

Minimally invasive coronary artery bypass grafting with ultrasonically skeletonized internal thoracic artery



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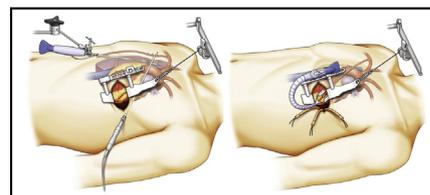
ABSTRACT

Objective: This study aimed to examine the feasibility and safety of minimally invasive cardiac surgery coronary artery bypass grafting using an ultrasonically skeletonized internal thoracic artery in the authors' initial experience.

Methods: From February 2012 to May 2021, 247 consecutive patients who underwent minimally invasive coronary artery bypass grafting using an ultrasonically skeletonized internal thoracic artery were reviewed retrospectively. Internal thoracic arteries were harvested in a full skeletonized fashion using an ultrasonic scalpel via left minithoracotomy. Bilateral internal thoracic arteries were used in 108 patients, and the internal thoracic arteries as in situ grafts were used in 393 anastomoses. Total arterial revascularization was performed in 126 patients, and 142 patients underwent aortic nontouch minimally invasive coronary artery bypass grafting.

Results: The patients' mean (range) age was 65.9 ± 11.5 (30-90) years. The mean (range) number of anastomoses performed was 2.6 ± 1.1 (1-6). Forty-six patients (18.6%) had 4 grafts, 94 patients (38.1%) had 3 grafts, and 60 patients (24.3%) had 2 grafts. Minimally invasive coronary artery bypass grafting was completed without conversion to sternotomy in all patients. Cardiopulmonary bypass was performed in 3 patients (1.2%), reinterventions due to bleeding were performed in 7 patients (2.8%), and chest wound infections were observed in 5 patients (2.0%). There was 1 (0.4%) mortality.

Conclusions: Minimally invasive coronary artery bypass grafting using an ultrasonically skeletonized internal thoracic artery is feasible and has shown good perioperative outcomes. This approach has the potential for further optimization with revascularization strategies. (JTCVS Techniques 2022;14:107-13)



Set-up for MICS CABG with ultrasonically skeletonized BITA.

CENTRAL MESSAGE

MICS CABG with an ultrasonically skeletonized ITA will help optimize MICS CABG using the in situ ITA and can become an alternative standard for surgical coronary revascularization.

PERSPECTIVE

Skeletonized ITA harvested using an ultrasonic scalpel will enable MICS CABG with in situ arterial grafts. When the rationale for not using the BITA is based on a concern for sternal wound infections, MICS CABG with this technique would allow the use of the BITA and might improve the survival of patients previously not considered as candidates for BITA revascularization.

▶ Video clip is available online.

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The concept of performing surgical revascularization through sternal-sparing incisions was popularized in the 1990s and described as a minimally invasive direct coronary artery bypass (MIDCAB).¹ It was generally limited to left internal thoracic artery (LITA) anastomosis to the left anterior descending (LAD) coronary artery. Subsequently, minimally invasive cardiac surgery coronary artery bypass grafting (MICS CABG) was introduced as an alternative coronary revascularization strategy through sternal-sparing incisions with excellent outcomes.^{2,3} MICS CABG is differentiated from MIDCAB by its ability to achieve a more extensive revascularization via a multivessel operation. Despite its advantages, a limitation of MICS CABG has been the technical difficulty of harvesting the internal thoracic artery (ITA), especially the right internal thoracic artery (RITA). Therefore, the authors improved these techniques to harvest the bilateral internal thoracic

Abbreviations and Acronyms

BITA	= bilateral internal thoracic artery
CABG	= coronary artery bypass grafting
CPB	= cardiopulmonary bypass
CT	= computed tomography
GEA	= gastroepiploic artery
ICS	= intercostal space
ITA	= internal thoracic artery
LAD	= left anterior descending
LITA	= left internal thoracic artery
MICS CABG	= minimally invasive cardiac surgery coronary artery bypass grafting
MID CABG	= minimally invasive direct coronary artery bypass
OPCAB	= off-pump coronary artery bypass
RA	= radial artery
RITA	= right internal thoracic artery

arteries (BITAs) in a skeletonized fashion using an ultrasonic scalpel via a small thoracotomy incision. This study examined the authors' initial experience of consecutive cases with MICS CABG using ultrasonically skeletonized ITA.

