CLINICAL STUDY

Impacts of Skeletonized Bilateral Internal Mammary Artery Bypass Grafting on the Risk of Deep Sternal Wound Infection: Insights from a Single-Center Study of Propensity Score-Matched Data

Qiang Ji,1* MD, Yun Zhao,2* MD, Huan Liu,1 MD, Ye Yang,1 MD, YuLin Wang,1 MD, WenJun Ding,1 MD, LiMin Xia,1 MD, Lai Wei,1 MD and ChunSheng Wang,2 MD

Summary
This single-center study aimed to evaluate the incidence of deep sternal wound infection (DSWI) following skeletonized bilateral internal mammary artery (BIMA) harvest in a Chinese cohort. Using propensity score matching, this study also provided a present-day assessment of the impacts of skeletonized BIMA grafting versus skeletonized single internal mammary artery (SIMA) grafting on early outcomes.

From January 2014 to December 2017, 2403 eligible patients were entered into either a BIMA group (n = 368) or a SIMA group (n = 2035). The incidence of DSWI was recorded. Analysis of early outcomes was further performed for propensity score-matched (1:1) cohorts.

The BIMA group received a similar incidence of DSWI as did the SIMA group (1.6% versus 0.9%, P = 0.247). No significant differences between subgroup diabetic-BIMA, subgroup nondiabetic-BIMA, subgroup diabetic-SIMA, and subgroup nondiabetic-SIMA were found regarding the incidence of DSWI (2.0%, 1.4%, 1.0%, and 0.7%, respectively; P > 0.05 between groups). After matching, treatment type (skeletonized BIMA grafting versus skeletonized SIMA grafting) was not an independent risk factor for postoperative DSWI (OR = 1.309, 95% CI 0.897-2.714, P = 0.704) or predictors of other early outcomes. Additionally, the two matched groups shared similar early outcomes (including postoperative DSWI), regardless of whether or not the merger with diabetes (all P > 0.05).

Skeletonized BIMA harvest as compared with skeletonized SIMA harvest was not associated with an increased risk of DSWI, regardless of whether or not the merger with diabetes. Patients with skeletonized BIMA grafting received similar surgical mortality and major postoperative morbidity as did matched patients with skeletonized SIMA grafting.

Key words: Coronary artery bypass grafting, Artery skeletonization, Diabetes mellitus, Propensity score matching

The clinical benefits related to the use of bilateral internal mammary artery (BIMA) during coronary artery bypass grafting (CABG) were clearer than ever. Nevertheless, it was used sparingly and remained widely underutilized, accounting for only 4% of CABG procedures in the USA.1 The main barrier to the use of BIMA was the generalized concern for a higher probability of sternal wound complications associated with it and its ensuing complications.2 The incidence of deep sternal wound infection (DSWI) following BIMA grafting has been reported to range widely from 0.3% to as high as 14.0%.2 In a large study including more than 9000 CABG surgeries, Omran, et al. have reported a perioperative mortality rate of 14% for CABG patients who developed DSWI versus 1.1% for uncomplicated cases.3 So, the concern was understandable.

Previous studies have shown that a large arterial collateral network was located near the internal mammary artery (IMA), which, if not damaged, could sustain adequate perfusion of the sternum after bilateral IMAs harvest.4 This can be done by harvesting the IMA in a skeletonized fashion with division of the branches close to it. Animal experiment has shown that skeletonized BIMA harvest can help reduce damage to a large arterial collateral network near the IMA.5 Also, several observational studies have reported that skeletonized BIMA harvest reduced the incidence of DSWI to as low as 1%-2% from 10%-11% observed with the pedicled technique in diabetic patients.6-8

