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# Use of Incisional Negative Pressure Wound Therapy on Closed Median Sternal Incisions after Cardiothoracic Surgery: Clinical Evidence and Consensus Recommendations

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Negative pressure wound therapy is a concept introduced initially to assist in the treatment of chronic open wounds. Recently, there has been growing interest in using the technique on closed incisions after surgery to prevent potentially severe surgical site infections and other wound complications in high-risk patients. Negative pressure wound therapy uses a negative pressure unit and specific dressings that help to hold the incision edges together, redistribute lateral tension, reduce edema, stimulate perfusion, and protect the surgical site from external infectious sources. Randomized, controlled studies of negative pressure wound therapy for closed incisions in orthopedic settings (which also is a clean surgical procedure in absence of an open fracture) have shown the technology can reduce the risk of wound infection, wound dehiscence, and seroma, and there is accumulating evidence that it also improves wound outcomes after cardiothoracic surgery. Identifying at-risk individuals for whom prophylactic use of negative pressure wound therapy would be most cost-effective remains a challenge; however, several risk-stratification systems have been proposed and should be evaluated more fully. The recent availability of a single-use, closed incision management system offers surgeons a convenient and practical means of delivering negative pressure wound therapy to their high-risk patients, with excellent wound outcomes reported to date. Although larger, randomized, controlled studies will help to clarify the precise role and benefits of such a system in cardiothoracic surgery, limited initial evidence from clinical studies and from the authors' own experiences appears promising. In light of the growing interest in this technology among cardiothoracic surgeons, a consensus meeting, which was attended by a group of international experts, was held to review existing evidence for negative pressure wound therapy in the prevention of wound complications after surgery and to provide recommendations on the optimal use of negative pressure wound therapy on closed median sternal incisions after cardiothoracic surgery.

**MeSH Keywords:** **Cardiovascular Infections • Mediastinitis • Negative-Pressure Wound Therapy**

**Abbreviations:** **BMI** – body mass index; **CABG** – coronary artery bypass graft; **CI** – confidence interval; **CIM** – closed incision management; **DSWI** – deep sternal wound infection; **GFR** – glomerular filtration rate; **GOLD** – Global initiative for chronic Obstructive Lung Disease; **IMA** – internal mammary artery; **MRSA** – methicillin-resistant *Staphylococcus aureus*; **MVR** – mitral valve replacement; **NPWT** – negative pressure wound therapy; **RCT** – randomized controlled trial; **SSI** – surgical site infection; **SWI** – sternal wound infection

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## Background

Surgical site infections (SSIs) are serious complications after cardiothoracic surgery and contribute significantly to post-operative morbidity, mortality, and healthcare costs [1–3]. Studies have reported that up to 15% of patients develop a wound infection after cardiac surgery [4–7]; with rates of SSIs ranging from 0.5 to 22.2% [8–14]. Incidence rates for deep sternal wound infection (DSWI) have ranged from 0.4 to 2.6%, with mortality rates of between 7 and 35% reported with conventional therapies such as surgical revision with open packing dressing, rewiring over a surgical drain(s), or reconstruction with vascularized soft tissue flaps compared with only 2.7–7.1% in uninfected controls [2,6,11,15–23]. Mortality rates are especially high (up to 74%) in patients with DSWI due to methicillin-resistant *Staphylococcus aureus* (MRSA) [24,25].

Host factors contributing to the risk of SSIs after cardiothoracic surgery have been well described in the literature and include obesity, renal insufficiency, diabetes mellitus, advanced age, gender, chronic obstructive pulmonary disease, smoking, steroid use, and length of hospitalization (>5 days) [1,19,22,23,26]. Surgical risk factors include the use of 1 or 2 internal mammary artery (IMA) grafts (especially bilaterally and when using the pedicle IMA), duration of surgery and perfusion time, prolonged mechanical ventilation, use of an intra-aortic balloon pump, post-operative bleeding, re-operation, sternal rewiring, extensive electro-cautery, shaving with razors, and use of bone wax [1,23].

Surgical incisional wounds have traditionally been closed by primary intention using sutures, staples, or a combination of these methods. After closure of clean surgical incisions, wound care may include the use of traditional gauze dressings, and more advanced therapies such as hydrocolloids, growth factors, cultured skin, low-energy ultrasound, and negative pressure wound therapy (NPWT) (V.A.C.<sup>®</sup> Therapy, Kinetic Concepts, Inc., San Antonio, TX, USA).

NPWT is a treatment concept introduced initially to assist in the treatment of acute and chronic open wounds [27,28]. NPWT uses a negative-pressure device and specific dressings to create a negative-pressure environment at the wound site. This helps to hold the incision edges together [29], reduces lateral tension and edema [30,31], stimulates perfusion [27,32–36], enhances the development of granulation tissue [27,37,38], reduces bacterial colonization of wound tissues [27,39], and protects the surgical site from external infectious sources [40].

NPWT has also become a well-established method for improving outcomes after skin grafting, where the technique is used to prepare the wound surface for graft acceptance and to stabilize the graft to prevent shearing and removal [41–43].



**Figure 1.** Closed incision management system to deliver negative pressure wound therapy. (Prevena™ Incision Management System, Kinetic Concepts, Inc., San Antonio, TX, USA).

In this clinical setting, removal of exudate reduces the risk of hematoma and seroma formation and helps to prevent contamination [44]. Increased granulation facilitates revascularization and attachment of the graft to the wound bed [45]. Numerous clinical studies have shown the successful use of NPWT in the management of both skin and biomatrix grafts (reviewed by Gupta in 2012) [45].

