Original Article

Innovations
2022, Vol. 17(4) 310–316

DOI: 10.1177/15569845221115149
journals.sagepub.com/home/inv
SAGE

Cost Analysis of Endoscopic Conduit Harvesting Technique Using a Non-Sealed System for Coronary Artery Bypass Surgery

Fabrizio Rosati[1], MD, Mohammad Bin Pervez[2], MD, FCPS, Camila Mayorga Palacios[3], BSc, Cesare Tomasi[1], PhD, Giorgio Mastroiacovo[4], MD, Sergio Pirola[4], MD, Alice Bonomi[5], PhD, Gianluca Polvani[4,6], MD, and Gianluigi Bisleri[2], MD, FRCSC

Abstract

Objective: Endoscopic vessel harvest (EVH) is evolving as the standard of care for coronary artery bypass grafting. However, the increase in upfront equipment-related costs has resulted in reluctance of uptake globally. We investigated the costs involving a non-sealed technique for EVH versus open vessel harvesting techniques (OVH) for both the greater saphenous vein and radial artery with a 6-month follow-up. **Methods:** From September 2016 to December 2018, 226 patients underwent OVH while 251 patients underwent EVH using a reusable non-sealed system and a single-use radiofrequency sealing system. Cumulative costs for OVH versus EVH were calculated as a summation of total operative and in-hospital stay costs. Costs related to harvest site complication management were also analyzed for up to 6 months. **Results:** Total operative costs were greater in the EVH group (Can$2,283.70 [Can$1,377.60 to $4,183.50] vs Can$1,742.40 [Can$998.50 to $3,628.10], $P < 0.001$). Total length of stay was significantly shorter for the EVH group (5.9 [4 to 43] days vs 6.8 [4 to 55] days, $P = 0.018$). Cumulative costs were comparable at the end of the hospitalization period (EVH, Can$6,534.70 [Can$2,076.50 to $33,087.70] vs OVH, Can$6,112.50 [Can$3,322.30 to $45,503.50], $P = 0.06$). After discharge, harvest site–related complications occurred more frequently in the OVH group (27% vs 4.4%, $P < 0.001$), resulting in increased use of antibiotics (2.2% vs 0.8%, $P = 0.02$) as well as more frequent requirement for home nursing assistance in the OVH group (5.7% vs 0.8%, $P = 0.002$) at 6 months of follow-up. **Conclusions:** Cumulative costs did not show a statistical difference between OVH and EVH, with higher intraoperative costs for EVH being offset by higher harvest site management costs in the OVH group.

Central Message

Endoscopic vessel harvest for the radial artery and greater saphenous vein increases upfront equipment-related costs, which is offset by cost savings arising from a shorter length of stay and reduced incidence of harvest site complications compared with traditional open vessel harvesting.

Keywords

minimally invasive cardiac surgery, bypass surgery, endoscopic conduit harvesting

Introduction

Endoscopic vessel harvest (EVH) of the saphenous vein (SV) was introduced in the 1990s with the objective of overcoming conduit harvest site issues including pain, infection, poor wound healing, and cosmesis, with recent innovations also bringing radial artery (RA) harvest into the folds of EVH.[1,2] Initial consternations about the potential impact of EVH on the long-term patency of conduits were addressed, with several studies showing noninferiority in terms of long-term outcomes in patients undergoing surgical myocardial revascularization using conduits harvested by EVH.[3,4] The data in favor of EVH have been sufficiently convincing, such that

[1]Division of Cardiac Surgery, Spedali Civili di Brescia, University of Brescia, Italy
[2]Division of Cardiac Surgery, St Michael's Hospital, University of Toronto, ON, Canada
[3]Center for Neuroscience Studies, Queen's University, Kingston, ON, Canada
[4]Department of Cardiac Surgery, Centro Cardiologico Monzino, IRCCS, Milan, Italy
[5]Unit of Biostatistic, Centro Cardiologico Monzino, IRCCS, Milan, Italy
[6]Department of Biomedical, Surgical, and Dental Sciences, University of Milan, Italy