From the 1Department of Cardiovascular Surgery, Zhongshan Hospital Fudan University, Shanghai, China and 2Shanghai Municipal Institute for Cardiovascular Diseases, Shanghai, China.
*These authors contributed equally to this work.
Address for correspondence: ChunSheng Wang, MD, Shanghai Municipal Institute for Cardiovascular Diseases, 1609 Xietu Road, Shanghai, 200032, China. E-mail: zscardiacs2016@163.com or Lai Wei, MD, Department of Cardiovascular Surgery of Zhongshan Hospital Fudan University, Shanghai. 180 Fenglin Road, Shanghai, 200032, China. E-mail: wei.lai@zs-hospital.sh.cn
Received for publication June 16, 2019. Revised and accepted November 21, 2019.
Released in advance online on J-STAGE March 14, 2020.
doi: 10.1536/ihj.19-311
All rights reserved by the International Heart Journal Association.
Despite the reported advantages, skeletonized technique of IMA harvest has so far been used by a minority of surgical groups, especially in China. Data about the incidence of DSWI following skeletonized BIMA harvest and the impacts of skeletonized BIMA grafting on clinical outcomes came almost entirely from American, European, and Japanese published studies; nevertheless, data from Chinese patients were lacking. On the basis of the above analysis, this study aimed to evaluate the incidence of sternal wound complications following skeletonized BIMA harvest versus skeletonized SIMA harvest in a single-center cohort of 2403 consecutive Chinese patients. Additionally, utilizing propensity score (PS) matching, this study aimed to provide a present-day assessment of the impacts of skeletonized BIMA grafting versus skeletonized SIMA grafting on early outcomes (including surgical mortality and major postoperative morbidity).

Methods

Study protocol: This study protocol was approved by the ethics committee of the Zhongshan Hospital Fudan University and was consistent with the Declaration of Helsinki.

Eligible patients should meet the following criteria: first time, scheduled, isolated CABG; ≥ 2 grafts received; skeletonized IMA harvest; surgical strategies including skeletonized BIMA grafting to the left coronary system with or without additional venous or radial-artery grafting or skeletonized SIMA grafting to the left anterior descending coronary artery (LAD) with additional venous or radial-artery grafting. Patients with prior CABG surgery, prior open-heart surgery, or a history of chest radiotherapy were excluded from this study.

According to the treatment type, all of the included patients were divided into two groups: patients in the BIMA group received both left and right skeletonized IMAs grafting to the two important coronary arteries with additional vein or radial-artery grafting to other coronary arteries and patients in the SIMA group experienced a single left or right skeletonized IMA grafting to the LAD plus supplemental vein or radial-artery grafting to other coronary arteries.

Baseline characteristics, surgical data, and the incidence of DSWI were investigated. DSWI, which was defined according to the guidelines of the Centers for Disease Control and Prevention, with patients meeting at least one of the following criteria: (1) isolation of an organism from culture of mediastinal tissue or fluid; (2) evidence of mediastinitis during sternal re-exploration; or (3) chest pain, sternal instability, or fever present in combination with purulent discharge from the mediastinum or an isolated organism from blood or tissue cultures. The presence of DSWI was diagnosed either at the time of hospitalization or during the first 24 hours after discharge. The incidence of DSWI was calculated for diabetics and non-diabetics, respectively. Patients treated for diabetes mellitus and patients not previously known as diabetics but with a fasting glucose of more than 125 mg/dL were considered diabetic patients, according to international guidelines.

The impacts of treatment type (skeletonized BIMA grafting versus skeletonized SIMA grafting) on early outcomes, including surgical mortality and major postoperative morbidity, were evaluated after PS matching (1:1). Surgical mortality was all deaths within 30 days of operation irrespective of where death occurred and all inhospital deaths after 30 days among patients who had not been discharged after the index operation. Major postoperative morbidity included myocardial infarction associated with CABB, prolonged ventilation of more than 24 hours, re-operation before discharge from the hospital, red blood cell transfusion, stroke, DSWI, and superficial wound infection. Superficial wound infection was defined as an infection involving only skin or subcutaneous tissue at the incision site. The amount of drainage during the first 24 hours was also recorded.

Surgical procedure: Saphenous veins and radial arteries were harvested with an open technique. A skeletonized IMA graft was dissected from the adjacent veins and muscle. Care was taken to identify the correct plane of dissection to minimize damage to the IMA and to avoid excessive devascularization of the sternum. The dissection of skeletonized IMA graft was distally commenced (caudal), progressing proximally to their emergence from the subclavian arteries with low settings (15-20W) on the electrocautery. Arterial branches were ligated with titanium clips from the bifurcation of the IMA to the first rib and divided with small scissors. The right IMA graft was harvested identically to the left IMA graft. The IMA graft was divided 3 minutes after systemic heparinization and was left in a sponge soaked with papaverine, whereas the distal end was clamped with a small bulldog clamp. The pleural spaces were not always opened, and the pericardium was incised to avoid any tension on the IMA graft.