Recently, there has been growing interest in using the technique on closed incisions to prevent potentially severe SSIs and other wound complications in high-risk individuals. This paper aims to review existing evidence for NPWT in the prevention of wound complications after surgery and to provide consensus recommendations on optimizing the use of NPWT after cardiothoracic procedures. The paper has been developed from a consensus meeting held in Amsterdam in November 2011.

## NPWT for Prevention of Wound Complications: Clinical Evidence

Randomized controlled trials (RCTs), retrospective studies, and case series provide a substantial body of evidence that the use of either NPWT or closed incision management (CIM; Prevena™ Therapy [Kinetic Concepts, Inc., San Antonio, TX, USA]) (Figure 1) may reduce the incidence of wound infections and other wound complications in a variety of post-surgical wound types (Table 1) [28,42–53]. Orthopedic studies were included as well as cardiac surgery, because both are considered to be clean surgery [54]. In case of infection, the

**Table 1.** Summary of studies using negative pressure wound therapy on closed, clean surgical incisions.

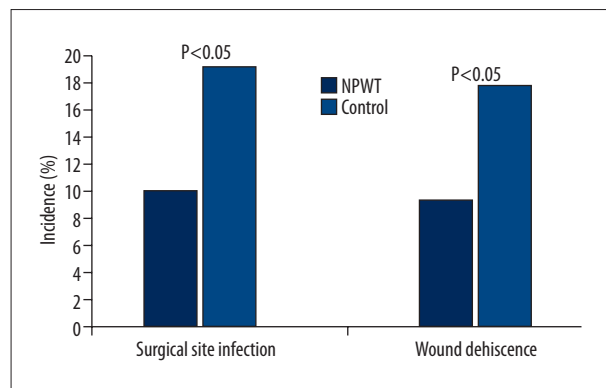
Reference	Study type	Patients	Results/conclusions
[52]	2 RCTs of NPWT vs. standard post-operative dressings (control)	44 patients with high-energy trauma wounds with draining hematomas (n=31 control; n=13 NPWT) 44 patients with high-risk fractures (n=24 control; n=20 NPWT)	High-energy trauma wounds: Control group drained a mean of 3.1 days vs. 1.6 days for NPWT (p=0.03)  High-risk fractures: Control group drained a mean of 4.8 days vs. 1.8 days for NPWT (p=0.02)
[53]	RCT of NPWT vs. standard post-operative dressings (control)	249 patients with 263 high risk lower extremity fractures requiring stabilization (n=122 control; n=141 NPWT)	Significant decrease in infections with NPWT: 14 infections; 9.7% of fractures (NPWT) vs. 23 infections; 19% of fractures (controls) (p=0.049)  Relative risk of developing an infection was 1.9 times higher in control group than in NPWT group (95% CI 1.03–3.55)  Significant decrease in risk of wound dehiscence after discharge with NPWT: 12 dehiscences; 8.6% of fractures (NPWT) vs. 20 dehiscences; 16.5% of fractures (control) (p=0.044).
[49]	RCT of NPWT vs. standard dry wound dressings (control)	19 patients following total hip arthroplasty (n=10 control; n=9 NPWT).	Incidence of seroma at 10 days: 44% of patients (NPWT) vs. 90% of patients (control)  Significant reduction in average seroma volume with NPWT: 1.97±3.21 mL (NPWT) vs. 5.08±5.11 mL (control) (p=0.021)
[56]	Prospective comparative study CIM vs. standard wound dressing (control)	150 obese patients following sternotomy (n=75 control; n=75 CIM)	Significant reduction of sternal wound infections: 4% vs. 16% (p=0.0266).
[47]	Prospective cohort of patients receiving NPWT	10 high-risk patients following CABG	All wounds healed completely; no complications reported  No statistical information provided
[57]	Retrospective study of CIM vs. standard wound dressing (control)	3745 patients following sternotomy (n=3508 control; n=237 CIM)	Significant reduction of wound infection: 1.3% vs. 3.4% (p<0.05)
[46]	Retrospective chart review of patients receiving NPWT	57 adults with sternal wounds at high risk of infection	Based on risk assessment, at least 3 sternal wound infections were anticipated, but none were reported  NPWT was easily applied and well tolerated  No statistical information provided
[50]	Retrospective chart review of patients receiving NPWT	19 morbidly obese patients (BMI >40) with acetabular fractures	No reported complications  No statistical information provided

**Table 1 continued.** Summary of studies using negative pressure wound therapy on closed, clean surgical incisions.

Reference	Study type	Patients	Results/conclusions
[51]	Retrospective chart review: NPWT vs. standard post-operative dressings (control)	301 patients with acetabular fractures (n=66 control; n=235 NPWT)	Incidence of deep wound infections: 6.15% (4/66) of patients (control) vs. 1.27% (3/235) (NPWT) (p=0.0414)  Incidence of dehiscence: 3.03% (2/66) (control) vs. 0.04% (NPWT)
[49]	Case series of patients receiving NPWT	35 patients with foot and ankle trauma, revision hip arthroplasty, proximal femoral and tibial fracture fixation	Average time of NPWT use just over 3 days, which saved an average of 4 conventional dressing changes  No statistical information was provided in the publication  No infections had occurred in high-risk patients receiving NPWT at 3 months post-operatively  No statistical information provided
[28]	Case series of patients receiving NPWT	4 high-risk patients following CABG using internal mammary arteries (n=1), transmetatarsal amputation (n=1), or abdominal hysterectomy (n=2)	All wounds healed well; no complications reported  No statistical information provided

