Interactive CardioVascular and Thoracic Surgery (2019) 1–6
doi:10.1093/icvts/ivz088

ORIGINAL ARTICLE

Cite this article as: Albert M, Nagib R, Ursulescu A, Franke UFW. Total arterial myocardial revascularization using bilateral internal mammary arteries and the role of postoperative sternal stabilization to reduce wound infections in a large cohort study. Interact CardioVasc Thorac Surg 2019; doi:10.1093/icvts/ivz088.

Total arterial myocardial revascularization using bilateral internal mammary arteries and the role of postoperative sternal stabilization to reduce wound infections in a large cohort study†

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Received 23 August 2018; received in revised form 5 February 2019; accepted 13 February 2019

Key question

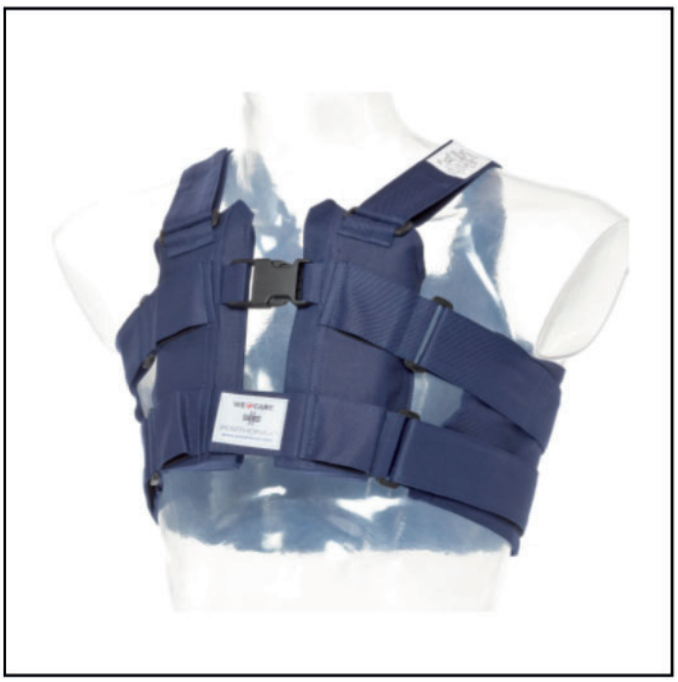
Does external sternal stabilization using a vest (e.g. the Posthorax ® vest) lower the incidence of wound complications?

Key finding(s)

External stabilization lowered the incidence of wound infections and length of stay when a wound complication did occur.

Take-home message

The routine use of a sternum stabilization vest after bilateral mammary artery harvesting may be considered.



Abstract

OBJECTIVES: Total arterial myocardial revascularization using bilateral internal mammary arteries shows improved results for mortality, long-term survival and superior graft patency. It has become the standard technique according to recent guidelines. However, these patients may have an increased risk of developing sternal wound infections, especially obese patients or those with diabetes. One reason for the wound complications may be early sternum instability. This situation could be avoided by using a thorax support vest (e.g. Posthorax® vest). This retrospective study compared the wound complications after bilateral internal mammary artery grafting including the use of a Posthorax vest.

METHODS: Between April 2015 and May 2017, 1613 patients received total arterial myocardial revascularization using bilateral internal mammary artery via a median sternotomy. The Posthorax support vest was used from the second postoperative day. We compared those

†Presented at the 31st Annual Meeting of the European Association for Cardio-Thoracic Surgery, Vienna, Austria, 7–11 October 2017.

patients with 1667 patients operated on via the same access in the preceding 26 months. The end points were the incidence of wound infections, when the wound infection occurred and how many wound revisions were needed until wound closure.

RESULTS: The demographic data of both groups were similar. A significant advantage for the use of a thorax support vest could be seen regarding the incidence of wound infections ($P = 0.036$) and the length of hospital stay when a wound complication did occur ($P = 0.018$).

CONCLUSIONS: As seen in this retrospective study, the early perioperative use of a thorax stabilization vest, such as the Posthorax vest, can reduce the incidence of sternal wound complications significantly. Furthermore, when a wound infection occurred, and the patient returned to the hospital for wound revision, patients who were given the Posthorax vest postoperatively had a significantly shorter length of stay until wound closure.