MATERIALS AND METHODS

From February 2012 to May 2021, 247 patients underwent MICS CABG as performed by 3 surgeons (K.K., A.Y., and K.T.) at multiple institutes. The LITA and RITA were harvested in a full skeletonized fashion under direct vision through an 8- to 10-cm left minithoracotomy incision, and off-pump MICS CABG (OPCAB) was done basically. The preoperative patient characteristics are shown in Table 1. During the same period, the same surgeons performed 642 consecutive sternotomy CABG procedures. MICS CABG can be performed in patients, except in those with severe hemodynamic compromise, severe pectus excavatum, or severe pulmonary disease, as tolerance of single-lung ventilation. Relative contraindications to MICS CABG include emergency surgery, left ventricular ejection fraction of less than 40%, and the absence of femoral pulses bilaterally. Preoperatively, 3-dimensional computed tomography (CT) scans were routinely obtained to examine the ascending aorta, the length and diameter of the BITA, and the relation between the intercostal space (ICS) and the left ventricular apex. Emergency cases and acute myocardial infarction cases were not considered candidates for MICS CABG because the operation required preoperative planning with a CT angiogram; therefore, the case series consisted entirely of elective cases.

Surgical Technique

The patient was positioned in a 40° right lateral decubitus position and intubated with a double-lumen tube for selective right lung ventilation. An 8- to 10-cm left thoracotomy was made on the ICS below the left nipple.^{4,5} The fifth ICS was most commonly opened based on a 3-dimensional CT evaluation. After opening the ICS, the intercostal muscle was divided extensively to avoid rib fractures.

Before harvesting, the fat tissues were dissected from the dorsum of sternum over the entire area and the endothoracic fascia is exposed by dissecting the pleura. The RITA was harvested before the LITA using the ultrasonically skeletonized technique (Video 1). The right lung was depressed using an Octopus NUVO stabilizer (Medtronic, Inc) inserted

TABLE 1. Preoperative patient characteristics (N = 247)

Age, y	65.9 ± 11.5
Male/female	194/53
Height, cm	162.7 ± 9.4
Weight, kg	64.8 ± 12.8
Stable angina	174 (69.9%)
Unstable angina	74 (29.7%)
Acute MI	0 (0%)
Ejection fraction, %	58.8 ± 9.2
1-vessel disease	39 (15.7%)
2-vessel disease	70 (28.1%)
3-vessel disease	138 (55.4%)
Left main trunk	59 (23.7%)
Diabetes mellitus	116 (46.6%)
Hypertension	186 (74.7%)
Smoking history	85 (34.1%)
Chronic pulmonary disease	11 (4.4%)
Chronic renal insufficiency	27 (10.8%)
Hemodialysis	13 (5.2%)
Prior myocardial infarction	81 (32.5%)
Prior PCI	53 (21.3%)

MI, Myocardial infarction; PCI, percutaneous coronary intervention.

via a 1-cm subxiphoid incision. A 5-mm port was inserted into the opened ICS 5 cm from the incision. A 32-cm dissecting hook-type Harmonic scalpel (Ethicon Endo-Surgery, Inc) was inserted through the surgical port to harvest the RITA in a full skeletonized fashion (Figure 1). The space between the medial satellite vein and the ITA was carefully dissected using the ultrasonic scalpel (output level: 3). The fatty tissue between the medial satellite vein and the ITA was foamed and easily removed by moving the ultrasonic scalpel parallel to the length of the vessel ("parallel touch" method). Through minithoracotomy, it is difficult to move the scalpel quickly along several centimeters of the vessel as main trunk ("quick touch" method) reported by Higami and colleagues⁶ and Higami and Tachibana.⁷ After exposing a branch, the hook inside the tip of the blade was placed on the branch at least 1 mm from the trunk (output level: 3). The branch was sealed by ultrasonic protein coagulation within 3 to



VIDEO 1. Surgical technique of BITA harvesting using an ultrasonic scalpel. Video available at: [https://www.jtcvs.org/article/S2666-2507\(22\)00304-2/fulltext](https://www.jtcvs.org/article/S2666-2507(22)00304-2/fulltext).