BMI – body mass index; CABG – coronary artery bypass graft; CI – confidence interval; DSWI – deep sternal wound infection; NPWT – negative pressure wound therapy; RCT – randomized controlled trial.

typical microbes involved in both patients populations are comparable, mainly involving *Staphylococcus species* [54]. In the case of postoperative wound infection in cardiothoracic patients, the sternum is usually involved, as well as osteomyelitis if there is a deep wound infection. Therefore, based on the Evidence Rating Scale for Therapeutic Studies developed by the American Society of Plastic Surgeons (ASPS) level 1 orthopedic studies, we included high-quality, multicenter or single-center, randomized controlled trials with prospective cohorts [44]. Stannard et al. (2012) [55] examined the use of NPWT to prevent wound dehiscence and infection following high-risk lower extremity fractures [53]. This multicenter, prospective, randomized, controlled study included 249 patients with 263 fractures. Patients were randomized to receive standard post-operative dressings (control group; n=122 fractures) or NPWT (n=141 fractures) over the surgical incision after open reduction and internal fixation of the fractures [53]. A total of 14 infections (9.7% of fractures) were reported in the NPWT group compared with 23 infections (19% of fractures) in the control group (p=0.049) (Figure 2). The relative risk of developing an infection was 1.9 times higher in control patients than in those treated with NPWT (95% confidence interval, 1.03–3.55). A significant reduction in the risk of wound dehiscence after discharge was also observed in the NPWT group (8.6% of fractures) versus the control group (16.5% of fractures) (p<0.044).



**Figure 2.** Incidence of surgical site infection and wound dehiscence in a randomized, controlled study of negative pressure wound therapy (NPWT) versus standard dressings over surgical incisions after open reduction and internal fixation of 263 fractures in 249 patients [50].

NPWT was applied for a mean of 2.5 days (range, <1–9.0 days) in this study, and these patients were ready for hospital discharge half a day earlier than patients in the control group (not statistically significant), which more than offset the cost of the NPWT. The investigators concluded that, based on the results of the study, prophylactic application of NPWT to high-risk wounds before their failure appeared to be an efficacious

treatment strategy. These findings confirm earlier reports of 2 small, randomized controlled trials of NPWT in trauma patients, in which NPWT was associated with decreased draining from surgical incisions and improved wound healing [52].

Pachowsky et al. (2012) conducted a prospective, randomized evaluation of NPWT using CIM after total hip arthroplasty [49]. In the study, 19 patients were randomized to receive either standard dry wound dressings (control group;  $n=10$ ) or CIM ( $n=9$ ) over the sutured wound area. All patients received 2 Redon drains: 1 in the deep areas of the wound close to the prosthesis and 1 above the closed fascia. Ultrasound examination on Day 10 post-surgery revealed that 90% of patients in the control group and 44% of the patients in the NPWT group had developed a seroma. The average seroma volume was  $5.08\pm 5.11$  mL in the control group compared with only  $1.97\pm 3.21$  mL in the NPWT group ( $p=0.021$ ). The control group received antibiotics for a mean of  $11.8\pm 2.8$  days compared with  $8.4\pm 2.2$  days in the NPWT group ( $p=0.005$ ).

Retrospective studies [50,51] and case series [49] suggest similar benefits of NPWT in terms of a low incidence of infections and other complications after orthopedic surgery.

Evidence for the benefits of NPWT in preventing wound complications after cardiothoracic surgery has accumulated through published retrospective chart review studies [46,57] and case studies [28,47].

Grauhan et al. [56] published a prospective comparative study on 150 consecutive obese patients undergoing classic cardiac surgery by sternotomy. Standard wound dressing was performed in 75 patients compared with 75 patients receiving CIM. The study showed that patients with CIM had significantly fewer sternal wound infections 3/75 (4%) versus 12/75 (16%) in the control group (OR: 4.57; 95% CI: 1.23–16.94),  $p=0.0266$ .

A retrospective study from the same group [57] compared 237 patients with CIM versus 3508 with standard wound dressing. The primary endpoint of the study showed a significant reduction of wound infections in the CIM group 3/237 versus 119/3508 in the control group ( $p<0.05$ ; OR 2.74).

Atkins et al. (2009) reported on 57 adult cardiac surgery patients who had received NPWT (mainly clean, closed median sternotomy incision) because they were considered to be at increased risk of sternal wound infection (SWI) and other wound healing complications [46]. At completion of the cardiac surgical procedure, the sternotomy incision was closed as per routine practice. A single layer of non-adhesive gauze was placed over the clean, closed incision followed by a thin strip (1.0–1.5 cm) of silver-impregnated foam (V.A.C. GRANUFOAM SILVER® DRESSING, Kinetic Concepts, Inc., San Antonio, TX, USA).

**Table 2.** Post-operative details of 57 high-risk adult cardiac surgery patients who received negative pressure wound therapy on the clean, closed sternotomy incision immediately after surgery and for 4 days post-operatively [40].

Variable	
Hospital length of stay (mean $\pm$ SD, days)	9.8 $\pm$ 10
Median length of hospital stay (days)	7.0*
Number of patients readmitted** (%)	10 (17.5%)
Heart failure	7
Pleural/pericardial effusion	3
Number of sternal wound infections predicted/observed	3/0
Mortality, $n$ (%)	1 (1.8%)

\* Range for hospital stay not provided. \*\* Within the first 30 days after initial hospital discharge.

