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Case Report

First Results of the Single Heartstring Aortotomy for Multiple Off-Pump Vein Grafts: A Case Series

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To validate the technique of the single Heartstring aortotomy for multiple off-pump venous bypass grafts (described in 2015), the results of a 38-month follow-up study of 18 patients, including high-risk patients, are presented. No early deaths or cardiac or cerebral complications occurred. During the follow-up period, 2 patients died of non-cardiac causes, and 3 developed coronary ischemia. Ischemia occurred due to late graft occlusion in 2 patients, both of whom had normal postoperative courses and correct graft flow. The presence of acute symptoms 24 months after surgery in these patients indicated that technical graft failure was unlikely. This safe technique combines the advantages of simple and reproducible revascularization, the off-pump approach, and minimal aortic manipulation.

Keywords: Coronary artery bypass, Off-pump, Saphenous vein, Neurologic manifestation, Ascending aorta

Case report

Patients who were operated on by the same surgeon (the investigator) using the single Heartstring aortotomy for multiple off-pump venous bypass grafting were identified retrospectively [1]. Their characteristics and outcomes are described in detail in Table 1. In brief, with the Heartstring device (Maquet Cardiovascular, Wayne, NJ, USA), it is possible to perform a proximal venous aortic anastomosis without aortic side-clamping. However, this single-use device is expensive and requires a safety distance of at least 1.5 cm between anastomoses in cases of multi-venous grafting. The use of a single Heartstring aortotomy for multiple venous grafts therefore offers, in addition to the corresponding cost savings, the possibility of performing a complete revascularization with reduced aortic injury (Fig. 1).

The included patients underwent multi-venous off-pump coronary artery bypass graft surgery (CABG) between 2014 and 2016. These patients were preferably ineligible for bi-mammary revascularization because of their advanced age (72% were over 70 years old at the time of surgery), increased surgical risk (due to malignant tumor or cardiogenic shock), or elevated risk of developing sternal healing disorders (as in patients with obesity or diabetes).

Data collection was conducted in 2019, allowing a complete follow-up period of at least 2 years for all patients. Patients who underwent multiple arterial and on-pump CABG were excluded. Major adverse cardiac and cerebral vascular events (MACCE: cardiac death, non-fatal infarction, target revascularization, or stroke) in the early (30-day) and midterm follow-up periods were identified. The follow-up was conducted by contacting the treating general practitioner or cardiologist.

Ethical approval was guaranteed according to international recommendations by the institutional review board of the investigator's center. Individual consent was waived in order to allow the inclusion of possible deaths during the observation period.

Eighteen patients (mean age, 73.1±5.2 years; range, 63 to 82 years), corresponding to 14% of all off-pump CABG procedures performed by the investigator during the observation period, were identified. The mean logistic Euroscore II was 2.6%±3.8% (range, 0.9% to 17.1%), and the mean Society of Thoracic Surgeons mortality risk was 3.8%±1.5% (range, 1.8% to 6.9%). All patients underwent successful surgery (i.e.,

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Table 1. Demographic data, risk scores, and early and midterm follow-up data