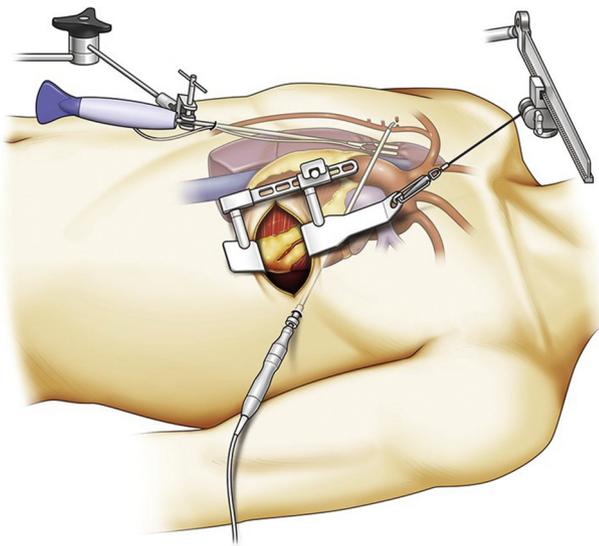


FIGURE 1. Set-up for RITA harvesting via left minithoracotomy. (1) ThoraTrak MICS Retractor System (Medtronic, Inc). (2) Octopus NUVO stabilizer (Medtronic, Inc). (3) A 32-cm dissecting hook-type Harmonic scalpel (Ethicon Endo-Surgery, Inc).

4 seconds with averaged force compression and then spontaneously divided with complete hemostasis, without injuring the main trunk (“Hook coagulation”). In contrast, it is hard to divide it safely by using only the tip (blunt side) of the blade reported previously.^{6,7}

After harvesting the distal and middle positions of the RITA, the Octopus NUVO stabilizer was positioned next to the superior vena cava to harvest the first intercostal branch of the RITA. The LITA was harvested similarly. On the other hand, the view of LITA through left minithoracotomy is the reverse of sternotomy’s view and the distal site of LITA was covered with musculus transversus thoracis. The ITA was harvested from the bifurcation of the musculophrenic and superior epigastric arteries up to the upper margin of the first rib or higher, which is just distal to the phrenic nerve in the hemithorax. The RITA harvested in such way enables in situ anastomosis for most regions of the left anterior descending artery and diagonal branch, whereas the LITA enables in situ anastomosis for the anterior descending artery region and the entire course of the circumflex branch.

A 5-cm mid-abdominal incision was required for harvesting the gastroepiploic artery (GEA). After harvesting the BITA, the pericardium was opened completely from the distal side of the ascending aorta to the left apex and the inferior vena cava along the diaphragm. The left sides of the pericardium were retracted to the left lateral chest wall. In the proximal anastomosis, the main pulmonary artery was retracted caudally with the Octopus NUVO stabilizer, and a Cygnet (Vitalitec, Inc) flexible side-biting clamp was placed on the ascending aorta. The proximal anastomoses were made on the ascending aorta with 6-0 monofilament sutures and tied using a knot pusher.⁵ Distal anastomoses were completed as is done in OPCAB through the thoracotomy with the 3 deep pericardium sutures with an Octopus tissue stabilizer (Figure 2). The RITA as an in situ graft to the left anterior descending (LAD) artery is the authors’ preferred strategy for LAD revascularization. After stabilization with the Octopus tissue stabilizer, an end-to-side anastomosis is performed between the RITA and the LAD with 8-0 polypropylene. All grafts were assessed intraoperatively using Transit Time Flow Measurement (Medistim).

Collected Data and Statistical Analysis

The study was approved by the institutional review board of Hakodate Goryoukaku Hospital, Hakodate, Japan (Approval No. 2021-053; approved

August 5, 2021). Because this was a retrospective study, individual patient informed consent was waived. Preoperative patient demographics, intraoperative variables, and data pertaining to postoperative outcomes were collected retrospectively. Data were expressed as the mean \pm standard deviation, median and ranges, or proportions. Linear regression analysis was used to study the association between the number of patients per surgeon and the operation times. Data analysis was performed using SPSS version 27.0 (SPSS).

