Closed Incision Negative Pressure Therapy for Laparotomy Wounds: A Review

Fowler AL* and Barry MK
Department of Surgery, National University of Ireland, Ireland

Abstract

Background: Open abdominal surgery is associated with high rates of wound complications. Surgical site infection (SSI) carries a significant burden to the healthcare system and the patient and is associated with prolonged length of stay, delayed treatment and high rates of readmission. Negative pressure wound therapy over closed incisions (ciNPWT) is a novel approach to prevention of SSI. We reviewed the outcomes of studies comparing ciNPWT and standard therapy on laparotomy wounds to assess the efficacy of the current evidence base.

Aim: To assess the effect of negative pressure wound therapy used over closed incisions in open abdominal surgery.

Methods: Search of relevant terms was conducted on PubMed and Google Scholar to identify relevant studies published between Jan 2006 - Dec 2017. Studies were chosen based on specific inclusion and exclusion criteria. An additional search was conducted to identify epidemiology, risk factors and cost-burden of SSI. Articles were screened to assess demographics, study design and outcomes.

Results: Five retrospective and four prospective randomised controlled trials were identified for inclusion, totalling 1470 participants. 454 received ciNPWT and 1016 received standard treatment. Studies assessed a mix of surgeries (4=colorectal, 1=pancreatoduodenectomy, 1=gynaecologic, 2=mixed). ciNPWT was statistically significant in reducing SSI in 8 of 9 studies (p<0.05).

Conclusion: ciNPWT is a promising therapy for reducing the rate of SSI in open abdominal surgery however; its effect on other wound complications is unclear. Further multicenter, prospective studies are needed to assess cost-benefit, appropriate patient-selection and assess efficacy of closed incision negative pressure therapy in open abdominal surgery.

Keywords: Negative pressure wound therapy; Laparotomy; Open abdominal surgery; Surgical site infection; Complication

Introduction

Postoperative wound issues are a frequent cause of surgical morbidity and a large-scale health problem [1-5]. Wound issues can range from superficial surgical site infection to deep surgical site infection, organ space infection and complete wound dehiscence (Figure 1) [6]. Hospital associated infections affect one in twenty patients, with surgical site infection (SSI) being one of the most common causes [7].

SSI represents a significant healthcare cost both directly and indirectly [3]. Studies in the UK found that treatment for SSI costs between £814 and £6626 per patient [4]. Wound complications cause high rates of morbidity, prolonged postoperative length of stay and increased readmission rates. Furthermore, it can lead to a delay in further treatment in those undergoing adjuvant chemotherapy and radiotherapy [4]. A significant mortality risk of 3% exists for those with surgical site infection, which is directly related to SSI occurrence in 75% of cases [8].

Current perioperative guidelines for the prevention of SSI in Ireland include hair removal with clippers, correct usage and timing of antibiotic prophylaxis, use of appropriate skin preparation and maintenance of perioperative normothermia and normoglycemia [7]. Similar guidelines are replicated worldwide [6]. Despite these methods, rates of SSI remain high. To date, research has been conducted to further reduce SSI with techniques such as application of topical antimicrobial agents, use of debriding agents, wound protectors and various dressing types to prevent infection and stimulate wound healing [9-13].
The incidence of wound complications after laparotomy is amongst the highest in surgical practice particularly in colorectal surgery, where incidence of SSI is found to be as high as 45% [2,14-16]. SSI occurs in the absence of perforation, representing a risk to any patient undergoing bowel resection [17]. The most frequent causative organisms are those found in the gastrointestinal tract, suggesting that infection develops from contamination of the wound by intraluminal organisms [5]. Mechanisms to clear pathogens from the wound have been proposed to reduce the incidence of surgical site infection [5].

Negative pressure wound therapy (NPWT) is a model of therapy used in wound care since the 1990s and was originally introduced as a novel method of management for chronic open wounds [18,19]. NPWT consists of a pump attached to foam or gauze dressing via a tubing system. The device generates either intermittent or continuous negative pressure ranging from 20-125 mmHg and collects fluid away from the wound [16,20]. Its mechanism of action includes reducing oedema, promoting blood flow and angiogenesis, draining exudate and contracting wound edges [21-24]. Its success in this area has lead to its introduction in other areas of wound care such as acute open wounds [25], particularly in the setting of trauma and more recently, in closed postoperative incisions. Initially trialled in orthopaedic surgery, “incisional NPWT” has shown promising results in reduction of SSI rates across vascular, cardiothoracic, plastic and abdominal surgery [26-29].

