Sternal Closure with Rigid Plate Fixation for Isolated Coronary Artery Bypass Grafting: Can Sternal Plating Increase the Feasibility of Bilateral Internal Thoracic Artery Usage in High-Risk Patients?

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Abstract

Objectives Long-term survival after coronary artery bypass grafting (CABG) appears superior with bilateral internal thoracic artery (BITA) grafting over grafting a single internal thoracic artery. BITA grafting is recommended in CABG without excessive risk of infection. However, there is concern about an increased risk of sternal wound infection when BITAs are harvested. A recent report demonstrated that sternal closure with rigid plate fixation provided better sternal healing and fewer complications. Thus, a retrospective study was performed to investigate whether BITA grafting can be safely performed in CABG with rigid plate fixation for patients at high risk of sternal wound infection. **Methods** From June 2017 to December 2018, a total of 31 patients who were deemed preoperatively to be at high risk of sternal wound infection underwent isolated CABG $\pm$ pulmonary vein isolation. BITAs were skeletonized, and the chest was closed with rigid plate fixation in all cases. The surgical results were retrospectively reviewed, and the incidence of sternal wound complications was evaluated. **Results** Each patient had at least 2 risk factors, and the average number of risk factors per patient was 3.1. A total of 14 patients (45%) had obesity, with mean BMI of 31 ± 8.1 kg/m², and 27 patients (86%) had diabetes mellitus, with mean HbA1c of $7.6 \pm 1.5\%$. There was one patient with superficial sternal wound infection (3%) and one with wound dehiscence (3%); they were medically treated at the outpatient clinic without readmission. There was no incidence of deep sternal wound infection. **Conclusions** BITA grafting could be performed in high-risk patients without increasing sternal wound complications. Rigid sternal plating fixation may increase the feasibility of BITA grafting in high-risk patients.

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Short title: Sternal Plating for BITA

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Jota Nakano: Data curation; Formal analysis; Investigation; Methodology; Resources; Software; Visualization; Writing—original draft; Writing—review & editing.

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Abstract

Objectives

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Methods

From June 2017 to December 2018, a total of 31 patients who were deemed preoperatively to be at high risk of sternal wound infection underwent isolated CABG $\pm$ pulmonary vein isolation. BITAs were skeletonized, and the chest was closed with rigid plate fixation in all cases. The surgical results were retrospectively reviewed, and the incidence of sternal wound complications was evaluated.

Results

Each patient had at least 2 risk factors, and the average number of risk factors per patient was 3.1. A total of 14 patients (45%) had obesity, with mean BMI of 31 ± 8.1 kg/m², and 27 patients (86%) had diabetes mellitus, with mean HbA1c of $7.6 \pm 1.5\%$. There was one patient with superficial sternal wound infection (3%) and one with wound dehiscence (3%); they were medically treated at the outpatient clinic without readmission. There was no incidence of deep sternal wound infection.

Conclusions

BITA grafting could be performed in high-risk patients without increasing sternal wound complications. Rigid sternal plating fixation may increase the feasibility of BITA grafting in high-risk patients.

Keywords: Coronary artery bypass grafting, Sternal wound infection, Bilateral internal thoracic arteries, Rigid plate fixation

Abbreviations

CABG Coronary artery bypass grafting
 BITA Bilateral internal thoracic artery
 DM Diabetes mellitus
 COPD Chronic obstructive pulmonary disease
 DSWI Deep sternal wound infection
 BMI Body mass index
 GEA Gastroepiploic artery
 CT Computed tomography
 RCT Randomized, controlled trial

Introduction

Long-term survival after coronary artery bypass grafting (CABG) appears superior with bilateral internal thoracic artery (BITA) grafting over grafting a single internal thoracic artery [1, 2]. The Society of Thoracic Surgeons Guidelines recommend use of BITAs in selected patients [3]. However, there is concern about an increased risk of sternal infection when BITAs are harvested. In fact, only 5% of patients undergoing CABG did so with BITAs in the United States during the last 2 decades [4]. Many surgeons hesitate to use BITAs especially for patients with diabetes mellitus (DM), chronic obstructive pulmonary disease (COPD), end-stage renal disease, obesity, smoking history, previous sternotomy, hypoalbuminemia, congestive heart failure, peripheral vascular disease, or chronic steroid use. Female sex is also known as a risk factor for wound complications after CABG [5, 6].