RESULTS

Of the 247 patients who underwent MICS CABG with full skeletonized ITA, the operation was completed without cardiopulmonary bypass (CPB) in 244 patients (98.8%). An intraoperative on-pump conversion was required in 3 patients. Two cases used CPB due to hemodynamic instability during distal anastomosis in the early period, and 1 case had to go on CPB on an emergency basis. Five ITA injuries were observed in the early series, including 4 LITA grafts and 1 RITA graft. Three simple repairs of LITA were performed to recover these accidents. We gave up the use of 1 LITA and 1 RITA graft that adhere to the bone. We injured 4 LITA grafts in initial stage. It is because that the view of LITA through left minithoracotomy is the reverse view of sternotomy and that the different anatomic view of LITA grafts cause these injuries of mid of LITA body during learning curve. There was a case in which the incision was extended to control the bleeding. There were no cases of sternotomy conversion.

Table 2 shows the operative characteristics. The mean (range) number of grafts was 2.6 ± 1.1 (1-6). A total of 200 patients (81.0%) received 2 or more grafts, and 108 patients (43.4%) received BITA grafting with the second ITA as an in situ ($n = 78$) or free graft ($n = 30$) procedure. The sequential bypass technique was used in 97 patients (39.3%). The distribution of conduits and target vessels is

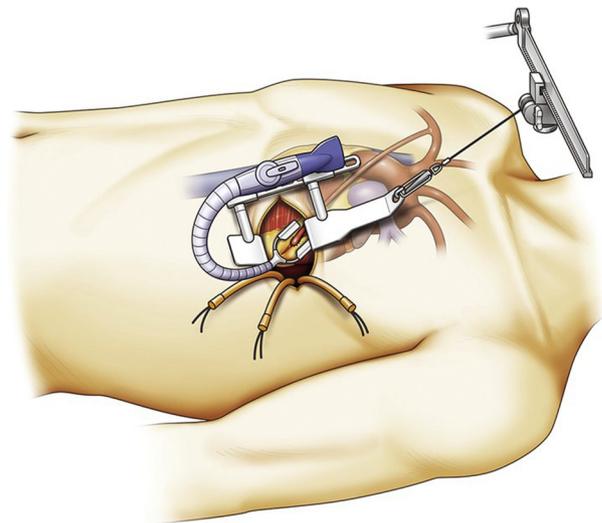


FIGURE 2. Set-up for distal anastomosis via left minithoracotomy. (1) ThoraTrak MICS Retractor System. (2) Octopus tissue stabilizer. (3) Deep pericardium sutures.

described in Table 3. The 393 anastomoses underwent a procedure using in situ ITAs, 293 anastomoses using the LITA, and 100 anastomoses using the RITA. A saphenous vein graft, a radial artery (RA) graft, and GEA graft were used in 223, 39, and 26 anastomoses, respectively. In situ ITA was used as a source of composite graft in 59 anastomoses. Free ITA, saphenous vein graft, RA, and GEA grafts were used as composite grafts in 30, 28, 30, and 8 anastomoses, respectively. Therefore, total arterial revascularization was performed in 126 patients (51.0%). Aortic nontouch MICS CABG was performed in 142 patients (57.5%). Ten patients had hybrid coronary revascularization with percutaneous coronary intervention performed after MICS CABG. The length of procedure time gradually decreased significantly with increasing experience (Figure 3). The postoperative outcomes are outlined in Table 4. The total perioperative mortality occurred in 1 patient (0.4%). The cause of death was cerebral hemorrhage. There were no cases of stroke. Seven patients (2.8%) required reoperation due to bleeding. Five (2.0%) surgical site infections were observed, including 4 leg wound complications and 1 superficial chest wound infection. The median duration of postoperative hospital stay was 11.5 days.

