Does the surgeon’s experience have an impact on outcome after total arterial revascularization with composite T-grafts? A risk factor analysis

Julia Umminger, Michael Reitz, Sebastian V. Rojas, Penelope Stiefel, Malakh Shrestha, Axel Haverich, Issam Ismail and Andreas Martens*

Clinic for Cardiothoracic, Transplantation and Vascular Surgery, Hannover Medical School, Hannover, Germany

* Corresponding author. Clinic for Cardiothoracic, Transplantation and Vascular Surgery, OE 6210, Hannover Medical School, Carl-Neuberg-Str. 1, 30625 Hannover, Germany. Tel: +49-511-5326582; fax: +49-511-5328285; e-mail: martens.andreas@mh-hannover.de (A. Martens).

Received 15 September 2015; received in revised form 6 April 2016; accepted 26 May 2016

Abstract

OBJECTIVES: When composite T-grafting is performed, total arterial revascularization (TAR) can be accomplished with only two grafts. There is the belief that composite grafting poses a risk of graft failure due to its single inflow via the left internal thoracic artery (LITA). High surgical quality is essential for left internal thoracic artery preparation, T-grafting and length estimation. We investigated whether the surgeon’s experience influences postoperative outcome.

METHODS: We analysed the data of 1080 consecutive patients (88% male, age: 62 ± 9 years) who underwent composite T-grafting between 1996 and 2011 in our institution. Patients were operated on either by experienced surgeons (Group A) or by surgeons early on in their career (Group B). Primary end-points were mortality, myocardial ischaemia, graft dysfunction and low cardiac output syndrome. Secondary end-points were persistent neurologic deficits (PNDs), blood transfusions and re-thoracotomy. Logistic regression analysis was performed to reveal independent risk factors for adverse outcome.

RESULTS: Patients in Group B had a lower logistic EuroSCORE (2.8 vs 2.3%; P < 0.05), longer operative times (cross-clamp time: 41 ± 11 vs 47 ± 14 min; P < 0.001) and received less anastomoses (3.2 ± 0.7 vs 3.1 ± 0.7; P = 0.005). Mortality was low in both groups (Group A 0.6% vs Group B 0.4%; P = 1.0). Myocardial ischaemia occurred in 2.3% (Group A) and 2.5% (Group B; P = 0.82). Graft dysfunction was seen in 0.6% (Group A) and 1.4% (Group B; P = 0.25). Incidence of postoperative low cardiac output syndrome was comparable (Group A 1.4% vs Group B 0.7%; P = 0.53). Both groups showed similar incidence of secondary end-points (persistent neurologic deficit: Group A 2.9% vs 3.2% in Group B; P = 0.84; re-thoracotomy: 1.6% in Group A vs 1.8% in Group B, P = 1.0). Blood transfusions were more common in Group B (P = 0.005). Less surgical experience could only be identified as an independent risk factor for blood transfusion (P = 0.001).

CONCLUSIONS: Total arterial revascularization with composite T-grafts can be performed safely by surgeons with different surgical experience. Despite differences in surgical performance parameters (e.g. operation times, blood transfusions), complication rates were extremely low, irrespective of the surgeon’s operative experience. Surgeons can be introduced to these procedures in an early phase of training.

Keywords: Total arterial revascularization • T-graft • Surgical experience • Learning curve • Risk factor analysis

INTRODUCTION

The radial artery (RA) has become a popular conduit option for composite T-grafting in total arterial coronary revascularization (TAR). Several studies reported its superior long-term patency compared with saphenous vein grafts [1–4]. Composite T-grafting allows complete revascularization using two grafts only and avoids unnecessary aortic manipulation [5–7].

© The Author 2016. Published by Oxford University Press on behalf of the European Association for Cardio-Thoracic Surgery. All rights reserved.
hypothesised additional surgical risk. Whether surgical experience may have a direct impact on early outcome after TAR using T-grafts has not been answered in the past.

METHODS

Study population

The study was conducted in accordance with the principles of the Declaration of Helsinki. The local ethics committee approved the study, and the requirement for individual patient consent was waived. We retrospectively analysed all patients who underwent isolated, elective TAR with a left internal mammary artery (LIMA)/RA T-graft between 1996 and June 2011 in our institution. Exclusion criteria were re-do operations, emergency revascularization, off-pump coronary artery bypass surgery (OPCAB) and patients receiving concomitant cardiac or vascular procedures. A total of 1080 patients were included in the study.