Wire cerclage remains the primary method of sternotomy closure for most cardiac surgeons because of its low cost. Rigid plate fixation has also been used to close median sternotomies to achieve better healing and reduce wound complications [7–9]. The objective of this study was to determine whether BITAs can be harvested without increasing deep sternal wound infections (DSWIs) when rigid plate fixation is used for median sternal closure.

Patients and Methods

Patients

Data for this project were obtained from the Bluhm Cardiovascular Institute’s Clinical Trial Units Cardiovascular Research Database, approved by the Institutional Review Board at Northwestern University (project # STU00012288). Informed consent was waived by the study participants.

A total of 31 patients underwent CABG with BITA grafts and rigid plate fixation (SternaLock Blu and 360 Primary Closure System, Zimmer Biomet, Warsaw IN) at the time of sternal closure at Northwestern Memorial Hospital between June 2017 and December 2018. All patients were deemed to be at high risk for DSWI based on their preoperative characteristics (Table 1). The risk factors for DSWI include female sex, obesity (body mass index (BMI) ≥ 30 kg/m²), DM, chronic kidney disease, COPD, history of tobacco use, previous sternotomy, chronic steroid or immunosuppressant use, hypoalbuminemia (albumin < 3.0 mg/dL), congestive heart failure, and peripheral vascular disease. The patients had 2 or more risk factors. All the other CABG patients with ≥ 1 risk factor underwent sternal closure with wire cerclage (n=57) during the same time period.

Operative Technique

Hair around the surgical site was removed with clippers just before the incision. The surgical site was scrubbed with a chlorhexidine solution. An antimicrobial drape (Ioban; 3M, Brookings, SD) was applied to the surgical site. A median sternotomy approach was used in all cases. BITAs were harvested in skeletonized fashion using an ultrasonic scalpel (Harmonic Synergy Blades, Johnson & Johnson, New Brunswick, NJ).

BITAs were used to revascularize left coronary artery territories. Additional grafts including saphenous vein grafts, right gastroepiploic arteries (GEAs), and radial arteries were harvested to achieve complete revascularization. All anastomoses were performed under cardiopulmonary bypass. The ascending aorta was cross-clamped after an epiaortic echocardiogram scan to rule out atheroma and/or calcification of the aortic wall. Cardiac arrest was achieved with antegrade and retrograde delivery of cold-blood cardioplegia. After the patient was weaned from cardiopulmonary bypass and hemostasis was obtained, the sternum was closed with 3 stainless steel wires. The mediastinum and sternum were washed with warm saline. A total of 3 rigid plates (SternaLock Blu or 360) were applied to the sternum according to the company's instructions. The presternal space was closed with two layers of nonabsorbable monofilament single sutures, followed by a continuous absorbable skin suture.

Perioperative Management

Cephalosporin and vancomycin were routinely administered from just before the incision until 48 hours after the surgery. The doses were repeated every 4 hours intraoperatively. They were administered twice daily postoperatively. Blood glucose was measured and controlled with an insulin infusion to maintain blood glucose below 150 mg/dL during and after the surgery.

Wound Management

Each sternal wound was checked daily during hospitalization. The patients were followed in the outpatient clinic 2 weeks after discharge up to at least 6 months after the index surgery. Wound infections were categorized into three types: impaired wound healing, superficial wound infections, and deep wound infections. Impaired wound healing was defined as wound erythema and a discharge necessitating additional antibiotic agents. Diagnoses of superficial and deep infections were based on the wound swab culture results. All wound infections were defined on the basis of the guidelines of the US Centers for Disease Control.

Statistical Analysis

Statistical analyses were performed using SAS version 9.2 (SAS Institute, Inc., Cary, NC). Continuous variables are reported as means $\pm$ 1 SD. Categorical variables are reported as counts and percentages.

Results

A total of 31 patients underwent CABG with BITAs, and the sternum was closed with rigid plate fixation. The patients' mean age was 62 $\pm$ 7 years, of whom 9 (29%) were female. BMI was 31 $\pm$ 8.1 kg/m², and the BMIs of 14 patients (45%) were $\geq$ 30 kg/m² (Table 1). Twenty-nine patients (92%) had diabetes mellitus, and 16 (51% of all) were insulin-dependent. Mean HbA1c was 7.6 $\pm$ 1.5%, and diabetes was poorly controlled preoperatively in 20 patients (HbA1c $>$ 7.0%). Table 2 shows the risk factors associated with sternal wound infection. Thirteen patients (42%) had stage 3 or greater renal dysfunction, of whom 6 (19%) were on chronic hemodialysis. Whereas 4 patients were diagnosed with COPD based on pulmonary function tests, 23 (74%) had a history of tobacco use. Of note, not all patients underwent preoperative pulmonary function tests. Three patients were taking steroid drugs or immunosuppressants. Peripheral vascular disease was diagnosed in 5 patients. All patients had two or more risk factors listed in Table 2. The mean number of risk factors was 3.3 $\pm$ 1.0.

