INTRODUCTION

Previous literature has noted the contribution of Julian and associates in recalling Milton’s median sternotomy approach to facilitate thoracic cavity access for intracardiac surgical procedures. Median sternotomy is a commonly enlisted incision for multiple types of heart surgery. However, surgical site complications (SSCs) after median sternotomy, such as deep sternal wound infection and sternal dehiscence, are rare but can be catastrophic. If undetected, there is an elevated risk of mortality. Reconstructive surgery consisting of debridement, sternectomy, and muscle flap coverage is widely used as standard of care for deep sternal wound infection.

Methods: This was an observational, retrospective cohort study of patients with SSCs following index cardiothoracic procedures. A single surgeon performed chest wall reconstruction using muscle flaps followed by closed incision negative pressure therapy (ciNPT; −125 mm Hg) using a ciNPT specialty dressing with an expanded coverage area to resolve sternal defects. Dressing changes occurred every 7 days. Postoperative follow-up appointments occurred after 30 days.

Results: Sixteen consecutive sternal reconstruction patients (six women and 10 men) with multiple comorbidities and an average age of 61.1 years were included in an initial evaluation of the ciNPT specialty dressing over median sternotomy incisions revised using flaps. The duration of ciNPT was 14 days with a single dressing change at day 7. At the initial dressing change, 93.8% of incisions were closed. Within 30 days postreconstruction, 18.8% of the patients had SSCs (hematoma or dehiscence). No seromas were noted. At 30-day follow-up appointments, 93.8% of incisions remained closed. Patients reported reduced pain and swelling. Average inpatient length of stay was 12.2 ± 14.2 days.

Conclusion: In these patients, ciNPT using the ciNPT specialty dressing helped to facilitate positive healing outcomes in patients with deep sternal wound infections following sternal defect reconstruction post cardiothoracic surgery. (Plast Reconstr Surg Glob Open 2022;10:e4623; doi: 10.1097/GOX.0000000000004623; Published online 22 November 2022.)
following DSWI or poststernotomy mediastinitis (PSM) represents the standard of care, and patient outcomes may be improved the sooner closure may be achieved. However, sternal instability or other factors might make a patient ineligible for immediate closure. Before reconstruction, surgical debridement of nonviable soft tissue and sternectomy of osseous tissue are generally required. The choice of flaps is contingent upon dimensions of the defect. Bilateral pectoralis major flaps are characterized as mainstay flaps and are primarily enlisted for reconstruction of sternal defects. Alternatively, flaps derived from the rectus abdominis, latissimus dorsi, and omentum majus have also been used for sternal reconstruction.

Obdeijn et al proposed the use of negative pressure wound therapy (NPWT) after debridement of PSM wounds to promote a healed, stabilized sternotomy wound. Likewise, closed incision negative pressure therapy (ciNPT) for incision management administers continuous negative pressure but was developed to help mitigate the risk of SSI development. ciNPT helps hold incision edges together, removes fluid and infectious materials, and provides a barrier to external contaminants. Recently, a ciNPT specialty dressing with an expanded coverage area has been developed.

Incisional resolution is dependent upon periwound health/integrity, which may be eroded by sternal dehiscence. Here, we evaluate the use of ciNPT and a ciNPT specialty dressing applied to the incisions of 16 consecutive patients who underwent sternal reconstruction using muscle flaps and who had previously developed SSCs following their index cardiothoracic procedures.