In our center, off-pump CABG was introduced in 1998 and has been the first choice in patients who were referred for surgical revascularization, whereas on-pump CABG was conducted in patients with severely impaired left ventricular function, deeply intramyocardial target vessels, previous cardiac surgery, or concomitant open-heart surgery. The details of the off-pump and on-pump CABG procedure were consistent with those in previous studies. Surgeons were at liberty to choose single or bilateral IMAs harvest for each case. Factors influencing surgeons’ preference for BIMA grafting may have included anticipated life expectancy of more than 10 years, planning complete left-sided IMA grafting, shortage of available vein grafts, and preconceptions regarding the safety and efficacy of BIMA grafting. The quality of grafting was assessed with a transit time flow probe (Medistim Butterfly Flow Meter, Oslo, Norway) before neutralization of heparin by protamine.

Statistical analysis: Perioperative data were obtained from our institutional database and reviewed using a standard data collection form. Patients were regularly followed up at 1 and 6 months following surgery. Follow-up data were obtained via a clinic visit, WeChat, or telephone. Data collection was performed by trained staff (two people). The trained staff, however, were not informed of the purpose of this study.

Normally distributed continuous variables were ex-
comes were evaluated using conditional logistic regression (BIMA grafting versus skeletonized SIMA grafting) on early outcome, standardized differences of the means were calculated. To assess the balance between the groups after matching, a PS was generated for each patient from a multivariable logistic regression model with treatment type (skeletonized BIMA grafting versus skeletonized SIMA grafting) as a binary dependent variable and 17 baseline characteristics (as listed in Table I) as independent variables. As measured potential confounders in the data set, a PS was generated for each patient from a multivariable logistic regression model with treatment type (skeletonized BIMA grafting versus skeletonized SIMA grafting) and 17 baseline characteristics (as listed in Table I) as independent variables. For the purpose of matching, 258 patients were obtained using the greedy matching algorithm to implement nearest-neighbor 1:1, with a caliper width of 0.2 of standard deviation of the logit of the PS. To assess the balance between the groups after matching, standardized differences of the means were calculated. The impacts of treatment type (skeletonized BIMA grafting versus skeletonized SIMA grafting) on early outcomes were evaluated using conditional logistic regression analysis. A two-sided P-value less than 0.05 was considered statistically significant. Statistical analysis was performed with SPSS statistical package version 22.0 (SPSS Inc., Chicago, IL, USA).

Results

Study population: A total of 2429 consecutive Chinese patients who underwent isolated CABG surgery in our center from January 2014 to December 2017 (accounting for 80.3% of all CABG patients over the same timespan) met the inclusion criteria. Twenty-six patients were excluded due to prior CABG surgery (four patients), prior open-heart surgery (16 patients), and prior chest radiotherapy (six patients), which left 2403 eligible patients for data analysis. According to treatment type, 368 patients were included in the BIMA group, and the remaining 2035 patients were entered into the SIMA group.

Baseline characteristics are shown in Table I. Patients in the BIMA group as compared with the SIMA group were younger (60.5 ± 5.4 years versus 64.6 ± 6.2 years, P < 0.0001) and were more likely to present with hyperlipidemia (29.9% versus 22.2%, P = 0.001). Compared with the SIMA group, the BIMA group had a lower proportion of female (7.1% versus 11.1%, P = 0.020). Additionally, the BIMA group, compared with the SIMA group, had a significantly higher left ventricular ejection fraction (0.53 ± 0.11 versus 0.51 ± 0.13, P = 0.005). No significant difference between groups was found regarding the propor-