Two patients on intra-aortic balloon pumps underwent urgent CABG, whereas the remainder underwent elective CABG. One patient underwent concomitant pulmonary vein isolation for paroxysmal atrial fibrillation. The mean number of coronary anastomoses was 4.1 $\pm$ 0.8. BITA grafts were used in all cases. Other grafts were saphenous vein grafts in 18 (58%), radial artery grafts in 6 (19%), and GEA grafts in 15 (48%). Aortic cross-clamp time and cardiopulmonary bypass time were 104 $\pm$ 32 and 117 $\pm$ 36 minutes, respectively. Time from cardiopulmonary bypass termination and skin closure including rigid plate placement was 105 $\pm$ 25 minutes.

Early postoperative outcomes are shown in Table 3. There was no mortality. One patient (3%) developed acute kidney injury. Another patient had pneumonia. Intubation time was 9.1 $\pm$ 8.1 hours. No patient

required mechanical ventilation for more than 48 hours postoperatively, or re-intubation. The morphine equivalent dose of total opioid use was 74 $\pm$ 55 mg [10]. There was no superficial or deep sternal wound infection observed during the index admission.

All patients were seen and followed up in our outpatient clinic, up to at least 6 months postoperatively. Two patients (6%) developed sternal wound complications: one was a superficial sternal wound infection (3%), and the other was wound dehiscence without infection (3%). The former patient was a 61-year-old man with a history of non-ST elevation myocardial infarction, congestive heart failure, type 2 DM on insulin injections, and previous tobacco use. He was also obese, with a body mass index of 31 kg/m². He underwent quadruple CABG with BIMA, GEA, and radial artery grafts. The patient presented to the clinic after discharge to home with a dehiscence sternal wound with purulent discharge. The culture of the fluid was positive for *Staphylococcus epidermidis*. A computed tomography (CT) scan showed no evidence of osteomyelitis of the sternum. The wound healed with a vacuum-assisted closure system and oral antibiotics without admission to the hospital. The latter patient was a 68-year-old woman with a history of peripheral vascular disease, type 2 DM on oral medication, previous tobacco use, and systemic lupus erythematosus on chronic steroids. She underwent quadruple CABG and was discharged to an inpatient rehabilitation facility. The patient came back to the clinic with a dehiscence wound. Wound culture from the laboratory came back negative. A CT scan was performed, and there was no sign of sternal instability or infection. This wound was treated conservatively and healed without readmission.

Discussion

In this study, no DSWI was observed in patients at high risk for sternal wound complications who underwent CABG with BITA grafting and sternal plating. Although one patient developed a superficial sternal wound infection (3%), this rate is comparable with that reported in previous studies on sternal complications after CABG in the general population, which is 1.3% to 2.8% [11]. There have been two randomized controlled trials (RCTs) that compared rigid plate fixation and wire cerclage [7–9]. Both studies demonstrated better sternal healing when plates were applied compared to when wire cerclage was used, as evaluated by CT scan. When the sternum is stable and shows better healing, there is a lower chance that a seroma or hematoma may occur around it [12]. Even when the superficial wound develops delayed healing, which can be an entry point for bacterial infection, the infection may not spread into the mediastinum given the stable sternum and lack of seroma or hematoma.

BITA Usage

Although many studies have shown the long-term benefit of BITA over SITA use, only 5% of patients in the United States underwent CABG with BITA grafting over the last 2 decades, possibly owing to the risk of sternal wound complications, the longer time required, and the complexity of the surgery [4, 5]. Diabetic patients with complex coronary artery disease are more likely to benefit from CABG than percutaneous interventions [13]. BITA grafting can even enhance the benefits of CABG in this cohort of patients [14], which may be further increased by use of rigid plate fixation. During the study period, 57 patients underwent CABG in addition to the 31 study patients. None developed DSWI. Of the total 88 patients, BITA grafting was performed in 37 patients (42%) with [?]1 risk factor, whereas the 31 study patients (35%) with [?]2 risk factors underwent BITA grafting with rigid plate fixation. Thus, we were able to expand BITA usage from 42% to 77% of the CABG patients with the introduction of rigid plate fixation.

