)	2.5 (0.6)	2.5 (0.6)	0.94
2	319 (54.1)	159 (53.9)	160 (54.2)	>0.99
3	243 (41.2)	122 (41.4)	121 (41)	
4	26 (4.4)	13 (4.4)	13 (4.4)	
5 and more	2 (0.3)	1 (0.3)	1 (0.3)	

[a]Missing data

Abbreviations: CPB, cardiopulmonary bypass; CPR, cardiopulmonary resuscitation; IABP, intra-aortic balloon pump; IV, intravenous; LAAO, left atrial appendage occlusion; ONCAB, on-pump coronary artery bypass; OPCAB, off-pump coronary artery bypass; SD, standard deviation; other — see Table 1

Table 3. Grafts and anastomoses after propensity score-matching

	Total (590)	Non-TAR (295)	TAR (295)	*P*-value
LIMA, n (%)	556 (94.2)	261 (88.5)	295 (100)	<0.001
RIMA, n (%)	96 (16.3)	1 (0.3)	95 (32.2)	<0.001
BIMA, n (%)	96 (16.3)	1 (0.3)	95 (32.2)	<0.001
Pedicled IMA[a], n (%)	251 (42.5)	153 (51.9)	98 (33.2)	<0.001
Skeletonized IMA[a], n (%)	250 (42.4)	75 (25.4)	175 (59.3)	<0.001
Radial artery, n (%)	95 (16.1)	1 (0.3)	94 (31.9)	<0.001
Sequential anastomoses[a], n (%)	243 (16.5)	76 (10.3)	167 (22.7)	<0.001
Composite anastomoses[a], n (%)	107 (7.3)	32 (4.3)	75 (10.2)	<0.001
Number of arterial grafts (LIMA + RIMA + RA), mean (SD)	1.6 (0.9)	0.9 (0.4)	2.2 (0.7)	<0.001

[a]Missing data

Abbreviations: BIMA, bilateral internal mammary artery; LIMA, left internal mammary artery; RA, radial artery; RIMA, right internal mammary artery; SD, standard deviation; other — see Table 1

Concomitant ablation was reported in 54 (9.2%) cases (29 vs. 25; *P* = 0.67 in TAR and non-TAR CABG, respectively). Left internal mammary artery grafts were used in 94.2% of patients (100% vs. 88.5%; *P* <0.001); skeletonized internal mammary artery (IMA) was preferred over pedicled IMA in the TAR group. The RIMA was used in 32.2% and the radial artery in 31.9% of TAR cases. Further details on grafts and anastomoses are described in Table 3. The median (IQR) HLoS was 8 (6–11) days in the TAR group and 7 (6–12) days in the non-TAR group (*P* for difference = 0.25). The median ICU stay was 15.4 (12.0–19.7) hours in the TAR group vs. 15.1 (12.0–18.7) hours in the non-TAR group (*P* = 0.47). There was no difference between TAR and non-TAR patients in hospital outcomes (Table 4), as well as in 30-day mortality rates: HR, 0.74 (0.40–1.35); *P* = 0.33 (Figure 1). The median follow-up of the study was 4.1 (IQR, 1.9–6.8, max. 15.1) years. Total arterial revascularization was associated with an almost 30% reduction in mortality hazard at late follow-up: HR, 0.72 (0.55–0.93); *P* = 0.01 (Figure 2).

Figure 3 lists the subgroup estimates after PS matching. The direction of benefit with TAR was maintained across subgroups of patients, yet most pronounced in younger patients (age <70 years; $P_{interaction}$ = 0.03) who underwent off-pump surgery ($P_{interaction}$ = 0.03). The effect was also more pronounced in patients with lower EuroSCORE II and no diabetes but without statistically significant between-subgroup differences. In a separate analysis restricted to patients receiving TAR or non-TAR according to LAD grafts only, it was found that the use of LIMA for LAD revascularization in the TAR group was associated with superior survival as compared to the use of a vein for LAD revascularization: HR, 0.33 (0.20–0.53); *P* <0.001 for long-term mortality (Supplementary material, *Figure S3*).