Table I. Baseline Characteristics

| Variables | Unmatched population | Matched population |
|-----------|----------------------|--------------------|
|           | BIMA group (n = 368) | SIMA group (n = 2035) | P | BIMA group (n = 258) | SIMA group (n = 258) | P |
| Demographics | | | | | | |
| Age (years) | 60.5 ± 5.4 | 64.6 ± 6.2 | < 0.001 | 61.8 ± 4.5 | 62.1 ± 4.8 | 0.464 |
| Gender (female) | 26 (7.1%) | 226 (11.1%) | 0.020 | 22 (8.5%) | 24 (9.3%) | 0.883 |
| Obesity | 44 (12.0%) | 307 (15.1%) | 0.118 | 36 (13.9%) | 38 (14.3%) | 0.908 |
| Smoking history | 158 (42.9%) | 828 (40.7%) | 0.420 | 108 (41.9%) | 107 (41.5%) | 0.929 |
| Concomitant diseases | | | | | | |
| Hypertension | 191 (51.9%) | 1079 (53.0%) | 0.692 | 135 (52.3%) | 136 (52.7%) | 0.930 |
| Diabetes mellitus | 151 (41.0%) | 830 (40.8%) | 0.929 | 105 (40.7%) | 107 (41.5%) | 0.858 |
| Diet | 24 (15.9%) | 119 (14.3%) | 18 (17.1%) | 16 (15.0%) |
| Orally treated | 120 (79.5%) | 635 (76.5%) | 0.179 | 81 (77.1%) | 82 (76.6%) | 0.703 |
| Insulin | 7 (4.6%) | 76 (9.2%) | 6 (5.8%) | 9 (8.4%) |
| Hyperlipidemia | 110 (29.9%) | 452 (22.2%) | 0.001 | 74 (28.7%) | 72 (27.9%) | 0.934 |
| COPD | 30 (8.2%) | 236 (11.6%) | 0.053 | 23 (8.9%) | 24 (9.3%) | 0.978 |
| Prior CVA | 27 (7.3%) | 181 (8.9%) | 0.328 | 21 (8.1%) | 22 (8.5%) | 0.973 |
| Renal dysfunction | 63 (17.1%) | 301 (14.8%) | 0.252 | 42 (16.3%) | 40 (15.5%) | 0.912 |
| Preoperative cardiac status | | | | | | |
| Previous PCI | 97 (26.4%) | 578 (28.4%) | 0.422 | 70 (27.1%) | 71 (27.5%) | 0.921 |
| Recent MI | 121 (32.9%) | 580 (28.5%) | 0.089 | 81 (31.4%) | 79 (30.6%) | 0.937 |
| Chronic AF | 9 (2.4%) | 37 (1.8%) | 0.419 | 6 (2.3%) | 5 (1.9%) | 1.000 |
| NYHA III-IV | 39 (10.6%) | 288 (14.2%) | 0.065 | 30 (11.6%) | 33 (12.8%) | 0.674 |
| LVEF | 0.53 ± 0.11 | 0.51 ± 0.13 | 0.005 | 0.52 ± 0.08 | 0.52 ± 0.07 | 1.000 |
| Extent of CAD | | | | | | |
| 2-vessel | 43 (11.7%) | 202 (9.9%) | 0.305 | 27 (10.5%) | 26 (10.1%) | 0.885 |
| 3-vessel | 325 (88.3%) | 1833 (90.1%) | 0.603 | 231 (89.5%) | 232 (89.9%) |
| LM | 105 (28.5%) | 608 (29.9%) | | 74 (28.7%) | 76 (29.4%) | 0.846 |

Values are expressed as mean ± SD or n (percent). BIMA indicates bilateral internal mammary artery; SIMA, single internal mammary artery; BMI, body mass index; COPD, chronic obstructive pulmonary disease; CVA, cerebro-vascular accident; PCI, percutaneous coronary intervention; MI, myocardial infarction; AF, atrial fibrillation; NYHA, New York heart association; LVEF, left ventricular ejection fraction; LVD, left ventricular dysfunction; CAD, coronary artery disease; and LM, left main trunk disease. Obesity defined body mass index of more than 30 kg/m²; Renal dysfunction, a serum creatinine level of 2.0 mg/dL or more or the use of renal replacement therapy; and Recent MI, evidence of myocardial infarction within the last 30 days before surgery.
Incidence of DSWI: Six out of 368 patients developed DSWI following skeletonized BIMA harvest, and the incidence of DSWI in group BIMA was 1.6%. The BIMA group, compared with the SIMA group, had a slightly higher incidence of DSWI, but no significant difference was found (1.6% versus 0.9%, \( P = 0.247 \)).

In the overall cohort, 151 patients in the BIMA group (41.0%) and 830 patients in the SIMA group (40.8%) suffered from diabetes mellitus (\( P = 0.929 \)). The incidence of DSWI in subgroup diabetic-BIMA, subgroup nondiabetic-BIMA, subgroup diabetic-SIMA, and subgroup nondiabetic-SIMA were 2.0% (3/151), 1.4% (3/217), 1.0% (9/830), and 0.7% (9/1205), respectively. As shown in the Figure, no significant differences between the four subgroups were found regarding the incidence of DSWI (\( P > 0.05 \) between subgroups).

Patients who developed postoperative DSWI were treated with wound irrigation and debridement and vacuum-assisted wound closure therapy as well as antibiotics. Among 24 patients with postoperative DSWI, only one patient with concomitant diabetes in the SIMA group died of severe sepsis, and the remaining 23 patients discharged from the hospital with wound healing.

