



Contents lists available at ScienceDirect

## The American Journal of Surgery

journal homepage: [www.americanjournalofsurgery.com](http://www.americanjournalofsurgery.com)

# Incisional wound VAC and risk-adjusted SSI rates in colorectal surgery: A tertiary centre experience

Mitchell A. Webb\*, Michael S. Bleszynski, Leo Chen, Jack Chiu, Adam Meneghetti, Ormond N. Pantou

University of British Columbia Department of Surgery, Division of General Surgery, 2775 Laurel Street, 11th Floor, Vancouver, B.C. V5Z 1M9, Canada

## ARTICLE INFO

### Article history:

Received 8 November 2018

Received in revised form

13 December 2018

Accepted 14 December 2018

## ABSTRACT

**Background:** In colorectal surgery, indications for incisional negative pressure wound therapy (iVAC) remain unclear. We sought to compare rates of surgical site infection (SSI) in patients who received iVAC or standard sterile dressing (SSD).

**Methods:** Institutional colorectal NSQIP data between 2014 and 2018 was reviewed. SSI rates were compared between iVAC and SSD cohorts using the NSQIP surgical risk calculator (NSQIP SRC) for risk-adjusted analysis. Secondary outcomes included other wound complications, morbidity, mortality, disposition destination and overall length of stay.

**Results:** 145 patients received iVAC while 544 received SSD. SSI was greater in iVAC than SSD (17% vs 9%,  $p = 0.009$ ). iVAC was independently associated with SSI (OR 2.3, 95% CI 1.3–3.9). The presence of a colostomy strengthened this relationship. There was no difference in secondary outcomes.

**Conclusion:** iVAC was independently associated with SSI with risk-adjusted analysis. This relationship was stronger in patients with a colostomy.

© 2018 Elsevier Inc. All rights reserved.

## Introduction

Surgical site infections (SSIs) rank as the most common health-care-associated infections in western countries, accounting for over 20% of all.<sup>1,2</sup> The incidence of SSI in America has been estimated between 160 and 300 thousand, with up to 60% regarded as preventable and incurring significant cost due to prolonged hospitalization and readmission.<sup>3,4</sup> Furthermore, SSI development is an independent risk factor for post-operative morbidity and mortality.<sup>2,5</sup> This is a particular problem in clean-contaminated wounds, such as those in colorectal surgery, which inherently carry a high rate of SSIs ranging from 20% to 48%.<sup>6–8</sup> In colon cancer, post-operative complications are known to be associated with a lack and delay of adjuvant chemotherapy.<sup>9</sup>

With the rise of patient-specific SSI risk factors such as obesity, diabetes, increased age, and other comorbidities, clinicians continue to search for techniques to mitigate SSI risk. This has led to the study of prophylactic incisional Negative Pressure Wound Therapy (iVAC) in high risk wounds. To date, many groups have

published encouraging results, demonstrating an overall risk reduction between 0.40 and 0.58 in meta-analyses.<sup>10–12</sup> Yet, there still remains limited evidence for iVAC in colorectal literature and further study is needed in order to understand the indications and characteristics of iVAC therapy in this population.<sup>13</sup> The primary objective of this study was to analyze rates of SSI between iVAC and standard dressings in colorectal surgery. Secondly, we sought to compare rates of seroma/hematoma formation, wound separation, morbidity, mortality, disposition destination, and hospital length of stay.

## Methods

Data was obtained from the institutional NSQIP program after the study received approval from the UBC research ethics board. This study did not receive funding or sponsorship.

Data was prospectively collected by NSQIP Surgical Clinical Reviewers (SCRs) between Jan 1st, 2014 and Dec 31st, 2017. In addition to standard demographic data and comorbidities, operative characteristics and 30-day outcomes were recorded as part of the standard set of NSQIP variables.<sup>14</sup> In addition to these variables, the type of wound dressing was also documented. Thirty-day follow up was conducted via telephone interview or written correspondence

\* Corresponding author.

E-mail address: [Mitchell.webb@alumni.ubc.ca](mailto:Mitchell.webb@alumni.ubc.ca) (M.A. Webb).

with patients. SCRs recorded the occurrence of common complications such as: SSI, seroma/hematoma, wound separation, post-operative length of stay, disposition destination, mortality, pneumonia, UTI, etc ... SSIs were defined according to CDC criteria.<sup>15</sup> In summary, a superficial SSI involved only skin and subcutaneous tissue and demonstrated either purulent drainage, cultured organisms, or was opened by the surgical team in the presence of pain, localized swelling, erythema, or heat.