MATERIALS AND METHODS

This was an observational, monocentric, retrospective cohort study of 16 consecutive patients, who developed SSCs following index cardiothoracic procedures. This study evaluated our initial experience with a ciNPT specialty dressing with an expanded coverage area (3M Prevena Restora BellaForm Dressing, 3M, St Paul, Minn.) developed to protect incisions while using a commercially available ciNPT system (3M Prevena Restora BellaForm Incision Management System, 3M). Patients provided informed consent for data collection and usage, and institutional review board approval was obtained. Oral (cephalexin) or intravenous antibiotics (cefazolin, meropenem, or vancomycin) were administered perioperatively. Before the chest wall reconstruction procedure, preoperative evaluation of the sternal defects included medical radiography to image the thoracic cavity. Incisions measured 15–20 cm. A single surgeon surgically debrided nonviable tissue and excised any infected osseous tissue and sent for culture. In these cases, miniplates were used; however, at the time of debridement, they were all removed. The wounds were 4–6 weeks after coronary artery bypass graft (CABG) and 1–2 weeks following debridement depending on stability of patient and wound condition (ie, wound bed preparation) that was being managed by instillation therapy. To obtain coverage of mediastinum, chest wall reconstruction used either bilateral/unilateral pectoralis major myocutaneous advancement flaps, unilateral pectoral advancement flaps, or a dual flap method using unilateral pectoral advancement and rectus abdominis muscle flaps. During chest wall reconstruction, surgical drains were placed, as necessary. To achieve skin closure, incisions were sutured or stapled. Immediately postoperatively, the ciNPT specialty dressing was placed over the closed incision and ciNPT (−125 mm Hg) was initiated. In accordance with the manufacturer’s instructions for use, the ciNPT specialty dressing was used for a maximum of 7 days. Every 7 days, the ciNPT specialty dressing was changed. ciNPT was discontinued upon the patient attaining their therapeutic goal of an intact incision. After the completion of the chest reconstruction procedure, patients recovered in the surgical intensive care unit. Patients were evaluated for whether an incision was intact after the first dressing change, an incision remained closed at 30-day follow-up appointment, SSI development within 30 days, SSC (eg, seroma, hematoma, and dehiscence) development within 30 days, and functional outcomes (eg, edema and/or pain). Postoperative follow-up appointments occurred after 30 days.

RESULTS

Sixteen (n = 16) consecutive patients who underwent index cardiothoracic procedures and subsequently developed SSCs were included in this case series. The patient population consisted of six female (37.5%) patients and 10 male (62.5%) patients with a mean age of 61.1 ± 11.6 years. The mean body mass index (BMI) for the patients was 31.8 ± 7.0 kg/m² (range, 21–43 kg/m²). Common comorbidities encompassed obesity (BMI > 30 kg/m²), hypertension, coronary artery disease, myocardial infarction, and diabetes. Each patient underwent chest wall reconstruction with flap coverage. Median sternotomy incisions were either 15 cm (n = 1) or 20 cm (n = 15) in length. Table 1 captures patient characteristics and comorbidities.

Table 2 captures perioperative characteristics and information regarding the surgical procedures and ciNPT specialty dressing usage. For sternal coverage, patients received either unilateral or bilateral flaps. Unilateral right rectus abdominis flaps were used in eight patients (50%). Bilateral pectoralis major advancement flaps were used in four chest wall reconstruction patients

Takeaways

Question: How well does closed incision negative pressure therapy (ciNPT) using a specialty foam dressing with expanded coverage area help to support healing after sternal reconstruction?

Findings: Following 16 chest wall reconstructions using advancement flaps managed with ciNPT, 93.8% of flaps remained closed after the initial dressing change and at postoperative day 30.

Meaning: ciNPT using a specialty dressing with expanded coverage area was effective in managing advancement flap edges post sternal reconstruction.
Table 1. Patient Characteristics and Comorbidities