Multiple studies and reviews have been conducted to assess efficacy, cost-effectiveness and overall treatment benefit of closed incision NPWT (ciNPWT) [9,15,16,20,23,26-34]. To our knowledge, this is the first literature review to assess the use of ciNPWT in open abdominal surgery.

**Aims and Objectives**

**Primary aim**

To assess the effect of negative pressure wound therapy used over closed incisions in open abdominal surgery.

**Secondary aims**

1) To assess the impact of SSI in abdominal surgery 2) to assess current risk-reduction strategies in prevention of SSI in abdominal surgery 3) to assess cost-savings associated with the use of ciNPWT 4) to assess potential complications associated with the use of ciNPWT in abdominal surgery.

**Materials and Methods**

**Data search**

PubMed and Google Scholar search engines were used to identify relevant studies published between Jan 2006 - Dec 2017. The search was conducted from November 2017 - January 2018. Keywords included the terms “incisional negative pressure wound therapy”, “vacuum therapy”, “vacuum assisted closure”, “closed incision”, “closed wound”, “topical negative pressure”, “negative pressure therapy”, “NPWT”, “INPWT”, “Prevena”, “PICO”, combined with terms; “abdominal surgery”, “laparotomy”, “abdomen”, “general surgery”.

A further search was performed to identify risk-factors and epidemiology of surgical site infection using the terms; “surgical site infection”, “SSI”, “surgical site event”, “wound complication(s)”, “surgical wound dehiscence”, “prevention”.

Additional search terms were identified from the keywords of relevant articles identified. A “snowball” search method was utilised (continued search of relevant references found in the literature). Systematic, literature reviews and meta-analysis in the area of interest were also identified for comparison.

**Inclusion criteria**

Studies were included if they met the following search criteria: 1) Studies comparing closed incisional negative pressure wound therapy (ciNPWT) to standard dressings in abdominal surgery, 2) study participants >18 years, 3) human studies, 4) studies in English, 5) full-text articles, 6) primary/secondary end-point of surgical site event (SSE)/surgical site infection (SSI) (Table 1).

**Exclusion criteria**

Exclusion criteria included 1) negative-pressure wound therapy over open wounds, 2) use of negative pressure wound therapy in wound management in other surgical specialties, 3) negative pressure wound therapy for existing wound issues or abdominal wall reconstruction, 4) preclinical or animal studies, 5) paediatric studies, 6) non-comparative study design (Table 1).

**Data extraction**

Following removal of duplicate records, articles were screened for relevance. Abstracts and full articles deemed eligible were assessed. Remaining publications were read to ensure they met inclusion and exclusion criteria. The references of suitable articles were searched for additional articles that may fit the criteria. Data of interest included 1) year of publication 2) inclusion/exclusion criteria 3) study design 4) postoperative follow-up 5) patient characteristics 6) type of surgery 7) incidence and type of postoperative wound complications.

**Results**

Initial search of the databases identified 4714 results. After removing duplicates and application of inclusion and exclusion criteria, a total of nine studies remained. Studies are described in Table 2.

The review identified five retrospective and four prospective trials containing a total of 1470 participants. Of those, 454 received NPWT versus 1016 undergoing conventional treatment. Vacuum-assisted closure (V.A.C, KCI, San Antonio, TX) was the most common type of negative pressure therapy to be administered (n=4). All studies followed patients for a minimum of 30 days (n=9) Five studies assessed NPWT in those at high risk of SSI, including abdominal oncologic resection for colorectal, pancreatic and peritoneal disease, oncologic pancreaticoduodenectomy, oncologic gynaecologic resection and bowel resection/stricturoplasty for Crohn’s disease. Four studies assessed open colorectal surgery only. Duration of NPWT ranged from 3 to 7 days. Four studies assessed solely elective surgery, with the rest assessing a mix of elective and emergency surgery. Most studies assessed clean or clean-contaminated operations (n=7).