Characteristic	Value
Demographics/clinical data/operative risk	
Sex	
Female	1 (6)
Male	17 (94)
Mean age (yr)	73.1±5.2
Age >70 yr	13 (72)[a]
Mean BMI (kg/m^2)	27.3±5.1
Obese (BMI >30 kg/m^2)	6 (33)
Diabetes (on insulin)	5 (28)
Arterial hypertension	15 (83)
Dyslipidemia	12 (67)
Smoking	8 (44)
Systemic anticoagulation	3 (17)
Chronic atrial fibrillation	2 (11)
Permanent pacemaker	2 (11)
Extracardiac arteriopathy	2 (11)
Chronic lung disease	1 (6)
Recent myocardial infarction (≤30 days)	5 (28)
Previous percutaneous coronary intervention	4 (23)
Renal impairment (calculated creatinine clearance, mL/min)	
Normal (>85)	8 (44)
Moderate (50–85)	8 (44)
Severe (<50)	2 (11)
CCS grading of angina pectoris	
I	8 (44)
II	7 (39)
III	1 (6)
IV	2 (11)
Left ventricular ejection fraction (%)	52±14
Good (>50)	11 (61)
Moderate (31–50)	5 (28)
Poor (21–30)	1 (6)
Very poor (20)	1 (6)
EuroSCORE II (%)	2.6±3.8 (0.9–17.1)
STS score	
Mortality (%)	3.8±1.5 (1.8–6.9)
Morbidity or mortality (%)	18.6±4 (12.2–26.2)
Permanent stroke (%)	2.1±0.7 (1.2–4.1)
Renal failure (%)	2.8±1.5 (1.2–7)
Prolonged ventilation (%)	12.8±3.4 (8.3–21.6)
Deep sternal wound infection (%)	0.2±0.1 (0.1–0.5)
Reoperation (%)	3.2±1.3 (2–6.4)
Transit-time flow measurements	
Circumflex/marginal artery	
MGF (mL/min)	40±16 (25–70)
PI	2.7±0.5 (1.6–3.3)
Right coronary artery/PDA	
MGF (mL/min)	44±21 (16[b]–90)
PI	2.7±1.1 (1.1–4.2[b])
Diagonal artery	
MGF (mL/min)	49±25 (32–67)
PI	2.0±0.2 (1.8–2.1)
Early (30 days) follow-up	
Mortality	-
Major adverse cardiac and cerebral vascular events	-
Hemodynamic instability with increased aminergic support[c]	3 (17)
Pericardial hemorrhage/reoperation	1 (5.6)
Minor neurological disorders (i.e., postoperative delirium)	4 (22.2)
New atrial fibrillation	6 (33)
Acute kidney failure	3 (17)[d]
Mediastinitis	-
Midterm follow-up	
Follow-up duration (mo)	35.1±13.4 (3–56)
Overall deaths	2 (11)
Graft occlusion/revascularization	2 (11)
No. of venous anastomoses (total=40)	3 (7.5)
Non-fatal myocardial infarction	-
Stroke	-

Values are presented as number (%), mean±SD, or mean±SD (range).
SD, standard deviation; BMI, body mass index; CCS, Canadian Cardiovascular Society; EuroSCORE II, European System for Cardiac Operative Risk Evaluation II; STS, Society of Thoracic Surgeons; MGF, mean graft flow; PI, pulsatility index; PDA, posterior descending artery.
[a]5 patients were ≤70 years old: 2 had an increased surgical risk (1 severe dysfunction+1 myelo dysplastic), 2 were diabetic and obsese, and 1 was diabetic. [b]One borderline result for a PDA graft with an uneventful follow-up at 24 months. [c]Including the patient with active pericardial bleeding. [d]Deterioration of existing preoperative chronic renal insufficiency in all 3 patients.

(Continued on next page)

no conversions to on-pump CABG or other technical limitations were encountered); in particular, the feasibility of the proximal anastomosis was taken into account. A total of 62 distal anastomoses were performed (with sytematic use of intra-coronary shunts), including 40 venous anastomoses using 36 grafts. Of these, 19 (47.5%) anastomoses were sutured to the left circumflex or obtuse marginal (OM) arteries, 17 (42.5%) to the right coronary or posterior descending (PDA) arteries, and 4 (10%) to the left diagonal branches (DIAG). The remaining 22 anastomoses were performed using the left internal mammary artery, which was bypassed to the anterior descending artery in all patients, with an additional DIAG anastomosis in 4 patients. Double platelet aggregation inhibition was maintained postoperatively for 3 months, followed by administration of 100 mg/day of aspirin alone if no contraindications were present.

In-hospital (30-day) outcomes

All patients survived, and no MACCEs occurred. Three initially unstable patients required increased catecholamine support. Due to an extensive anterior infarction, this patient was admitted to the operating room after successful cardiopulmonary resuscitation and placed under continuous catecholamine support. An intra-aortic balloon pump was placed before surgery. The postoperative course was favorable, with the improvement of the patient's left ventricular (LV) function (35%), recovery from acute renal failure, and a documented survival of at least 37 months without heart problems. The second patient had myelodysplastic syndrome and developed severe thrombocytopenia. The cancer was discovered shortly before surgery, and the triple-vessel coronary disease, which was diagnosed almost simultaneously, had to be surgically re-vascularized before chemotherapy could be started. The patient's calculated life expectancy would have been greater than 1 year if the patient had responded to treatment. In addition to red blood cells, the patient received repeated platelet transfusions for recurrent thrombocytopenia. Nevertheless, the initial postoperative course was favorable, and the patient was discharged on day 20 for cardiac rehabilitation (see midterm follow-up). The third patient had hemorrhagic tamponade and was readmitted to the operating room for open pericardial drainage and hemostasis, after which the postoperative course was uneventful. Four other patients exhibited