Operative technique

All operations were performed via a midline sternotomy. The LIMA and RA (the latter typically from the non-dominant arm) were harvested with minimal trauma as pedicled grafts and treated with papaverine solution prior to use. Before harvesting of the RA, collateral blood flow to the hand was analysed by Doppler sonography and Allen’s test. The T-graft anastomosis (Fig. 1) was completed prior to cannulation for cardiopulmonary bypass (CPB) in all patients. After systemic heparinization (300–400 U heparin/kg), CPB was commenced. Myocardial protection was achieved using intermittent antegrade cardioplegia. Typically cold crystalloid cardioplegia was used. Cold blood cardioplegia (Buckberg) was used in patients with reduced ejection fraction. More recently warm blood cardioplegia (Calafiore) was introduced for routine cases. The type of cardioplegia was chosen at the surgeon’s discretion. After induction of cardioplegic cardiac arrest, coronary revascularization was performed in a ‘back to front’ fashion beginning with the inferior wall. Obtuse marginal branches were sequentially anastomosed to the RA. Diagonal branches were typically revascularized using a sequential IMA anastomosis. Intermediate branches were connected either to the RA or to the IMA depending on the individual anatomy. The surgical technique is shown in Video 1.

Risk score

Based on learning curve investigations by others [8], we devised a risk score to distinguish between ‘experienced’ and ‘inexperienced’ surgeons regarding TAR with T-grafts. Surgical trainees or surgeons who had completed their training less than 1 year ago received a baseline risk score of 5 points. Every additional year of experience after training completion reduced the baseline score by 1 point until a minimum score of 0 is reached after 5 years of practice. In addition, each surgeon received 1 demerit point for the first 10 T-graft procedures.

Hence, for each patient in the study, a risk score between 0 and 6 was calculated. A higher risk score stands for a higher risk to suffer from complications due to lack of surgical experience. A risk score between 0 and 2 points defines ‘experienced’ surgeons (risk score 0–2, n = 796). A risk score of 3 points and greater describes the ‘less experienced’ surgeons (risk score 3–6, n = 284).

Patient characteristic

For risk analysis, the following parameters were documented and included into the risk model: age, male, body mass index (BMI), hypertension, diabetes mellitus (DM), hyperlipidaemia (HLP), peripheral vascular disease (PVD), current smoking, renal impairment, chronic obstructive pulmonary disease (COPD), left ventricular ejection fraction (LV-EF), CCS and NYHA functional class, left main stem (LMS) disease, prior myocardial infarction (MI), number of vessels affected by coronary artery disease (CAD) and the logistic EuroSCORE.

Figure 1: Illustration of a total arterial revascularization using a LITA and RA T-graft configuration. LITA: left internal thoracic artery; RA: radial artery; LCA: left coronary artery; RCA: right coronary artery; LCX: circumflex artery; PDA: posterior descending artery; LAD: left anterior descending artery; PDA: posterior descending artery.
Perioperative data

The number of grafts, operation time, CPB time, cross-clamp time and the number of anastomoses were evaluated. The surgeon’s surgical experience was categorized using the risk score described above.

The following postoperative parameters were analysed: time of ventilation, intensive care unit (ICU) stay, hospital stay, need for inotropic medication and blood transfusions, creatinine-kinase (CK and CK-MB) levels, postoperative ECG and use of mechanical circulatory support by an intra-aortic balloon pump (IABP) or extracorporeal life support (ECLS).

Study end-points and definitions

The following primary postoperative end-points that possibly reflect surgical performance were analysed: mortality, bypass dysfunction, myocardial ischaemia and low cardiac output syndrome.