DISCUSSION

The main findings of the current study are that in propensity-matched patients with underlying AF: (1) perioperative and 30-day mortality was no different between TAR and

Table 4. In-hospital outcomes after propensity score-matching

	Non-TAR (295)	TAR (295)	Risk ratio (95%CI)	*P*-value
Early postoperative mortality (<24 hours), n (%)	6 (2)	1 (0.3)	0.17 (0.02–1.38)	0.12
Cardiac tamponade and/or rethoracotomy, n (%)	17 (5.8)	9 (3.1)	0.53 (0.24–1.17)	0.16
Periprocedural MI, n (%)	6 (2)	8 (2.7)	1.33 (0.47–3.80)	0.78
Respiratory failure, n (%)	23 (7.8)	24 (8.1)	1.04 (0.60–1.81)	>0.99
Prolonged ICU stay (> 48 hours), n (%)	8 (2.7)	8 (2.7)	1.00 (0.38–2.63)	>0.99
Neurologic complications, n (%)	9 (3.1)	7 (2.4)	0.78 (0.30–2.06)	0.80
Multiorgan failure, n (%)	6 (1.0)	4 (0.7)	0.67 (0.19–2.34)	0.75
Gastrointestinal complications, n (%)	5 (1.7)	5 (1.7)	1.00 (0.29–3.42)	>0.99
Acute kidney failure and/or dialysis, n (%)	12 (4.1)	11 (3.7)	0.92 (0.41–2.04)	>0.99
Superficial sternal wound infection, n (%)	5 (1.7)	8 (2.7)	1.60 (0.53–4.83)	0.58
Deep sternal wound infection, n (%)	4 (1.4)	4 (1.4)	1.00 (0.25–3.96)	>0.99
Mediastinitis, n (%)	2 (0.7)	3 (1)	1.50 (0.25–8.91)	>0.99
PPI, n (%)	0 (0)	1 (0.3)	3.00 (0.12–73.35)	>0.99
ECMO, n (%)	0 (0)	0 (0)	NA	NA
IABP, n (%)	12 (4.1)	8 (2.7)	0.67 (0.28–1.61)	0.50

Abbreviations: CI, confidence interval; ECMO, extracorporeal membrane oxygenation; IABP, intra-aortic balloon pump; ICU, intensive care unit; MI, myocardial infarction; NA, not applicable; PPI, permanent pacemaker implantation; other — see Table 1

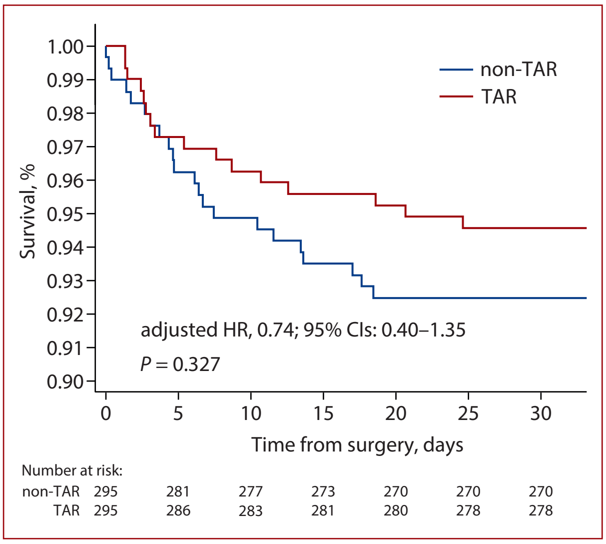

Figure 1. Thirty-day mortality. Kaplan–Meier survival curves. Comparison of TAR vs. non-TAR CABG for the analysis of 30-day mortality. Hazard ratios and respective 95% confidence intervals in TAR as compared to non-TAR CABG adjusted for propensity scores

Abbreviations: CABG, coronary-artery bypass grafting; other — see Table 1

non-TAR; (2) TAR was associated with 30% improved late survival, sustained in subgroup analyses, as appraised in low-risk patients (<70 years old; EuroSCORE II <2; no diabetes); (3) LAD grafting with LIMA, as compared to venous graft, resulted in 70% disproportionately higher late survival benefit in this higher risk population.