Corresponding Author:
Gianluigi Bisleri, Division of Cardiac Surgery, St Michael's Hospital – University of Toronto, 30 Bond St E, Toronto, ON M5B 1W8, Canada.
Email: gianluigi.bisleri@utoronto.ca

after reviewing 76 relevant studies, a consensus statement was released in 2017 supporting the use of endoscopic vein harvest techniques as the new standard of care.[5] The recent 2021 American College of Cardiology (ACC) guidelines also recommend EVH of the SV in patients with a risk of wound complications in the coronary artery bypass graft (CABG) best practice guidelines section.[6] Despite these recommendations, EVH has not been widely adopted at a global level because of monetary concerns. Given that EVH requires specialized instruments, which in some instances are single-use devices, there is an associated increase in upfront operative costs. Whether the benefits of EVH justify the increased operative costs and whether they extend to lower costs outside the operation theater is a matter of ongoing investigation in the medical community. At our center, we have been using EVH for both RA and SV harvest using a non-sealed system for endoscopic graft harvesting. We therefore conducted a retrospective comprehensive cost analysis comparing EVH and open vessel harvesting (OVH) techniques for patients undergoing surgical myocardial revascularization extending into the 6-month period after discharge.

Methods

From September 2016 to December 2018, 539 consecutive patients with multivessel coronary artery disease were scheduled to undergo surgical revascularization with the use of RA and/or SV as grafts for targets other than the left anterior descending artery. The decision for surgical revascularization in preference to percutaneous coronary intervention was made through a multidisciplinary consensus via a heart team in all cases. Conventional OVH was performed in 288 patients, whereas 251 patients underwent EVH for both RA and SV by means of a non-sealed endoscopic technique using a specifically designed endoscopic reusable retractor (Karl Storz, Tuttlingen, Germany) and an impedance-controlled radiofrequency device as a vessel-sealing system (LigaSure Maryland, Medtronic, Dublin, Ireland). Among 288 patients in the OVH group, 62 patients had SVs harvested by means of a bridge technique and were excluded, resulting in a final total of 226 patients.

Patient baseline characteristics were retrospectively collected from the institutional electronic medical record system as well as data regarding operative details and postoperative in-hospital stay. As part of standard practice, harvesting site wounds were assessed daily until discharge. Wound findings such as minor or major discharge, redness, dehiscence, antibiotic prescription, need for debridement, and dressing were reported as complications either during hospitalization or during 6-month follow-up, and associated costs such as antibiotics and local wound care were recorded.

Cost Analysis

Cost calculations were performed using values provided by the Kingston General Health Science financial department from fiscal year 2018 to 2019. These rates included direct costs of nursing and consumables while excluding any imaging, labs, and allied overhead. Total CABG cost was calculated as the sum of supply cost and operatory room (OR) cost calculated by multiplying the hourly OR utilization rate by the length of the procedure and accounted for an average staffing of 2 registered nurses, 1 registered practical nurse, and 1 registered nurse physician assistant while excluding physician and perfusionist fees. Surgical supply costs were calculated separately based on the type of harvesting with EVH, including the additional cost of antifogging agent, camera drape, endoscope tray, and the disposable vessel-sealing system (LigaSure Maryland). Intensive care unit (ICU) and ward stay costs were calculated by multiplying the respective unit cost by length of stay and adding both for cumulative hospital stay costs. Harvest site–related postdischarge costs were followed for 6 months, including emergency visits, clinic visits, readmissions, and utilization of at-home services with exclusion of visits not related to harvest site complications. Emergency room (ER) costs were provided by the financial department as costs associated with a mean ER visit stay of 4 h multiplied by the number of ER visits. Similarly, clinic visit costs were calculated by multiplying the cost of a single clinic visit by the number of visits per patient. For patients who required readmission, the cost was calculated using the previously described ward stay calculation method. Lastly, costs for out-of-hospital resource utilization such as at home nursing visits (Community Care Access Center [CCAC]) for wound care were calculated by frequency of visits. For privacy reasons, the individual costs for external care services could not be procured and were not included in the final analysis. Of note, all costs are expressed as Canadian dollars (Can$).

Surgical Techniques

OVH graft procurement was performed by experienced physician assistants, and both SV and RA were harvested as a pedicle. Endoscopic RA and SV harvesting was carried out by the same operators once full proficiency was achieved after a period of supervision by 2 experienced surgeons in this field with more than 100 cases performed (G.B. and F.R.). A modified Allen test using a pulse oximetry device was performed in patients undergoing RA harvesting in order to avoid hand ischemia. The nondominant arm was preferentially used unless there was a recent radial angiography or a positive Allen test. The SV was mapped by means of ultrasound in the OR after induction to rule out any unfavorable anatomical variations.

