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Original Research

Does Closed Incision Negative Pressure Wound Therapy Reduce Surgical Site Infection in Endometrial Carcinoma Patients Undergoing Laparotomy? A Multicentre Retrospective Cohort Study

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Abstract

Background: Endometrial cancer is the most common gynaecological cancer and has a strong association with obesity. Surgical site infection (SSI) carries high morbidity and is more frequent in obese patients. Closed incision negative pressure wound therapy (ciNPWT) has been proposed to reduce wound morbidity but is more expensive than standard dressings whilst the evidence has been very heterogenous. There is limited evidence to justify this expensive dressing as related to its effectiveness in gynaecological oncology patients. ciNPWT was introduced in New Zealand in 2017 based on the available evidence from studies on SSI in the obstetric population. The aim of this study is to investigate the rate of SSI in patients with endometrial carcinoma undergoing laparotomy using standard surgical dressings compared to ciNPWT. **Methods**: We performed a retrospective analysis of 170 patients who underwent a laparotomy for endometrial carcinoma between 2018 and 2019 across three hospitals in New Zealand after the introduction of ciNPWT. Dressings were applied according to individual surgeons' preferences. Standard dressings and ciNPWT were compared in the occurrence of SSI, wound dehiscence, readmission and return to theatre rates using logistic regression in order to account for potential confounding due to the patient demographics and oncologic and surgical characteristics. **Results**: There were 129 patients in the standard dressing group and 41 patients in the ciNPWT group. The mean age was 60.4 years (range 25–86). The mean body mass index (BMI) was 38.2 kg/m^2 (range 20–69 kg/m^2). The percentage of patients who experienced a SSI was higher in the ciNPWT group (34.2% *vs.* 20.9%; $p = 0.159$). There was no significant difference between the dressing groups in the occurrence of superficial SSI rate, return to theatre, or readmission. Wound dehiscence and deep/organ space SSI were however worse with ciNPWT (adjusted odds ratio (aOR) 4.09 and aOR 7.19, respectively). **Conclusions**: This study demonstrated no evidence for the benefit of ciNPWT, and higher rates of deep/organ space SSI. More randomised trials are needed to investigate whether gynaecological oncology patients may benefit from ciNPWT thus justifying the extra cost of this dressing.

Keywords: surgical site infection; negative pressure wound therapy; endometrial carcinoma

1. Introduction

Endometrial carcinoma is the most common gynaecological cancer worldwide [1]. With the current global obesity pandemic, rates of endometrial carcinoma are increasing [2] as obesity represents the most common causative factor. Worldwide, endometrial carcinoma is the sixth most commonly occurring cancer in women [3].

Surgical treatment of endometrial carcinoma utilises laparotomy in varying amounts in comparison to laparoscopy [4]. Minimally invasive surgery is preferable, but some patients are not candidates due to the size of the uterus or comorbidities that prevent adequate pneumoperitoneum insufflation. Larger central abdominal adiposity in the obese population increases laparotomy rates [5]. New Zealand gynae-oncology centres overall follow the recommendations of The European Society of Gynaecological Oncology (ESGO) for the management of patients with endometrial cancer [6]. These acknowledge that morbid obesity may preclude patients from surgery, and radiotherapy can be considered instead [6].

Surgical site infection (SSI) is defined by the Centers for Disease Control and Prevention as an infection that occurs after surgery at the body site where the surgery took place [7]. The rate of SSI in patients undergoing laparotomy for endometrial carcinoma can be as high as 34% [8]. Obesity is an independent risk factor for SSI, which confers

morbidity and can delay adjuvant treatment. This has been shown to have an impact on survival in ovarian carcinoma patients [9]. The cost of SSI is a burden on healthcare systems globally and therefore it is important to prevent an SSI from occurring.

Closed incision negative pressure wound therapy (ciNPWT) is a sealed non-invasive system that applies negative pressure to the wound site that has been closed [10]. It has been introduced worldwide to help reduce SSI in obese patients. The suggested benefits on SSI rates are based on the following mechanisms: reduced lateral tension, increased blood flow, exudate drainage, and stimulation of granulation tissue formation [11].

The initial evidence supporting ciNPWT is heterogenous. Studies included patients from orthopaedics, trauma, general surgery, and obstetrics. Recent research has strived to investigate more homogenous patient populations. A small number of retrospective studies have suggested ciNPWT is of some benefit for gynaecological oncology patients [12,13]. However, two recent randomized trials failed to identify any benefits from using ciNPWT for gynaecological oncology patients [14,15]. A trial of gynaecological oncology patients has been carried out and publication is awaited [16]. This type of dressing was introduced in New Zealand in 2017 but its use remains surgeon-dependent and is not part of routine practice. This technology is much more expensive than standard dressings; ciNPWT dressings include PREVENA© which costs between NZ$184 and NZ$210 per patient, and PICO© which costs between NZ$260 and NZ$470 per patient. This compares to standard dressings which cost between NZ$26 and NZ$36. Evidence from randomised trials is lacking in this patient group to justify this added cost [14,15].