An occlusive transparent dressing was placed over the foam, and negative pressure was applied to the foam through an incision in the drape via a pressure-sensing pad (T.R.A.C.™ Pad, Kinetic Concepts, Inc., San Antonio, TX, USA) with tubing connected to the therapy unit (V.A.C.® Therapy, Kinetic Concepts, Inc., San Antonio, TX, USA), thereby creating the environment for NPWT. Therapy was continued for 4 days post-operatively.

Of the 57 NPWT-treated patients, 77.2% were obese, 54.4% were diabetic, and 50.9% were obese and diabetic. Overall, 50.9% of the NPWT-treated patients underwent coronary artery bypass graft (CABG) with 1 internal mammary artery, almost 20% underwent concomitant CABG and other cardiac procedures such as valvular heart surgery or atrial maze procedure, and 14% underwent CABG with bilateral mammary artery use. NPWT was well tolerated by all patients until completion, and no recordable amount of exudate wound fluid was reported in any patient. The estimated risk for post-operative DSWI was based on risk scores developed by Fowler et al. in 2005 [14]. This scoring system assigns points for individual pre-operative and intra-operative risk factors for major post-operative infection, enabling a probability of infection (%) to be estimated [13]. Based on this system, the estimated average risk for developing post-operative DSWI in this group of high-risk surgical patients was  $6.1\pm 4.0\%$ ; therefore, at least 3 cases of DSWI were anticipated in this series of 57 patients. Ten patients (17.5%) required readmission within the first 30 days after discharge; however, no admissions were due to sternal wound complications (Table 2) [45]. In this population of high-risk patients treated with NPWT, there were no reports of DSWI or superficial SWI, leading the authors to recommend that NPWT should be strongly considered for patients with

increased risk of SWI. No data relating to a 1-year follow-up of these patients were reported in the paper.

More recent evidence comes from Colli, who used CIM over the surgical incisions in a small prospective cohort study of 10 patients at high risk for SWI (Fowler risk score, 8–30) following CABG surgery [47]. All 10 patients received CIM for 5 continuous days immediately following standard wound closure. Wounds and surrounding skin were inspected following removal of the CIM dressing and at Day 30 after surgery. The system was well tolerated and all patients experienced complete wound healing with no evidence of early or late wound infections.

These preliminary findings demonstrate the favorable efficacy and safety of CIM in preventing wound complications after cardiac surgery; however, larger, randomized controlled trials are warranted to more clearly define the patient population and wound types that would benefit most from this type of therapy. Whether CIM will be able to prevent sternal dehiscence or DSWI with sternal involvement remains a key issue, but according to current clinical evidence, the benefits of the system in terms of promoting skin healing may help to impede dehiscence and/or the development of DSWI. Indeed, most recent findings from a prospective study indicated that NPWT may prevent post-operative wound infections [56].

#### Consensus statement

- Based on current published evidence, NPWT appears to effectively prevent wound complications when used over clean, closed surgical incisions, including median sternal incisions.

### Modern Approaches to Applying NPWT/CIM

NPWT systems have evolved substantially in recent years and are now available as single-use devices designed specifically for the management of closed incisions in patients at risk of post-operative wound complications. The CIM device used in the studies by Colli (2011) [47] and Pachowsky et al. (2012) [49] consists of a single-use (i.e., completely disposable) NPWT unit, canister, and dressing that are designed for application over clean, closed, sutured, or stapled incisions in a simple peel-and-place process. The dressing is a polyurethane film with acrylic adhesive that adheres the dressing to the skin surrounding the incision and a polyurethane shell that encapsulates the foam bolster and interface layer, providing a closed system. The dressing has a built-in pressure indicator and a skin interface layer containing 0.019% ionic silver, which wicks fluid from the skin surface and reduces bacterial colonization within the fabric. The single-use, battery-powered therapy unit delivers negative pressure in the system at between –75 and

–125 mmHg. The system also contains a sterile 45-mL canister for collection of incision exudate and additional drape patch strips that may be used to help seal leaks around the dressing.

#### Consensus recommendation

- Single-use devices such as CIM are recommended for the management of closed incisions in patients at high risk of post-operative wound complications.

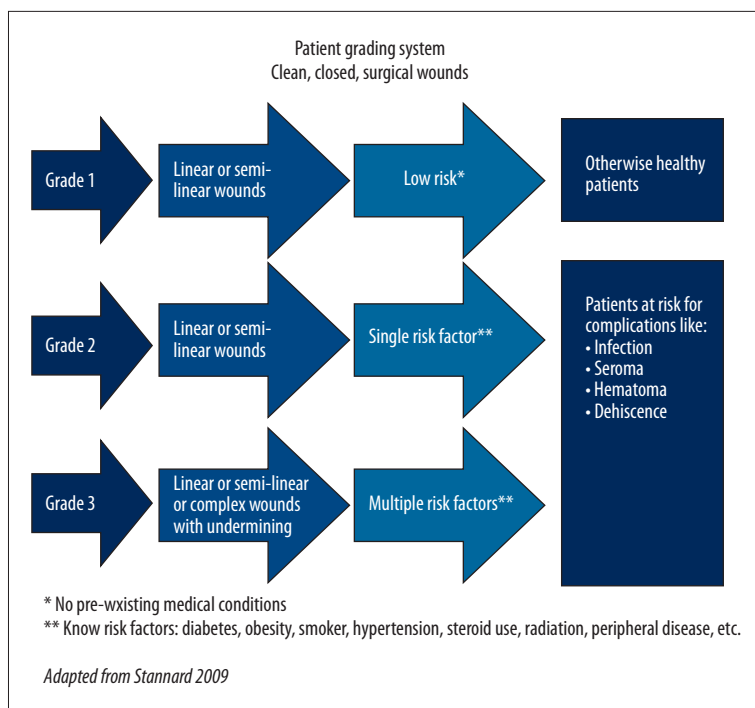
### Using NPWT in Cardiothoracic Surgery: Selecting Appropriate Patients

Prevention of surgical site infections remains a pressing concern to all healthcare professionals, and relies on the use of strict pre-, intra-, and post-operative infection control measures to optimize the patient's condition and to minimize contamination risk [57,58]. Appropriate choice of incisional wound dressing and treatment, which are integral to most infection control guidelines, will depend on local preferences and availability, but should always be based on robust cost-effectiveness evidence.