Mortality was defined as 30-day or in-hospital mortality. Bypass dysfunction was defined as the need for early postoperative surgical or interventional procedures due to malignant arrhythmias, acute cardiac failure with signs of MI or proven bypass graft dysfunction as shown by coronary angiography. Postoperative diagnosis of MI according to classical criteria is impaired by non-pathological postoperative CK elevation due to perioperative cardioplegic arrest and postoperative pacing. In addition, not all patients received repeated ECG documentation during the early postoperative course to retrospectively compare CK levels and ECG changes. Troponin T is not routinely measured during the postoperative course in our institution. For the purpose of this study, myocardial ischaemia was defined either as a 5-fold increase of the CK-MB level if CK-MB exceeded 7% of the total CK level or if clear signs of MI such as significant ST segment elevation in ECG or malignant arrhythmias not explained by other pathologies occurred. Low cardiac output syndrome was defined as the need for significant inotropic support to stabilize haemodynamics (>6 µg/kg min dobutamine or >0.1 µg/kg min adrenaline for >4 h) or the need for mechanical stabilization by IABP or ECLS. The combined end-point of mortality, bypass dysfunction, myocardial ischaemia and low cardiac output syndrome was also documented and analysed.

Secondary end-points possibly reflecting surgical performance were the need for re-thoracotomy due to infection or bleeding, need for blood transfusions and persistent neurological deficits (PNDs).

Statistical analysis

Statistical analysis was performed using GraphPad Prism 6 (GraphPad Software Inc., La Jolla, USA) and SPSS 22 (SPSS Inc., Chicago, USA) for Windows. Continuous variables were tested for normal distribution with the Kolmogorov–Smirnov test and are summarized as mean ± standard deviation (SD) or median (interquartile range). Differences were analysed using the t-test or Mann–Whitney U Test, as appropriate. Categorical variables were presented in absolute numbers and percentages. Fisher’s exact test was used for analysis. Univariable analysis was performed to identify risk factors for study end-points. Multivariable analysis using a backward stepwise logistic regression model was performed to identify independent risk factors for study end-points. Results were reported as odds ratio (OR) with a 95% confidence interval (CI). Two-tailed P-values <0.05 were considered significant. Analysis was performed in cooperation with the Institute of Biometrics of Hannover Medical School.

RESULTS

Risk score

Distribution of the patients between the risk score groups 0–6 is presented in Table 1. Patients in the total cohort (n = 1080) were operated by 32 different surgeons. The caseload per surgeon in each group increased strongly with a decreasing risk score. The average caseload per surgeon was 6.3 (5.8–12.9). The majority of patients (n = 796, 73.6%) had their surgery performed by an experienced surgeon (risk score 0–2), while the remaining 284 patients (26.4%) were operated on by residents or surgeons with less experience (risk score 3–6).

Patient characteristics

Preoperative patient characteristics are summarized in Table 2. TAR was mostly performed in a young, low-risk patient population (age 62 ± 9 years; log EuroSCORE 2.7 ± 3.0%). Patients treated by experienced surgeons had a significantly higher risk profile, as shown by the log. EuroSCORE (2.8 ± 3.2 vs 2.3 ± 2.1; P = 0.003). They were older, presented a high incidence of HLP and more commonly exhibited a severely impaired ejection fraction and a CCS classification ≥3. However, obesity and current smoking were more common in the patient group treated by the less experienced surgeons.

Perioperative data

Perioperative data are presented in Table 3. In patients in the risk score 3–6 group, significantly less distal anastomoses were performed (P = 0.005). Nevertheless, operation time, CPB time and cross-clamp time were significantly higher in this group.

Postoperative outcome

The postoperative outcome parameters are presented in Table 4. The overall incidence of complications was low with an early mortality of <1% in both study groups. The combined primary end-point occurred in 3.3% (risk score 0–2) and 3.5% (risk score 3–6), respectively. There were no significant differences in the incidence of primary study end-points and the combined primary end-point

<table>
<thead>
<tr>
<th>Table 1: Risk score distribution and caseload per surgeon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk score</td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>
between the two study groups. Likewise, the incidence of surgical re-exploration, postoperative renal failure and stroke did not differ significantly. However, patients treated by less experienced surgeons had a significantly longer hospital stay ($P < 0.001$) and needed more blood transfusions ($P = 0.005$).

Univariable risk factor analysis revealed significant association of primary end-points with classical preoperative risk factors that reflect the severity of coronary disease (e.g. previous MI, CCS classification, reduced LV function) and comorbidities (e.g. GFR < 60 ml/min). In addition, CPB time and cross-clamp time significantly affected primary outcome parameters, indicating the impact of intraoperative complexity. Surgical experience as defined by the surgical risk score was not associated with a higher incidence of primary end-points. Secondary end-points possibly reflecting surgical quality and experience were mostly affected by patient-specific preoperative risk factors (e.g. GFR < 60 ml/min, DM). However, the surgical risk score showed a significant association of surgical experience with the need for postoperative blood transfusions. The univariable risk factor analysis is depicted in Table 5.