Keywords: Surgical site infection • Bilateral mammary artery • External sternum stabilization

INTRODUCTION

According to recent guidelines, manipulation of the ascending aorta should be kept to a minimum or even avoided [1]. The best way to achieve this goal is total arterial off-pump myocardial revascularization using bilateral mammary arteries, because it represents a real 'aortic-no-touch' technique. Unquestionably, the left internal mammary artery is used as the first arterial graft in almost every procedure, but for the second graft the surgeons have a variety of options: the radial arteries, the gastroepiploic artery or the right internal mammary artery, which has the best patency rate of all 3 vessels [2–4]. Although the bilateral use of the mammary arteries is favourable, especially in obese patients or in patients with a medical history of chronic obstructive pulmonary disease, a New York Heart Association functional score >3, peripheral vascular disease or diabetes, it is feared that this graft selection has a higher incidence of sternal instability and surgical site infections [5–7]. Besides higher health care costs caused by the increased use of materials, infrastructure, human resources and a longer duration of hospitalization, these adverse events increase the perioperative morbidity and mortality rates significantly [8–10]. By using an external stabilization system like a thorax support vest (e.g. the Posthorax® vest), many of these issues could possibly be avoided. This retrospective study compared the wound complications after bilateral internal mammary artery (IMA) grafting and the use of a Posthorax vest.

MATERIALS AND METHODS

Since 2007, total arterial off-pump revascularization using bilateral IMA has been the standard bypass grafting procedure in our department. For this study we investigated 3280 consecutive patients receiving isolated coronary artery revascularization using exclusively both internal thoracic arteries. The IMAs are harvested skeletonized and are usually used as T grafts to all 3 target areas: the anterior, lateral and inferior/posterior walls. Our goal was to perform the procedure off pump, but in case of cardiac instability, we converted to extracorporeal circulation without cardiac arrest (on-pump beating heart). The sternum-closure procedure followed the institutional practice of using 8 sternal wire sutures passed through the sternum in a single loop technique. The wires were tied and twisted to avoid extensive tension. A gentamycin collagen implant (Sulmycin®/Collatamp®, EUSA Pharma, Hemel Hempstead, UK/Aralez Pharmaceuticals, Mississauga, ON, Canada) is placed on top of the wires, followed by the standard 3-layer skin closure.

For this study, we defined a wound infection as a condition that needs a surgical revision. Surgical site infections without an indication for wound revision were not taken into account because they could not be identified retrospectively. The indications for a surgical treatment that were used in the study were sternum instability (clicking or pain) or wound dehiscence reaching the fascia regardless of exudate. The patients were taken to the operating theatre and a wound revision was performed with the patient under general anaesthesia: complete necrotomy and removal of all visible sternal wires. We put on a vacuum dressing (V.A.C.® Therapy, KCI, San Antonio, TX, USA) and changed the dressing in the operating theatre every 4 days. As soon as the wound condition was sterile without necrosis, the wound was closed, using either a pectoral muscle plastic or an omentum plastic. If the sternal wires had been removed previously and the sternum was unstable or dehiscent, osteosynthesis using plates and screws (DePuy Synthes, West Chester, PA, USA) was performed. In all cases, the patients received intravenous antibiotics during their entire stay in the hospital.

In April 2015 we introduced the Posthorax vest (Posthorax™ Inc., Vienna, Austria) for all patients after median sternotomy. The vest is designed to provide sternum stabilization following sternotomy to relieve pressure on the sternal wires and reduce pain when breathing, coughing and exercising during rehabilitation, thereby preventing sternum instability and surgical site infection.

In the 26 months between April 2015 and May 2017, 1613 patients received total arterial myocardial revascularization using bilateral IMA via a median sternotomy; a Posthorax support vest was used from the second postoperative day. The patients were instructed to wear the vest for 8 weeks after sternal osteosynthesis, so the patients used the vest after discharge in rehabilitation and during the remaining weeks at home. The 8-week period began anew if an osteosynthesis had to be performed during treatment of the surgical site infection, and the patients were instructed separately about elongation of the vest usage time. We compared these patients with the 1667 patients operated on via the same access in the preceding 26 months from February 2013 until March 2015, which served as the control group. For this study, every patient receiving a bypass procedure with bilateral IMA grafts was included. No patient was excluded because of risk factors for surgical site infections such as obesity, insulin-dependent diabetes, preoperative resuscitation, peripheral vascular disease or dialysis-dependent renal failure.