NPWT is an advanced technology that, based on data from a randomized controlled trial by Stannard et al. [53], has been shown to be a cost-effective option when used for the prevention of wound infection and dehiscence in high-risk patients. However, questions remain over the best way to define high-risk patients in clinical practice.

In the studies by Atkins et al. (2009) [46] and Colli (2011) [47], the risk of DSWI was assessed using the Fowler system [13]. According to this system, the use of both internal mammary arteries is assumed to double the risk of surgical wound infection, based on a previous evaluation of DSWI in this setting [60]. Additionally, a distinction is made between obese individuals with a body mass index (BMI) of 30–40 kg/m<sup>2</sup> and those with a BMI >40 kg/m<sup>2</sup>, with increased risk of surgical wound infection assigned to the latter category.

Stannard et al. (2009) proposed a simpler universal patient grading system to help determine which closed surgical incisions may be best suited for NPWT (Figure 3) [29]. Under this system, Grade 1 patients have linear or semi-linear wounds and no pre-existing medical conditions and are considered at low or no risk of developing post-surgical wound complications such as infection, seroma, hematoma, or dehiscence. Grade 2 patients have linear or semi-linear wounds and at least 1 moderate- to high-risk factor (diabetes, obesity, smoking, hypertension, steroid use, or radiation exposure), making them candidates for post-surgical NPWT. Grade 3 patients have linear, semi-linear, or complex wounds with undermining and 1



**Figure 3.** Patient grading system adapted from Stannard et al. (2009) [28] for determination of which closed surgical incisions are best suited for incisional negative pressure wound therapy.

or more risk factors and may, therefore, benefit most from prophylactic use of incisional NPWT.

We believe that risk factors for major infections after cardiothoracic surgery can be divided into 3 categories: major, intermediate, and minor (Table 3). Like Fowler et al. (2005) [13], we consider a BMI  $\geq 40$  kg/m<sup>2</sup> and insulin-dependent diabetes to be major risk factors, but we also include a low BMI ( $< 18$  kg/m<sup>2</sup>) and chronic kidney disease (GFR  $< 30$  mL/min/1.73 m<sup>2</sup> for  $\geq 3$  months) requiring dialysis in this category. Intermediate, but still important, risk factors include a BMI between 35 and 39 kg/m<sup>2</sup>, diabetes mellitus requiring oral hypoglycemic medications, chronic kidney disease not requiring dialysis, the use of both internal mammary arteries, and long-term immunosuppressive medication. Some of the minor risk factors include BMI 30–34 kg/m<sup>2</sup>, female sex, and age  $> 75$  years.

### Consensus recommendations

- CIM should be considered for use in all high- or at-risk patients, regardless of skin type, with the aim of preventing wound infection and dehiscence after surgery.
- Selection of high-risk patients for post-operative use of NPWT should be based on a careful assessment of pre-operative risk factors.
- Patients with 1 or more major risk factors (BMI  $< 18$  or  $\geq 40$  kg/m<sup>2</sup>, insulin-dependent diabetes mellitus, or dialysis treatment for chronic kidney disease) are strong candidates for prophylactic use of NPWT.

- Patients with 2 or more intermediate (or major) risk factors (e.g., use of bilateral mammary arteries, diabetes mellitus, chronic lung disease, or receiving long-term immunosuppressive medication) may also benefit from post-operative NPWT.
- We strongly recommend using CIM in heart, lung, and heart/lung transplantation patients in view of the high degree of immunosuppression required; however, sternum stability is vital.

### Optimizing the use of NPWT in Cardiothoracic Surgery

The authors of this consensus document have considerable experience in using the CIM for the prevention of wound complications after cardiothoracic surgery and have found the system to be easy to use and well tolerated by patients. The system should be applied immediately after surgery, in a sterile field (while the patient is still in the operating room and before the sterile drapes have been removed), to clean, closed incisions for a period of 5–7 days. When used preventively, the system should ideally be left undisturbed for at least 5 days, unless the patient develops clear signs of wound infection, such as pain. If the dressing is lifted to observe the incision, a new dressing should be applied.

If the wound extends beyond the length of the dressing, the dressing can be applied over part of the incision. It should not be placed over drains or wires, should not be used to treat open or dehisced surgical incisions, and should not be used in patients with sensitivity to silver.

