Introduction

Coronary artery bypass grafting (CABG) is one of the most common cardiac surgical procedures over half a century. The left internal mammary artery (LIMA) graft is the gold standard of CABG. The use of a saphenous vein in CABG was very successful in the 1970s and 1980s due to numerous advantages: easier harvesting and handling, high procedure reproducibility, and good outcomes. Suzuki et al published the first report about bilateral internal mammary artery (BIMA) to revascularize coronary arteries in Circulation in 1973. The common use of LIMA as a conduit to left anterior descending artery appears after the Landmark Paper from the Cleveland Clinic group, reporting good surgical outcomes at 10 years. Progressively, despite superior results of BIMA grafting, this technique remains generally underused: 20% in Europe, ≤4.5% in the United States, and approximately 30% in Japan. The main common reasons discouraging surgeons in using BIMA grafting are technical challenges, longer operating time, and higher incidence of SWI. Even in studies promoting the use of BIMA, there are often restrictions concerning diabetic patients (DM), elderly patients (EP), and their propensity to co-morbidities, and obese patients. The risk of SWI and sternal complications due to the higher sternal devascularisation in these high-risk categories tends to avoid them for BIMA grafting procedures. This study aims to convince surgeons about the safe use of BIMA even in these categories.

Patients and Methods

Patients

A single-center retrospective observational study on 319 patients undergoing CABG made in our center (Grand Hôpital de Charleroi, Gilly, Belgium) from December 23, 2011, until December 27, 2015, was included. Coronary artery bypass grafting using BIMA and one or more additional grafts were only included. Surgical procedures using a single internal mammary artery (SIMA) were excluded from the study. The presence of an SWI was defined by the criteria of the Centers for Disease Control and Prevention: (1) an organism isolated from culture of mediastinal tissue or fluid,
pull on the wires was used to twist the wires tightly until the 2 bone edges were close to one another. Three double sternal (DoubleWire; A&E Medical Corp, Farmingdale, NJ, USA) and 3 single sternal wires were used (SingleWire; A&E Medical Corp). The double sternal wire was placed with the double twistier. Subcutaneous tissue was closed with poly-sorb 0 and the intradermic plan was made with rapid vicryl.

Statistical analysis

The continuous variables were tested for normality using the Shapiro-Wilk test. The continuous variable being non-Gaussian, the nonparametric Wilcoxon-Mann-Whitney test was used to compare EuroSCORE II, age, and BMI. The discrete variables were tested using the $\chi^2$ test. A $P$ value of <.05 was considered significant.

Results

We included 319 patients, 258 men (81%) and 61 women (19%). The median age was 65 years (range from 39 to 86 years). There were 234 patients with HTA (73%), 118 patients were DM (37%), of whom 28 were treated by insulin (9%). There were 32 patients COPD (10%) and 29 patients with renal failure (9%). The median BMI was 29 kg/m² (range from 17 to 45 kg/m²). Extracorporeal circulation (ECC) was used in 228 patients (71%) and 91 CABGs were done off-pump (29%). In all, 26 patients had CVD (8%) and 19 patients died (6%). A total of 1161 distal arterial anastomoses were made: 228 proximal arterial anastomoses and 47 distal venous anastomoses. The mean EuroSCORE was 4.9.

Three main outcomes were evaluated: SWI (group 1), SI (group 2), and RIB (group 3), using the above defined criteria.

In group 1, 14 patients on 319 patients were recorded (4%). The mean age was 67 years (range from 49 to 86 years). Only 2 patients were considered as EP (14%). The mean BMI was 28 kg/m². Mean EuroSCORE was 5.8. Six patients had 3 distal arterial anastomoses and 13 patients had 1 proximal arterial anastomosis. Only 1 patient had 2 distal venous anastomoses. One radial graft was harvested in this group. Teen CABGs were made under ECC. Seven patients had an SI associated (50%). When comparing with patients without SWI, all comparisons in subgroups were nonsignificant for SWI. In this study, SWI was not a risk factor in these categories. Data are recorded in Figure 1.

In group 2 (Figure 2), 11 patients (3%) were recorded. The mean age was 67 years (range from 51 to 76 years). Two patients were EP (18%). The mean BMI was 29 kg/m². Every patient had 1 proximal arterial anastomosis. One distal venous anastomosis was made on 3 patients. The biggest number of distal arterial anastomosis was 6 on 2 patients. One radial artery was harvested in 1 patient. Dead patients were not the oldest ones. The mean EuroSCORE was 4.4. Four patients had an SWI associated (36%).
Six patients were counted (2%) in group 3 (Figure 3). Every procedure was made in early postoperative period (48 hours postsurgery). The mean age was 66 years (range from 56 to 78 years), with 2 EP (33%). The mean BMI was 28 kg/m². Twenty-five distal arterial anastomoses and 6 proximal arterial anastomoses were made. No distal venous anastomosis was made. One patient had an SI associated (17%) and no SWI was recorded in this group. Mean EuroSCORE was 12.8. Incidence
of death was more than 6 times higher in patients with RIB ($P = .004$).