DISCUSSION

MICS has gained much attention in recent years in various domains, including coronary, valvular, and mechanical circulatory support and operations for arrhythmias with favorable outcomes.^{8,9}

In revascularization, MIDCAB involving the surgical revascularization of the coronary artery via left anterior thoracotomy has been advocated as an acceptable alternative to standard CABG via full sternotomy. MICS CABG is different from MIDCAB, because it is associated with excellent results but restricted to the performance of a single

LITA-LAD graft.^{10,11} Also, the thoracotomy of MICS CABG is more lateral, allowing rib spreading with less risk of a rib injury and the use of the space normally occupied by the left lung to perform procedures. Finally, the BITA can readily be harvested over the entire length of a sternotomy CABG.

In MICS CABG, multivessel revascularizations via a small left thoracotomy are gaining acceptance as an alternative revascularization approach in recent reports that demonstrated reduced hospital length of stay, fewer wound infections, reduced need for blood transfusions, and expedited postoperative recovery compared with the conventional OPCAB via a median sternotomy.¹² However, multivessel MICS CABG, especially that using BITAs, has only been successfully implemented in a few specialized centers.¹³⁻¹⁵ Although MICS CABG has favorable attributes, one of its limitations has been the technical difficulty of using BITAs. The authors have examined their clinical experience of 247 consecutive cases of MICS CABG since starting the program, including multivessel grafting using BITAs. Techniques to directly visualize, harvest, and use the RITA as an in situ graft to achieve BITA revascularization in MICS CABG were introduced.⁴

Many studies have indicated that the BITA further improves survival and reduces the need for revascularization.¹⁶⁻²⁰ Nevertheless, many surgeons avoid the BITA because of the potential for an increased risk of deep sternal wound infections.

Diabetes was not considered a contraindication for the BITA approach, given the survival benefit of BITA revascularization observed in diabetic patients.^{21,22} More important, MICS CABG avoids median sternotomy and essentially eliminates the risk of sternal wound infections.^{23,24} When the rationale for not using the BITA is based on a concern for sternal wound infections, MICS CABG with this technique would allow the use of the BITA and might improve the survival of patients previously not considered as candidates for BITA revascularization.

In these initial periods, patients with a low ejection fraction, significant cardiomegaly, poor targets, diffuse multivessel disease, or atherosclerotic ascending aorta were excluded. The indications for MICS CABG using the BITA have been expanded since then, as the surgical team became more comfortable with the procedure. However, those presenting as emergency cases and those with acute MI, severely low ejection fraction, cardiomegaly, diffuse multivessel disease, and a history of lung disease were still excluded.

Based on the authors' experience, the graft design of multivessel MICS CABG changed as harvesting the RITA became more comfortable to perform. With an ultrasonic scalpel, intact ITAs can be readily obtained in a relatively short period, with minimal invasion compared with

TABLE 2. Operative characteristics

No. of grafts	
1 graft	47 (19.0%)
2 grafts	60 (24.3%)
3 grafts	94 (38.1%)
4 grafts	46 (18.6%)
Use of BITA	108 (43.4%)
Sequential bypass	97 (39.3%)
Average distal anastomosis	2.62 ± 1.1
Aortic no-touch technique	142 (57.0%)
Total arterial revascularization	126 (50.6%)
Use of cardiopulmonary bypass	3 (1.2%)
Conversion to sternotomy	0 (0%)
Hybrid coronary revascularization	10 (4.0%)
Procedure time (min)	288.6 ± 112.7

BITA, Bilateral internal thoracic artery.

TABLE 3. Distribution of conduits and target vessels (n = anastomosis)

Target coronary	No	In situ ITA (n = 393)		Free ITA (n = 31)		RA (n = 39)	GEA (n = 26)	SVG (n = 223)
		LITA (n = 293)	RITA (n = 100)	LITA (n = 6)	RITA (n = 25)			
		Individual/composite	Individual/composite	Individual/composite	Individual/composite			
LAD	242	166/2	65/1	1/1	0/2	2/0	0/0	1/2
Diagonal	64	23/3	5/2	0/1	0/4	0/0	0/0	23/2
OM	109	28/10	3/9	0/1	0/10	0/12	0/0	29/7
PL	138	42/8	1/8	0/2	0/6	1/6	0/5	51/8
PDA	159	0/11	1/5	0/0	0/3	6/12	18/3	91/9
Total	712	259/34	75/25	1/5	0/25	9/30	18/8	195/28