Few randomized controlled trials (RCTs) assessed the benefit of TAR; the two biggest failed to show a survival benefit with this approach although they were limited by only one-year follow-up [11, 14]. In the study by Damgaard et al. [14], no differences were observed between the TAR and non-TAR groups in graft patency and cardiac events, although the reported 85% RA graft patency is somewhat lower than what was observed in other studies [15–17]. Indeed, a patient-level meta-analysis of 6 RCTs reported patency of RA at 92% at 5-year mean follow-up [5]. Large observational studies almost unequivocally point to survival benefits with TAR [18, 19]. The analysis of 2132 matched patients showed significant benefits of TAR in terms of survival and MI [19]. Furthermore, the meta-analysis of

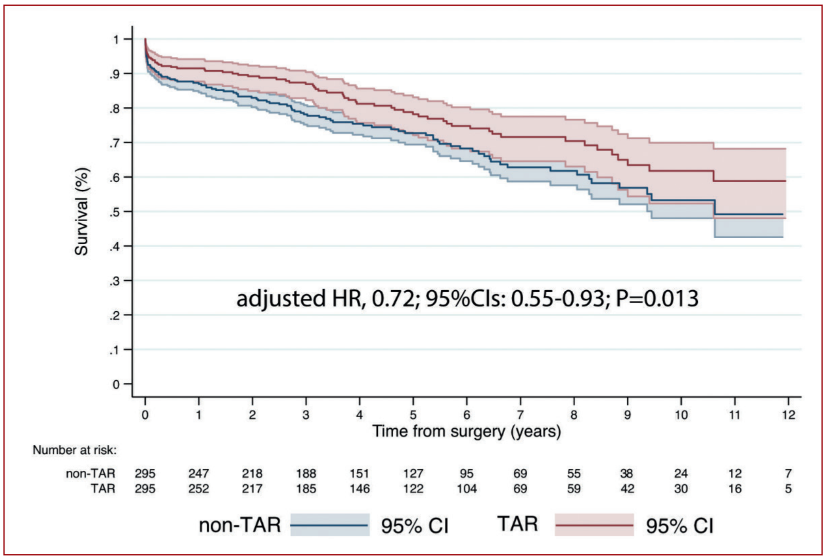

Figure 2. Long-term mortality. Kaplan–Meier survival curves. Comparison of TAR vs. non-TAR CABG for the analysis of long-term survival. Hazard Ratios and respective 95% confidence intervals in TAR as compared to non-TAR CABG adjusted for propensity scores