Across all studies, 118 patients receiving NPWT experienced postoperative wound complications, with the majority being superficial infections requiring oral antibiotic therapy only. All studies found NPWT to prevent surgical site infection and this was statistically significant in 8 of 9 studies (p<0.05).

**Discussion**

**Impact of surgical site infection**

Surgical site infections affect approximately 25% of those...
undergoing surgical procedures and are the second most common healthcare associated infection [38]. Wound complications, specifically SSI, are common after open abdominal surgery resulting in some of the highest rates amongst surgical specialties [14,32,39,40].

The economic burden of surgical site complications is huge, both from direct cost and from impact on length of stay and readmission rates [1,26]. A study by Wick et al. demonstrated a 30-day SSI rate of 18.9% in colorectal surgery; the presence of SSI doubling the risk of readmission. This was associated with a median cost of $12835 per readmission [1]. Indirect cost is also accrued from the long-term impact of surgical site events (SSE), which leads to morbidity in the form of chronic wound issues and incisional hernia [41]. The impact is apparent both on the healthcare system and on the patient, with many reporting adverse effects on their quality of life following wound complications and is most evident in those requiring further surgical intervention [42].

Identifying risk factors for SSI

Multiple strategies have been developed to target high-risk patients, identify operations and recognise intraoperative factors, which may lead to the development of wound complications. These are described in Table 3.

Willy et al. performed a literature review across surgical specialties and identified patient-related, operation-related and specialty-related factors leading to the development of SSI. Comorbidities most frequently cited as risk factors for SSI include male gender, diabetes mellitus, ASA grade ≥ 3, BMI ≥ 30, hypoalbuminemia, renal disease, active alcoholism, smoking, corticosteroid use and immunosuppression. Surgical factors include prolonged operation time, emergency operation, re-operation and increased intraoperative blood loss. They also identified certain operations carrying a higher risk of wound issues; in general surgery, this included any open procedures and incisional hernia repair [38].

Specific to colorectal surgery, Wick et al. analysed 1646 patients undergoing colon or rectal resection and identified BMI ≥ 30 (p=0.008), platelet count <150/microl (p=0.021), age > 55 (p=0.045) and operation duration >180 min (p=0.034) as statistically significant risk factors for SSI [14]. Similar findings have been replicated by other authors [26,27]. These results are useful in identifying high-risk patients, but relatively small patient cohorts in these studies could not be used to develop a risk reduction tool.

Using data obtained from the American College of Surgeons National Surgical Quality Improvement Programme (ACS-NSQIP), Walraven et al. proposed a risk scoring system (Site Infection Risk Score) to identify patient related and procedure related predictors for SSI. Whilst this was validated, it was found to be limited in its application in routine practice [43]. A similar, easy-to-use predictive tool was also developed by Hedrick et al but has not been validated in practice [44]. To date, a clinically useful tool to target those at risk still remains to be seen.

Current prevention mechanisms

National Institutes of Health have recognised the need to decrease SSE and have developed guidelines for the reduction of postoperative surgical site occurrences. In 2006, the US Centers for Medicare & Medicaid Services developed the Surgical Care Improvement Project, which aimed to reduce SSI incidence and associated morbidity [45]. This introduced seven perioperative measures including administration of prophylactic intravenous antibiotics within 1 hr of incision, correct antibiotic selection, cessation of prophylactic antibiotics within 24 hr, appropriate hair removal, perioperative euglycemia, normothermia and removal of urinary catheters within 48 hr. Similar guidelines have been introduced in Ireland and much of this practice is now routine [7].

In addition to this, the development of the ACS-NSQIP has been found to reduce SSI rates and costs associated with them. Analysis
NPWT: Negative Pressure Wound Therapy; CG: Control Group