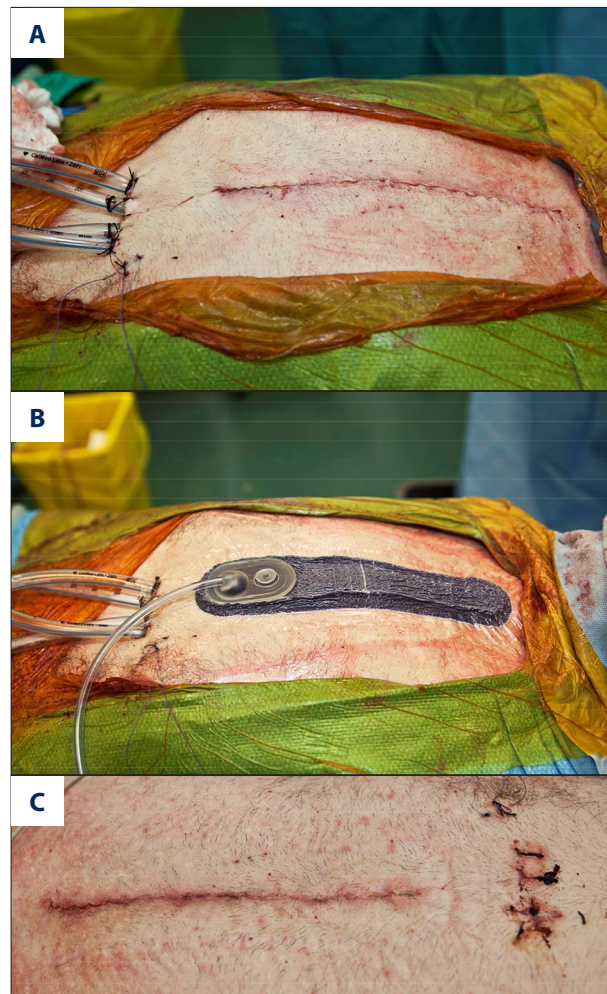
**Table 3.** Proposed classification of pre-operative risk factors for major infections after cardiothoracic surgery.

Major
BMI <18 or ≥40 kg/m <sup>2</sup>
Insulin-dependent diabetes mellitus
Dialysis in patients with chronic kidney disease (GFR <30 mL/min/1.73 m <sup>2</sup> for ≥3 months)
Intermediate
BMI 35–39 kg/m <sup>2</sup>
Diabetes mellitus (type 1 or 2 receiving oral hypoglycemic medication or diet)
Chronic kidney disease (GFR <30 mL/min/1.73 m <sup>2</sup> for ≥3 months)
Use of bilateral mammary arteries
Long-term immunosuppressive medication
Previous chest wall radiotherapy
Chronic lung disease (GOLD class >II).
Minor
BMI 30–34 kg/m <sup>2</sup>
Peripheral vascular disease
Female gender
Age >75 years
Cardiac reoperation for CABG procedure
Left ventricular ejection fraction <30%
Acute myocardial infarction within 90 days prior to surgery
Hospitalized at least 7 days before surgery

BMI – body mass index; CABG – coronary artery bypass graft; GFR – glomerular filtration rate; GOLD – Global initiative for chronic Obstructive Lung Disease.

Skin preparation should include the use of chlorhexidine, iodine, or alcohol, with careful drying to prevent foil blistering. Drains should be placed in a lower position when planning to use CIM (see case studies).

The system should be removed carefully with the vacuum turned off. Adequate closure of the wound, no redness at the incision site, and no evidence of edema upon dressing removal suggest that the wound has healed adequately. In our experience, concerns regarding the canister becoming too full of fluid are unfounded. A summary of consensus recommendations for optimizing the use of CIM after cardiothoracic surgery is presented in Table 4.



**Figure 4.** Closed incision management of a 70-year-old male following coronary artery bypass graft and mitral valve replacement via sternotomy. Images reproduced with the patient's permission. (Photos courtesy of Dr Zane Atkins).

## Case Studies

The 3 case studies presented here show examples of the prophylactic use of NPWT over clean, closed surgical incisions after cardiothoracic surgery.

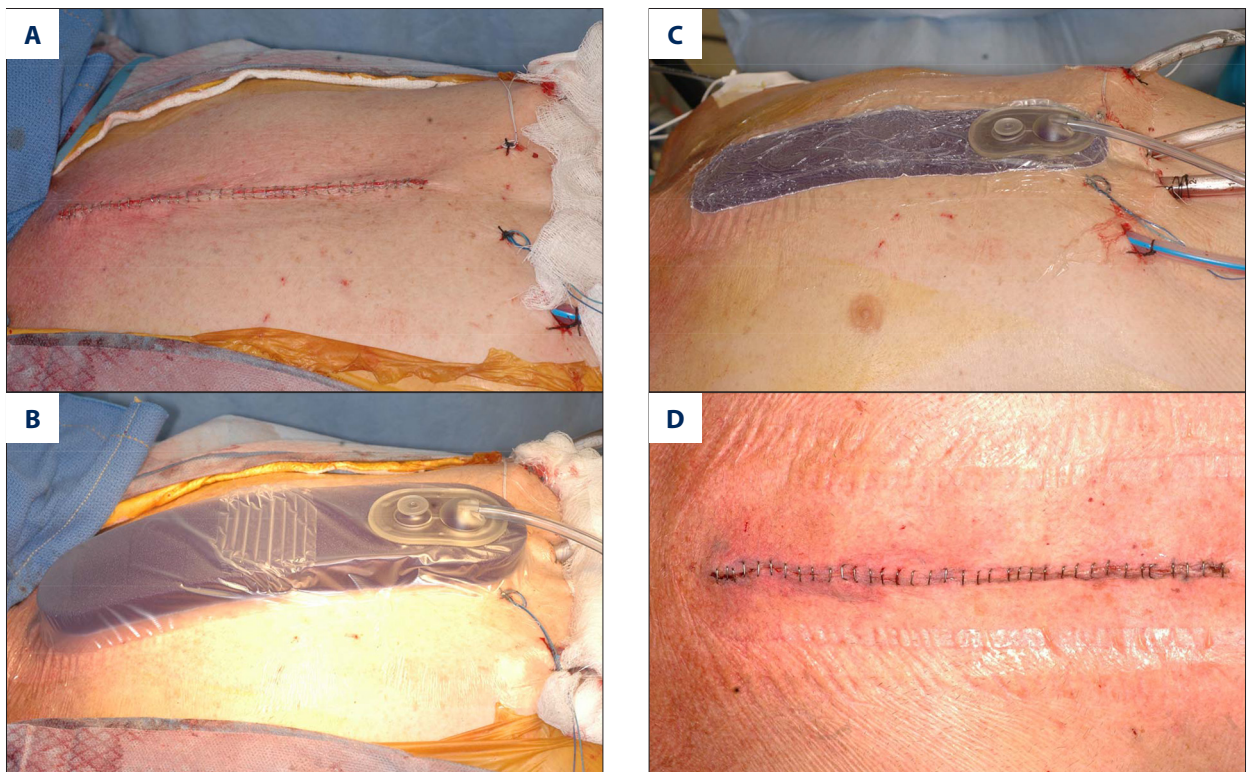
### Case study 1: Urgent triple CABG and mitral valve replacement (MVR) via sternotomy