ITA, Internal thoracic artery; LITA, left internal thoracic artery; RITA, right internal thoracic artery; RA, radial artery; GEA, gastroepiploic artery; SVG, saphenous vein graft; LAD, left anterior descending; OM, obtuse marginal artery; PL, posterolateral artery; PDA, posterior descending artery.

conventional cautery knives.⁶ Especially in the treatment of the branches, the skeletonization technique using an ultrasonic scalpel has significant advantages via minithoracotomy. After exposing a branch, the blunt side or the hook inside the blade's tip was placed on the branch at least 1 mm from the trunk. The branch was sealed by ultrasonic protein coagulation approximately 5 seconds with average force compression and then spontaneously divided with complete hemostasis without causing injury to the main trunk. The BITA was harvested from the bifurcation of the musculophrenic and superior epigastric arteries up to the upper margin of the first rib or higher, just distal to the phrenic nerve in the hemithorax. The frequently reported clinical advantages of the skeletonization of the ITA include an increased effective length of the ITA³ and

an increase in vessel diameter, leading to improved free flow through the ITA.²⁵ The increase in the usable length overcomes one of the main limitations of pedicled ITA use, that is, difficulty in reaching the distal target sites, and facilitates the performance of total arterial revascularization and complex ITA grafting. There are few reports of MICS CABG with ultrasonically skeletonized ITA.^{4,5} McGinn and colleagues² showed LITA grafting harvested with conventional cautery knives to LAD. They did not use RITA graft preferably. Davierwala and colleagues³ reported skeletonized BITA grafting harvested with cautery knives. They anastomosed RITA to the circumflex territory as a Y-composite graft. On the other hand, the ultrasonically skeletonized technique enables us to use BITA as in situ graft for the left coronary territory. In this series, 92.6%

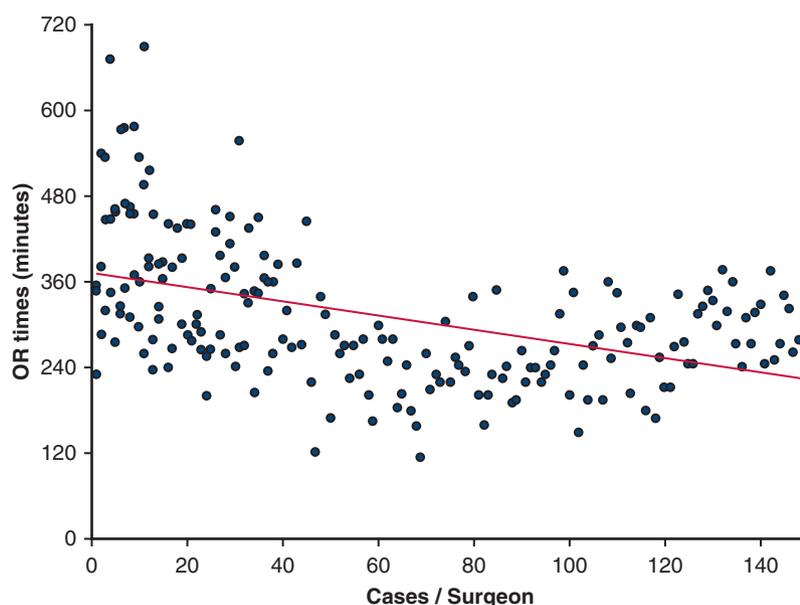


FIGURE 3. Scatter plot showing a linear regression between number of patients who underwent multivessel MICS CABG and total operation time. OR, Operating room.

TABLE 4. Postoperative outcomes

In-hospital mortality	1 (0.4%)
Stroke	0 (0%)
Reoperation for bleeding	7 (2.8%)
Perioperative transfusion	47 (18.9%)
Respiratory insufficiency	4 (1.6%)
New-onset atrial fibrillation	23 (9.3%)
New-onset renal failure	2 (0.8%)
Pleural effusion	39 (15.8%)
Surgical site infection	5 (2.0%)
Median days of hospitalization (IQR)	11.5 (9-15)

IQR, Interquartile range.