The multivariable analysis is summarized in Table 6. Independent risk factors that were discriminated for primary outcome parameters reflect the severity of the underlying disease. CCS classification $\geq 3$ was a strong predictor for bypass dysfunction, low cardiac output syndrome and the combined primary end-point. Especially impaired ejection fraction and preoperative renal failure were independent risk factors for mortality. In addition, perioperative parameters independently affected outcome. Increased CPB time predicted mortality, bypass dysfunction, low cardiac output syndrome and the combined primary end-point, whereas increased cross-clamp time was a predictor for postoperative signs of myocardial ischaemia.

### Table 2: Preoperative patient characteristics

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Risk score, 0–2</th>
<th>Risk score, 3–6</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients, $n$ (%)</td>
<td>1080 (100)</td>
<td>796 (73.7)</td>
<td>284 (26.3)</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>62.2 ± 8.8</td>
<td>62.9 ± 8.8</td>
<td>60.1 ± 8.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sex, male, $n$ (%)</td>
<td>949 (87.8)</td>
<td>706 (88.4)</td>
<td>245 (86.3)</td>
<td>0.34</td>
</tr>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>27.8 ± 4.4</td>
<td>27.6 ± 4.0</td>
<td>28.2 ± 4.3</td>
<td>0.016</td>
</tr>
<tr>
<td>Hypertension, $n$ (%)</td>
<td>903 (83.5)</td>
<td>661 (83.0)</td>
<td>242 (85.2)</td>
<td>0.46</td>
</tr>
<tr>
<td>Diabetes mellitus, $n$ (%)</td>
<td>294 (27.2)</td>
<td>216 (27.1)</td>
<td>78 (27.5)</td>
<td>0.94</td>
</tr>
<tr>
<td>Hyperlipidaemia, $n$ (%)</td>
<td>788 (73.0)</td>
<td>596 (74.9)</td>
<td>192 (67.6)</td>
<td>0.024</td>
</tr>
<tr>
<td>PVD, $n$ (%)</td>
<td>191 (17.7)</td>
<td>136 (17.1)</td>
<td>55 (19.4)</td>
<td>0.42</td>
</tr>
<tr>
<td>Smoking, $n$ (%)</td>
<td>366 (33.9)</td>
<td>251 (31.5)</td>
<td>115 (50.5)</td>
<td>0.007</td>
</tr>
<tr>
<td>GFR (ml/min)</td>
<td>98 ± 31</td>
<td>97 ± 31</td>
<td>102 ± 32</td>
<td>0.005</td>
</tr>
<tr>
<td>GFR &lt; 60 ml/min, $n$ (%)</td>
<td>90 (8.3)</td>
<td>72 (9.0)</td>
<td>18 (6.3)</td>
<td>0.17</td>
</tr>
<tr>
<td>COPD, $n$ (%)</td>
<td>89 (8.2)</td>
<td>65 (8.2)</td>
<td>24 (8.5)</td>
<td>0.90</td>
</tr>
<tr>
<td>LV-EF (%)</td>
<td>60.2 ± 13.9</td>
<td>59.8 ± 13.6</td>
<td>61.6 ± 12.5</td>
<td>0.062</td>
</tr>
<tr>
<td>LV-EF &lt;50%, $n$ (%)</td>
<td>297 (27.5)</td>
<td>223 (28.0)</td>
<td>74 (26.0)</td>
<td>0.54</td>
</tr>
<tr>
<td>LV-EF &lt;30%, $n$ (%)</td>
<td>34 (3.1)</td>
<td>30 (3.8)</td>
<td>4 (1.4)</td>
<td>0.050</td>
</tr>
<tr>
<td>CCS 3 + 4, $n$ (%)</td>
<td>545 (50.5)</td>
<td>417 (52.4)</td>
<td>128 (45.1)</td>
<td>0.038</td>
</tr>
<tr>
<td>CCS 4, $n$ (%)</td>
<td>41 (3.8)</td>
<td>31 (3.9)</td>
<td>10 (3.5)</td>
<td>0.080</td>
</tr>
<tr>
<td>NYHA 3 + 4, $n$ (%)</td>
<td>493 (45.6)</td>
<td>376 (47.2)</td>
<td>117 (41.2)</td>
<td>0.083</td>
</tr>
<tr>
<td>NYHA 4, $n$ (%)</td>
<td>39 (3.6)</td>
<td>30 (3.8)</td>
<td>9 (3.2)</td>
<td>0.22</td>
</tr>
<tr>
<td>Previous MI, $n$ (%)</td>
<td>365 (33.8)</td>
<td>272 (34.2)</td>
<td>93 (32.7)</td>
<td>0.72</td>
</tr>
<tr>
<td>Previous PCI, $n$ (%)</td>
<td>231 (21.4)</td>
<td>165 (20.7)</td>
<td>66 (23.2)</td>
<td>0.40</td>
</tr>
<tr>
<td>Left main disease, $n$ (%)</td>
<td>274 (25.4)</td>
<td>205 (25.6)</td>
<td>69 (24.3)</td>
<td>0.69</td>
</tr>
<tr>
<td>2-vessel CAD, $n$ (%)</td>
<td>254 (23.5)</td>
<td>182 (22.9)</td>
<td>72 (25.4)</td>
<td>0.42</td>
</tr>
<tr>
<td>3-vessel CAD, $n$ (%)</td>
<td>826 (76.5)</td>
<td>614 (77.1)</td>
<td>212 (74.6)</td>
<td>0.42</td>
</tr>
<tr>
<td>Log. EuroSCORE (%)</td>
<td>2.7 ± 3.0</td>
<td>2.8 ± 3.2</td>
<td>2.3 ± 2.1</td>
<td>0.003</td>
</tr>
</tbody>
</table>