**Table 2: Results of studied included.**

<table>
<thead>
<tr>
<th>Study Name</th>
<th>Authors</th>
<th>Study Design</th>
<th>Study Period</th>
<th>No. of participants</th>
<th>NPWT Device</th>
<th>Type of surgery</th>
<th>Follow up</th>
<th>Outcome (rate of SSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevention of SSI in High-Risk Patients with Laparotomy Incisions using NPT [26]</td>
<td>Blackham et al.</td>
<td>Retrospective</td>
<td>July 2006 – Sept 2010</td>
<td>87 104</td>
<td>VAC</td>
<td>Oncologic resections (elective)</td>
<td>30 days</td>
<td>6.0% (n=11) NPWT vs. 35.5% (n=68) CG (p=0.015)</td>
</tr>
<tr>
<td>Incisional Negative Pressure Wound Therapy Reduces SSI in Open Colorectal Surgery [27]</td>
<td>Bonds et al.</td>
<td>Retrospective</td>
<td>Aug 2009 – Aug 2011</td>
<td>222 32</td>
<td>VAC</td>
<td>Colorectal (elective and emergency)</td>
<td>30 days</td>
<td>12.5% (n=32) NPWT vs. 29.3% (n=74) CG (p=0.05)</td>
</tr>
<tr>
<td>Primary Placement of Incisional NPWT at Time of Laparotomy for Gynecologic Malignancies [35]</td>
<td>Lynam et al.</td>
<td>Retrospective</td>
<td>Oct 2009 – March 2014</td>
<td>208 22</td>
<td>VAC</td>
<td>Oncologic gynaecology resections (elective)</td>
<td>30 days</td>
<td>4.54% (n=1) NPWT vs. 7.21% (n=15) CG (p=0.40)</td>
</tr>
<tr>
<td>New Advances in NPWT for Surgical Wounds of Patients Affected with Crohn’s disease [31]</td>
<td>Pellino et al.</td>
<td>Prospective RCT</td>
<td>Jan 2010 – Dec 2012</td>
<td>25 25</td>
<td>PICO</td>
<td>Open abdominal (elective)</td>
<td>12 months</td>
<td>8% (n=2) NPWT vs. 48% (n=12) CG (p=0.004)</td>
</tr>
<tr>
<td>Closed incision NPT in High-risk General Surgery Patients Following Laparotomy [32]</td>
<td>Zaidi et al.</td>
<td>Retrospective</td>
<td>Oct 2010 – March 2012</td>
<td>112 69</td>
<td>PREVENA</td>
<td>Open abdominal (elective and emergency)</td>
<td>30 days</td>
<td>2.9% (n=2) NPWT vs. 20.5% (n=23) CG (p=0.0009)</td>
</tr>
<tr>
<td>Preventative NPWT over closed incisions in general surgery: Does age matter? [30]</td>
<td>Pellino et al.</td>
<td>Prospective RCT</td>
<td>Sept 2012 – May 2014</td>
<td>25 25</td>
<td>PICO</td>
<td>Colorectal surgery</td>
<td>3 months</td>
<td>8% (n=2) NPWT vs. 44% (n=11) CG (p=0.008)</td>
</tr>
<tr>
<td>Prophylactic Negative Pressure Dressing Use in Closed Laparotomy Wounds Following Abdominal Operations [33]</td>
<td>O’Leary et al.</td>
<td>Prospective RCT</td>
<td>Feb 2013 – Apr 2014</td>
<td>25 24</td>
<td>PICO</td>
<td>Open abdominal (emergency and elective)</td>
<td>30 days</td>
<td>8.3% (n=2) NPWT vs. 32.0% (n=8) CG (p=0.043)</td>
</tr>
<tr>
<td>The Use of NPWT to prevent post-operative SSI following pancreaticoduodenectomy [36]</td>
<td>Burkhardt et al.</td>
<td>Retrospective</td>
<td>Oct 2014 – May 2016</td>
<td>274 120</td>
<td>IVAC</td>
<td>Open pancreatico-duodenectomy (elective)</td>
<td>90 days</td>
<td>3.6% (n=14) vs. 16.2% (n=64) (p=0.015)</td>
</tr>
<tr>
<td>Reducing Surgical Site Infection With NPWT After Open Abdominal Surgery [37]</td>
<td>Li et al.</td>
<td>Prospective RCT</td>
<td>May 2015 – Dec 2015</td>
<td>38 33</td>
<td>VSD</td>
<td>Open abdominal (elective and emergency)</td>
<td>30 days</td>
<td>3.0% (n=1) NPWT vs. 23.7% (n=9) CG (p=0.031)</td>
</tr>
</tbody>
</table>