| Case | Age | Sex | BMI  | Comorbidities                                                                 |
|------|-----|-----|------|--------------------------------------------------------------------------------|
| 1    | 40  | F   | 43   | HTN, ischemic cardiomyopathy, ESRD, CAD, COPD, CHF, diabetes, hospitalization, Staphylococcal infection, Status post CABG, status post ciNPT |
| 2    | 65  | M   | 31   | STEMI, chronic obstructive pulmonary disease, COPD, CHF, diabetes, hospitalization, Status post CABG, Status post ciNPT |
| 3    | 43  | M   | 25   | CAD, ischemic cardiomyopathy, CHF, STEMI, VFib cardiac arrest, chest wall abscess due to sternal fracture, MRSA bacteremia and sepsis |
| 4    | 63  | F   | 38   | Aortic stenosis, paroxysmal atrial fibrillation, asthma, DM, fatty liver disease, hypertension, diabetes, obesity, CHF, CAD, and angina |
| 5    | 69  | F   | 28   | CHF, DM, hypertension, hypothyroidism, obesity, NSTEMI |
| 6    | 81  | M   | 21   | Paroxysmal atrial fibrillation, DVT, aortic root dilation, atherosclerosis, CHF, CAD, and stroke |
| 7    | 69  | M   | 42   | Obesity, diabetes, hypercholesterolemia, hypertension, CAD with stable angina pectoris |
| 8    | 69  | M   | 36   | NSTEMI, hypertension, diabetes, hidradenitis suppurativa, obesity, CAD, and HLD |
| 9    | 56  | M   | 26   | CAD, HLD, hypertension, myocardial infarction, diabetes, and RA |
| 10   | 69  | M   | 24   | DM, obesity, hypertension, CAD with unstable angina pectoris, aortic valve surgery, chronic kidney disease, peripheral vascular disease, diabetes, and CKD stage 3 |
| 11   | 55  | M   | 36   | HTN, ischemic cardiomyopathy, chronic hepatitis B, fatty liver disease, DM, CAD, and angina |
| 12   | 56  | F   | 41   | CABG × 4, PVD, AAA, DM, HLD, obesity, hypertension, CAD, and CHF |
| 13   | 42  | F   | 24   | CAD, HLD, hypertension, myocardial infarction, diabetes, and RA |
| 14   | 66  | M   | 29   | CAD, ischemic cardiomyopathy, CHF, diabetes, hospitalization, Status post CABG, Status post ciNPT |
| 15   | 71  | M   | 31   | Obesity, diabetes, hypercholesterolemia, hypertension, CAD with stable angina pectoris |
| 16   | 63  | M   | 33   | Obesity, diabetes, hypercholesterolemia, hypertension, CAD with stable angina pectoris |

AAA, abdominal aortic aneurysm; AFib, atrial fibrillation; CAD, coronary artery disease; CHF, congestive heart failure; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; CPR, cardiopulmonary resuscitation; DM, diabetes mellitus; DVT, deep vein thrombosis; ESRD, end-stage renal disease; HLD, hyperlipidemia; HTN, hypertension; MI, myocardial infarction; MRSA, Methicillin-resistant Staphylococcus aureus; NSTEMI, Non-ST segment elevated myocardial infarction; PVD, peripheral vascular disease; RA, rheumatoid arthritis; s/p, status post; STEMI, ST-segment elevated myocardial infarction; VFib, ventricular fibrillation; VT, ventricular tachycardia.

*Patient with SSI also developed incisional dehiscence.

Reduced swelling/edema 16 (100.0)
Reduced pain 16 (100.0)
Functional outcomes
Surgical site hematoma 2 (12.5)
Incisional dehiscence 1 (6.3)
Surgical site seroma 0 (0.0)
SSI 1 (6.3) *
Surgical site complications within 30 days, n (%)  At first dressing change (POD 7) 15 (93.8)
POD 30 15 (93.8)
Surgical site infections 3 (18.8)  Treated conservatively 15 (93.8)
Surgical site infections 0 (0.0)  Requiring incisional dehiscence repair 1 (6.3)
Surgical site infections 1 (6.3)  Surgical site hematoma 2 (12.5)

Table 3. Surgical Outcomes

| Surgical Outcomes | n (%) |
|-------------------|-------|
| Inpatient length of stay (d), mean (SD) | 12.2 (14.2) |
| Incision remained closed, n (%) | At first dressing change (POD 7) 15 (93.8) POD 30 15 (93.8) |
| Surgical site complications within 30 days, n (%) | At first dressing change (POD 7) 15 (93.8) POD 30 15 (93.8) |
| Surgical site seroma | 0 (0.0) |
| Incisional dehiscence | 1 (6.3) |
| Surgical site hematoma | 2 (12.5) |
| Functional outcomes | Reduced pain 16 (100.0) Reduced swelling/edema 16 (100.0) |