**Propensity score-matched cohort:** Bivariate analyses were conducted to examine differences in baseline characteristics between patients in the BIMA group (\( n = 368 \)) and those in the SIMA group (\( n = 2035 \)). PSs were then calculated using a multivariate logistic regression model based on predefined 17 variables. The Hosmer-Lemeshow goodness for the model was 4.79 (\( P = 0.775 \)). Also, the model achieved good discrimination power with the receiver operating curve resulting in the area under the curve of 0.74 (95% CI, 0.65-0.81, \( P = 0.020 \)). Finally, 258 pairs out of 2403 included patients were successfully matched.
established in a 1:1 manner. The absolute standardized differences of all 17 baseline characteristics after matching were <10%, indicating an adequate balance.

The two matched groups were comparable for baseline variables (as shown in Table I). Patients in the two matched groups had a comparable proportion of off-pump/on-pump CABG and received a similar number of grafts (Table II).

Clinical outcomes of the matched population: Despite more drainage during the first 24 hours (567 ± 115 mL versus 463 ± 98 mL, P < 0.001), patients in the matched BIMA group received a similar ratio of red blood cell transfusion and a similar incidence of redo for bleeding with those in the matched SIMA group (10.5% versus 9.3%, P = 0.658, and 1.6% versus 1.2%, P = 1.000, respectively). As shown in Table III, no significant differences were found between the two matched groups regarding surgical mortality and major postoperative morbidity (including the incidence of DSWI).

The impacts of treatment type (the matched BIMA group versus the matched SIMA group) on surgical mortality and major postoperative morbidity via conditional logistic regression analysis are shown in Table IV. As a result, treatment type was not an independent risk factor for postoperative DSWI (OR = 1.309, 95% CI 0.897-2.714, P = 0.704). Additionally, treatment type was not an independent risk factor for surgical mortality or another major postoperative morbidity.

After discharge, no death or repeat revascularization occurred during the 6-month follow-up.

Clinical outcomes of the matched population between diabetics and non-diabetics: In the matched population, 105 patients in the BIMA group (40.7%) and 107 patients in the SIMA group (41.5%) suffered from diabetes mellitus (P = 0.858). There was no significant difference between the two matched groups in terms of the incidence of DSWI, regardless of whether or not the merger with diabetes (2.9% for diabetic-BIMA, 0.7% for nondiabetic-BIMA, 1.9% for diabetic-SIMA, and 0.7% for nondiabetic-SIMA, P = 0.337). As shown in Table V, the two matched groups shared similar surgical mortality and another major postoperative morbidity, regardless of whether or not the merger with diabetes (all P > 0.05).

Discussion

This single-center study reviewed 2403 consecutive Chinese patients undergoing isolated CABG procedures with skeletonized BIMA grafting or skeletonized SIMA grafting and found that (1) skeletonized BIMA harvest as compared with skeletonized SIMA harvest was not associated with an increased risk of DSWI, regardless of whether or not the merger with diabetes and (2) patients with skeletonized BIMA grafting received similar surgical mortality and major postoperative morbidity as did matched patients with skeletonized SIMA grafting, whether or not the patient had diabetes.

The major finding of this study was that compared with skeletonized SIMA harvest, skeletonized BIMA harvest was not associated with an increased risk of DSWI.
regardless of whether or not the merger with diabetes. In this cohort of 2403 consecutive isolated CABG patients, no significant differences were found regarding the incidence of DSWI between the BIMA group and the SIMA group and between four subgroups (subgroup diabetic-BIMA, subgroup nondiabetic-BIMA, subgroup diabetic-SIMA, and subgroup nondiabetic-SIMA), respectively. After PS matching (1:1), the matched BIMA group and matched SIMA group received a similar incidence of DSWI; furthermore, this result was confirmed by logistic regression analysis. Additionally, this study showed that there was no significant difference between the two matched groups in terms of the incidence of DSWI, regardless of whether or not the merger with diabetes. Therefore, this study suggested that skeletonized BIMA harvest received a similar risk of postoperative DSWI as did skeletonized SIMA harvest, regardless of whether or not the merger with diabetes. In the Arterial Revascularization Trial (ART), the only randomized trial, Taggart et al. have reported a marked increase in sternal wound complications in the BIMA group compared with the SIMA group. However, a post hoc analysis of the ART trial data at 1 year found that more careful dissection of the IMA (the “skeletonized” technique) was associated with a lower risk of sternal wound complications regardless of whether single or bilateral IMA grafts were used. DeSimone et al. conducted a multicenter, retrospective analysis of 47984 consecutive CABG surgeries (1482 BIMA patients and 46502 SIMA patients) performed from 1992 to 2014 among seven medical centers, and results showed that BIMA patients and SIMA patients received a similar incidence of sternal wound complications, regardless of whether patients were complicated with diabetes mellitus or not. In the same cohort, still no significant difference was found in the incidence of sternal wound complications between the two groups after PS matching (1:3). These results were in line with the results of this study. By contrast, in a meta-analysis of 29 observational studies with a total of 89399 patients, Buttar et al. reported that the incidence of DSWI was increased in BIMA cohort compared with LIMA cohort. This evidence differed from the results of this study. The reason for this difference may be the technique of IMA harvest, regarding that patients in less than one-fourth of studies in that meta-analysis underwent skeletonized IMA harvest, whereas all included patients in this study underwent skeletonized IMA harvest. So this study stressed once again the importance of the technique of skeletonized IMA harvest, especially for BIMA grafting.