Endoscopic Vessel Harvesting

Endoscopic RA and SV harvesting was performed as previously described.[7,8] In particular, a minimally invasive non-sealed approach was used. This means active CO_2 insufflation through an occlusive port was not required, although CO_2

may be used for visual flush. This avoids active pressurization in the dissection tunnel, which has been theorized to damage the conduit.[9–11] The RA was isolated as a pedicle through a 2 to 2.5 cm incision at the level of the volar surface of the forearm 1 cm proximally to the styloid prominence of the radial bone, while SV was harvested starting with a 2 to 2.5 cm incision above the knee. Once completely isolated, a specific reusable endoscopic retractor (Karl Storz) was inserted to achieve an endoscopic view of the RA or the SV. Endoscopic dissection of both the RA and SV pedicles as well as division from surrounding tissue and side branches was performed by means of an impedance-controlled radiofrequency vessel-sealing system (LigaSure Maryland) until the antecubital fossa or the groin was reached for RA and SV harvesting, respectively. Endoscopic harvesting usually provides 18 to 20 cm length of RA, while endoscopic SV harvesting can easily provide 35 cm of venous graft. Once the SV is isolated up to the groin, harvesting maneuvers may be continued below the knee from the same incision in case extra length is required. Graft retrieval was performed by means of a single-incision approach. The vessel-sealing system was used to directly divide the RA or SV at the level of the elbow or the groin, respectively. The conduits were then retrieved via the starting incision at the level of the wrist or knee.

Statistical Analyses

Data were analyzed using IBM SPSS Statistics, Version 26.0 (IBM Corp., Armonk, NY, USA) and SAS 9.4 (SAS Institute Inc., Cary, NC, USA). Categorical data were expressed as percentages, and differences between the OVH and EVH groups were assessed by means of the chi-squared test. The Kolmogorov–Smirnov test was used to assess the normal distribution of continuous variables. Parametric data were expressed as mean ± standard deviation, while nonparametric data were expressed as median with maximum to minimum values. Differences were analyzed using *t* tests or Mann–Whitney tests. Tests were considered statistically significant at $P < 0.05$ (2-tailed).

Results

Baseline patient characteristics and intraoperative details are depicted in Table 1 and Table 2, respectively. As shown, no significant differences were seen in preoperative variables between the EVH and OVH groups. In particular, the median number of bypasses per patient (OVH, 3 [1 to 6] vs EVH, 3 [1 to 5], $P = 0.35$) as well as the surgical operative time (OVH, 3.1 [1.6 to 8.9] h vs EVH, 3.2 [1.3 to 7.2] h, $P = 0.97$) were comparable among the 2 groups, with no patients in the EVH population requiring conversion to the open approach. Of note, no differences in frequency of use for RA (OVH, 18.5% [42 of 226] vs EVH, 16.3% [41 of 251], $P = 0.518$), SV (OVH, 67.7% [153 of 226] vs EVH, 65.7% [165 of 251], $P = 0.717$), or both (OVH, 13.7% [31 of 226] vs EVH, 17.9% [45 of 251], $P = 0.210$) were recorded between the 2 groups.

The median postoperative ICU stay was comparable among the OVH and EVH groups (2 [0.1 to 17.2] days vs 2 [0.7 to 12.4] days, $P = 0.56$). Conversely, the regular ward length of stay was significantly shorter in the EVH group (3.7 [0.7 to 40.1] days vs 4.2 [0.6 to 41.9] days, $P = 0.015$), thus leading to a shorter total hospital length of stay in the EVH group (5.9 [0 to 43] days vs 6.8 [1 to 55] days, $P = 0.018$).

Table 3 depicts the postoperative complications in both groups. During the period between surgery and discharge,

Table 1. Preoperative Details.