This primary aim of this retrospective cohort study was to assess whether ciNPWT reduces SSI rates when compared to standard dressings in patients undergoing laparotomy for endometrial carcinoma. The secondary aims of the study were to compare ciNPWT and standard dressings in the occurrence of wound dehiscence, readmission, and return to theatre rates. The setting was three hospital sites in New Zealand.

2. Materials and Methods

This retrospective cohort study was approved by the health and disability ethics committee in New Zealand (Ref: 19/CEN/222). One hundred and seventy patients who underwent a laparotomy for endometrial carcinoma were identified from the regional gynaecological oncology database. Laparoscopically treated endometrial carcinoma patients were excluded. Patients were included who underwent laparotomy for endometrial cancer between 2018 and 2019 when ciNPWT was freely available. The choice of dressing was at the discretion of the operating surgeon. Three hospital sites were included across Auckland, New Zealand. Two are gynaecological cancer units, whilst one is a tertiary cancer centre.

The type of ciNPWT used by surgeons in this study was a PICO© or PREVENA© dressing. Negative pressure of minus 80 mmHg was applied to PICO© dressings [17] and minus 125 mmHg for PREVENA© [18]. Patients whose wounds were covered with PICO© or PREVENA© were combined for the purpose of analyses and constituted the ciNPWT group.

Data was collected from hospital electronic patient records. Demographic details were collected, including age and ethnicity. Factors considered to increase wound complications were also recorded, including body mass index (BMI), diabetes mellitus, smoking status, previous abdominal surgery, stage, grade, length of surgery, estimated blood loss, transfusion status, mode of abdominal incision, and type of dressing. The type of incision was surgeon-dependent. Only one of the three centres involved favoured midline laparotomy and performed nodal staging due to the New Zealand hub and spoke model of cancer care.

SSI rates was the primary outcome and was examined according to the Centers for Disease Control and Prevention definition [7]. The occurrence of SSIs (classified as none, superficial and deep/organ space) were compared between the dressing groups (ciNPWT *vs.* standard dressing). Secondary outcomes included wound dehiscence (yes *vs.* no), readmission (yes *vs.* no), return to theatre for debridement (yes *vs.* no), and other postoperative infections (yes *vs.* no). The primary and secondary outcomes were identified through analysis of inpatient progress notes before discharge and postoperative follow-up for 90 days after the procedure by utilizing the hospital computer system and hospital notes. General practitioner prescribing of antibiotics was documented on the regional electronic patient record accessible from hospital records.

During the study period, factors affecting SSI rates were modified by multiple hospital-wide interventions following a series of World Health Organization (WHO) recommendations [19]. These include preoperative antibiotics within 120 minutes of knife to skin and alcohol based skin preparation which were part of a group of management changes introduced by surgical departments internationally called “surgical care bundles” [19]. These parameters were also recorded and therefore have been taken into account.

Statistical Analysis

The dressing groups (standard *vs.* ciNPWT) were compared in their demographic and clinical characteristics, and outcomes using bivariate statistical hypothesis tests. Distributional assumptions in the continuous variables were verified and the dressing groups were compared using the independent samples *t*-test (test statistic denoted by *t*). The dressing groups were compared in categorical variables using the Chi-Squared test (test statistic denoted by χ^2) and, when invalid, Fisher’s Exact test was used (test statistic denoted by FI). Degrees of freedom were abbreviated to df.

Table 1. Patient demographics and clinical characteristics.