Patients who received colorectal surgery during the study period and were over 18 years of age were included in the review. Cases of SSI present at time of surgery or that did not feature closure of all abdominal layers at index OR were excluded.

In elective cases, patients were managed according to an Enhanced Recovery After Surgery protocol<sup>16</sup> and surgical site prevention guidelines.<sup>17</sup> Patients received an educational pamphlet and receive pre-operative antibiotics and, depending on surgeon's preference, mechanical bowel preparation. On the morning of surgery, a carbohydrate-rich drink was provided and decolonization with mupirocin was performed if indicated. Prior to the operation, hair was removed with clippers and skin was washed with chlorhexidine alcohol solution. Patients received pre-operative IV antibiotics and were monitored to achieve normothermia and euglycemia. At time of closure, a clean instrument set was used and the surgical team changed gloves. Fascia was sutured with looped PDS, and skin was closed with staples. If indicated, maturation of an ostomy was performed after completing wound closure.

All dressings were applied under sterile conditions at the completion of the operation. iVAC was implemented in similar fashion to Gomoll's description, using the KCI V.A.C. ULTA™ Negative Pressure Wound Therapy System.<sup>18</sup> First, a skin-protecting membrane was cut to size and placed overlying the wound and surrounding skin. Then polyurethane foam was placed overlying the membrane, followed by occlusive adhesive dressings. Suction tubing was applied and connected to the dressing in order to provide 100–125 mmHg vacuum, low continuous setting. These dressings were kept intact for 3–5 days following surgery. Incisions that did not receive iVAC were covered using a standard sterile dressing (SDD): Mepore® absorbent adhesive dressing. Such dressings were removed on postoperative day 2. Following removal of dressings, all wounds were inspected daily for signs of wound complications and treated thereafter at the discretion of the team of house staff and attending surgeons.

Statistical analysis was performed using R version 3.3.3. Categorical variables were compared using chi-squared and Fischer's exact tests. Student's t-test was used for continuous data. Univariate analysis of demographic and operative variables was performed to identify risk factors for SSI. Independent variables for SSI were determined using logistic regression with backward elimination. The online ACS NSQIP Surgical Risk Calculator (NSQIP SRC) was used calculate individual SSI risk scores.<sup>19</sup> The NSQIP SRC is a clinically validated tool which estimates post-surgical outcomes based on demographic characteristics and CPT codes.<sup>20–22</sup> Results were reported as odds ratios with 95% confidence intervals. P-values less than 0.05 were deemed to be statistically significant.

## Results

Institutional NSQIP data was obtained from the period between Jan 1, 2014 and Dec 31, 2017. In total, 703 urgent and scheduled colorectal cases were performed. 14 cases did not receive complete wound closure at the index operation and, hence, were excluded. 689 cases were included for review. 145 received iVAC and 544 did not. Of all operations performed, the majority were partial colectomies (55%) and anterior or low anterior resections (35%). Open

surgery was performed in 225 cases (33%) compared to 428 (62%) cases that consisted of minimally invasive, laparoscopic-assisted, or hand-assisted approaches. 36 cases were converted from MIS to open laparotomies. The overall majority of cases were elective (69%), clean/contaminated (89%), featured primary anastomosis (76%) and were performed for malignant disease (66%). 46% of patients had an American Society of Anaesthesiologists (ASA) grade greater than 3. The average calculated risk of SSI, as predicted by the NSQIP SRC, was 8.4%, ( $\sigma$  4.5%).

As seen in Tables 1 and 2, baseline demographics and high-risk features of SSI were similar between iVAC and SSD. Characteristics such as: age, BMI, functional health status, hypertension, diabetes and other comorbidities, were equally represented in each cohort. Gender was significantly different, with proportionally fewer females receiving iVAC (37% vs 48%,  $p = 0.02$ ). An underlying malignant diagnosis was also more common with iVAC (77% vs 64%,  $p = 0.005$ ). There was no difference in the proportion of procedure type, presence of stoma, or wound classification between wound treatment groups. Average surgical duration was 187 min in each group ( $p = 0.98$ ). There was a significant difference seen with respect to surgical approach and wound protector use; iVAC was used less often after laparotomies (27% vs 41%,  $p = 0.003$ ) and more often with wound protectors (21% vs 4%,  $p < 0.005$ ). SSI-propensity, as calculated by the NSQIP SRC, was similar between treatment groups, as well.