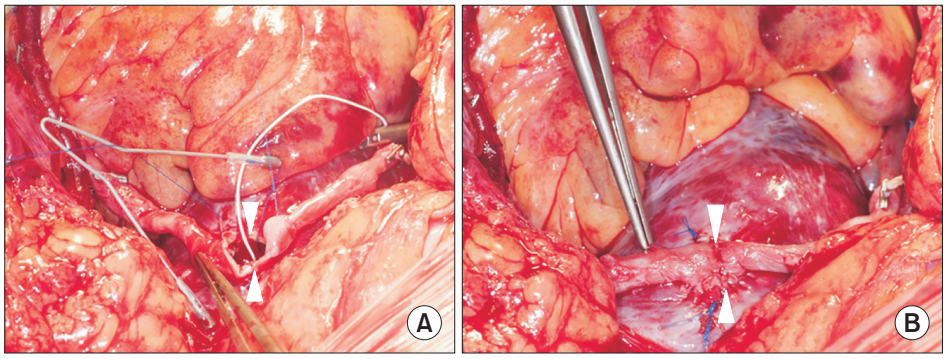

Fig. 1. Intraoperative view of the single Heartstring aortotomy for multiple off-pump venous bypass grafts. (A) Image of the aortic suture of both vein grafts with the suture nearly finished. (B) Immediately after removal of the device and final knotting (small arrows).

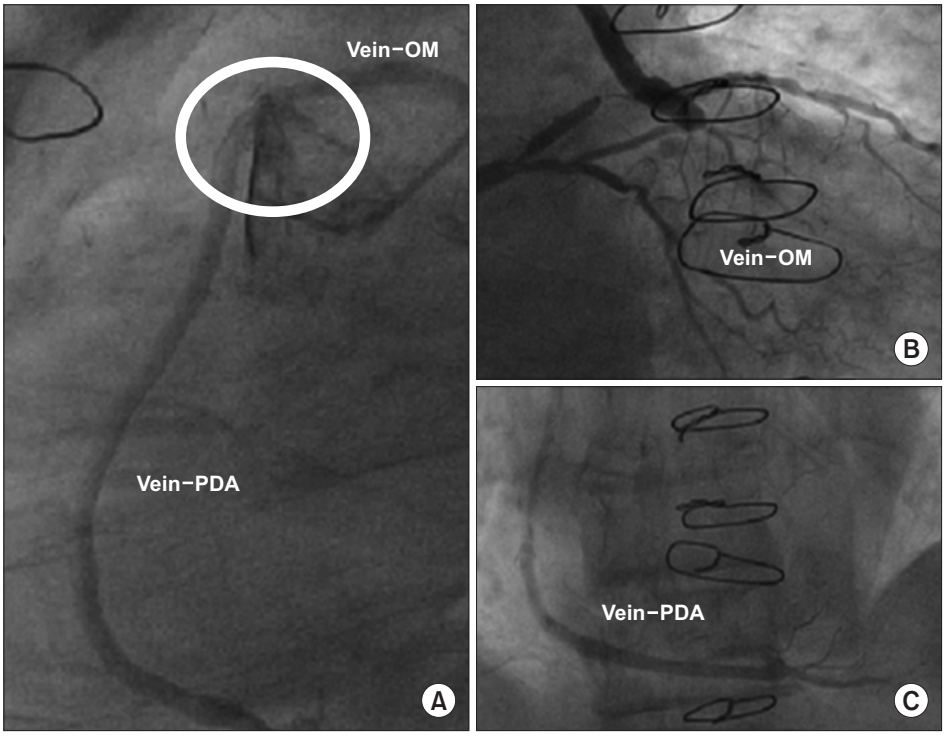

Fig. 2. (A) Contrast injection through the proximal single aortic anastomosis (circle), showing patent venous grafts to the (B) OM artery (vein–OM) and the (C) PDA (vein–PDA) 11 months after surgery. OM, obtuse marginal; PDA, posterior descending artery.

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temporary postoperative delirium, but all recovered within a few days.

Follow-up

The completeness (≥24 months) of the follow-up was 100%. During the follow-up period (mean follow-up duration, 38±13 months; range, 3 to 56 months), 2 patients died. The patient with myelodysplastic syndrome died 3 months after CABG, after being readmitted to the hospital with spontaneous pleural bleeding caused by severe thrombocytopenia. Due to the rapid progression of the tumor, it was decided (mainly at the patient's request) not to perform any further invasive life-sustaining measures. The last cardiac parameters (cardiac enzymes, electrocardiogram, and echocardiogram) of the patient were normal. A second non–cardiac-related death occurred 48 months after surgery. Overall, this corresponded to a survival rate of almost 90% and a 24-month follow-up survival rate of 94%.