**Table 3: Factors affecting risk of SSI [38].**

<table>
<thead>
<tr>
<th>Patient Factors</th>
<th>Intraoperative Factors</th>
<th>Specialty Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Emergency operation</td>
<td>Open operation (gynaecological, colorectal, urological)</td>
</tr>
<tr>
<td>Male gender</td>
<td>Prolonged operative time</td>
<td>Incisional hernia operation</td>
</tr>
<tr>
<td>Comorbidities (ASA &gt;3)</td>
<td>Reoperation</td>
<td></td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>Increased intraoperative blood loss</td>
<td></td>
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<tr>
<td>Malnutrition (albumin &lt;30)</td>
<td>Wound under tension</td>
<td></td>
</tr>
<tr>
<td>Corticosteroid use/immunosuppression</td>
<td>Intraoperative contamination</td>
<td></td>
</tr>
<tr>
<td>CKD</td>
<td>Smoking history</td>
<td></td>
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<tr>
<td>Active C2H5OH excess</td>
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</tbody>
</table>

of cost-savings in one centre found a reduction of 2.5 million dollars attributable to a decline in SSI rates over a two year period [46]. A ten-hospital collaborative formed in Tennessee looked at all NSQIP data across ten hospitals over two separate periods. They reported a decline in deep incisional SSI (RR 0.82, 95% CI 0.63 to 1.06) and a significant decrease in superficial site infections of 18.9% (RR 0.81, 95% CI 0.71 to 0.92) due to introduction of SSI programmes. They proposed that this was potentially limited by a "Hawthorne effect" and that decreases in SSI could not be directly attributable to improvement programmes alone, but are more likely due to awareness of practice [47].

The true impact of these reduction measures on the rate of SSI is controversial and remains uncertain [48,49]. Alternative methods to reduce wound issues have yielded mixed results with limited efficacy. These include use of gentamycin-soaked sponges placed in the surgical wound [10], use of subcutaneous drains [11], use of wound protectors [12,13], and use of topical antimicrobials [50]. As yet, no single method has been found to be useful in prevention of SSI in those undergoing open abdominal surgery.

**Use of negative pressure wound therapy in closed incisions**

Since its introduction in 1997, NPWT has shown promising results in the treatment of chronic and otherwise difficult-to-manage wounds [18,19]. Its efficacy was confirmed in a meta-analysis published by Cochrane, which assessed several randomised controlled trials comparing ciNPWT to conventional wound management across specialties and demonstrated improvement in wound size and reduction in time to healing with NPWT [51].

Studies assessing the mechanism of NPWT suggest effectiveness through a number of methods. Firstly, increased lymphatic clearance leads to reduced tissue oedema and removal of excess fluid from the wound. Contraction of wound edges decreases lateral wound
tension thereby preventing stress at the incision site, improving scar appearance and risk of wound breakdown. Finally, regions of hypoperfusion at the wound edges caused by NPWT stimulate production of angiogenic vascular endothelial growth factor increasing blood flow to the wound and deposition of granulation tissue [21,22,24].

The success of NPWT has led to its introduction in other wound management scenarios, initially in the setting of acute open wounds and most recently as a preventative measure over closed surgical incisions. Use of ‘incisional’ NPWT was first trialled in orthopaedic surgery by Gomoll et al. [23]. They demonstrated a reduction in SSI with use of incisional vacuum-assisted therapy in high-risk patients undergoing a multitude of orthopaedic procedures including revision hip arthroplasty, femoral and tibial fracture fixation, and foot and ankle trauma [23]. Closed-incision negative pressure wound therapy has since shown promising results across a range of surgical specialties [28,29,33].

Most recently, ‘closed-incision Negative Pressure Wound Therapy (ciNPWT) has been introduced in open abdominal surgery. Current guidelines recommend covering incisions with a sterile wound dressing prior to removal of surgical drapes at the end of the procedure, leaving the dressing intact for 48 hrs [7]. Laparotomy poses an increased risk of SSI and for this reason the mechanism of NPWT provides potential for the successful prevention of surgical site complications in this setting. Additional prophylactic benefits including sealing of the wound to exogenous bacteria and contamination are particularly useful in the setting of laparotomy with stoma formation [16,32].