The summary of outcomes is presented in Table 3. Superficial SSI occurred in 10% of patients. Additionally, there were 10 cases (1%) of deep SSI and 34 cases (5%) organ space SSI. Superficial SSI was significantly increased in iVAC compared to SSD (17% vs 9%,  $p = 0.009$ ). Deep and organ space SSI incidence was no different between groups. Additionally, there was no difference in secondary outcomes such as hospital length of stay (LOS), postoperative complications, discharge disposition, or 30-day mortality following surgery. The overall occurrence of seroma/hematoma and wound disruption was low (7 and 11, respectively) with 1 seroma/hematoma and 2 wound disruptions occurring in the iVAC group. Thirty-day follow-up was completed in 87.6% of iVAC and 88.4% of SSD patients ( $p = 0.90$ ).

Univariate analysis was performed on all demographic and operative characteristics to establish risk factors for SSI. The significant variables are presented in Table 4a. Notably among these, iVAC and NSQIP SRC greater than 8% were significant. To identify independent risk factors for SSI, we performed multivariate logistic regression with backward elimination, using the significant variables found in univariate analysis. As BMI, ASA, dyspnea, and sepsis are factors already used in the NSQIP SRC, these variables were not included. After iteratively excluding non-significant variables, only iVAC and NSQIP SRC were found to be significantly associated with SSI. Of patients with the same NSQIP SRC score for SSI, those treated with iVAC had over twice the odds of developing SSI (OR 2.22, 95% CI 1.27–3.79) (Table 4b).

Subgroup analysis found an increased SSI rate among patients treated with iVAC and colostomy. Of the 19 patients who received colostomy and iVAC, 9 (47%) developed SSI compared to only 10 (13%) of the 75 who received colostomy and SSD ( $p = 0.003$ ). For those who did not receive colostomy, the relationship was not significant. Of the 126 treated with iVAC, 15 (12%) developed SSI, while 37 (8%) SSIs were observed in the 467 who had SSD ( $p = 0.22$ ). Risk-adjusted logistic regression confirmed a significant association between iVAC and SSI in the colostomy group (OR 5.2, 95% CI: 1.7–17.0,  $p = 0.005$ ) and no significant association in the no-colostomy group (OR 1.7, 95% CI: 0.89–3.3,  $p = 0.09$ ). Logistic regression in the colostomy subgroup also failed to demonstrate an independent relationship between NSQIP SRC score and SSI (OR 1.0, 95% CI: 0.94–1.1,  $p = 0.44$ ). Conversely, in those who did not receive

**Table 1**  
Preoperative and demographic characteristics of iVAC vs SDD.

	All N = 689	iVAC n = 145	SSD n = 544	p
Age, years; mean (SD)	68 (13.9)	67 (12.4)	68 (14.0)	0.95
Female; N (%)	313 (45)	53 (37)	260 (48)	<b>0.02</b>
HTN; N (%)	284 (42)	62 (43)	222 (41)	0.74
BMI ≥ 30; N (%)	141 (20)	35 (24)	73 (13)	0.84
immunosuppressed; N (%)	39 (6)	9 (6)	30 (6)	0.91
Diabetes mellitus; N (%)	79 (11)	19 (13)	60 (11)	0.58
Smoker; N (%)	74 (11)	20 (14)	54 (10)	0.24
Dependent Functional Status; N (%)	15 (2)	3 (2)	12 (2)	>0.99
COPD; N (%)	27 (4)	7 (5)	20 (4)	0.69
Dialysis; N (%)	7 (1)	2 (1)	5 (1)	0.98
Disseminated cancer; N (%)	52 (8)	11 (8)	41 (8)	>0.99
CHF; N (%)	3 (0.4)	1 (1)	2 (0.4)	>0.99
Weight loss; N (%)	18 (3)	3 (2)	15 (3)	0.87
Bleeding disorder; N (%)	21 (3)	4 (3)	17 (3)	>0.99
Preoperative transfusion; N (%)	26 (4)	5 (3)	21 (4)	>0.99
Any preoperative SIRS/Sepsis; N (%)	41 (6)	8 (6)	33 (6)	0.95
ASA class; N (%)				
ASA 1	21 (3)	1 (1)	18 (3)	
ASA 2	345 (50)	79 (54)	266 (49)	
ASA 3	269 (39)	52 (36)	217 (40)	
ASA 4	54 (8)	11 (8)	43 (8)	0.25

\*SD: standard deviation, HTN: hypertension, BMI: body mass index, COPD: chronic obstructive pulmonary disease, CHF: congestive heart failure, SIRS: systemic inflammatory response syndrome, ASA: American Society of Anaesthesiologists.