	OVH ($n = 226$)	EVH ($n = 251$)	*P* value
Age, years	66.0 (41–83)	66.0 (42–83)	0.695
Female	54 (23.9)	53 (21.1)	0.468
Hypertension	162 (71.7)	172 (68.5)	0.453
Diabetes	83 (36.7)	86 (34.3)	0.574
Dyslipidemia	118 (52.2)	123 (49.0)	0.433
COPD	33 (14.6)	34 (13.5)	0.740
Obesity	100 (44.2)	93 (37.1)	0.110
Body mass index	29.4 (20–48)	28.7 (15–50)	0.127
Arteriopathy	13 (5.8)	11 (4.4)	0.494
eGFR, mL/min	81.0 (15–95)	83.0 (11–98)	0.776
History of AF	12 (5.3)	13 (5.2)	0.949
Previous pacemaker	7 (3.1)	3 (1.2)	0.148
Previous MI	86 (38.1)	101 (40.2)	0.625
Previous PCI	1 (0.4)	1 (0.4)	0.941
Previous cardiac surgery	25 (11.1)	35 (13.9)	0.343
Number of diseased vessels	3 (1–6)	3 (1–5)	0.803
LVEF, %	55.0 (10–80)	55.0 (20–90)	0.051
EuroSCORE II	2.2 (1–31)	2.4 (1–25)	0.590

Abbreviations: AF, atrial fibrillation; COPD, chronic obstructive pulmonary disease; eGFR, estimated glomerular filtration rate; EuroSCORE, European System for Cardiac Operative Risk Evaluation; EVH, endoscopic vessel harvesting; LVEF, left ventricle ejection fraction; MI, myocardial infarction; OVH, open vessel harvesting; PCI, percutaneous coronary intervention.
Data are presented as median (min–max) or frequency (%).

Table 2. Operative Details.

	OVH ($n = 226$)	EVH ($n = 251$)	*P* value
CPB time, min	66 (19–174)	67 (20–175)	0.944
Cross-clamp time, min	53.5 (0–169)	56 (14–154)	0.186
Surgical time, h	3.1 (1.6–8.9)	3.2 (1.3–7.2)	0.971
Grafts per patient	3 (1–6)	3 (1–5)	0.350
Radial artery graft	42 (18.5)	41 (16.3)	0.518
Saphenous vein graft	153 (67.7)	165 (65.7)	0.717
Radial artery + saphenous vein graft	31 (13.7)	45 (17.9)	0.210
IABP	16 (7.1)	7 (2.8)	0.072

Abbreviations: CPB, cardiopulmonary bypass; EVH, endoscopic vessel harvesting; IABP, intra-aortic balloon pump; OVH, open vessel harvesting.
Data are presented as median (min–max) or frequency (%).

Table 3. Postoperative Course.

	OVH ($n = 226$)	EVH ($n = 251$)	*P* value
Complications			
Cardiogenic shock	1 (0.4)	0	0.041
Atrial fibrillation	85 (37.6)	66 (26.3)	0.009
Pleural effusion	7 (3.1)	5 (2.0)	0.441
Acute kidney injury	4 (1.8)	2 (0.8)	0.507
Transfusion	79 (35.0)	102 (40.6)	0.190
In-hospital mortality	4 (1.8)	3 (1.2)	0.610
Harvesting site complications			
Incision complications[a]	61 (27.0)	11 (4.4)	<0.001
Peripheral edema	15 (6.6)	4 (1.6)	0.005
Antibiotic prescription	5 (2.2)	2 (0.8)	0.018

Abbreviations: EVH, endoscopic vessel harvesting; OVH, open vessel harvesting.
Data are presented as frequency (%).
[a]Incision complications: discharge, redness, dehiscence, antibiotic prescription, and need for debridement.

Table 4. Six-Month Follow-up.

	OVH ($n = 226$)	EVH ($n = 251$)	*P* value
Angina	1 (0.4)	0	0.941
Myocardial infarction	0	0	0.291
Heart failure	1 (0.4)	1 (0.4)	0.941
Reoperation	2 (0.8)	1 (0.4)	0.502
Death	0	1 (0.4)	0.317
Harvesting site incision healing[a]			
30 days	201 (88.9)	241 (96.1)	<0.001
6 months	224 (99.1)	251 (100.0)	0.066
Harvesting site infection[b]			
30 days	2 (0.8)	0	0.139
6 months	2 (0.8)	0	0.141
ER visits	1 (1–2)	1 (1–1)	0.889
Clinic visits	1.5 (1–5)	1.1 (1–4)	0.001
Patients requiring CCAC	13 (5.7)	2 (0.8)	0.002

Abbreviations: CCAC, community care access center; ER, emergency department; EVH, endoscopic vessel harvesting; OVH, open vessel harvesting.
Data are presented as median (min–max) or frequency (%).
[a]Harvesting site incision healing considered in the absence of wound discharge, redness, dehiscence, and need of debridement.
[b]Harvesting site infection considered for wound-related antibiotic prescription.

harvesting site–related complications occurred more frequently in the OVH group (27.0% vs 4.4%, $P < 0.001$), which is reflected in the higher incidence of antibiotic prescription for harvesting site–related infection (2.2% vs 0.8%, $P = 0.018$).