A 70-year-old male presented with a non-ST elevation myocardial infarction (Figure 4). His medical history included type 2 diabetes, peripheral vascular disease, renal insufficiency, hyperlipidemia, and pulmonary hypertension. The patient was diagnosed with triple vessel coronary artery disease and severe mitral insufficiency. Urgent triple CABG and MVR were performed.



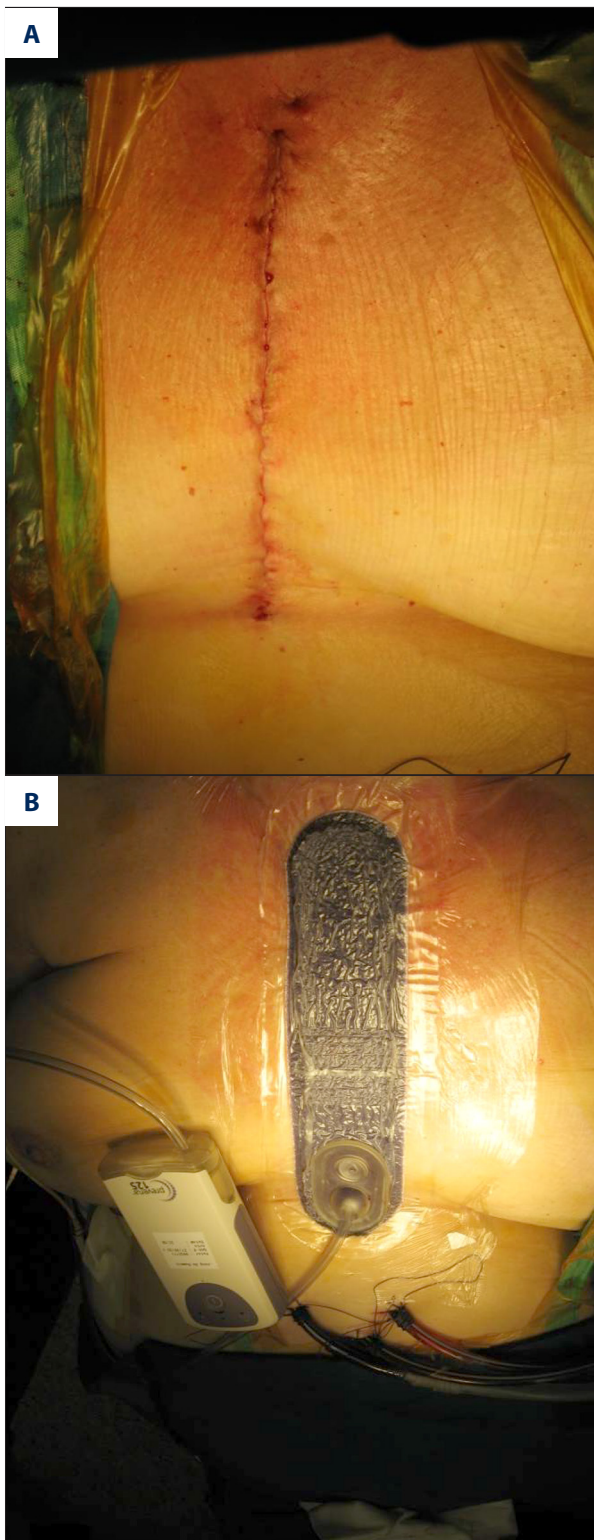
**Table 4.** Consensus recommendations for optimizing the use of closed incision management after cardiothoracic surgery.