**Table 2**  
Operative characteristics: iVAC vs SDD.

	All N = 689	iVAC n = 145	SSD n = 544	p
Procedure; N (%)				
Partial colectomy	376 (55)	71 (49)	305 (56)	
Subtotal colectomy	12 (2)	2 (1)	10 (2)	
Total proctocolectomy	9 (1)	2 (1)	7 (1)	
LAR/Ant resection	243 (35)	59 (41)	184 (34)	
APR	29 (4)	6 (4)	23 (4)	
Proctectomy	9 (1)	3 (2)	6 (1)	
Exent	11 (2)	2 (1)	9 (2)	0.73
Elective; N (%)	478 (69)	105 (73)	373 (69)	0.43
Approach; N (%)				
Open	225 (33)	33 (23)	192 (35)	
Converted to open	36 (5)	6 (4)	30 (6)	
MIS/Lap-assisted/Hand-assisted/Robotic	428 (62)	106 (73)	322 (59)	<b>0.009</b>
Stoma; N (%)				
Anastomosis	527 (76)	108 (75)	419 (77)	
Ileostomy	66 (10)	17 (12)	49 (9)	
Colostomy	94 (14)	19 (13)	75 (14)	0.60
Wound classification; N (%)				
Clean-contaminated	612 (89)	131 (91)	451 (89)	
Contaminated	30 (4)	5 (4)	25 (4)	
Dirty	46 (7)	8 (6)	38 (7)	0.56
OR duration; min (SD)	187 (89)	187 (89)	187 (91)	>0.99
Wound protector; N (%)				
Unknown	514 (74)	90 (62)	424 (78)	
No	122 (18)	25 (17)	97 (18)	
Yes	53 (8)	30 (21)	23 (4)	<b>&lt;0.0001</b>
Diagnosis; N (%)				
Neoplasm (malignant)	453 (66)	109 (77)	344 (64)	
Neoplasm (benign)	90 (13)	10 (7)	80 (15)	
Non-neoplastic	139 (20)	23 (16)	116 (21)	<b>0.008</b>
NSQIP SRC; % (SD)	8.4 (4.5)	8.2 (4.5)	8.4 (4.6)	0.54

\*SD: standard deviation, NSQIP SRC: National Surgical Quality Improvement Program Surgical Risk Calculator.

colostomy, NSQIP SRC score and SSI were significantly associated (OR 1.1, 95% CI: 1.0–1.2, p = 0.001).

## Discussion

Since the development of modern negative pressure wound therapy (NPWT) systems in the 1990s, there has been mounting evidence in clinical and basic science literature to support their use

in complex wounds.<sup>23</sup> Although not fully elucidated, proposed mechanisms for improved wound healing include mechanical support of opposing wound edges, an increase in local perfusion, stimulation of angiogenesis, reduction of edema and removal of inflammatory mediators.<sup>24–27</sup> Furthermore, the occlusive dressing used to seal the vacuum provides a theoretical barrier to contamination.

Gomoll was the first to describe the application of negative

**Table 3**  
Outcomes: iVAC vs SSD.

	All N = 689	iVAC n = 145	SSDn = 544	p
Superficial SSI; N (%)	71 (10)	24(17)	47 (9)	<b>0.009</b>
Deep SSI; N (%)	10 (1)	2 (1)	8 (1)	>0.99
Organ Space SSI; N (%)	34 (5)	6 (4)	17 (5)	0.75
<sup>a</sup> Seroma/Hematoma; N (%)	7 (1)	1 (1)	6 (1)	>0.99
<sup>b</sup> Wound disruption; N (%)	11 (2)	2 (1)	9 (2)	>0.99
LOS (days)	11 (2)	13 (9)	10 (2)	0.32
Discharged Home; N (%)	638 (93)	136 (94)	500 (92)	0.56
Pneumonia; N (%)	34 (5)	9 (6)	25 (5)	0.56
UTI; N (%)	20 (3)	1 (1)	19 (3)	0.13
Sepsis; N (%)	31 (4)	7 (5)	24 (4)	>0.99
Mortality in 30 days; N (%)	13 (2)	3 (2)	10 (2)	>0.99
30-day f/u; N (%)	608 (88)	127 (88)	481 (88)	0.90

\*SSI: surgical site infection, LOS: length of stay, UTI: urinary tract infection, 30-day f/u: thirty day follow up.