At 6 months after hospital discharge, neither group experienced readmissions related to harvesting wound issues. At 30 days after discharge, 96.1% of EVH patients (241 of 254) had healed harvesting incisions, and all EVH patients had healed harvest incisions by 6 months after discharge. In contrast, only 88.9% of OVH patients experienced healed harvesting incisions at 30 days after discharge (Table 4). Correspondingly, patients who underwent OVH required more clinic appointments compared with EVH patients (1.5 [1 to 5] visits vs 1.1 [1 to 4] visits, $P < 0.001$). In addition, referral and utilization of at-home CCAC for harvesting wound treatment was significantly higher in the OVH group (5.7% vs 0.8%, $P = 0.002$).

Cost Analysis

As expected, total operative costs were higher in the EVH group compared with OVH (Can$2,283.70 [Can$1,377.60 to $4,183.50] vs Can$1,742.40 [Can$998.50 to $3,628.10], $P < 0.001$) arising primarily from the additional cost of the minimally invasive harvesting tools, in particular due to the vessel-sealing system (LigaSure Maryland) used to perform endoscopic SV/RA harvesting by means of a non-sealed approach. Conversely, regular ward stay costs were significantly higher in the OVH group (Can$1,435.70 [Can$305.10 to $20,159.90] vs Can$1,417.50 [Can$345.30 to $19,207.30], $P = 0.017$), resulting in no difference in final hospital costs at the end of the hospitalization period between the OVH and EVH groups (Can$6,112.50 [Can$3,322.30 to $45,503.50] vs Can$6,534.70 [Can$2,076.50 to $33,087.70], $P = 0.06$). Lastly, clinic visit costs were significantly higher in patients who underwent OVH (Can$30.40 [Can$20 to $102] vs Can$24.10 [Can$20 to $82], $P < 0.001$; Table 5).

Discussion

EVH is the new standard of care for procuring conduits for CABG given comparable long-term outcomes with fewer harvest site-related complications.[4,5] Recent trials such as the REGROUP trial have further bolstered this perspective.[12] The literature shows an increasing percentage of surgeons using EVH in some countries, such as the United States, where the Society of Thoracic Surgeons database indicates the use of EVH in up to 80% of cases. However, conduit procurement for CABG globally is still predominantly performed via conventional open techniques, with EVH numbers in Europe estimated to be as low as 10%.[13,14] This is despite the fact that complications such as wound healing, pain, and discomfort at the harvesting site represent an important issue related to the conventional approach and were the reasons EVH was developed in the first place.[12] At this stage, the major concern barring wider adoption of EVH is cost-effectiveness in an environment where value-based care is becoming increasingly important for cardiac surgery and more innovations are being proposed than ever before.[15] CABG is the most common cardiac procedure performed worldwide, and this translates to even minor cost efficiencies, multiplying to a significant monetary impact at a global level.[16]

We therefore performed a cost analysis in 477 patients undergoing CABG who had the RA and/or SV harvested by means of OVH (226 patients) or EVH (251 patients) with the use of a non-sealed approach. Preoperative characteristics including harvesting site–related risk factors including

Table 5. Cost Analysis Expressed in Canadian Dollars.

	OVH ($n = 226$)	EVH ($n = 251$)	*P* value
Operative costs	1,742.40 (998.50–3,628.10)	2,283.70 (1,377.60–4,183.50)	<0.001
OR staffing costs	902.20 (462.00–2,583.10)	915.30 (377.70–2,094.90)	0.971
Surgical supply costs	189.50 (189.50–362.80)	752.00 (752.00–752.00)	<0.001
ICU stay costs	2,763.90 (1,096.70–23,712.30)	2,720.70 (1,023.10–17,175.80)	0.561
Regular ward stay costs	1,435.70 (305.10–20,159.90)	1,417.50 (345.30–19,207.30)	0.017
Total stay costs	4,403.60 (1,860.50–42,213.60)	4,118.70 (1,790.50–30,496.60)	0.113
Total hospital costs	6,112.50 (3,322.30–45,503.50)	6,534.70 (2,076.50–33,087.70)	0.060
ER visit costs	158.10 (135.50–270.90)	135.50 (135.50–135.50)	0.889
Readmission costs	—	—	—
Clinic visit costs	30.40 (20.00–102.00)	24.10 (20.00–82.00)	0.001