This study reported a relatively low incidence of DSWI following skeletonized BIMA harvest. Previous observational studies have reported that the incidence of DSWI following BIMA harvest ranged from 0.6% to 4.2%. Recently, a meta-analysis has reported that the incidence of DSWI after BIMA grafting ranged widely from 0.3% to as high as 14%. In the ART, the rate of sternal wound infection was 3.5% for BIMA harvest. For diabetic cohorts, the incidence of DSWI following BIMA grafting has been reported to be 1.7%–5.2%. This study reported that the incidence of DSWI following skeletonized BIMA harvest was 1.6% for the overall cohort and 2.0% for diabetic cohort. The results of this study were better than the results of the majority of previous reports.

| Outcomes/subgroup          | Matched BIMA group NOP | Matched BIMA group Freq | Matched SIMA group NOP | Matched SIMA group Freq | P     |
|----------------------------|------------------------|-------------------------|------------------------|-------------------------|-------|
| DSWI                       |                        |                         |                        |                         |       |
| Diabetics                  | 105                    | 3 (2.9%)                | 107                    | 2 (1.9%)                | 0.337 |
| Non-diabetics              | 153                    | 1 (0.7%)                | 151                    | 1 (0.7%)                |       |
| Superficial wound infection|                        |                         |                        |                         |       |
| Diabetics                  | 105                    | 6 (5.7%)                | 107                    | 5 (4.7%)                | 0.574 |
| Non-diabetics              | 153                    | 4 (2.6%)                | 151                    | 5 (3.3%)                |       |
| MI associated with CABG    |                        |                         |                        |                         |       |
| Diabetics                  | 105                    | 3 (2.9%)                | 107                    | 4 (3.7%)                | 0.479 |
| Non-diabetics              | 153                    | 2 (1.3%)                | 151                    | 2 (1.3%)                |       |
| RBC transfusion            |                        |                         |                        |                         |       |
| Diabetics                  | 105                    | 12 (11.4%)              | 107                    | 10 (9.3%)               | 0.944 |
| Non-diabetics              | 153                    | 15 (9.8%)               | 151                    | 14 (9.3%)               |       |
| Redo for bleeding          |                        |                         |                        |                         |       |
| Diabetics                  | 105                    | 2 (1.9%)                | 107                    | 2 (1.9%)                | 0.837 |
| Non-diabetics              | 153                    | 2 (1.3%)                | 151                    | 1 (0.7%)                |       |
| Stroke                     |                        |                         |                        |                         |       |
| Diabetics                  | 105                    | 1 (1.0%)                | 107                    | 2 (1.9%)                | 0.901 |
| Non-diabetics              | 153                    | 1 (0.7%)                | 151                    | 2 (1.3%)                |       |
| Prolonged ventilation      |                        |                         |                        |                         |       |
| Diabetics                  | 105                    | 7 (6.7%)                | 107                    | 5 (4.7%)                | 0.399 |
| Non-diabetics              | 153                    | 5 (3.3%)                | 151                    | 4 (2.6%)                |       |
| Surgical mortality         |                        |                         |                        |                         |       |
| Diabetics                  | 105                    | 1 (1.0%)                | 107                    | 1 (0.9%)                | 0.934 |
| Non-diabetics              | 153                    | 1 (0.7%)                | 151                    | 2 (1.3%)                |       |