<sup>a</sup> Seroma/hematoma was poorly recorded with 74% “unknown” data.

<sup>b</sup> Wound disruption was poorly recorded with 74% “unknown” data.

pressure therapy to an intact surgical wound. His group reported a series of 35 high-risk wound treated with –75 mmHg for 3–5days after orthopaedic surgery and found no SSIs with 3-month follow up.<sup>18</sup> The first randomized trial was conducted by Stannard et al.<sup>28</sup> After surgery for high-energy orthopaedic trauma, iVAC was found to exhibit near-significant results with respect to SSI and superficial dehiscence. iVAC has been studied in multiple settings and gained acceptance as prophylactic management of high-risk wounds.<sup>29,30</sup> In an effort to consolidate this body of knowledge, the WHO commissioned De Vries et al. to conduct a meta-analysis of available iVAC literature.<sup>11</sup> They found encouraging results for iVAC in the reduction of SSI incidence (OR 0.56, 95% CI: 0.32–0.96). However, when assessing the quality of evidence available, their group had to conclude it was of low-grade given the risk of bias and patient selection.

In 2017, a review by Strugula et al. focused on one type of iVAC system (PICO™ Single Use Negative Pressure Wound Therapy System, Smith and Nephew).<sup>10</sup> Reviewing 10 RCTs and 6 observational studies, SSI rates were demonstrably reduced with iVAC (OR 0.43, 95% CI: 0.32–0.57) as were rates of dehiscence and duration of hospitalization. Only three of these studies, however, dealt with colorectal surgery. O’Leary’s trial featured 50 patients and failed to demonstrate a significant difference in SSI rate (12% vs 32%,  $p = 0.07$ ).<sup>31</sup> Two observational studies by Pellino and Selvaggi were also based on small numbers and had remarkable high SSI rates in control groups. Yet, they found significance in the reduction of SSI rates with iVAC (8% vs 44%;  $p = 0.01$ , 8% vs 48%,  $p = 0.005$ , respectively).<sup>7,32</sup>

Shen and Blackham’s group completed a 4-year trial involving 265 cases of abdominal oncologic surgery.<sup>33</sup> Previously, they had

**Table 4b**  
Multivariate analysis: Independent factors for SSI.

	Odds Ratio	95% CI	p-value
NSQIP SRC score	1.10	1.06–1.16	0.00002
iVAC	2.22	1.27–3.79	0.004

AIC 438.26.

R-squared 0.045.

published a retrospective study significantly demonstrating lower SSI rates in clean-contaminated wounds after iVAC compared to SSD.<sup>34</sup> However, when analysed in a prospective trial, they failed to show a difference between superficial and deep SSIs in iVAC and SSD dressings (12.9% vs 12.8%;  $p > 0.99$ , 3.0% vs 3.0%;  $p > 0.99$ , respectively). They noted that, in their trial, control dressings were kept in situ for 4 days, as opposed to 2 days in their first study. This led the authors to question if duration of wound coverage is a confounding factor.

Most recently, Curran’s group published a large observational study using NSQIP data and a validated scoring tool for SSI risk adjustment.<sup>35</sup> Selecting patients at high risk for SSI who received colorectal surgery through a laparotomy, they included 315 patients for analysis. The Prevena™ incision management system was associated with lower SSI rates than the control dressing (6.5% vs 15.1%,  $p = 0.05$ ), with even greater effect seen after SSI risk matching (6.5% vs 25.3%,  $p < 0.01$ ). Two trials are nearing completion and will serve to clarify the role of iVAC after colorectal surgery.<sup>37,38</sup>

To our knowledge, this study is the first to report increased rates of SSI with iVAC use. Even after adjusting for SSI-risk propensity using a validated prediction tool, the odds ratio of developing an SSI was more than double with the use of iVAC over SSD (OR 2.2, 95% CI: 1.27–3.79). No difference, however, was observed in mortality or other sources of morbidity, which is consistent with current literature.