Goal of treatment	<ul style="list-style-type: none"> <li>Prevention of wound infection and dehiscence in all at-risk patients</li> </ul>
Appropriate patients	<ul style="list-style-type: none"> <li>All heart, lung and heart/lung transplantation patients</li> <li>All patients with major or multiple intermediate risk factors (see Table 3)</li> </ul>
Length of treatment	<ul style="list-style-type: none"> <li>5–7 days (aim for at least 5 days undisturbed)</li> </ul>
Skin preparation	<ul style="list-style-type: none"> <li>Chlorhexidine, alcohol or iodine with careful drying</li> </ul>
Placement	<ul style="list-style-type: none"> <li>Should not be placed over drains or wires</li> <li>Position drains in a lower position when planning to use system post-operatively</li> </ul>
Re-application frequency	<ul style="list-style-type: none"> <li>Single-use dressing only. If lifted to observe the incision, a new dressing must be applied</li> </ul>
Treatment success criteria	<ul style="list-style-type: none"> <li>Adequate wound closure</li> <li>No redness at the incision site</li> <li>No evidence of edema</li> </ul>
Precautions	<ul style="list-style-type: none"> <li>Should not be used to treat open or dehisced surgical incisions or patients who have excessive amounts of exudate that may exceed the 45-mL canister limit</li> <li>Should be used with caution on patients with fragile skin surrounding the incision and patients who are at increased risk of bleeding</li> </ul>
Contraindications	<ul style="list-style-type: none"> <li>Silver sensitivity</li> </ul>

**Figure 5.** Closed incision management of a 65-year-old male following coronary artery bypass graft and mitral valve replacement via sternotomy. Images reproduced with the patient's permission. (Photos courtesy of Dr Zane Atkins).

Due to his elevated risk of post-operative incision complications, the CIM system was used, with the dressing applied along the incision (Figure 4A), with special care taken to leave sufficient distance between the inferior aspect of the incision and the

chest tubes in order to secure an adequate seal (Figure 4B). On post-operative day 3, the patient experienced a cardiopulmonary arrest requiring immediate resuscitative chest compressions. However, the integrity of CIM dressing was maintained.



**Figure 6.** Closed incision management (CIM) of a 77-year-old, morbidly obese female who underwent elective coronary artery bypass graft. Images reproduced with the patient's permission. (A) Day 0: Clean closed surgical incision. (B) Day 0: Placement of CIM dressing. (C) Day 6: Surgical incision following removal of CIM system. (Photos courtesy of Dr. A.L.P. Markou).

patient was discharged home on post-operative day 18, with his incision continuing to heal well.

#### Case study 2: CABG and MVR via sternotomy

A 65-year-old male presented with progressive angina and a positive exertional stress test (Figure 5). His medical history included diabetes mellitus, obesity (BMI 38 kg/m<sup>2</sup>), and chronic obstructive pulmonary disease. Cardiac catheterization demonstrated severe 3-vessel coronary artery disease.

Four-vessel CABG was performed using left IMA to left anterior descending coronary artery and reverse saphenous vein grafts to the right coronary artery, ramus intermedius artery, and first diagonal artery, separately. The standard median sternal incision was approximately 10 inches in length. Sternal re-approximation was performed with stainless steel cables and the skin was closed with subcuticular sutures. The CIM dressing was applied in the operating theater and remained in place until it was removed on post-operative day 5. The patient was discharged on post-operative day 6.

#### Case study 3: Elective CABG in a morbidly obese female

This 77-year-old morbidly obese (BMI 57.5 kg/m<sup>2</sup>) female underwent an elective CABG due to angina functional class III/IV (Figure 6). She was at high risk of developing DSWI as a result of her obesity, insulin-dependent diabetes mellitus, and long-term use of systemic prednisolone for chronic obstructive pulmonary disease (Gold [Global initiative for chronic Obstructive Lung Disease] class II).

On post-operative day 8, the CIM dressing was removed. The incision edges appeared well apposed and were healing appropriately (Figure 4C). In contrast, the chest tube sites, which were not treated with CIM, demonstrated some drainage. The

Revascularization was achieved using bilateral internal mammary grafting, as the saphenous vein and the radial artery were both unusable. Transdermal stitches were used to close the incision. The CIM system was selected prior to surgery, allowing the drains to be placed in a low position in order to accommodate both the dressing and the short stature of the patient. The CIM dressing was applied carefully, under sterile conditions, along the incision and left undisturbed for 5 days.

The dressing was removed on post-operative day 6; there was no edema or infection present, and the wound was healing well. The patient was discharged on post-operative day 10, with no surgical wound infection, even at the 30-day follow-up.

To date, the CIM system has been used successfully on 32 of the contributing author's (AM) patients with no signs of surgical wound infection during hospitalization or at the 30-day follow-up.

## Summary and Conclusions

There is growing interest in the use of NPWT on closed incisions after cardiothoracic surgery to prevent potentially severe SSIs in high-risk individuals. Use of NPWT on closed incisions has been shown to reduce the risk of wound infection, wound dehiscence, and seroma in randomized, controlled studies of patients in orthopedic settings [47,51]. NPWT also enhances graft adherence and survival after skin and biomatrix grafting [43].

Evidence is now accumulating that NPWT improves wound outcomes after cardiothoracic procedures [28,44,45]. Based on published data and clinical evidence, we recommend that NPWT should be considered in at-risk patients with the aim of preventing DSWI after surgery.

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Identifying at-risk individuals for whom prophylactic use of NPWT would be most cost-effective remains a challenge. However, several risk-stratification systems have been proposed [13,28], and should be evaluated more fully. In the meantime, we believe that patients with 1 or more major risk factors or multiple intermediate risk factors are strong candidates for prophylactic use of NPWT, and that any patient undergoing heart, lung, or heart/lung transplantation should receive this treatment.

The availability of the peel-and-place, single-use CIM system offers surgeons a convenient and practical solution to overcome SSIs in high-risk patients, and CIM is recommended by the authors based on their own clinical experiences. Larger, randomized studies will help to clarify the precise role and benefits of NPWT on closed incisions after cardiothoracic surgery; however, initial data appear very promising.

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## Conflict of interest

All authors declare they have no conflicts of interest.

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