Abbreviations: CABG, coronary artery bypass graft; ER, emergency department; EVH, endoscopic vessel harvesting; ICU, intensive care unit; OR, operating room; OVH, open vessel harvesting.
Data are presented as median (min–max).

obesity, diabetes, renal failure expressed as estimated glomerular filtration rate, and peripheral vascular disease were not statistically different; hence, the 2 groups were comparable (Table 1).[4]

In our study, the use of a non-sealed EVH technique added an average upfront cost of Can$752 intraoperatively per CABG, with most of the cost increment arising from the vessel-sealing device (LigaSure Maryland). The median total surgical time ($P = 0.971$), extracorporeal circulation time ($P = 0.944$), and total aortic cross-clamp time ($P = 0.186$) were found to be similar among the 2 groups. Furthermore, no significant differences were found in the median number of bypasses performed; thus, reducing confounding factors that could have prolonged the surgical procedure and indirectly increased surgical costs. As a result, operating room utilization costs per hour were comparable between EVH and OVH (Table 5). Of note, surgical times were also found to be similar in those patients who required both SV and RA harvesting, which constituted 18.0% of the overall sample (86 of 477), 13.7% of the OVH group (31 of 226), and 17.9% of the EVH group (45 of 251). In these cases, the same device was used starting with the arterial conduit and then moving on to the venous conduit, hence optimizing procedural costs.

Postoperatively, patients followed a regular clinical pathway, which included ICU followed by regular ward stay. Consistent with other studies, there was a significantly shorter hospital stay in the EVH group compared with the OVH group by almost an entire day (6.8 vs 5.9 days). The OVH group required a more frequent use of antibiotics and special dressing for wound-related complications as compared with the EVH group (5.7% vs 0.8%), acting as an additive factor potentially responsible for the prolonged length of stay experienced by patients in the OVH group. However, this result could have been influenced by the significantly higher incidence of postoperative atrial fibrillation that occurred in the OVH group (Table 3), although a statistical association between harvesting technique (OVH vs EVH) and incidence of atrial fibrillation is unlikely. Only 1 patient experienced cardiogenic shock in the OVH group, and despite the statistical significance, we hardly believe that this specific aspect could be a factor influencing the longer length of stay for the whole OVH group. Therefore, analysis of the total cost for the entire hospitalization duration showed no cumulative differences between the 2 groups, with additional costs of equipment use in the EVH group being potentially offset by the relatively cheaper postoperative care in the form of shorter hospital stay and lower harvest site care costs (Table 5).

Given the paucity of postdischarge follow-up for EVH versus OVH in the literature, we extended our analysis into the 6-month postoperative period and found that patients in the OVH group required cost-bearing medical attention at a higher rate than the EVH group.[17] More frequent follow-up appointments for harvest site complications resulted in significantly higher costs in the OVH group at both 30 days and 6 months after discharge. Furthermore, there were increased costs related to more frequent domiciliary assistance required for the OVH group. In fact, almost 6% of patients in the OVH group required home nursing, with an average of 3 domiciliary appointments per week lasting up to 6 to 8 weeks. Owing to concerns for patient privacy, we did not retrieve the specifics of CCAC treatment and could not add the increased cost to the final cumulative cost differential for OVH versus EVH. However, considering home nursing cost per day was prolonged for 6 to 8 weeks at 3 times per week, we can safely extrapolate that this would further increase the treatment cost for the OVH group above what we have reported in this article.