Although univariate analysis found several factors that were significant for SSI, only the iVAC and NSQIP score were independently associated with SSI rates. There are several potential explanations for this. Firstly, given the unblinded nature of this study, reporting bias cannot be ruled out. Patients who receive iVAC therapy may have been monitored for SSI more closely than SSD counterparts. Secondly, it is possible that risk-adjusted analysis was not sufficient in accounting for the true underlying SSI risk for each patient. The NSQIP SRC is well validated, yet it is designed to be a clinical tool and may not be fully comprehensive. Finally, it is possible that iVAC contributed to SSI development. Although there are many proposed mechanisms by which iVAC benefits wound healing, there are likely mechanisms by which it does not. For example, iVAC are known to ensure a moist wound bed, which is optimal for wound healing. Yet, this might also promote bacterial

**Table 4a**  
Univariate analysis: Risk factors for SSI.

	SSI n = 71	no SSI n = 618	p	OR [95% CI]
Obesity; N (%)	22 (31)	116 (19)	0.017	1.9 [1.1–3.3]
Dyspnea; N (%)	9 (13)	21 (3)	0.001	4.1 [1.8–9.2]
Sepsis; N (%)	9 (13)	32 (5)	0.03	2.6 [1.2–5.7]
ASA > 2; N (%)	44 (62)	273 (44)	0.009	2.0 [1.2–3.3]
Open Approach; N (%)	40 (56)	216 (35)	0.007	2.0 [1.2–3.3]
Colostomy; N (%)	19 (27)	72 (12)	0.001	2.7 [1.5–4.9]
Contaminated or dirty wound; N (%)	16 (22)	60 (10)	0.003	2.7 [1.4–4.9]
OR duration > 240min; N (%)	25 (35)	123 (20)	0.006	2.1 [1.3–3.6]
Non-neoplastic diagnosis; N (%)	21 (30)	116 (19)	0.042	1.8 [1.0–3.2]
iVAC; N (%)	24 (34)	119 (19)	0.041	2.1 [1.2–3.6]
NSQIP SRC > 8; N (%)	48 (68)	245 (40)	<0.00002	3.1 [1.8–5.2]

growth in the presence of contamination. Perhaps most importantly, if the iVAC vacuum seal fails or leaks, a nonsterile environment is suctioned into the wound bed. Subgroup analysis is in support of this. When comparing SSI rates between iVAC and SSD in patients who had colostomies, the association between iVAC and SSI was significant. Conversely, the association between iVAC and SSI was insignificant in patients who did not receive a colostomy. The colostomy, perhaps, acts as a nearby source of contamination for the negative pressure wound environment and amplifies the deleterious effects of a leak, when present.

Regarding secondary outcomes, due to the low occurrences, we are unable to comment on the impact of iVAC vs SSD in preventing seroma/hematoma or wound separation. This is also true for other postoperative complications. Unfortunately, we cannot comment on the cause for mortality in those who passed away within the 30-day period following their operation. This data was not collected.

This study is limited by the shortcomings of all observational studies. As mentioned, the potential for reporting bias exists along with selection bias. Also, although the use of the NSQIP dataset is a strength, it is not without limitations.<sup>36</sup> Namely, surgical outcomes were gathered from patient follow up interviews and chart review after discharge from hospital. The quality of data is, therefore, dependent on the detail offered in these interviews and documents. The dataset was also limited by 12% incomplete follow-up, shared equally between iVAC and SSD groups. In a worse-case scenario, with all SSD patients developing SSI and no SSI in iVAC, the difference in SSI would be insignificant between groups. The NSQIP SRC deserves mention as well. This calculator has been externally validated and demonstrated good in-study performance in predicting the actual SSI rate observed in SSD patients. Additionally, the score was found to be an independent factor for SSI. However, whether this score is better than surgeon intuition to risk-stratify wounds according to SSI propensity is uncertain.

## Conclusion

This is the largest observational, risk-stratified review of iVAC therapy in colorectal surgery to date. Unlike previous studies, a strong association between iVAC and SSI was found. Of particular interest was the high rate of SSI in patients who received colostomy and iVAC. This stresses the importance of proper application, education and maintenance of iVAC systems and colostomy appliances when used together. Otherwise, it may be best to avoid negative pressure devices in this group. Taken in context with the current landscape of evidence for iVAC, these findings highlight the importance of establishing appropriate indications for use of this technology with further randomized trials.

## Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## References

- Allegretti B, Bischoff P, de Jonge Stjn, et al. New WHO recommendations on preoperative measures for surgical site infection prevention: an evidence-based global perspective. *Lancet*. 2006;16:276–287.
- Ban KA, et al. *American College of Surgeons and Surgical Infection Society: Surgical Site Infection Guidelines, 2016 Update*. The American College of Surgeons; 2016. <https://doi.org/10.1016/j.amcollsurg.2016.10.029>.
- Anderson DJ, Podgorny K, Berrios-Torres SI, et al. Strategies to prevent surgical site infections in acute care hospitals. *Infect Control Hosp Epidemiol*. 2014;35(6):605–627. <https://doi.org/10.1086/676022>.
- Scott RD. *The Direct Medical Cost of Healthcare-associated Infections in U.S. Hospitals and the Benefits of Prevention*. Atlanta: Centres for Disease Control and Prevention; 2009. [http://www.cdc.gov/hai/pdfs/hai/scott\\_costpaper.pdf](http://www.cdc.gov/hai/pdfs/hai/scott_costpaper.pdf). Accessed Oct 7, 2018.

- Astagneau P, Rioux C, Golliot F, Brucker G. Morbidity and mortality associated with surgical site infections: results from the 1997–1999 INCISO surveillance. *J Hosp Infect*. 2001;48:267–274.
- Bonds AM, Novick TK, Dietert JB, Araghizadeh FY, Olson CH. Incisional negative pressure wound therapy significantly reduces surgical site infection in open colorectal surgery. *Dis Colon Rectum*. 2013;56(12):1403–1408.
- Selvaggi F, Pellino G, Sciaudone G, et al. New advances in negative pressure wound therapy (NPWT) for surgical wounds of patients affected with Crohn's disease. *Surg Technol Int*. 2014;24:83–89.
- Hoang SC, et al. Colon and rectal surgery surgical site infection reduction bundle: to improve is to change. *Am J Surg*. Jan 2019;217(1):40–45. <https://doi.org/10.1016/j.amjsurg.2018.07.008>.
- Kim IY, Kim BR, Kim YW. Factors affecting use and delay (>8 Weeks) of adjuvant chemotherapy after colorectal cancer surgery and the impact of chemotherapy-use and delay on oncologic outcomes. *PLoS One* 10(9): e0138720. Doi:10.1371/journal.pone.0138720.
- Strugula V, Martin R. Meta-analysis of comparative trials evaluating a prophylactic single-use negative pressure wound therapy system for the prevention of surgical site complications. *Surg Infect*. 18(7):810–819. Doi:10.1089/sur.2017.156.
- De Vries FE, Wallert ED, Solomkin JS, et al. A systematic review and meta-analysis including GRADE qualification of the risk of surgical site infections after prophylactic negative pressure wound therapy compared with conventional dressings in clean and contaminated surgery. *Medicine*. 2016;95(36):1–9. <https://doi.org/10.1097/MD.0000000000004673>.
- Hyldig N, et al. Meta-analysis of negative-pressure wound therapy for closed surgical incisions. *BJS*. 2016;103:477–486. <https://doi.org/10.1002/bjs.10084>.
- Willy C, Agarwal A, Andersen CA, et al. Closed incision negative pressure therapy: international multidisciplinary consensus recommendations. *Int Wound J*. 2016. <https://doi.org/10.1111/iwj.12612>.
- ACS NSQIP Participant Use Data File. [https://www.facs.org/-/media/files/quality%20programs/nsqip/nsqip\\_puf\\_userguide\\_2016.ashx](https://www.facs.org/-/media/files/quality%20programs/nsqip/nsqip_puf_userguide_2016.ashx). Last accessed Sept 1st, 2018.
- National Healthcare Safety Network, Centers for Disease Control and Prevention. Surgical site infection (SSI) event. <http://www.cdc.gov/nhsn/pdfs/pscmanual/9pscscscurrent.pdf>. Accessed August 20, 2018. Published Jan 2017.
- Gustafsson UO, et al. Guidelines for perioperative care in elective colonic surgery: enhanced Recovery after surgery (ERAS®) society recommendations. *World J Surg*. 2013;37:259–284.
- Berrios-Torres S, et al. Centers for disease control and prevention guideline for the prevention of surgical site infection. *JAMA Surg*. 2017;152(8):784–791. <https://doi.org/10.1001/jamasurg.2017.0904>.