Table 2. Perioperative Characteristics

| Perioperative Characteristics | n (%) |
|------------------------------|-------|
| Surgery type | Chest wall reconstruction 16 (100.0) |
| Antibiotics | Oral 1 (6.3) Intravenous 15 (93.8) |
| Muscle flaps used | Bilateral, right and left pectoralis major 4 (25.0) Unilateral, left pectoralis major 2 (12.5) Unilateral, right rectus abdominis 8 (50.0) Right rectus abdominis plus right pectoralis major 1 (6.25) Right rectus abdominis plus left pectoralis major 1 (6.25) |
| Method of skin closure | Staples 15 (93.8) Suture 1 (6.3) |
| Therapy duration | At least one ciNPT dressing change 16 (100.0) |
| Total days of ciNPT | 14 d 16 (100.0) |

Therapy duration
At least one ciNPT dressing change 16 (100.0)
Total days of ciNPT 14 d 16 (100.0)
Here, we present a representative case of a patient with a sternal defect, who received the ciNPT specialty dressing intraoperatively following skin closure post chest wall reconstruction with flap coverage.

Case 3
A 65-year-old man underwent a median sternotomy cardiothoracic procedure. He had a BMI of 31 kg/m². The patient’s medical history and comorbidities include myocardial infarction, hypertension, coronary artery disease, chronic obstructive pulmonary disease, fatty liver disease, central hypothyroidism, panhypopituitarism, hyperlipidemia, prediabetes, adrenal cortical insufficiency, and chronic kidney disease (stage 3). The patient developed sternal osteomyelitis status after CABG (Fig. 1A). The patient underwent chest wall reconstruction using bilateral pectoralis major flaps for revision of the sternal defect. Following primary closure using sutures, the ciNPT specialty dressing was applied immediately postoperatively and ciNPT was initiated (Fig. 1B). After 7 days, the ciNPT dressing was removed (Fig. 1C), and a second ciNPT dressing was placed for an additional 7 days. After a total of 14 days, ciNPT was discontinued. Patient LOS was 3 days. On POD 17, a hematoma was noted. Following hematoma evacuation, the patient healed without further incident. Drains were removed on PODs 21 and 27.

DISCUSSION
The Centers for Medicare and Medicaid characterizes PSM following CABG as a hospital-acquired condition required to be scrutinized. A 2017 report published by the Agency for Healthcare Research and Quality estimated that SSIs cost in the range $11,778–$42,177 with an additional cost estimate for a hospital-acquired SSI of $28,219 and suggested 26 excess deaths for every 1000 cases of SSI. With the high burden of SSIs, attention to patient perioperative risk and the use of enhanced preventive techniques can assist in preempting the incidence of sternal instability and dehiscence. In this pilot study, 16 consecutive patients with SSCs following intracardiac surgery underwent chest wall reconstruction using muscle advancement flaps followed by surgical incision management using a ciNPT specialty dressing with ciNPT over a revised median sternotomy incision. The use of ciNPT with the specialty dressing was associated with a 93.8% intact incision rate at the initial dressing change (POD 7) and at the 30-day follow-up appointment. Additionally, the absence of seromas and the reduction of pain and edema were noted in all patients.

In 1997, NPWT enlisting subatmospheric pressure for the treatment of wounds was described by Morykwas, and it has been incorporated into the armamentarium of medical professionals of varied clinical specialties. NPWT use has been reported in patients following primary and revised cardiothoracic surgery with reduced incidence of hematoma and SSIs, and shortened hospital LOS. With the postoperative improvements associated with NPWT use over closed incisions, a ciNPT system designed specifically for surgical incision management was developed.