		Dressing Applied		Total	Test Statistics
		Standard	ciNPWT		
Age at Operation (years)	Mean (SD)	62.7 (11.87)	53.2 (12.61)	60.4 (12.68)	$t = 4.35$, df = 167, $p < 0.001$, diff = 9.41, 95% CI (5.14, 13.68)
	Median (LQ:UQ)	62 (55.5:71)	56.0 (44:61)	60.0 (53:70)	
	Minimum:Maximum	25:86	29:77	25:86	
BMI at Operation (kg/m^2)	Mean (SD)	34.6 (9.09)	49.6 (9.31)	38.2 (11.17)	t = –9.20, df = 168, $p < 0.001$, diff = –15.1, 95% CI (–18.30, –11.83)
	Median (LQ:UQ)	33 (28:39)	47 (42:56)	37 (30 :45)	
	Minimum:Maximum	20:63	32:69	20:69	
Categorised BMI	>18.5, ≤24.9	12 (9.3%)	0	12 (7.1%)	FI = 56.36, df = 4, $p < 0.001$
	≥25, ≤29.9	26 (20.2%)	0	26 (15.3%)	
	≥30, ≤34.9	34 (26.4%)	1 (2.4%)	35 (20.6%)	
	≥35, ≤39.9	25 (19.4%)	3 (7.3%)	28 (16.5%)	
	≥40	32 (24.8%)	37 (90.2%)	69 (40.6%)	
Smoking Status	Smoker	7 (5.4%)	11 (26.8%)	18 (10.6%)	$p < 0.001$, df = 1 (Fisher's Exact test)
	Non-smoker	122 (94.6%)	30 (73.2%)	152 (89.4%)	
Ethnicity	Māori/Pacific Island	54 (41.9%)	34 (82.9%)	88 (51.8%)	FI = 21.30, df = 2, $p < 0.001$
	NZ/European	58 (45.0%)	6 (14.6%)	64 (37.6%)	
	Other	17 (13.2%)	1 (2.4%)	18 (10.6%)	
Diabetes	No	88 (68.2%)	26 (63.4%)	114 (67.1%)	$\chi^2 = 0.33$, df = 1, $p = 0.703$
	Yes	41 (31.8%)	15 (36.6%)	56 (32.9%)	
Previous Abdominal Surgery	No	91 (70.5%)	33 (80.5%)	124 (72.9%)	$\chi^2 = 1.56$, df = 1, $p = 0.234$
	Yes	38 (29.5%)	8 (19.5%)	46 (27.1%)	
Antibiotics at Induction	No	0	1 (2.4%)	1 (0.6%)	$p = 0.241$, df = 1 (Fisher's Exact test)
	Yes	129 (100.0%)	40 (97.6%)	169 (99.4%)	
Skin Preparation	No	2 (1.8%)	1 (3.8%)	3 (2.2%)	$p = 0.476$, df = 1 (Fisher's Exact test)
	Chlorhexidine	107 (98.2%)	25 (96.2%)	132 (96.4%)	
Type of Incision	Midline	95 (73.6%)	23 (56.1%)	118 (69.4%)	$\chi^2 = 4.51$, df = 1, $p = 0.051$
	Pfannenstiel	34 (26.4%)	18 (43.9%)	52 (30.6%)	

Unless otherwise stated, figures are frequencies plus percentages within each dressing group plus overall. The statistics are for the comparison of the two dressing groups.

BMI, Body mass index; SD, Standard deviation; LQ, Lower quartile; UQ, Upper quartile; NZ, New Zealand ; ciNPWT, Closed incision negative pressure wound therapy; df, Degrees of freedom; diff, Mean difference; CI, Confidence interval; FI, Fisher's exact test statistic.

Table 2. Oncologic and surgical variables.

		Dressing Applied—number (%)		Total	Test Statistics
		Standard	ciNPWT		
Type of Operation	TAH	2 (1.6%)	0	2 (1.2%)	FI = 12.67, df = 6, p = 0.011
	TAH & BS	1 (0.8%)	6 (14.6%)	7 (4.1%)	
	TAH & BSO	75 (58.1%)	22 (53.7%)	97 (57.1%)	
	TAH & BSO Nodes	47 (36.4%)	13 (31.7%)	60 (35.3%)	
	TAH & BS Nodes	0	0	0	
	Nodes only	2 (1.6%)	0	2 (1.2%)	
	Other	2 (1.6%)	0	2 (1.2%)	
Categorised Type of Operation	TAH, TAH & BS, TAH & BSO	78 (60.5%)	28 (68.3%)	106 (62.4%)	FI = 1.18, df = 2, p = 0.544
	TAH & BSO & Nodes, TAH & BS & Nodes	47 (36.4%)	13 (31.7%)	60 (35.3%)	
	Nodes only, Other	4 (3.1%)	0	4 (2.4%)	
Transfused	No	123 (95.3%)	40 (97.6%)	163 (95.9%)	p = 1.00, df = 1 (Fisher's Exact test)
	Yes	6 (4.7%)	1 (2.4%)	7 (4.1%)	
Skin Closure Material	Monocryl	29 (23.2%)	11 (26.8%)	40 (24.1%)	χ^2 = 0.22, df = 1, p = 0.676
	Staples	96 (76.8%)	30 (73.2%)	126 (75.9%)	
Grade	1	70 (56.0%)	25 (61.0%)	95 (57.2%)	χ^2 = 0.43, df = 1, p = 0.769
	2	18 (14.4%)	6 (14.6%)	24 (14.5%)	
	3	37 (29.6%)	10 (24.4%)	47 (28.3%)	
Stage after Operation	IA	54 (41.9%)	27 (65.9%)	81 (47.6%)	FI = 7.70, df = 7, p = 0.332
	IB	26 (20.2%)	7 (17.1%)	33 (19.4%)	
	II	10 (7.8%)	3 (7.3%)	13 (7.6%)	
	IIIA	6 (4.7%)	1 (2.4%)	7 (4.1%)	
	IIIB	6 (4.7%)	0	6 (3.5%)	
	IIIC	8 (6.2%)	1 (2.4%)	9 (5.3%)	
	IVA	9 (7.0%)	1 (2.4%)	10 (5.9%)	
	IVB	10 (7.8%)	1 (2.4%)	11 (6.5%)	