Current evidence base for ciNPWT use in open abdominal surgery

Studies assessing the efficacy of ciNPWT in open abdominal surgery have demonstrated overall rates of SSI ranging from 14.1% to 28.0% [31,37]. Eight of the nine trials identified showed a statistically significant reduction in SSI associated with the use of ciNPWT. Moreover, most infections in those treated with NPWT were superficial and did not require further intervention. O’Leary et al. assessed 50 patients undergoing elective or emergency open abdominal procedures, with results showing only two SSI in the NPWT treatment group, all of which were superficial infection versus 8 in the control group [33]. Li et al. also found promising results in patients undergoing mostly elective open operations including colorectal resection, primary ventral hernia repair and intra-abdominal tumour resection. They demonstrated a decrease in SSI rate of 3.0% vs. 23.7% (p=0.031) with only one superficial infection in the ciNPWT group [37]. These studies included only small patient cohorts and so cost savings and overall benefit of NPWT across all patient groups is difficult to ascertain.

Most ciNPWT studies identified included only patients with risk factors for SSI, including malignancy, smoking history, immunosuppression, malnutrition, emergency surgery and inflammatory bowel disease and obesity [26,27,30,32,35-37]. Zaidi et al. analysed use of NPWT in clean contaminated or contaminated open colorectal surgery and demonstrated a reduction in SSI, with only two patients in the ciNPWT developing wound infection post operatively [32]. Selvaggi et al. conducted a study assessing use of ciNPWT in Crohn’s patients undergoing elective bowel resection or strictureplasty and found that NPWT was protective against SSI in this patient cohort (OR 0.21 95%CI 0.15-0.5, P=0.005). Moreover use of PICO dressings was found to prevent infectious SSE in patients on corticosteroid therapy (p=0.001) [31]. Positive results were also demonstrated by Blackham et al. who studied high-risk oncology patients undergoing elective surgery for colorectal, pancreatic and peritoneal malignancy. They found not only a reduction in SSI (6.7% versus 19.5% p=0.015) but also a decline in the rate of total complications (24% vs. 35.6% p=0.050). Of interest, they noted a higher rate of deep incisional infections in those in the NPWT group (n=5 vs. n=0). This was not statistically significant but may represent systemic physiological stresses resulting from decreased perfusion of the fascia, which cannot be prevented by use of incisional NPWT [26].

Additional benefits proven in the studies included a reduction in length of stay in patients treated with ciNPWT, as demonstrated by O’Leary et al. (6.1 days versus 14.7 days, p=0.019) and replicated in a study by Pellino et al. (7.1 vs. 12 days, p=0.001) [30,33]. There was also a reduction in rates of seroma in patients undergoing colorectal resection (8% vs. 40%, p=0.02) and in patients undergoing bowel resection or stricturoplasty for Crohn’s disease [31].

Only one study did not find a statistical benefit to use of ciNPWT in laparotomies. Lynam et al. performed a retrospective review of patients undergoing laparotomy for gynaecological malignancy [35]. Whilst there was a reduction in SSI in the NPWT, no statistical difference was demonstrated (p=0.40). It was noted that as a retrospective study, selection bias existed and those receiving NPWT were more likely to be obese (30.67 in control group versus 41.29 in NPWT group, p<0.001) [35]. This still represents a potential therapeutic benefit as reduction was still seen even in this high-risk group.

No adverse effects of ciNPWT were reported in any study analysed. In previous studies, such as that by Conde-Green et al., intact skin has become excoriated, irritated or bruised if exposed directly to the polyurethane foam of the NPWT dressing [9]. This was not found to be the case in any study assessed and is reduced by a barrier between the skin and the foam, which is found in most pre-made ciNPWT dressings [27]. Burkhart et al. found that those with iVAC dressing were more likely to have a pancreatic fistula; however those selected for VAC therapy were at increased risk of fistula formation [36]. There is also a theoretical risk that the device may conceal an SSI however cellulitis of the surrounding skin should be visible with most ciNPWT dressings. Selvaggi et al. found ciNPWT to be well tolerated by patients, included those sent home with the device, of which none required unscheduled follow-up to manage the device or dressing [31].