Effects on Pain, Opioid Usage, and Respiration

The two aforementioned RCTs demonstrated less postoperative pain, possibly from stability of the sternum fixed with rigid plating [8, 9]. Raman and colleagues reported less opioid usage (approximately 25%) with rigid plate fixation compared to wire cerclage, although this was not statistically significant [9]. This finding shed light on another post-cardiotomy issue—persistent opioid use [15]. Less postoperative pain can also lead to reduction in ventilation time and pulmonary complications [16]. Future studies should focus on these additional effects of rigid plate fixation.

Health Economics

Allen et al. evaluated the cost of rigid plate fixation versus wire cerclage in their RCT, and they suggested that the initial higher cost of rigid plate fixation could be offset by reduction in the total length of stay of both the index surgery hospitalization and the hospitalization for rehabilitation, and the lower sternal complication rates thereafter [8]. Given that readmissions related to DSWI are not reimbursed in the United States, from an economic perspective, rigid plate fixation may be a better option for patients at high risk for sternal wound complications, although this might not be true for all patients.

Limitations

First, this study is limited by its retrospective, observational nature. There was no control group for comparison, and the number of the study patients was limited. The patients in this study were assigned to sternal closure with rigid plate fixation based solely on their preoperative baseline characteristics, without exceptions. Of note, none of the CABG patients undergoing wire cerclage during the same time period developed DSWIs. Secondly, other factors such as BITA harvest methods could affect sternal wound healing. In addition, each risk factor listed in this study may have a different effect on sternal healing. For example, one study did not show beneficial effects on sternal complication rates when rigid sternal plates were used in patients with BMI $[?]35 \text{ kg/m}^2$ [17]. Thus, it is still not clear which patients with which risk factors would benefit from rigid plate fixation the most. The recent RCT by Allen et al. on rigid plate fixation versus standard wire cerclage excluded high-risk populations (i.e., those with BMI $>40 \text{ kg/m}^2$, COPD, dialysis-dependent renal failure, chronic steroid or narcotic use) [7]. Further studies comparing these two sternal closing techniques in patients with multiple risk factors for sternal wound complications, for whom rigid plate fixation might be most beneficial, will be necessary.

Conclusions

BITA grafting was able to be used in high-risk patients without increasing sternal wound complications. Rigid sternal plating fixation may increase the feasibility of BITA usage in high-risk patients.

Table 1

Age	62 $\pm$ 7.2
Female	9 (29%)
BMI (kg/m ²)	31 $\pm$ 8.1
Diabetes mellitus	29 (94%)
Non-insulin dependent	13 (42%)
Insulin-dependent	16 (51%)
Uncontrolled diabetes (HbA1c > 7.0)	20 (65%)
HbA1c (%)	7.6 $\pm$ 1.6
Hypertension	28 (90%)
Hypercholesterolemia	26 (83%)
Cerebral vascular accident	2 (6%)
Chronic kidney disease ([?]stage 3)	13 (42%)
On dialysis	6 (19%)
Creatinine (mg/dL)	2.2 $\pm$ 2.3
Albumin (g/dL)	3.9 $\pm$ 0.2
NSTEMI	8 (25%)
STEMI	1 (3%)
Congestive heart failure	6 (19%)
Atrial fibrillation	1 (3%)

BMI; body mass index, NSTEMI; non-ST elevated myocardial infarction, STEMI; ST elevated myocardial

infarction.

Table 2

Female	9 (29%)
Obesity (BMI [?] 30 kg/m ²)	14 (45%)
Diabetes mellitus	29 (94%)
Chronic kidney disease ([?] stage 3)	13 (42%)
Chronic obstructive pulmonary disease	4 (13%)
History of smoking / current smoker	23 (74%) / 4 (13%)
Previous sternotomy	1 (3%)
Chronic steroid or immunosuppressant use	3 (9%)
Hypoalbuminemia (< 3.0 g/dL)	1 (3%)
Congestive heart failure	7 (22%)
Peripheral vascular disease	5 (16%)

BMI; body mass index.

Table 3

Intubation time (hours)	9.1 ± 8.1
Time to off oxygen (hours)	74 ± 68
Time to out of bed (days)	1.2 ± 0.7
Opioid dosage (mg)*	74 ± 55
Length of hospital stay (days)	6.2 ± 3.7
Hospital death	0
Complications	
Exploration for bleeding	0
Stroke	0
Acute kidney injury	1 (3%)
Gastrointestinal bleeding	0
Low output syndrome	0
Pneumonia	1 (3%)
Superficial sternal wound infection	0
Deep sternal wound infection	0

* Morphine equivalent dose

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