NOP indicates number of patients; Freq, frequency.
Another important finding of this study was that patients with skeletonized BIMA grafting received similar surgical mortality and major postoperative morbidity as did matched patients with skeletonized SIMA grafting. Under conditions of comparable baseline variables and similar number of grafts after PS matching, the matched BIMA group received similar surgical mortality and major postoperative morbidity as did the matched SIMA group, regardless of whether or not the merger with diabetes. Furthermore, treatment type (skeletonized BIMA grafting versus skeletonized SIMA grafting) was not an independent risk factor for postoperative DSWI or predictors of surgical mortality or another major postoperative morbidity via logistic regression. This result agreed with the results of the overwhelming majority of previous studies.5

Results from this study showed that compared with skeletonized SIMA harvest, skeletonized BIMA harvest did not increase the risk of sternal wound complications regardless of whether or not the merger with diabetes and compared with skeletonized SIMA grafting, skeletonized BIMA grafting did not increase the risks of surgical mortality or major postoperative morbidity. This study serves as additional confirmation and a reminder that the time is right to change our old habits and to adopt a skeletonized approach as the standard technique for IMA harvesting. As with the development of any new skill set, the technique does involve a learning curve but the time would be well invested. Ultimately, the goal is to extend skeletonized BIMA grafting to the considerable proportion of CABG cases at risk for sternal wound complications, which will lead to substantial clinical benefit for our patients.

This study had some potential limitations. First, although using PS matching, this study was only a single-center, observational study, which may influence the generalizability. The unobserved confounds and selection biases among the two groups cannot be eliminated. A final determination would need a multicenter study involving a large sample size. Second, this study showed that adverse event rates were very low in either group and also showed that no significant differences were found between the two approaches regarding surgical mortality and major postoperative morbidity, which may be related to a small sample size. Finally, all included subjects were Chinese patients undergoing surgical revascularization with skeletonized bilateral or single IMA harvest, which limited the generalizability of the findings. Chinese patients generally have lower body mass index scores than Europeans or North Americans, which may have influenced the incidence of major postoperative morbidities, especially postoperative sternal wound complications.

Conclusion

In this single-center cohort of 2403 consecutive Chinese patients undergoing isolated CABG surgeries, the incidence of DSWI following skeletonized BIMA harvest was relatively low (1.6% for the overall cohort and 2.0% for diabetic cohort). Skeletonized BIMA harvest as compared with skeletonized SIMA harvest was not associated with an increased risk of DSWI, regardless of whether or not the merger with diabetes. Additionally, patients with skeletonized BIMA grafting received similar surgical mortality and major postoperative morbidity as did matched patients with skeletonized SIMA grafting.

Disclosure

Conflicts of interest: The authors declare no conflicts of interest.