The end points of this retrospective study were the incidence of wound infections according to the use of the vest, the onset of the infection, how many wound revisions were needed until wound closure and the overall length of stay because of the site infection.

Continuous, normally distributed variables are presented as mean ± standard deviation (SD); not normally distributed variables are presented either as median and range or as mean ± SD for reasons of comparability. Categorical variables are expressed

Table 1: Baseline characteristics

	Posthorax® vest ($n = 1613$)	No vest ($n = 1667$)	*P*-value
Age (years), mean ± SD	69.1 ± 9.8	68.9 ± 10.7	0.180
Male gender, *n* (%)	1357 (84.1)	1407 (84.4)	0.182
BMI (kg/m^2), mean ± SD	34.4 ± 6.3	30.2 ± 12.8	0.466
EuroSCORE, mean ± SD	6.5 ± 3.8	6.7 ± 3.4	0.197
Insulin-dependent diabetes, *n* (%)	126 (7.8)	133 (8.0)	0.770
Dialysis, *n* (%)	26 (1.6)	30 (1.8)	0.501
PVD, *n* (%)	158 (9.8)	171 (10.3)	0.505

BMI: body mass index; PVD: peripheral vascular disease; SD: standard deviation.

as absolute numbers and percentages. Patient groups were compared using the chi-square test for categorical variables; the unpaired *t*-test was used for continuous variables. *P*-values <0.05 were considered statistically significant. For all statistical comparisons, the SPSS statistical software package for Windows (IBM, Armonk, NY, USA) was used. The data will be shared upon request as stated in the 'Data Sharing Statement'.

RESULTS

Total arterial off-pump myocardial revascularization has been the standard technique in our department for coronary artery bypass grafting procedures for more than 10 years. As an innovation, we introduced the Posthorax vest in April 2015. For this retrospective study we compared all patients receiving that procedure in a 52-month period: In the first 26 months between February 2013 and March 2015, 1667 patients were operated on according to our institutional practice and standards; in the subsequent 26 months between April 2015 and May 2017, the patients received exactly the same procedure plus a Posthorax vest for sternum stabilization on the second postoperative day.

Because we included every patient receiving the standard procedure, we did not see any significant differences in the preoperative baseline characteristics (Table 1) regarding age, gender or EuroSCORE. Similar findings were noted regarding the preoperative risk factors for developing a surgical site infection: neither body mass index, a history of insulin-dependent diabetes, dialysis nor peripheral vascular disease showed significant differences.

No significant differences were seen regarding the perioperative risk factors for wound infection like skin-to-skin time, resuscitation for any reason, rethoracotomy for any cause except surgical site infections or dialysis (Table 2). Compared to the preoperative data, the number of patients in need of dialysis increased due to acute renal failure that some patients developed in the postoperative course (Table 3).

When a patient developed a surgical site infection, there was no significant difference seen regarding the onset of the infection or the number of wound revisions per patient. When a wound complication did occur, the use of a Posthorax support vest provided a significant advantage regarding the incidence of wound infection and the hospital length of stay (Table 4).

DISCUSSION

As reported in previous studies, surgical site infections after median sternotomy are frequent and associated with higher rates of morbidity and mortality. Those complications range from minor wound oozing, subclinical infections, breakage of wires and sternal dehiscence to major surgical site infections requiring multiple surgical revisions, use of a vacuum therapy and plastic surgery [11–14].

Different groups have shown a direct correlation between sternal instability and wound infections [8–10]; thus a good sternum fixation is needed. This cannot be done by sternal wires alone, because they have a risk of breaking or perforating the skin with subsequent sternal dehiscence, pain and infection [15–18]. The key for a good osteosynthesis is fixation of the sternum fracture at a reasonable cost using minimal resources. The routine use of rigid plate fixation in every patient at risk has been shown to be feasible and beneficial [19, 20], but it may be time-consuming and reimbursement for this system is uncertain in many countries (e.g. Germany). A cast, often used in peripheral fractures, is not an option because it restrains breathing and inhibits regular dressing changes. The ideal stabilization system allows postoperative exercise with the physiotherapists, regular bandage replacement and breathing, but at the same time it stabilizes the thorax during coughing or intrinsic movement. In addition, it would be better if it was preventive and available for every patient. To achieve these goals, it needs to be cost-effective and simple.