BMI: body mass index; PVD: peripheral vascular disease; GFR: glomerular filtration rate (Cockcroft-Gault equation); COPD: chronic obstructive pulmonary disease; LV-EF: left ventricular ejection fraction; CCS: Canadian Cardiovascular Society classification; NYHA: New York Heart Association classification; MI: myocardial infarction; PCI: percutaneous coronary intervention; CAD: coronary artery disease.

Boldface indicates $P < 0.05$.

### Table 3: Perioperative data

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Risk score, 0–2</th>
<th>Risk score, 3–6</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation time (min)</td>
<td>187 ± 30</td>
<td>185 ± 29</td>
<td>193 ± 32</td>
<td>0.002</td>
</tr>
<tr>
<td>CPB time (min)</td>
<td>71 ± 19</td>
<td>69 ± 17</td>
<td>77 ± 21</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cross-clamp time (min)</td>
<td>43 ± 12</td>
<td>41 ± 11</td>
<td>47 ± 14</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>No. of anastomoses, $n$</td>
<td>3.2 ± 0.7</td>
<td>3.2 ± 0.7</td>
<td>3.1 ± 0.7</td>
<td>0.005</td>
</tr>
<tr>
<td>No. of anastomoses &gt;3, $n$ (%)</td>
<td>296 (27.4)</td>
<td>232 (29.1)</td>
<td>64 (22.5)</td>
<td>0.036</td>
</tr>
</tbody>
</table>

Boldface indicates $P < 0.05$. 

Downloaded from https://academic.oup.com/icvts/article-abstract/23/5/749/2399376/Does-the-surgeon-s-experience-have-an-impact-on by guest on 07 October 2017
DISCUSSION

Current ESC/EACTS guidelines on myocardial revascularization recommend total arterial revascularization for patients with reasonable life expectancy [9]. Which conduit may be the best choice next to a LITA to LAD graft is still under debate [3]. Using an RA T-graft is one option that has been reported to result in excellent short- and long-term outcome [10, 11]. Potential downsides of RA T-grafts are the single inflow via the LITA, a hypothetical susceptibility to vasospasms and a more challenging surgical technique.

Whether there is a significant difference between T-grafts and free graft in patency rates is still discussed. Both anatomical
configurations have shown to result in excellent outcomes [4, 12]. Affleck et al. [7] have shown that the T-graft produces a sufficient flow to meet cardiac demand. In addition, LITA flow is increasing over time [13, 14].