Multiple systematic reviews and meta-analysis have been produced to assess incisional negative-pressure wound management. Most have pooled data from all specialties and have included case-series, observational studies as well as randomised controlled trials leading to heterogeneity of data [20,34,52,53]. Strugala et al. assessed use of PICO across orthopaedic, abdominal, colorectal and obstetric specialties, including 6 observational studies and 10 randomised trials [53]. They demonstrated a significant reduction in SSI across all specialties (RR 0.32, P<0.0001). Sandy-Hodgetts et al. analysed eight studies including two open abdominal surgery trials and found results in favour of ciNPWT in preventing SSI but conflicting results for reduction of wound dehiscence and seroma. They concluded benefits of ciNPWT in those deemed high-risk [20]. Similar results were published in a meta-analysis by Semsarzadeh et
al, which demonstrated a risk reduction (RR) of 29.4% with the use of NPWT [52]. Scalise et al. also found a decrease in the incidence of infection, sero-haematoma and re-operation rates with the use of closed-incision NPWT [34]. Only one systematic review from Pellino et al. focused on open abdomen trials and analysed colorectal studies specifically. They included five studies with a total of 493 patients of whom 147 received closed incision NPWT. They concluded in favour of use of cinPWT in colorectal surgery patients [16].

Future considerations for cinPWT use

To date, cinPWT has shown potential as a safe and effective treatment modality however the setting for its use remains unclear. The major downside is the associated cost of closed-incision negative pressure wound management systems, which are more expensive than traditional standard wound management. The PICO disposable incisional vacuum unit costs between £300 - £600 (PICO, Smith & Nephew, London, UK), and the Prevena system costs £500 (V.A.C. therapy KCI, San Antonio, TX). These costs can be somewhat defended when considering SSI can result in a mean increase in healthcare costs of 115% [3] but cost-effectiveness of cinPWT in open abdominal surgery is yet to be established.

Recent advice from the National Institute for Health and Care Excellence recommends use of PICO for those at risk of developing surgical site infection or for treatment surgical site complications. Specifically, PICO is a cost effective alternative to care for closed surgical incision. Whilst the cost of PICO ranges from £126.88 - £145.68 per dressing, they suggest that the additional cost can be offset by the potential reduction in surgical site infection, particularly in those at high risk where the cost of surgical site infection in a general surgical patient can be as high as £14,000 [54,55].

As aforementioned, identification of those at high-risk is also unclear. Many studies have proposed those at increased risk of SSI and most likely to benefit from cinPWT including presence of diabetes mellitus [27], incision length >20 cm, ASA >2 grade (37), age >65 yrs and stoma formation [2]. Willy et al. proposed consensus recommendations and an algorithm to identify those most likely to benefit from NPWT however this is yet to be rationalised in clinical practice [38]. More work is needed in this area to identify those who would benefit most from cinPWT.

PICO and Prevena systems have been developed specifically for use in closed-incision situations however limitations to their use have been established. The Prevena system contains a canister, which can be cumbersome for patient use and can only hold 45 ml of fluid. It is also significantly more expensive than standard conventional therapy. The PICO dressing becomes ineffective if saturated with over 200 ml of exudate. Furthermore, neither system has clearly defined ‘discontinuation criteria’ nor this may vary with the patient and type of incision. These points represent potential pitfalls of the devices and their usage [33,34].

Little prospective data is currently available to assess use of cinPWT and this is a potential area of development. At present, two trials are on-going which may shed more light on use of incisional vacuum therapy. The NEPTUNE trial is a single-institution, prospective, randomised, open blinded endpoint trial, which aims to recruit approximately 300 patients undergoing elective open colorectal surgery to either Prevena therapy or standard wound management. The primary outcome measure is SSI within the first 30 post-operative days, with secondary aims including length of stay, number of readmissions, cost and need for public health care.

The PONIY trial is a similar randomized, controlled observer multicenter clinical trial assessing the use of Prevena in open elective colorectal surgery.

Conclusion

cinPWT is a promising therapy for use in open abdominal surgery. It has been shown to have potential in reducing the rate of SSI in this area however, its effect on other areas of wound complications remains uncertain. Due to the potential for publication selection bias and heterogeneity of data, no conclusions can be drawn as to which patient cohorts will most benefit from this therapy. Further multicenter, prospective studies are needed to assess cost-benefit, appropriate patient-selection, duration of treatment and efficacy of closed incision negative pressure therapy in open abdominal surgery.

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