(393/424) of ITA and 80.0% (100/125) of RITA were used as in situ grafts. Although the RITA-LAD anastomosis is often difficult with pedicled ITA because of the long distance between the RITA and the LAD, this anastomosis was achieved in 74 cases of these series.

In addition, after the introduction of BITA grafting, total arterial graft designs became feasible, and the aorta no-touch technique is currently the authors' preferred approach. The RITA can also be used as in situ graft with the distal end extended by the RA as an I-composite graft to the circumflex artery. Furthermore, the visual field of RITA was interrupted by the prominent site of sternum via left minithoracotomy. An ultrasonic scalpel can resect the prominent site of sternum and ensure the view of the RITA to securely harvest skeletonized full-length RITA grafts.

Study Limitations

This was a retrospective study with a small number of consecutive patients treated by 3 surgeons. Therefore, selection bias may have remained throughout the study period and favored the selection of patients who were more likely to benefit from the avoidance of a sternotomy. A larger sample size would allow a more rigorous multivariate adjustment to compare the outcomes between MICS CABG with skeletonized BITA and established approaches, including conventional OPCAB or hybrid coronary revascularization. Such studies are needed to further argue for the efficacy of this strategy. The primary purpose of this study was to evaluate the feasibility and perioperative safety of this novel technique.

CONCLUSIONS

Skeletonized ITA can be safely harvested using an ultrasonic scalpel via a small left thoracotomy. This technique will help optimize MICS CABG using the in situ BITA with its associated benefits and without the invasiveness and related complications of median sternotomy. This surgical approach can become an alternative standard for

surgical coronary revascularization and can be further optimized.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

References

1. Subramanian VA. Less invasive arterial CABG on a beating heart. *Ann Thorac Surg.* 1997;63(6 Suppl):S68-71.
2. McGinn JT Jr, Usman S, Lapierre H, Pothula VR, Mesana TG, Ruel M. Minimally invasive coronary artery bypass grafting: dual-center experience in 450 consecutive patients. *Circulation.* 2009;120:S78-84.
3. Davierwala PM, Verevkin A, Sgouropoulou S, Hasheminejad E, von Aspern K, Misfeld M, et al. Minimally invasive coronary bypass surgery with bilateral internal thoracic arteries: early outcomes and angiographic patency. *J Thorac Cardiovasc Surg.* 2020;162:1109-19.
4. Kikuchi K, Une D, Endo Y, Matsuyama T, Fukada Y, Kurata A. Minimally invasive coronary artery bypass grafting using bilateral in situ internal thoracic arteries. *Ann Thorac Surg.* 2015;100:1082-4.
5. Kikuchi K, Une D, Suzuki K, Endo Y, Matsuyama T, Osaka S, et al. Off-pump minimally invasive coronary artery bypass grafting with a heart positioner: direct retraction for a better exposure. *Innovations.* 2015;10:183-7.
6. Higami T, Yamashita T, Nohara H, Iwashita K, Shida T, Ogawa K. Early results of coronary grafting using ultrasonically skeletonized internal thoracic arteries. *Ann Thorac Surg.* 2001;71:1224-8.
7. Higami T, Tachibana K. Harvesting: tip and pitfalls. In: Asai T, Ochi M, Yokoyama H, eds. *Off-pump Coronary Artery Bypass*. Chapter 14. Springer; 2016:111-20.
8. Svensson LG, Atik FA, Cosgrove DM, Blackstone E, Rajeswaran J, Krishnaswamy G, et al. Minimally invasive versus conventional mitral valve surgery: a propensity-matched comparison. *J Thorac Cardiovasc Surg.* 2010;139:926-32.
9. Chiu KM, Chen RJ, Lin TY, Chen J, Huang J, Huang C, et al. Right miniparasternotomy may be a good minimally invasive alternative to full sternotomy for cardiac valve operations: a propensity-adjusted analysis. *J Thorac Cardiovasc Surg.* 2016;57:111-20.
10. Boodhwani M, Ruel M, Mesana TG, Rubens FD. Minimally invasive direct coronary artery bypass for the treatment of isolated disease of the left anterior descending coronary artery. *Can J Surg.* 2005;48:307-10.
11. Holzhey DM, Jacobs S, Mochalski M, Walther T, Thiele H, Mohr FW, et al. Seven-year follow-up after minimally invasive direct coronary artery bypass: experience with more than 1300 patients. *Ann Thorac Surg.* 2007;83:108-14.
12. Rabindranauth P, Burns JG, Vessey TT, Mathiason MA, Kallies KJ, Paramesh V. Minimally invasive coronary artery bypass grafting is associated with improved clinical outcomes. *Innovations.* 2014;9:421-6.
13. Nambiar P, Kumar S, Mittal CM, Saksena K. Minimally invasive coronary artery bypass grafting with bilateral internal thoracic arteries: will this be the future? *J Thorac Cardiovasc Surg.* 2018;155:190-7.
14. Kikuchi K, Chen X, Mori M, Kurata A, Tao L. Perioperative outcomes of off-pump minimally invasive coronary artery bypass grafting with bilateral internal thoracic arteries under direct vision. *Interact Cardiovasc Thorac Surg.* 2017;24:696-701.
15. Srivastava S, Gadasalli S, Agusala M, Kolluru R, Naidu J, Shroff M, et al. Use of bilateral internal thoracic arteries in CABG through lateral thoracotomy with robotic assistance in 150 patients. *Ann Thorac Surg.* 2006;81:800-6.
16. Pick AW, Orszulak TA, Anderson BJ, Schaff HV. Single versus bilateral internal mammary artery grafts: 10-year outcome analysis. *Ann Thorac Surg.* 1997;64:599-605.
17. Lytle BW, Blackstone EH, Sabik JF, Houghtaling P, Loop FD, Cosgrove DM. The effect of bilateral internal thoracic artery grafting on survival during 20 postoperative years. *Ann Thorac Surg.* 2004;78:2005-12; discussion 2012-4.
18. Dorman MJ, Kurlansky PA, Traad EA, Galbut DL, Zucker M, Ebra G. Bilateral internal mammary artery grafting enhances survival in diabetic patients: a 30-year follow-up of propensity score-matched cohorts. *Circulation.* 2012;126:2935-42.