In our institution, the use of LITA-RA T-grafts for myocardial revascularization has been introduced in the late 1990s. Such operations were initially performed by senior surgeons and followed by routine angiographic controls.

With more experience and confidence in the procedure, TAR using T grafts was performed by an increasing number of surgeons over time. The present study shows excellent postoperative results after TAR with RA T-grafts over a long period of time in which the surgical technique has not been changed significantly and was performed by a large number of surgeons (n = 32). The mortality rate was extremely low. Due to the excellent outcomes, more and more surgeons were trained in our institution over the years to use the LITA-RA T-graft technique as a standard approach for myocardial revascularization in low-risk patients. Currently, our policy is to let residents operate TAR patients under guidance by a senior surgeon, after they have completed ~50 coronary procedures. The first surgical steps in the training are the T-graft anastomosis and the end-to-side anastomosis at the distal RA. Later residents are allowed to also perform the sequential side-to-side anastomoses. After completion of surgical training, young staff surgeons usually perform TAR cases under the assistance of experienced residents or similarly experienced staff surgeons. After ~3 additional years, they achieve a level of expertise that can be considered ‘experienced’ for most routine cases.

Whether our training protocol is sufficient to ensure adequate results, even if ‘less experienced’ surgeons perform TAR with T-grafts, was always a matter of debate. Hence we analysed the data of TAR patients receiving a TAR using RA T-grafts since 1996 with special focus on surgical experience.

First, a risk score was devised to define the surgical experience of the operating surgeon in every given case. The definition of the risk score was based on other publications regarding surgical experience and learning curves [15]. Since the risk score is calculated for every case, our model allows a continuous transition of a surgeon into a group with a lower risk score, which is favourable for our long observation period. To account for the fact that learning curves exist not only for the whole surgical experience of one surgeon but also for the surgical procedure itself, a demerit point was added to the risk score for the 10 initial TAR procedures performed by a surgeon. The total CABG caseload was considered equally distributed between surgeons in each age group and was therefore not included into the risk assessment. CABG procedures are covered by all staff surgeons and cardiothoracic residents. Team members were mixed on a day-to-day basis. There were no specialized surgical teams for these procedures over long periods. As a consequence, caseload and surgical techniques between surgeons are very similar.

The analysis of preoperative risk factors revealed small but significant differences between the groups, with patients being operated on by ‘less experienced’ surgeons typically having a slightly lower risk profile. This indeed is in line with the common practice that less complex patients for routine CABG are assigned to less experienced surgeons and vice versa. Nevertheless, absolute differences between the study groups can be considered as minimal. Factors like age, LV-EF, CCS classification and kidney function are known to influence the postoperative outcome negatively [16–18] and have caused a selection bias between study groups. This is reflected by the logistic EuroSCORE. Despite the significant