Outcome analyses by categories obese vs nonobese patients, DM vs no DM, and EP vs younger patients are resumed in Figures 1 to 4. Characteristics of each subgroup are resumed in Tables 1 to 3.

**Discussion**

We found a global incidence of SWI of 4% for BIMA patients. In this study, high-risk populations did not represent factors likely to cause sterna pathologies. Mortality was statistically increased in the group of reintervention for bleeding, whatever the target population is. The role of the skeletonizing technique is not highlighted here but did not seem to play some important roles. Distinguishing SWI from SI can help to clarify incidence of SWI in CABG including BIMA.

The incidence of SWI in the literature is variable. Itagaki et al. reported an incidence of SWI of 1.4%, without differentiating BIMA patients. However, this study compared BIMA with SIMA. All patients in our series had BIMA grafting, explaining the higher rate for SWI. Nevertheless, other studies reported higher incidence of SWI: Gatti et al. reported an incidence of 11.7% of SWI in their population of insulin-dependent DM (in our subgroup; incidence is 4%). Hirotani et al. earlier, published an incidence of chest wound infection of 5.7% in no DM (in our subgroup, incidence is 4%) and 10.0% in DM (in our subgroup, incidence is 4%). These studies aimed to compare incidence of SWI into 2 different groups of patients. At our knowledge, there is no work nowadays with the same design: we indifferently performed BIMA grafting in all our CABG despite patient’s comorbidities (eg, concurrent valve procedure included) and that is why our incidence of SWI is not comparable with other studies. The skeletonizing technique is often discussed for minimizing chest wall trauma and reducing risk of SWI by preserving intercostal collateral vessels and blood supply. However, Dai et al. also concluded that skeletonized BIMA should be the recommended procedure. In this study, we avoid the skeletonizing technique. Anyway, good results were obtained. Some works on canine models demonstrated that chest wall

![Figure 4. Outcomes in obese patients](image)

**Table 1. Characteristics of group 1.**

|                | SWI=YES | SWI=NO | $P$ VALUE |
|----------------|---------|--------|-----------|
| Gender (male/female) | 11 (79%)/3 (21%) | 247/58 | .822      |
| Death           | 2 (14%) | 17     | .178      |
| HTa             | 11 (79%) | 223    | .651      |
| DM              | 6 (43%) | 112    | .641      |
| DM treated by insulin | 1 (7%) | 27     | .825      |
| COPD            | 2 (14%) | 30     | .587      |
| Renal failure   | 3 (21%) | 26     | .100      |
| CVD             | 1 (7%)  | 25     | .887      |

Abbreviations: COPD, chronic obstructive pulmonary disease; CVD, cardiovascular disease; DM, diabetes mellitus; HTa, arterial hypertension; SWI, sternal wound infection.
vascularization was significantly decreased after internal mammary artery mobilization regardless the technique used.\(^9\) Even if the mainstream is to skeletonize the mammary artery, we think that this technique takes much more time in comparison with a nonskeletonized approach. Peterson et al.\(^{20}\) reported a difference of intraoperative time: 199 ± 75 minutes for a skeletonized approach and 184 ± 69 minutes for the conventional approach. Intraoperative time was not recorded in this study but this longer intraoperative time is certainly a factor that discourages surgeons to use BIMA. We agree with the fact that whatever the technique of harvesting used, the most important consideration is to preserve carefully the continuity between sternal and perforating vessels of mammary artery and sternal or intercostal branches.\(^{21}\) Performing this study, we want to tackle the topic of sternal closure and SI. Creating 3 groups according to the type and the extent of sternal disturbances allowed to distinct the different clinical entities. Even if subgroups of the different sternal complications contain few patients, distinction between SWI and SI was crucial. In our study, every patient with SWI had a bacteriological documentation. The criteria defining SWI include SI, which can be a major risk factor in the development of SWI.\(^{22}\) Sternal instability creates increased bones movements and local tissue necrosis that can promote a supportive environment for bacterial growth.\(^9\) Nevertheless, SI per se is defined by separation of the sternum at the midline due to bony fracture or disruption of the wires.\(^{16}\) However, this definition may be overly restrictive. Currently, there is no universally accepted definition of SI and accordingly no defined universally sternal precautions.\(^{23}\) Some ascertainment can be made: paramedian sternotomy leads much more often to SI, whatever the sternal closure technique used.\(^9\) There are several techniques of sternal closure that include stainless steel plates, stainless steel cables, and sternal screws with central lumen.\(^9\) In this study, the same material to make sternal closure was always used, namely, 3 double sternal wires and 3 single sternal wires. This material is quickly and easily installed and can be used in every patient, regardless the risk categories. However,
independently of the technique used to make sternal closure, we must have standard protocols: most possibleatraumatic sternotomy, adherence to aseptic technique, avoidance of dead spaces, careful hemostasis, and prophylactic use of intranasal antibiotics to prevent methicillin-resistant *Staphylococcus aureus* colonization.24 As a reminder, criteria defined by the Centers for Disease Control and Prevention were used to make the diagnosis of SWI and to distinguish it with SI. The distinction between these 2 entities can also explain the low incidence of SWI in our little sample. Indeed, distinction of different sternal complications may have an impact on the high-risk groups created, showing that with better definitions of sternal pathologies; high-risk groups may tend to become patients groups without restriction of use for coronary revascularization. Some other classifications to define SWI exist, such as Pairolero classification of infected median sternotomies that divides chest wounds into 3 categories based on duration and clinical findings.25 We agree with Bryan and Yarbrough26 that every case of SWI has to be reviewed and the main cause has to be analyzed.