One possible solution is the Posthorax vest. It has 2 pads placed longitudinally on each side of the sternum providing anterior-posterior stabilization of the 2 sternum halves and thus of the thorax instead of simple lateral compression (e.g. by using the standard elastic binding). Use of the vest leads to better bone healing of the sternum [8, 21]. In addition, the vest allows breathing and free movement with the prevention of intrinsic movement and serves as a shock absorber during coughing or physiotherapy.

We could confirm the following findings: After the introduction of the vest, the incidence of sternal wound infections decreased significantly compared to that noted during the period before initiation of that programme and was comparable with the decline reported in other publications. Taggart *et al.* [22] reported in the 5-year results of the Arterial Revascularization Trial (ART) a wound reconstruction rate of 1.9% in the 'bilateral-graft' group, which is exactly the same as that in our 'no-vest'-group. Moreover, by applying the vest routinely to those patients, we were able to lower even further the already low incidence of wound complications. Gorlitzer *et al.* [23, 24] demonstrated a reduction of mediastinitis by 54% and a significantly lower occurrence of a surgical site infection compared to the control group without the vest. After any surgery, early mobilization is necessary to prevent atelectasis and pneumonia [25]. After

Table 2: Perioperative variables

	Posthorax® vest (*n* = 1613)	No vest (*n* = 1667)	*P*-value
Skin–skin time (min), mean ± SD	188 ± 32	193 ± 38	0.463
Number of anastomoses, mean ± SD	3.1 ± 0.9	3.0 ± 1.0	0.313
Conversions: OPCAB → ECC, *n* (%)	11 (0.7)	17 (1.0)	0.067
Revascularization of anterior wall, *n* (%)	1609 (99.8)	1650 (98.9)	0.831
Revascularization of lateral wall, *n* (%)	1567 (97.1)	1595 (95.7)	0.587
Revascularization of posterior (inferior) wall, *n* (%)	1432 (88.8)	1457 (87.4)	0.661
Redo procedures, *n* (%)	23 (1.4)	14 (0.8)	0.348

ECC: extracorporeal circulation; OPCAB: off-pump coronary artery bypass (grafting); SD: standard deviation.

Table 3: Postoperative variables

	Posthorax® vest (*n* = 1613)	No vest (*n* = 1667)	*P*-value
Resuscitation postoperatively, *n* (%)	21 (1.3)	25 (1.5)	0.515
Rethoracotomy, *n* (%)	35 (2.2)	38 (2.3)	0.877
Dialysis (acute + chronic), *n* (%)	39 (2.4)	38 (2.3)	0.276
Myocardial infarction, *n* (%)	18 (1.1)	22 (1.3)	0.251
Mortality, *n* (%)	17 (1.1)	25 (1.5)	0.266
ICU length of stay (days), mean ± SD	1.4 ± 0.9	1.3 ± 1.2	0.455
Overall length of stay (days), mean ± SD	9.7 ± 9.0	9.5 ± 10.8	0.396

ICU: intensive care unit; SD: standard deviation.

Table 4: Patients with sternal surgical site infections

	Posthorax® vest (*n* = 1613)	No vest (*n* = 1667)	*P*-value
Wound complication, *n* (%)	7 (0.4)	32 (1.9)	0.006
Number of wound revisions per patient, mean ± SD	4.9 ± 2.9	5.1 ± 2.6	0.255
Onset of complication after operation (weeks), mean ± SD	2.8 ± 0.4	3.5 ± 2.7	0.088
Hospital length of stay with wound complication (days), mean ± SD	15.7 ± 4.1	29.8 ± 10.7	0.036
Hospital length of stay with wound complication (days), median (range)	12 (7–148)	16 (7–114)	

SD: standard deviation.

a median sternotomy, patients need extra care because, during exercise, the patients move their complete upper body, which causes shear stress on the 2 halves of the sternum and thus increases the risk of sternal instability. The vest stabilizes the sternum and at the same time allows movement and mobilization. This might be one reason for the decreased infection rate, because the intraoperative and postoperative care, as well as the physical therapy, did not change during the study period and followed the guidelines [26].