Table 6: Multivariable risk factor analysis

<table>
<thead>
<tr>
<th>Predictor</th>
<th>OR</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary end-points</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortality</td>
<td>11.6</td>
<td>1.2–109.3</td>
<td>0.032</td>
</tr>
<tr>
<td>LV-EF &lt; 50%</td>
<td>11.2</td>
<td>1.5–82.6</td>
<td>0.018</td>
</tr>
<tr>
<td>GFR &lt; 60 ml/min</td>
<td>1.06</td>
<td>1.01–1.10</td>
<td>0.008</td>
</tr>
<tr>
<td>CPB time</td>
<td>8.5</td>
<td>1.0–69.7</td>
<td>0.045</td>
</tr>
<tr>
<td>Low cardiac output syndrome</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GFR &lt; 60 ml/min</td>
<td>5.3</td>
<td>1.6–18.1</td>
<td>0.007</td>
</tr>
<tr>
<td>CPB time</td>
<td>5.3</td>
<td>1.2–24.1</td>
<td>0.032</td>
</tr>
<tr>
<td>CCS ≥ 3</td>
<td>1.03</td>
<td>1.01–1.05</td>
<td>0.030</td>
</tr>
<tr>
<td>Myocardial ischaemia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative MI</td>
<td>2.7</td>
<td>1.2–6.2</td>
<td>0.016</td>
</tr>
<tr>
<td>Cross-clamp time</td>
<td>1.03</td>
<td>1.01–1.06</td>
<td>0.016</td>
</tr>
<tr>
<td>Low cardiac output syndrome</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative MI</td>
<td>2.3</td>
<td>1.2–4.6</td>
<td>0.018</td>
</tr>
<tr>
<td>CCS ≥ 3</td>
<td>2.5</td>
<td>1.2–5.2</td>
<td>0.019</td>
</tr>
<tr>
<td>CPB time</td>
<td>1.02</td>
<td>1.01–1.04</td>
<td>0.002</td>
</tr>
<tr>
<td>Combined primary end-point</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Re-thoracotomy</td>
<td>1.04</td>
<td>1.00–1.09</td>
<td>0.049</td>
</tr>
<tr>
<td>Blood transfusion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>1.7</td>
<td>1.2–2.3</td>
<td>0.001</td>
</tr>
<tr>
<td>Risk score, 3–6</td>
<td>1.04</td>
<td>1.03–1.06</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CCS ≥ 3</td>
<td>0.19</td>
<td>0.11–0.31</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Gender male</td>
<td>1.5</td>
<td>1.1–2.2</td>
<td>0.021</td>
</tr>
<tr>
<td>Hypertension</td>
<td>2.8</td>
<td>1.5–5.1</td>
<td>0.001</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>3.2</td>
<td>1.2–8.4</td>
<td>0.016</td>
</tr>
<tr>
<td>GFR &lt; 60 ml/min</td>
<td>4.4</td>
<td>1.5–13.1</td>
<td>0.007</td>
</tr>
<tr>
<td>CPB time</td>
<td>1.04</td>
<td>1.01–1.06</td>
<td>0.009</td>
</tr>
</tbody>
</table>

LV-EF: left ventricular ejection fraction; GFR: glomerular filtration rate (Cockroft-Gault equation); CCS: Canadian Cardiovascular Society classification; MI: myocardial infarction; CPB: cardiopulmonary bypass; PND: permanent neurological deficit/stroke; OR: odds ratio; 95% CI: 95% confidence interval.
differences, both study groups comprised low-risk patients (log. EuroSCORE <3.0%). This is in line with the current recommenda-
tion that especially patients with a reasonable life expectancy
should be considered for TAR.

Expectedly, intraoperative parameters differed significantly
between ‘less experienced’ and ‘experienced’ surgeons. The latter
performed a higher number of distal anastomoses in a shorter
amount of time, which possibly affected the risk for adverse
outcome. Nevertheless, CPB times and cross-clamp times are low
compared with published data [7, 12], even for the group operated
on by ‘less experienced’ surgeons.

Outcome parameters that were considered to reflect surgical
quality and expertise were divided into cardiac complications
(primary end-points) and other complications (secondary end-
points). Due to the retrospective nature of the study and because a
routine control of coronary anastomoses (e.g. by TTFM or coronary
angiogram) was not performed in the majority of patients, only
indirect cardiac outcome parameters could be analysed that are
believed to be affected by surgical quality (early mortality, bypass
dysfunction/revision, low cardiac output syndrome and signs for
significant myocardial ischaemia). Since these parameters overlap
significantly, a combined primary end-point was also analysed.

Risk factors for mortality were identified as signs of advanced
CAD, including reduced LV-EF. In addition, reduced kidney function
was a strong predictor for mortality, possibly being caused by the
underlying ubiquitous arteriosclerosis, or a secondary organ failure
in patients with ischaemic cardiomyopathy. A prolonged CPB time
also independently predicted mortality. Our results are in line with
previous studies, identifying cardiac risk factors and perioperative
parameters as predictors for mortality in bypass surgery [16–18]. A
significant relation between the surgeon’s experience and mortality
could not be identified in our study. According to the logistic
EuroSCORE, the expected mortality rate for the study population
was 2.65%. The observed mortality rate was 0.6% in the risk factor
0–2 group and 0.4% in the risk factor 3–6 group.