Three patients were admitted for symptomatic coronary ischemia. One developed severe left main stenosis 11 months after CABG, and the left main artery of this patient was thus stented. This lesion was responsible for the ischemia of a previously non-bypassed DIAG territory. Coronary angiography confirmed the patency of all grafts (Fig. 2). The remaining 2 patients were diagnosed with vein graft occlusions after 26 and 27 months of follow-up, respectively. One patient was treated by stenting the corresponding graft, as the proximal part of the graft was open; in the other patient, both grafts were thrombosed, so treatment involved the stenting of 2 native coronary arteries (the OM and the PDA). The latter patient had already had severe LV dysfunction preoperatively (ejection fraction, 30%). Both patients had initially exhibited uneventful clinical courses, with good adaptation to physical effort and negative stress tests (via electrocardiogram) for myocardial ischemia at the 1-year follow-up. Transit-time flow measurements of the affected grafts had shown normal intraoperative values. The initially favorable course and the rapid onset of cardiac symptoms (dyspnea) more than 2 years after surgery indicate late graft failures, corresponding to a vein graft occlusion rate of 7.5%. This study was approved by the Institutional Review Board of Lausanne University (IRB approval no., 2017-01227). Patients provided written informed consent for publication of clinical details and images.

Discussion

The accepted guidelines contain technical advice regarding how to optimize the results of CABG. In the section describing procedural aspects, the authors of those guidelines recommend minimizing aortic manipulation in order to avoid possible, although rare, neurological complications [2]. From this point of view, complete arterial, an-aortic, off-pump revascularization would be ideal. However, this is undoubtedly not always possible, and other factors play important roles in the decision to use venous grafts.

In our article regarding the single Heartstring aortotomy for multiple off-pump venous bypass grafts, we described a technique to further reduce aortic manipulation [1]. The present case series focuses on the results of this technique in the context of early and mid-term follow-up. According to the (admittedly limited) quantitative data, this technique is safe and reproducible, despite the inclusion of high-risk patients, since no MACCE occurred and problems related to the surgical technique, in terms of non-feasibility, were not identified. Special attention was paid to the neurological outcomes, as the technique was developed in accordance with recommendations to minimize aortic manipulation based on the proven relationship between aortic manipulation and the potential for subsequent embolization [2-4].

The venous graft patency rate of 100% after 2 years and projected patency rate of 88% after 3 years demonstrated in the present study are comparable to previously reported results [5]. Correct graft flow, an uneventful early postoperative course, and the onset of cardiac symptoms more than 2 years after surgery make technique-related graft failure unlikely in patients with documented graft occlusions [6].

Alternative techniques for multiple vein grafting are still of interest, although the current trend is towards the increased use of arterial grafts. The role of multiple venous bypass is indirectly defined by the limitations of the use of the bilateral internal mammary arteries in CABG: "…a second arterial graft should be considered depending on… life expectancy, risk factors for sternal…complications, coronary anatomy, degree of target vessel stenosis, [and] graft quality…" [2].

The present technique is of interest because, in addition to its simplicity and reproducibility, it combines some advantages for the treatment of high-risk patients. Low systemic (off-pump) anticoagulation may be advantageous in patients with an increased risk of bleeding (as in myelodys-

plastic syndrome). Additionally, continuous coronary perfusion during beating-heart coronary revascularization may prevent additional ischemia (as in the patient with ongoing ischemia and severe LV dysfunction), and minimized aortic access may be helpful in cases of severe atherosclerosis [7,8].

In order to be able to make statements regarding the patency of vein grafts within 5 to 10 years, studies with a longer follow-up period and an increased number of patients are required. In the present study, the small proportion (14%) of patients recruited relative to the total off-pump CABG cohort (the majority of whom received bilateral internal mammary artery grafts) reflects the rigorous patient selection process for multi-venous off-pump CABG.

In summary, multiple venous CABG is still part of the daily repertoire of every cardiac surgeon and is mentioned accordingly in the current guidelines. In this context, it was shown that the single Heartstring aortotomy for multiple off-pump venous bypass grafts is a safe and reproducible method that combines the advantages of technically simple revascularization, the off-pump approach, and minimal aortic manipulation.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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