This study has some weaknesses and limitations. We made a single-center retrospective observational study including only 319 patients. This little sample size and its retrospective observational aspect make it undoubtedly a weak power study, comparing with other studies of higher amplitude. Moreover, this kind of approach does not make possible avoiding confounding factors. There is no “lost to follow-up” patients registered but it would have been better to perform a prospective, randomized controlled trial with BIMA vs SIMA. However, this study also reflects significant methodological weaknesses in collection’s data in peripheral institutions, explaining lack of more preoperative variable in the results. Retrospective design is always subjected to inherent selection bias too (no data on SIMA grafting). The database only reflects the work of 1 surgeon and these results cannot be extended to all the team. Outcomes after 2015 were not analyzed. However, we think that peripheral surgical method and analyses deserve credit for raising concerns about a part of the surgical current reality even if results cannot be compared with powerful study resulting from tertiary institution.

Finally, nowadays, potential advantages of BIMA grafting are recognized overall in terms of long-term survival3 and by not increasing operative morbidity.27 One of the major restrictions for extending the use of BIMA grafting is the current impossibility of generalizing the procedure to higher risk patients.28 This results tend to confirm recent results that promote the use of BIMA grafting in every kind of patients8,29 and consequently to confirm the generalization of the procedure, without being afraid of sternal complications.

The survival advantage of this procedure has to be better taken into account regardless the risk of SWI that seems to be more controlled nowadays and that needs to be clarified by definitions that are more precise. Some international consensus should be reached to give a single definition of this concept and to promote the best therapeutic attitude. Promoting a periodical review by a multidisciplinary medical audit of best practice for defining the best attitude in this field should be done. Future research works should be concentrated more on the way of using BIMA grafting without increasing preoperative risks than on the risk factors which tend to avoid their bilateral harvesting in CABG. One technique of surgical sternal closure is here pointed out but some research areas of research have to be investigated.

**Conclusions**

Obesity, age, and presence of insulin-dependent diabetes do not influence incidence of SWI on patients benefiting from CABG using BIMA. We emphasize that BIMA grafting is a good surgical procedure, even in EP, obese, and DM, without affecting significantly incidence of sternal wound complications. This study tends to convince surgeons about the advantages of BIMA grafting even in higher risk patients.

**Author Contributions**

JMR and PS conceived the presented ideas. CM analysed all the datas and performed the statistical analysis. TG and all authors discussed the results and commented on the manuscript. JMR wrote the paper with input from all authors.

**Ethical Approval**

Ethical approval was not required in our institution for this study.

**Meeting Presentation**

J Ravaux MD, T Guennaoui MD, C Mélot MD PhD, P Schraverus MD. Bilateral internal mammary artery bypass grafting and sternal wound infection in high risk population. Presentation at the abstract session of coronary surgery on May 12, 2017, at 66th international congress of the European Society for Cardiovascular and Endovascular Surgery, Thessaloniki, Greece.

J Ravaux MD, T Guennaoui MD, C Mélot MD PhD, P Schraverus MD. Infections sternales après pontages aortocoronariens bimammaires dans les populations à hauts risques. Presentation at commented cardiac poster session (2) on June 9, 2017, at the 70th congress of the French Society of Thoracic and Cardiovascular Surgery, Marseille, France.

J Ravaux MD, T Guennaoui MD, C Mélot MD PhD, P Schraverus MD. Bilateral internal mammary artery bypass grafting: extent of use and focus on sternal wound infection. Oral podium presentation on the coronary heart disease session, on September 3, 2017, at the 27th congress of the World Society of Cardiovascular and Thoracic Surgeons, Astana, Kazakhstan.

J Ravaux MD, T Guennaoui MD, C Mélot MD PhD, P Schraverus MD. Bilateral internal mammary artery bypass
grafting and sternal wound infection in high risk population (Abstract Book). The Journal of Cardiovascular Surgery June 2017; 58: 59.

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