19. Yi G, Shine B, Rehman SM, Altman DG, Taggart DP. Effect of bilateral internal mammary artery grafts on long-term survival: a meta-analysis approach. *Circulation*. 2014;130:539-45.
20. Magruder JT, Young A, Grimm JC, Conte JV, Shah AS, Mandal K, et al. Bilateral internal thoracic artery grafting: does graft configuration affect outcome? *J Thorac Cardiovasc Surg*. 2016;152:120-7.
21. Puskas JD, Sadiq A, Vassiliades TA, Kilgo PD, Lattouf OM. Bilateral internal thoracic artery grafting is associated with significantly improved long-term survival, even among diabetic patients. *Ann Thorac Surg*. 2012;94:710-5.
22. Aldea GS, Bakaen FG, Pal J, Fremes S, Head S, Sabik J, et al. The Society of Thoracic Surgeons Clinical Practice Guidelines on arterial conduits for coronary artery bypass grafting. *Ann Thorac Surg*. 2016;101:801-9.
23. Peterson MD, Borger MA, Rao V, Peniston CM, Feindel CM. Skeletonization of bilateral internal thoracic artery grafts lowers the risk of sternal infection in patients with diabetes. *J Thorac Cardiovasc Surg*. 2003;126:1314-9.
24. Deo SV, Shah IK, Dunlay SM, Erwin P, Locker C, Altarabsheh S, et al. Bilateral internal thoracic artery harvest and deep sternal wound infection in diabetic patients. *Ann Thorac Surg*. 2013;95:862-9.
25. Choi JB, Lee SY. Skeletonized and pedicled internal thoracic artery grafts: effect on free flow during bypass. *Ann Thorac Surg*. 1996;61:909-13.

Key Words: coronary artery bypass grafting, Harmonic scalpel, minimally invasive cardiac surgery, minimally invasive coronary artery bypass grafting, skeletonized internal thoracic artery