- Gomoll AH, Lin A, Harris MB. Incisional vacuum-assisted closure therapy. *J Orthop Trauma*. 2006;20(10):705–709.
- ACS NSQIP Surgical Risk Calculator. <https://riskcalculator.facs.org/RiskCalculator/PatientInfo.jsp>. Last accessed Sept 1st 2018.
- Billimoria KY, Liu Y, Paruch JL, et al. Development and evaluation of the universal ACS NSQIP surgical risk calculator: a decision aide and informed consent tool for patients and surgeons. *J Am Coll Surg*. 2013;217(5):833–842. <https://doi.org/10.1016/j.jamcollsurg.2013.07.385>.
- Cohen ME, Liu Y, Ko CY, Hall BL. An examination of American college of surgeons NSQIP surgical risk calculator accuracy. *J Am Coll Surg*. 2017;224(5):787–795. <https://doi.org/10.1016/j.jamcollsurg.2016.12.057>.
- Al Lawati R. *Utility of the ACS NSQIP Surgical Risk Calculator to Accurately Predict Postoperative Outcomes after Colon Resection*. Vancouver, Canada: University of British Columbia; 2016 (Unpublished master's thesis).
- Anghel EL, Kim PJ. Negative-pressure wound therapy: a comprehensive review of the evidence. *Plast Reconstr Surg*. 2016;138(3S):129–137.
- Jones SM, Banwell PE, Shakespeare PG. Advances in wound healing: topical negative pressure therapy. *Postgrad Med*. 2005;81:353–357.
- Paolo Erba, et al. Angiogenesis in wounds treated by microdeformational wound therapy. *Ann Surg*. 2001;253(2):402–409.
- Miller C. The history of negative pressure wound therapy (NPWT): from "lip service" to the modern vacuum system. *Journal of the American College of Clinical Wound Specialists*. 2014;4:61–62.
- Horsch R. Incisional negative pressure wound therapy for high-risk wounds. *J Wound Care*. 2015;24(4):21–28.
- Stannard JP, Volgas DA, McGwin G, et al. Incisional negative pressure wound therapy after high-risk lower extremity fractures. *J Orthop Trauma*. 2012;26(1):37–42.
- Ingargiola MJ, Daniali LN, Lee ES. Does the application of incisional negative pressure therapy to high-risk wounds prevent surgical site complications? A systematic review. *ePlasty*. 2013;13:e49.
- Semsarzadeh NN, Tadisina KK, Maddox J, Chopra K, Singh DP. Closed incision negative-pressure therapy is associated with decreased surgical-site infections: a meta-analysis. *Plast Reconstr Surg*. 2015;136(3):592–602.
- O'Leary DP, Peirce C, Anglim B, et al. Prophylactic negative pressure dressing use in closed laparotomy wounds following abdominal operations. *Ann Surg*. 2017;265(6):1082–1086.
- Pellino G, Sciaudone G, Candilio G, et al. Preventive NPWT over closed incisions in general surgery: does age matter? *Int J Surg*. 2015;12:S64–S68.
- Shen P, Blackham AU, Lewis S, et al. Phase II randomized trial of negative-pressure wound therapy to decrease surgical site infection in patients undergoing laparotomy for gastrointestinal, pancreatic, and peritoneal surface malignancies. *J Am Coll Surg*. 2017;224(4):726–737.

34. Blackham AU, Farrah JP, McCoy T, Schmidt BS, Shen P. Prevention of surgical site infections in high-risk patients with laparotomy incisions using negative-pressure therapy. *Am J Surg*. 2013;205(6):647–654.
35. Curran T, Alvarez D, Del Valle JP, Cataldo TE, Poylin V, Nagle D. Prophylactic closed incision negative pressure wound therapy is associated with decreased surgical site infection in high-risk colorectal surgery laparotomy wounds. *Colorectal Dis*. July 2018:1–9. <https://doi.org/10.1111/codi.14350>.
36. Parthasarathy M, Reid V, Pyne L, Groot-Wassink T. Are we recording postoperative complications correctly? Comparison of NHS hospital episode statistics with the American college of surgeons national surgical quality improvement program. *BMJ Qual Saf*. 2015;24(9):594–602.
37. Ashburn J. Prevena™ Incisional Negative Pressure Wound Therapy in Re-operative Colorectal Surgery. Clinicaltrials.gov. ID: NCT02509260.
38. Leitao M. Negative Pressure Wound Therapy in Post-Operative Incision Management. Clinicaltrials.gov. ID: NCT02682316.