We excluded patients with off-pump CABG and those who underwent open vein harvest with skin bridges to reduce confounding factors that could potentially influence the outcomes of our study. As most EVH studies emphasize the importance of the expertise level of the operators, we would like to note that our operators were closely supervised by 2 experienced surgeons (G.B. and F.R.) until full proficiency was reached, as is evidenced by no conversions from EVH to OVH and no increase in operative time in the EVH group.[12–18] In addition, our study had the advantage of including RA EVH, which has not been studied as extensively as SV EVH. While cost-effectiveness in RA-specific EVH, especially techniques involving disposable single-use systems like the one we used in our study, have been studied for years, recent comparative data are scarce.[19] Studies have even explored cost-saving options in EVH radial harvest such as starting EVH simultaneously with anesthesia line placement, for a decrease in total surgical time of 32 min.[20] Because the recent ACC guidelines state an increased preference for the RA as the conduit of choice for the second most important target, we anticipate a surge of interest in the clinical and cost feasibility of RA harvest.[6] Given that EVH for RA has been shown to be noninferior to OVH in terms of mortality, graft quality, and patency rates while being superior in terms of wound complications, the debate is inevitable.[21,22]

Current evidence shows variable results for costs associated with EVH, in that earlier studies indicated it is not cost-effective whereas newer studies show the opposite.[23] In vascular surgery, patients requiring infrainguinal peripheral vascular bypass were examined with an estimated total cost saving of approximately \$3,400 for patients who had EVH compared with OVH.[24] These differences were mainly related to the shorter length of hospital stay associated with the lower incidence of complications occurring in the EVH group. The significant difference in costs in their study, compared with ours, can potentially be explained by poorer harvest site healing anticipated in patients with peripheral vascular disease as opposed to cardiac surgical patients. Luckraz et al. also compared the costs of EVH versus OVH in patients undergoing CABG with a cost analysis including a variable time of follow-up performed at the wound clinic service until the surgical harvest site was completely healed. They also reported increased costs by 856.00 GBP per patient for patients receiving OVH over EVH.[25] Of note, those patients had a higher risk for surgical site infection, possibly explaining the costs favoring the EVH group.

It is a well-studied pattern in cardiac surgery in which higher upfront costs are offset by superior long-term gains, and this seems to be the case for EVH as well. However, complex cost-bearing dynamics influence methods, as the entire cost of the patient's treatment may not be borne by a single source that would benefit financially from late-stage cost saving. Hospitals that pay the additional upfront costs of EVH may not benefit from the long-term cost benefit and as such may be reluctant to adopt EVH even if there is a comparable cumulative cost. On the other hand, the onus may shift to government policy makers in countries where health care is funded by the government or by insurance companies that would bear the overall costs of the individual in the postdischarge period. All of these factors do not even take into account the patient agenda of reduced pain and improved cosmesis or cost savings in terms of incremental cost-effectiveness ratio (ICER) and quality-adjusted life-years (QALYs), with studies suggesting EVH has an ICER of \$19,858.87 per QALY.[26] Our results allay the perception that EVH should not be adopted for monetary reasons.

Conclusions

EVH by means of a non-sealed system coupled with impedance-based tissue-sealing systems does not increase the cumulative care costs for patients undergoing CABG when compared with the traditional OVH technique.

Acknowledgments

A special acknowledgment goes to Tarrah Ethier, BSc, Penny Mccreath, BSc, and Adam Ptack, BSc, from Queen's University, Kingston, ON, Canada, for the outstanding data collection work and support.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Dr Bisleri discloses a financial relationship with Karl Storz and Covidien. All other authors declared no conflicts of interest for this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Gianluigi Bisleri https://orcid.org/0000-0002-9816-1480

References

1. Raja SG and Sarang Z. Endoscopic vein harvesting: technique, outcomes, concerns & controversies. *J Thorac Dis* 2013; 5: S630–S637.
2. Sastry P, Rivinius R, Harvey R, et al. The influence of endoscopic vein harvest on outcomes after coronary artery bypass grafting: a meta-analysis on 276,525 patients. *Eur J Cardiothorac Surg* 2013; 44: 980–989.
3. Bisleri G, Giroletti L, Hrapkowicz T, et al. Five-year clinical outcome of endoscopic versus open radial artery harvesting: a propensity score analysis. *Ann Thorac Surg* 2016; 102: 1253–1259.
4. Bitondo JM, Daggett WM, Torchiana DF, et al. Endoscopic versus open saphenous vein harvest: a comparison of postoperative wound complications. *Ann Thorac Surg* 2002; 73: 523–528.
5. Ferdinand FD, MacDonald JK, Balkhy HH, et al. Endoscopic conduit harvest in coronary artery bypass grafting surgery: an ISMICS systematic review and consensus conference statements. *Innovations* 2017; 12: 301–319.
6. Lawton JS, Tamis-Holland JE, Bangalore S, et al. 2021 ACC/AHA/SCAI guideline for coronary artery revascularization: a report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *J Am Coll Cardiol* 2022; 79: e21–e129.
7. Mahmood D, Rosati F, Petsikas D, et al. Endoscopic radial artery harvesting with a non-sealed approach. *Multimed Man Cardiothorac Surg* 2019; 2019.