Abbreviations: see Table 1 and Figure 1

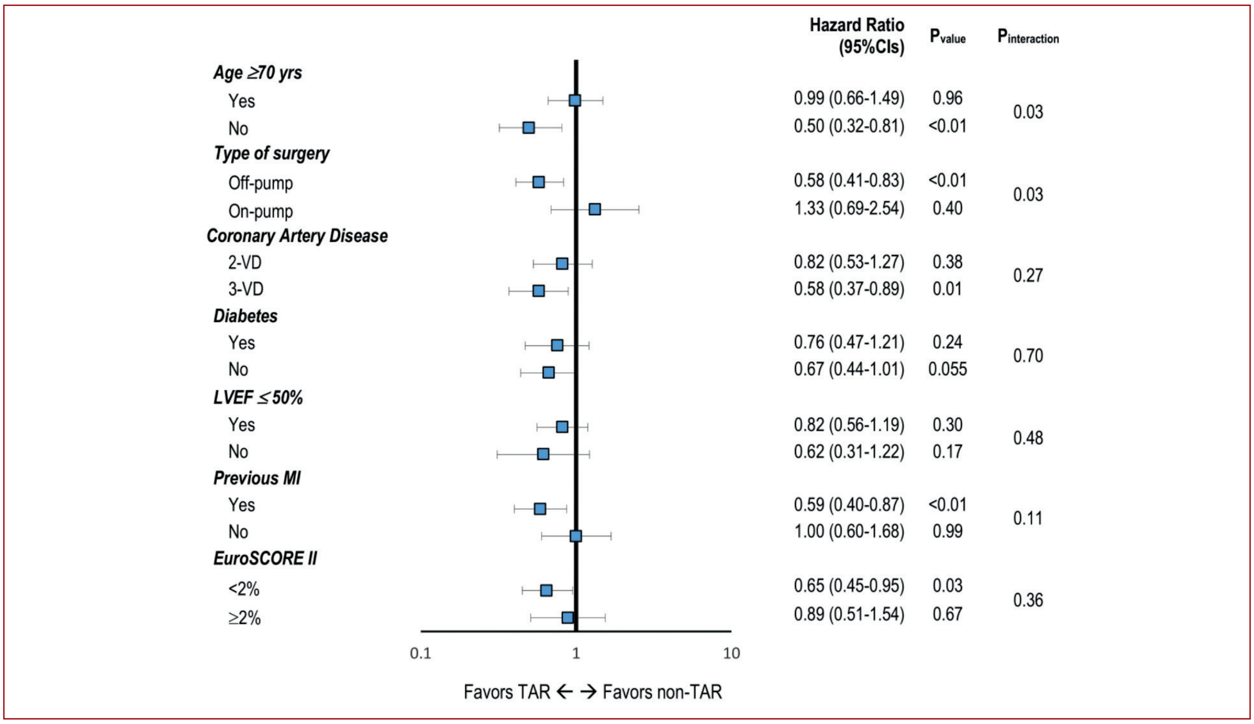

Figure 3. Subgroup analysis. Hazard ratios and 95% confidence intervals for death from any cause in TAR as compared to non-TAR according to selected characteristics

Abbreviations: LVEF, left ventricular ejection fraction; MI, myocardial infarction; SAG, single arterial grafting; VD, vessel disease; other — see Table 1

130 305 patients suggested that TAR is associated with lower long-term all-cause mortality compared to conventional CABG including the use of venous conduits [20].

Despite the available evidence, the use of TAR is low, the analysis by Rocha et al. [19] reported TAR in only 4.9% of patients. In the analysis of the Society of Thoracic Surgeons database by Schwann et al. [21], use of multiple arterial grafting (MAG) was 11.3% with a decreasing trend. Several reasons prevent the adoption of TAR; firstly, the absence of compelling evidence from RCTs. Observational studies are prone to bias due to patient selection. Surgeons tend to choose younger and healthier patients for arterial grafts because these patients can truly benefit from higher patency rates later in the follow-up, indeed, often forgetting that repeat revascularization of stenotic venous graft happens much sooner [22, 23]. Safety concerns, especially in the context of sternal wound infections (SWIs) with bilateral IMA grafting, are often raised as an argument against MAG and TAR. However, an analysis of wound infections in the ART trial demonstrated that the risk is only significantly higher when two pedicled grafts are used; the prevalence of sternal wound infections in the bilateral IMA group with skeletonized IMAs did not differ from the one in the single IMA group [24]. A meta-analysis by Deo et al. [25] reached the same conclusion for diabetic patients. In our current study, we also observed no increased risk of wound infections associated with TAR although a relatively high proportion of Ras, as compared to bilateral IMAs, must be noted.

The number of individuals referred for CABG with preoperative AF is reported to be between 8%–10% [26, 27] although in an analysis of the Medicare Database, which could be more accurate, the number of patients with preoperative AF and undergoing isolated CABG was 20% [28]. Preoperative AF is a known marker of high-risk patients as it was repeatedly shown to negatively influence survival after CABG [26, 29, 30]. Our previous study showed a marked survival benefit associated with MAG in this population; however, again, no randomized study has ever addressed this issue [31]. In the current analysis, the frequency of TAR was 6.2% (295 out of 4746) of CABG patients with preoperative AF. Interestingly, an analysis of Medicare patients with preoperative AF showed a significantly lower prevalence of arterial grafting in this population compared to sinus rhythm patients with few differences between the AF and no-AF groups in venous grafting [31]. In a recent retrospective sub-analysis of the ART study, TAR patients, despite propensity matching, suffered from preoperative AF half as often compared to single arterial grafting patients [32]. In the same analysis, preoperative AF was the strongest predictor of mortality and major adverse cardiac events although the overall prevalence of AF was low (1.3%).

The current study is the first to present long-term outcomes in AF patients undergoing CABG for MV-CAD, stratified by the choice of grafting material. Most contemporary operators opt for prompt revascularization that shortens CABG surgery time to reduce the high periprocedural risk for AF patients [27, 33]. Our data, however, show that while the choice of TAR vs. no-TAR was not associated with an increased risk of perioperative or short-term mortality, it resulted in long-term mortality reduction in the propensity-matched population. Notably, the survival benefit became apparent as soon as 2 years post operation, therefore sooner than in previous studies concerning TAR [14, 19]. Whether it is a result of preoperative AF or other patient factors not included in our PS model is yet to be determined.