Our preliminary analysis revealed that in patients with known
graft failures, CK-MB/CK ratios occasionally were lower than 10%.
Hence, we defined the cut-off value for significant signs of myocar-
dial ischaemia in this study to be 7% (if at the same time CK level
showed a higher than 5-fold increase compared with the reference
level) to increase test sensitivity. Since our definition does not cor-
respond with the classical definition of MI, and because ECGs were
not routinely documented together with CK/CK-MB levels, the
parameter was termed ‘myocardial ischaemia’, e.g. also reflecting
intraoperative myocardial protection issues. Both previous MI and
cross-clamp time were independent predictors for signs of myocar-
dial ischaemia. Whereas preoperative MI defines an advanced stage
of CAD, cross-clamp time not only reflects the severity of CAD but
also indicates that technical issues have an impact on myocardial
damage. This includes difficult anastomotic conditions, insufficient
myocardial protection and surgical errors that need re-evaluation.
The surgeon’s experience did not have a significant influence in our
analysis. Myocardial ischaemia as defined above was seen in only
2.3% of all patients in our study despite the low CK-MB/CK thresh-
old. A comparison to national or international results is difficult, be-
cause there are no data for isolated RA T-grafts.

In total, 1.2% of all patients suffered from cardiac output failure
postoperatively. Those patients were more likely to show an
impaired kidney function and a higher CCS score preoperatively.
Their average LV-EF was 48% compared with the rest of the study
population with an LV-EF of 60%. The higher incidence of chronic
renal insufficiency can be interpreted as a consequence of the

ischaemic cardiomyopathy. In our risk factor analysis, a reduced pre-
operative LV-EF could not be identified as an independent predictor
of postoperative cardiac failure, despite explicit data depicting a cor-
relation [19, 20]. Since an exact quantitative LV-EF value was not
available in every patient, LV-EF was included as a dichotomous
parameter into the regression model. This might have affected statis-
tical power. An impaired kidney function, a high CCS classification
and CPB time were identified as strongest predictors of postopera-
tive low cardiac output in our study. Again, these factors particularly
describe the severity of CAD. The level of surgical expertise did not
affect the incidence of postoperative low cardiac output.

The need for re-thoracotomy due to bleeding or infection was
low at 3.0%, without substantial differences between groups. The
only significant risk factor determined in the regression analysis was
the patient’s age, which is in accordance with other studies [21–23].

In our study, only DM was shown to predict postoperative
stroke, which was documented in 1.7% of all patients. Although
surgical experience hypothetically has an impact on complications
during aortic cannulation and cross-clamping, the surgical risk
score was not identified as a risk factor.

Of the total, 53% of patients needed blood transfusions with a
significantly higher incidence in the patient group operated on by
‘less experienced’ surgeons. This finding was confirmed by the
multivariable analysis, in which the surgeon’s experience—together
with multiple patient-specific parameters—was identified as an in-
dependent risk factor for the need of blood transfusions.

In summary, TAR using LITA-RA T-grafts can be performed in a
typical patient cohort with extremely low complication rates. Our
protocol of training residents and young surgeons results in excel-
ent outcomes and suggests that surgeons can be introduced to
TAR in an early phase of training. This is reasonable to increase the
number of low-risk patients who can benefit from TAR, especially
in teaching hospitals. We suggest that surgeons in training should
at least have performed 50 coronary cases before being trained in
TAR by a senior surgeon in a step-by-step approach. Nonetheless,
surgical experience does affect quality outcome parameters such
as the need for transfusions. The cohort of more complex patients
featuring more comorbidities should still be the domain of prac-
tised surgeons. Quality assurance and focused surgical training
programs should interact to ensure treatment quality and safety in
an environment of early surgical training.

Limitations

The retrospective nature of the study and the long period covered
are obvious limitations. The power of the statistical analysis is
limited due to the low incidence of some end-points. Therefore, a
combined primary end-point was defined. The results are influ-
enced by a selection bias, in line with common practice of assign-
ning less complex patients to less experienced surgeons. Hence,
logistic regression analysis was performed to identify indepen-
dent risk factors for outcome. Finding an objective definition of
‘surgical experience’ is always difficult. We incorporated length of
surgical training and the experience with the specific surgical pro-
cedure in our calculations. The total CABG caseload was consid-
ered to be equally distributed between surgeons and was not
included into the risk score. The dichotomous division between
‘less experienced’ and ‘experienced’ is based on empirical knowl-
edge and published data on surgical learning curves. Inclusion of
the risk score value as a metric parameter into the logistic regres-
sion model revealed identical results.
Conflict of interest: none declared.

REFERENCES