8. Mahmood D, Rosati F, Petsikas D, et al. Endoscopic saphenous vein harvesting with a non-sealed approach. *Multimed Man Cardiothorac Surg* 2019; 2019.
9. Brown EN, Kon ZN, Tran R, et al. Strategies to reduce intraluminal clot formation in endoscopically harvested saphenous veins. *J Thorac Cardiovasc Surg* 2007; 134: 1259–1265.
10. Rousou LJ, Taylor KB, Lu XG, et al. Saphenous vein conduits harvested by endoscopic technique exhibit structural and functional damage. *Ann Thorac Surg* 2009; 87: 62–70.
11. Burris NS, Brown EN, Grant M, et al. Optical coherence tomography imaging as a quality assurance tool for evaluating endoscopic harvest of the radial artery. *Ann Thorac Surg* 2008; 85: 1271–1277.
12. Zenati MA, Bhatt DL, Bakaeen FG, et al. Randomized trial of endoscopic or open vein-graft harvesting for coronary-artery bypass. *N Engl J Med* 2019; 380: 132–141.
13. Soni MK, Williams L and Raja SG. Use of endoscopic vein harvesting (EVH) during coronary artery bypass grafting in United Kingdom: the EVH survey. *Int J Surg* 2019; 69: 146–151.
14. Zenati MA, Gaziano JM, Collins JF, et al. Choice of vein-harvest technique for coronary artery bypass grafting: rationale and design of the REGROUP trial. *Clin Cardiol* 2014; 37: 325–330.
15. Ferket BS, Oxman JM, Iribarne A, et al. Cost-effectiveness analysis in cardiac surgery: a review of its concepts and methodologies. *J Thorac Cardiovasc Surg* 2018; 155: 1671–1681.
16. Gaudino M, Taggart D, Suma H, et al. The choice of conduits in coronary artery bypass surgery. *J Am Coll Cardiol* 2015; 66: 1729–1737.
17. García-Altés A and Peiró S. A systematic review of cost-effectiveness evidence of endoscopic saphenous vein harvesting: is it efficient? *Eur J Vasc Endovasc Surg* 2011; 41: 831–836.
18. Kiani S, Desai PH, Thirumvalavan N, et al. Endoscopic venous harvesting by inexperienced operators compromises venous graft remodeling. *Ann Thorac Surg* 2012; 93: 11–18.
19. Newman RV, Lammle WG and Matz KJ. Cost-effective endoscopic radial artery harvesting. *Ann Thorac Surg* 2006; 82: 353–364.
20. Wang H, Bilbao MS, Miller SL, et al. Endoscopic radial artery harvesting during anesthesia line placement reduces the time and cost of multivessel coronary artery bypass grafting. *Innovations* 2020; 15: 43–50.
21. Lei JJH, Ravendren A, Snosi M, et al. In patients undergoing coronary artery bypass grafting, is endoscopic harvesting superior to open radial artery harvesting? *Interact Cardiovasc Thorac Surg* 2021; 32: 447–451.
22. Williams JB, Peterson ED, Brennan JM, et al. Association between endoscopic vs open vein-graft harvesting and mortality, wound complications, and cardiovascular events in patients undergoing CABG surgery. *JAMA* 2012; 308: 475–484.
23. Oddershede L, Andreasen JJ, Brocki BC, et al. Economic evaluation of endoscopic versus open vein harvest for coronary artery bypass grafting. *Ann Thorac Surg* 2012; 93: 1174–1180.
24. Illig KA, Rhodes JM, Sternbach Y, et al. Financial impact of endoscopic vein harvest for infrainguinal bypass. *J Vasc Surg* 2003; 37: 323–330.
25. Luckraz H, Kaur P, Bhabra M, et al. Endoscopic vein harvest in patients at high risk for leg wound complications: a cost-benefit analysis of an initial experience. *Am J Infect Control* 2016; 44: 1606–1610.
26. Rao C, Aziz O, Deeba S, et al. Is minimally invasive harvesting of the great saphenous vein for coronary artery bypass surgery a cost-effective technique? *J Thorac Cardiovasc Surg* 2008; 135: 809–815.