Another interesting finding, that reinforces the importance of TAR is the fact that LIMA to LAD is associated with overwhelmingly superior long-term survival as compared to SVG to LAD. More importantly, the mortality rates for vein to LAD were as high as 59% at 4.1 years (Supplementary material, Figure S3) which is much higher than vein to LAD in the non-AF population [34]. This underscores the importance of LIMA to LAD, especially in AF patients. However, it must be noted that the sub-analysis of vein vs. LIMA to LAD was not adjusted for con-founders as no additional PS matching was performed, therefore the results have to be treated cautiously.

Limitations

Certain limitations to our study must be acknowledged. In AF patients undergoing CABG, concomitant ablation improves survival [33]; while in our cohort the ablation rates were low and could influence the mortality prevalence, they were balanced between two matched groups. Some data were not available (AF duration and type, angiographic follow-up, heart rhythm at discharge, repeat revascularizations, dual antiplatelet therapy and anticoagulation regimen, and drug compliance after surgery). Future studies focused on detailed revascularization analysis and concurrent AF management should be performed to address those issues specifically. Furthermore, we acknowledge that a 30% survival benefit in median follow-up of 4.1 years is higher, as compared to data from a meta-analysis of RCTs in the general population [18]. Lastly, differences between centers with regard to TAR adoption and techniques, as well as post-procedural patient management may remain. Although we addressed potential selection bias with propensity score matching according to baseline clinical variables; there exists risk, however, for hidden confounders to have influenced the results with respect to patient allocation and choice of grafting strategy. While we acknowledge the non-randomized nature of the current study, and at the same time paucity of randomized data and subanalyses of RCTs, an analysis of different revascularization strategies across AF and non-AF populations may add further insights into the role of arterial revascularization in this particular groups of patients.

CONCLUSIONS

We conclude that TAR in patients with preoperative AF is safe and possibly associated with improved survival. We observed particular survival benefits in younger low-risk patients undergoing off-pump CABG.

Supplementary material

Supplementary material is available at https://journals.viamedica.pl/kardiologia_polska

Article information

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REFERENCES

1. Hillis LD, Smith PK, Anderson JL, et al. 2011 ACCF/AHA guideline for coronary artery bypass graft surgery. Circulation. 2011; 124(23): e652–735, doi: 10.1161/cir.0b013e31823c074e, indexed in Pubmed: 22064599.
2. Neumann FJ, Sousa-Uva M, Ahlsson A, et al. et al.. 2018 ESC/EACTS guidelines on myocardial revascularization. Eur Heart J. 2019; 40(2): 87–165, doi: 10.1093/eurheartj/ehy394, indexed in Pubmed: 30165437.
3. Aldea GS, Bakaeen FG, Pal J, et al. The Society of Thoracic Surgeons clinical practice guidelines on arterial conduits for coronary artery bypass grafting. Ann Thorac Surg. 2016; 101(2): 801–809, doi: 10.1016/j.athoracsur.2015.09.100, indexed in Pubmed: 26680310.
4. Yamasaki M, Deb S, Tsubota H, et al. Radial artery and saphenous vein patency more than 5 years after coronary artery bypass surgery: results from RAPS (Radial Artery Patency Study). J Am Coll Cardiol. 2012; 60(1): 28–35, doi: 10.1016/j.jacc.2012.03.037, indexed in Pubmed: 22742399.
5. Gaudino M, Benedetto U, Fremes S, et al. Radial-artery or saphenous-vein grafts in coronary-artery bypass surgery. N Engl J Med. 2018; 378(22): 2069–2077, doi: 10.1056/nejmoa1716026, indexed in Pubmed: 29708851.
6. Iribarne A, Schmoker JD, Malenka DJ, et al. Does use of bilateral internal mammary artery grafting reduce long-term risk of repeat coronary revascularization? A multicenter analysis. Circulation. 2017; 136(18): 1676–1685, doi: 10.1161/CIRCULATIONAHA.117.027405, indexed in Pubmed: 29084776.
7. Kelly R, Buth KJ, Légaré JF. Bilateral internal thoracic artery grafting is superior to other forms of multiple arterial grafting in providing survival benefit after coronary bypass surgery. J Thorac Cardiovasc Surg. 2012; 144(6): 1408–1415, doi: 10.1016/j.jtcvs.2012.01.030, indexed in Pubmed: 22306219.
8. Lytle BW, Blackstone EH, Sabik JF, et al. The effect of bilateral internal thoracic artery grafting on survival during 20 postoperative years. Ann Thorac Surg. 2004; 78(6): 2005–2012, doi: 10.1016/j.athoracsur.2004.05.070, indexed in Pubmed: 15561021.
9. Taggart DP, Benedetto U, Gerry S, et al. Bilateral versus single internal-thoracic-artery grafts at 10 years. N Engl J Med. 2019; 380(5): 437–446, doi: 10.1056/NEJMoa1808783, indexed in Pubmed: 30699314.
10. Taggart DP, Gaudino MF, Gerry S, et al. Effect of total arterial grafting in the Arterial Revascularization Trial. J Thorac Cardiovasc Surg. 2022; 163(3): 1002–1009, doi: 10.1016/j.jtcvs.2020.03.013, indexed in Pubmed: 32305186.
11. Muneretto C, Bisleri G, Negri A, et al. Total arterial myocardial revascularization with composite grafts improves results of coronary surgery in elderly: a prospective randomized comparison with conventional coronary artery bypass surgery. Circulation. 2003; 108(Suppl 1): II29–II33, doi: 10.1161/01.cir.0000087941.75337.f5, indexed in Pubmed: 12970204.
12. Ngaage DL, Schaff HV, Mullany CJ, et al. Does preoperative atrial fibrillation influence early and late outcomes of coronary artery bypass grafting? J Thorac Cardiovasc Surg. 2007; 133(1): 182–189, doi: 10.1016/j.jtcvs.2006.09.021, indexed in Pubmed: 17198809.