Surgical incision management via ciNPT is intended to establish a barrier against the external environment, maintain incisal edges together, and remove fluid and infectious materials. Following the development and use of ciNPT, contemporary literature reviews have concluded that ciNPT usage should be considered by surgeons in the immediate postoperative period. Similarly, a published consensus recommendation concluded that ciNPT usage should be considered by surgeons in instances in which a patient might be at an elevated risk for SSC development, undergoing a high-risk procedure, or procedures in which morbid outcomes would be high due to an SSI. Additionally, a recent systematic review has concluded that there is moderate-certainty evidence to suggest that prophylactic application of NPWT or ciNPT may reduce the incidence of SSI in surgical wounds healing via primary closure. A separate meta-analysis also reported that ciNPT demonstrated a statistically significant reduction in the incidence of SSI relative to conventional wound dressings for randomized controlled trials, observational studies, and cardiothoracic surgery.
As the design of the ciNPT dressing is somewhat novel and was applied during sternal reconstruction opposed to an index cardiothoracic procedure via median sternotomy, no literature exists that would allow us to directly compare our findings with the extant literature. However, available published literature has reported positive postoperative outcomes with ciNPT usage following cardiothoracic surgery. In a single-center retrospective study, Suelo-Calanao et al. investigated the incidence of SWI in high-risk, cardiothoracic surgery patients who received ciNPT. Of the 1859 patient records reviewed, 927 in the control group received standard-of-care dressings, and 992 received ciNPT. This study reported a significant overall decrease in SWI incidence from 8.7% to 4.4% with the introduction of ciNPT. Among high-risk patients, there was a statistically significant difference in superficial and DSWIs (20 [12.4%] versus 9 [5.6%]). In a 10 patient prospective cohort study, after undergoing a CABG, the wound was dressed using ciNPT. Incisions were evaluated, and no complications were noted at POD 5 or POD 30. Similarly, Grauhan et al. investigated 150 consecutive obese patients who underwent cardiovascular surgery via median sternotomy. A significantly lower rate of SSIs was found in the ciNPT group. A study of 19 obese patients with DSWI following sternotomy observed patients who underwent reconstruction using either unilateral pectoralis major flap coverage with a conventional dressing or a combination of unilateral pectoralis major flap coverage and ciNPT. A significant statistical difference was noted given fewer surgical revisions for the group using ciNPT opposed to the control group. Similarly, a majority of the patients within our study did not develop postoperative SSCs.

In the present study, we noted the development of SSCs (one dehiscence secondary to SSI and two hematomas) in three sternotomy patients whose incisions were managed with ciNPT using the ciNPT specialty dressing. The SSCs were treated and resolved without further complication. Again, no literature exists that would allow us to directly compare our findings with the extant literature. However, Atwez et al. recently described the dissection of the pectoralis major during sternal defect revision, which does not release it from the overlying skin or its insertion. Immediately postoperatively, the surgical defect was dressed using gauze and covered with an adhesive antimicrobial drape. Although NPWT was not part of the treatment algorithm, it was occasionally enlisted between debridements for some patients. SSCs were noted in 15 patients (25.8%). Following the revision procedure, reoperations were necessary in seven of 58 consecutive patients (12%) due to failed flap closure (n = 4) or hematoma evacuation (n = 3). In the Suelo-Calanao study, the incidence of SWI was 9.9% (n = 16) in a subgroup of 162 high-risk control patients versus 5.7% (n = 9) in a subgroup of 158 high-risk patients receiving ciNPT. In the present study, we noted three SSCs, which are within the realm of the published literature.

We also observed the duration of inpatient hospitalization. The mean LOS in the present study was 12.2 ± 14.2 days. Our results report a similar LOS when compared with the Suelo-Calanao et al. study (LOS in the high-risk ciNPT group: 12.2 ± 15.6 days), a notable difference is that in our study, patients received ciNPT during sternal reconstruction and not the index cardiac surgical procedure. Our mean LOS was found to be slightly shorter than the median inpatient LOS (14 versus 19.5 days after flap coverage) of patients undergoing reconstruction following DSWI as reported within a study by Nickl et al. The limitations of this study are its small sample size, the absence of a control group to compare standard of care against ciNPT as an intervention, and its retrospective nature. In these 16 patients, ciNPT was effective in helping to reduce the incidence of SSIs. In our experience, the ciNPT specialty dressing protected incisions as well as the standard ciNPT dressing. The expanded coverage area of the ciNPT specialty dressing may also protect more of the periwound skin along the incisional edges. Additionally, having a continuous sterile coverage of both the incision and surrounding soft tissue in an ICU setting is important to minimize possible contamination. More robust studies with matched standard-of-care controls to assess the clinical effectiveness of ciNPT in cardiac patients as well as the development of health economic models to discern the cost-effectiveness of ciNPT are necessary.

Allen Gabriel, MD, FACS
703 Broadway Street, Suite 700
Vancouver, WA 98660
E-mail: gabrielallen@yahoo.com

ACKNOWLEDGMENT

The authors thank Willie M. Heard III, PhD (3M), for manuscript preparation support.

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