Furthermore, the Posthorax vest is reported to be comfortable, non-obstructive and ergonomically fitted for men and women. These factors may increase compliance and thus acceptance of the vest and could lead to patient compliance with the demanded utilization time of 8 weeks, even if the patient is already at home after discharge from the hospital or rehabilitation. The long-term stabilization of the sternum is important because many wound complications occur after hospital discharge. Some authors reported a rate of late sternal wound infections as high as 79% [27], and late onset sternal wound complications have a poorer prognosis than early onset complications. In our patient collective, we saw a mean onset of wound complications after 2.5–4 weeks, which is comparable to the other published results. Although statistical significance between the 2 groups was closely missed, in patients wearing a vest the onset of wound complications occurred nearly a week earlier than in the group without a vest. One reason might be better patient education. The patients receiving a vest are well informed about its rationale and capability. By wearing the vest daily, they do not lose sight of the possibility of wound complications. This practice leads to a more alert patient cohort, which might seek medical advice sooner. Usually, the result is less spread of the infection, which could be one possible explanation for the shorter overall length of hospital stay of the patients in the vest group.

Moreover, the vest stabilizes the sternum and enables better bone and wound healing [21]. One could argue that if a wound complication in patients wearing a vest occurs, it might not be

that severe before it becomes clinically apparent. In our clinical routine, we tend to keep patients after a severe infection longer before discharge compared to patients after a less severe infection, especially if they did not receive a secondary osteosynthesis. This practice may be another explanation for why we had a lower overall length of stay in the vest group for the same number of wound revisions.

As reported before, surgical site infections of the sternum are some of the most expensive complications in cardiac surgery [10, 28–30]. Patients have an increased length of stay. They need more antibiotics, wound dressings and surgical procedures, which impact the capacity of the operating theatre and the human resources needed for their care. Often vacuum therapy is needed: All of these factors lead to additional costs. An accurate assessment of the actual costs of a sternal surgical site infection is difficult to determine due to the different reimbursement systems used in every country. The amount ranges from 240% higher costs after isolated coronary artery bypass grafting due to mediastinitis [10], an increase of up to 227% in the use of hospital resources because of infections [28], to an average of $12 419 (10 953 €) per patient related to the increased length of stay and antibiotic treatment [29]. One European group from Helsinki estimated the increased costs at 6200 € ($7024) per patient [30]. Apart from the numbers, those studies demonstrate a massive increase in overall costs for patients developing a surgical site infection, which usually are not reimbursed. Any cost-efficient method to decrease the incidence of wound infections is, therefore, to be considered not only for monetary reasons but for the patients' quality of life as well.

Limitations

Some limitations should be addressed. First, the patients were not randomized to either of the 2 groups but were operated on consecutively. During the study period, we did not change the technique and postoperative wound care knowingly. Neither did the attendings change, but some residents performing all steps from chest closure to complete procedures did. Furthermore, because a surgical site infection is a serious complication, we had continuous training for the whole team to prevent wound complications. We cannot rule out that those details might have influenced the results. We aim to continue this research project with a randomized controlled study as the next step to avoid potentially biased conditions. Second, the patients who had surgical site infections must have been treated in our department to be part of this study. Although it is likely that every patient developing a wound infection after discharge was referred back to our department, we could not find any proof to the contrary. Nevertheless, we cannot rule out that some patients were treated in a different hospital, e.g. one closer to the rehabilitation facility or because of the explicit wish of the patient. Third, all patients were instructed to wear the vest during rehabilitation and at home for 8 weeks after osteosynthesis and on readmission for any cause. No patient admitted that he or she discontinued using the vest, but we do not know the actual duration of vest usage once the patient left the department.

CONCLUSION

As seen in this retrospective study, in patients receiving a bilateral IMA procedure, the early postoperative use of a thorax stabilization system such as the Posthorax vest can significantly reduce the incidence of sternal wound complications. Furthermore, when a surgical site infection occurs and the patient returns to the hospital for wound revision, use of the Posthorax vest means that the patient will have a significantly shorter length of stay until wound closure is achieved. Consequently, the prophylactic clinical practice of using the vest leads to shorter length of stay, fewer wound complications and thus lower hospital costs per patient. The routine use of the vest for all patients after bilateral IMA grafting should be considered.

Conflict of interest: none declared.

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