13. Austin PC. Statistical criteria for selecting the optimal number of untreated subjects matched to each treated subject when using many-to-one matching on the propensity score. Am J Epidemiol. 2010; 172(9): 1092–1097, doi: 10.1093/aje/kwq224, indexed in Pubmed: 20802241.
14. Damgaard S, Wetterslev J, Lund JT, et al. One-year results of total arterial revascularization vs. conventional coronary surgery: CARRPO trial. Eur Heart J. 2009; 30(8): 1005–1011, doi: 10.1093/eurheartj/ehp048, indexed in Pubmed: 19270315.
15. Goldman S, Sethi GK, Holman W, et al. Radial artery grafts vs saphenous vein grafts in coronary artery bypass surgery: a randomized trial. JAMA. 2011; 305(2): 167–174, doi: 10.1001/jama.2010.1976, indexed in Pubmed: 21224458.
16. Buxton BF, Raman JS, Ruengsakulrach P, et al. Radial artery patency and clinical outcomes: five-year interim results of a randomized trial. J Thorac Cardiovasc Surg. 2003; 125(6): 1363–1371, doi: 10.1016/s0022-5223(02)73241-8, indexed in Pubmed: 12830056.
17. Collins P, Webb CM, Chong CF, et al. Radial artery versus saphenous vein patency randomized trial: five-year angiographic follow-up. Circulation. 2008; 117(22): 2859–2864, doi: 10.1161/CIRCULATIONAHA.107.736215, indexed in Pubmed: 18506009.
18. Royse A, Pawanis Z, Canty D, et al. The effect on survival from the use of a saphenous vein graft during coronary bypass surgery: a large cohort study. Eur J Cardiothorac Surg. 2018; 54(6): 1093–1100, doi: 10.1093/ejcts/ezy213, indexed in Pubmed: 29893823.
19. Rocha RV, Tam DY, Karkhanis R, et al. Long-term outcomes associated with total arterial revascularization vs non-total arterial revascularization. JAMA Cardiol. 2020; 5(5): 507–514, doi: 10.1001/jamacardio.2019.6104, indexed in Pubmed: 32074240.
20. Yanagawa B, Verma S, Mazine A, et al. Impact of total arterial revascularization on long term survival: A systematic review and meta-analysis of 130,305 patients. Int J Cardiol. 2017; 233: 29–36, doi: 10.1016/j.ijcard.2017.02.010, indexed in Pubmed: 28185702.
21. Schwann TA, Habib RH, Wallace A, et al. Operative outcomes of multiple-arterial versus single-arterial coronary bypass grafting. Ann Thorac Surg. 2018; 105(4): 1109–1119, doi: 10.1016/j.athoracsur.2017.10.058, indexed in Pubmed: 29453002.
22. Li R, Lan B, Zhu T, et al. Preventing graft restenosis after coronary artery bypass grafting with tissue-type plasminogen activator. Eur J Med Res. 2017; 22(1): 18, doi: 10.1186/s40001-017-0259-8, indexed in Pubmed: 28606123.
23. Gürbak İ, Panç C, Şahin AA, et al. CHA2DS2-VASc score as a predictor of no-reflow phenomenon after saphenous vein graft percutaneous coronary intervention in patients with non-ST-segment elevation acute coronary syndromes. Kardiol Pol. 2020; 78(11): 1129–1136, doi: 10.33963/KP.15603, indexed in Pubmed: 32955817.