References

1. Tabata M, Grab JD, Khalpey Z, et al. Prevalence and variability of internal mammary artery graft use in contemporary multivessel coronary artery bypass graft surgery: analysis of the Society of Thoracic Surgeons National Cardiac Database. Circulation 2009; 120: 935-40.
2. Umakanthan J, Jeyakumar P, Umakanthan B, et al. Barriers to the universal adoption of bilateral internal mammary artery grafting. Int J Surg 2015; 16: 179-82.
3. Salehi Omran A, Karimi A, Ahmadi SH, et al. Superficial and deep sternal wound infection after more than 9000 coronary artery bypass graft (CABG): incidence, risk factors and mortality. BMC Infect Dis 2007; 7: 112.
4. Galbut DL, Kurlansky PA, Traad EA, et al. Bilateral internal thoracic artery grafting improves long-term survival in patients with reduced ejection fraction: a propensity-matched study with 30-year follow-up. J Thorac Cardiovasc Surg 2012; 143: 844-53.
5. Davierwala PM, Mohr FW. Bilateral internal mammary artery grafting: rationale and evidence. Int J Surg 2015; 16: 133-9.
6. Sajia LR. Strategies to reduce deep sternal wound infection after bilateral internal mammary artery grafting. Int J Surg 2015; 16: 171-8.
7. Peterson MD, Borger MA, Rao V, Penistion 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.
8. Behranwala AA, Raja SG, Dunning J. Is skeletonised internal mammary harvest better than pedicled internal mammary harvest for patients undergoing coronary artery bypass grafting? Interact Cardiovasc Thorac Surg 2005; 4: 577-82.
9. ElBardissi AW, Aranki SF, Sheng S, O’Brien SM, Greenberg CC, Gammie JS. Trends in isolated coronary artery bypass grafting: an analysis of the Society of Thoracic Surgeons adult cardiac surgery database. J Thorac Cardiovasc Surg 2012; 143: 273-81.
10. Mohr FW, Rastan AJ, Serruys PW, et al. Complex coronary anatomy in coronary artery bypass graft surgery: impact of complex coronary anatomy in modern bypass surgery? Lessons learned from the SYNTAX trial after two years. J Thorac Cardiovasc Surg 2011; 141: 130-40.
11. Yan BP, Clark DJ, Buxton B, et al. Clinical characteristics and early mortality of patients undergoing coronary artery bypass grafting compared to percutaneous coronary intervention: insights from the Australasian Society of Cardiac and Thoracic Surgeons (ASCTS) and the Melbourne Interventional Group (MIG) Registries. Heart Lung Circ 2009; 18: 184-90.
12. Rosenthal VA, Maki DG, Mehta Y, et al. International Nosocomial Infection Control Consortium (INICC) report, data summary of 43 countries for 2007-2012. Device-associated module. Am J Infect Control 2014; 42: 942-56.
13. Naito R, Miyauchi K. Coronary Artery Disease and Type 2 Diabetes Mellitus. Int Heart J 2017; 58: 475-80.
14. Ji Q, Lai H, Sun Y, et al. Impact of presurgical mild acute respiratory distress syndrome on surgical mortality after surgical re-
pair of acute type A aortic dissection. Int Heart J 2017; 58: 739-45.
15. Lin TC, Lu TM, Huang FC, et al. Coronary Artery Bypass Surgery versus Percutaneous Coronary Intervention for Left Main Coronary Artery Disease with Chronic Kidney Disease. Int Heart J 2018; 59: 279-85.
16. Swenne CL, Lindholm C, Borowiec J, Carlson M. Surgical-site infections within 60 days of coronary artery by-pass graft surgery. J Hosp Infect 2004; 57: 14-24.
17. Xia L, Ji Q, Song K, et al. Early clinical outcomes of on-pump beating-heart versus off-pump technique for surgical revascularization in patients with severe left ventricular dysfunction: the experience of a single center. J Cardiothorac Surg 2017; 12: 11.
18. Taggart DP, Altman DG, Gray AM, et al. Randomized trial of bilateral versus single internal-thoracic-artery grafts. N Engl J Med 2016; 375: 2540-9.
19. Benedetto U, Altman DG, Gerry S, et al. Pedicled and skeletonized single and bilateral internal thoracic artery grafts and the incidence of sternal wound complications: insights from the arterial revascularization trial. J Thorac Cardiovasc Surg 2016; 152: 270-6.
20. DeSimone JP, Malenka DJ, Weldner PW, et al. Coronary revascularization with single versus bilateral mammary arteries: is it time to change? Ann Thorac Surg 2018; 106: 466-72.
21. Iribarne A, Schmoker JD, Malenka DI, et al. Does use of bilateral internal mammary artery grafting reduce long-term risk of repeat coronary revascularization? A multicenter analysis. Circulation 2017; 136: 1676-85.
22. Buttar SN, Yan TD, Taggart DP, Tian DH. Long-term and short-term outcomes of using bilateral internal mammary artery grafting versus left internal mammary artery grafting: a meta-analysis. Heart 2017; 103: 1419-26.
23. Sajja LR, Mannam G, Dandu SB, Sompalli S. Reduction of sternal wound infections in diabetic patients undergoing off-pump coronary artery bypass surgery and using modified pedicle bilateral internal thoracic artery harvest technique. J Thorac Cardiovasc Surg 2012; 144: 480-5.
24. De Paulis R, de Notaris S, Scaffa R, et al. The effect of bilateral internal thoracic artery harvesting on superficial and deep sternal infection: The role of skeletonization. J Thorac Cardiovasc Surg 2005; 129: 536-43.
25. Weiss AJ, Zhao S, Tian DH, Taggart DP, Yan TD. A meta-analysis comparing bilateral internal mammary artery with left internal mammary artery for coronary artery bypass grafting. Ann Cardiothorac Surg 2013; 2: 390-400.
26. 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.
27. Kieser TM, Rose MS, Aluthman U, Montgomery M, Louie T, Belenkie I. Toward zero: deep sternal wound infection after 1001 consecutive coronary artery bypass procedures using arterial grafts: implications for diabetic patients. J Thorac Cardiovasc Surg 2014; 148: 1887-95.