24. Benedetto U, Altman DG, Gerry S, et al. Pedicled and skeletonized single and bilateral internal thoracic artery grafts and the incidence of sternal wound complications: Insights from the Arterial Revascularization Trial. J Thorac Cardiovasc Surg. 2016; 152(1): 270–276, doi: 10.1016/j.jtcvs.2016.03.056, indexed in Pubmed: 27112712.
25. Deo SV, Shah IK, Dunlay SM, et al. Bilateral internal thoracic artery harvest and deep sternal wound infection in diabetic patients. Ann Thorac Surg. 2013; 95(3): 862–869, doi: 10.1016/j.athoracsur.2012.11.068, indexed in Pubmed: 23352296.
26. Malaisrie SC, McCarthy PM, Kruse J, et al. Burden of preoperative atrial fibrillation in patients undergoing coronary artery bypass grafting. J Thorac Cardiovasc Surg. 2018; 155(6): 2358–2367.e1, doi: 10.1016/j.jtcvs.2018.01.069, indexed in Pubmed: 29523404.
27. Batra G, Ahlsson A, Lindahl B, et al. Atrial fibrillation in patients undergoing coronary artery surgery is associated with adverse outcome. Ups J Med Sci. 2019; 124(1): 70–77, doi: 10.1080/03009734.2018.1504148, indexed in Pubmed: 30265179.
28. McCarthy PM, Davidson CJ, Kruse J, et al. Prevalence of atrial fibrillation before cardiac surgery and factors associated with concomitant ablation. J Thorac Cardiovasc Surg. 2020; 159(6): 2245–2253.e15, doi: 10.1016/j.jtcvs.2019.06.062, indexed in Pubmed: 31444073.
29. Batra G, Ahlsson A, Lindahl B, et al. Atrial fibrillation in patients undergoing coronary artery surgery is associated with adverse outcome. Ups J Med Sci. 2019; 124(1): 70–77, doi: 10.1080/03009734.2018.1504148, indexed in Pubmed: 30265179.
30. Zyśko D, Persson A, Obremska M, et al. The importance of the longest R-R interval on 24-hour electrocardiography for mortality prediction in patients with atrial fibrillation. Kardiol Pol. 2021; 79(3): 311–318, doi: 10.33963/KP.15820, indexed in Pubmed: 33599460.
31. Kowalewski M, Pasierski M, Litwinowicz R, et al. Multiple versus single arterial coronary arterial bypass grafting surgery for multivessel disease in atrial fibrillation. Semin Thorac Cardiovasc Surg. 2021; 33(4): 974–983, doi: 10.1053/j.semtcvs.2020.11.015, indexed in Pubmed: 33188882.
32. Lin MH, Kamel H, Singer DE, et al. Perioperative/postoperative atrial fibrillation and risk of subsequent stroke and/or mortality. Stroke. 2019; 50(6): 1364–1371, doi: 10.1161/STROKEAHA.118.023921, indexed in Pubmed: 31043148.
33. Tyras DH, Barner HB, Kaiser GC, et al. Bypass grafts to the left anterior descending coronary artery. J Thorac Cardiovasc Surg. 1980; 80(3): 327–333, doi: 10.1016/s0022-5223(19)37757-8, indexed in Pubmed: 6968006.
34. Suwalski P, Kowalewski M, Jasiński M, et al. Surgical ablation for atrial fibrillation during isolated coronary artery bypass surgery. Eur J Cardiothorac Surg. 2020; 57(4): 691–700, doi: 10.1093/ejcts/ezz298, indexed in Pubmed: 31665277.