Table 2. Continued.

		Dressing Applied—number (%)		Total	Test Statistics
		Standard	ciNPWT		
Length of Operation (minutes)	Mean (SD)	137.3 (59.30)	146.0 (52.84)	139.5 (57.75)	t = –0.84, df = 165, p = 0.404, diff = –8.7, 95% CI (–29.22, 11.89)
	Median (LQ:UQ)	120 (90:180)	140 (105:180)	120 (90:180)	
	Minimum: Maximum	59:360	60:299	59:360	
EBL (mls)	Mean (SD)	378.2 (329.58)	397.5 (249.09)	382.8 (311.48)	t = –0.35, df = 164, p = 0.734, diff = –19.3, 95% CI (–131.24, 92.59)
	Median (LQ:UQ)	300 (200:400)	400 (200:500)	300 (200:500)	
	Minimum: Minimum	50:2000	100:1500	50:2000	
Length of Stay (days)	Mean (SD)	3.6 (1.84)	5.0 (4.43)	4.0 (2.75)	p = 0.003
	Median (LQ:UQ)	3 (3:4)	4 (3:5)	3 (3:4)	
	Minimum: Maximum	2:15	2:30	2:30	

Unless otherwise stated, figures are frequencies plus percentages within each dressing group plus overall. The statistics are for the comparison of the two dressing groups.
EBL, Estimated blood loss; SD, Standard deviation; LQ, Lower quartile; UQ, Upper quartile; ciNPWT, Closed incision negative pressure wound therapy; df, Degrees of freedom; diff, Mean difference; CI, Confidence interval; FI, Fisher's exact test statistic; TAH, Total abdominal hysterectomy; BS, Bilateral salpingectomy; BSO, Bilateral salpingo-oophorectomy.

Table 3. Infection and postoperative outcomes.

		Dressing Applied		Total	Test Statistics
		Standard	ciNPWT		
Surgical Site Infection (SSI)	No	102 (79.1%)	27 (65.9%)	129 (75.9%)	FI = 3.24, df = 2, p = 0.159
	Yes: Superficial	23 (17.8%)	12 (29.3%)	35 (20.6%)	
	Yes: Deep Organ	4 (3.1%)	2 (4.9%)	6 (3.5%)	
Dehiscence	No	114 (88.4%)	28 (68.3%)	142 (83.5%)	χ^2 = 9.12, df = 1, p = 0.004
	Yes	15 (11.6%)	13 (31.7%)	28 (16.5%)	
Return to Theatre	No	123 (96.9%)	34 (89.5%)	157 (95.2%)	p = 0.083, df = 1 (Fisher's Exact test)
	Yes	4 (3.1%)	4 (10.5%)	8 (4.8%)	
Readmission	No	118 (93.7%)	36 (92.3%)	154 (93.3%)	p = 0.723, df = 1 (Fisher's Exact test)
	Yes	8 (6.3%)	3 (7.7%)	11 (6.7%)	
Adverse Wound Outcome	No	98 (76.0%)	25 (61.0%)	123 (72.4%)	χ^2 = 3.50, df = 1, p = 0.073
	Yes	31 (24.0%)	16 (39.0%)	47 (27.6%)	
Other Postoperative Infection	No	114 (89.8%)	31 (81.6%)	145 (87.9%)	p = 0.254, df = 1 (Fisher's Exact test)
	Yes	13 (10.2%)	7 (18.4%)	20 (12.1%)	

Figures are frequencies plus percentages within each dressing group plus overall. The statistics are for the comparison of the dressing groups.
ciNPWT, Closed incision negative pressure wound therapy; df, Degrees of freedom; FI, Fisher's exact test statistic.

Continuous variables were summarised using the following descriptive statistics: mean, standard deviation, median, lower and upper quartiles, and minimum and maximum values. Categorical variables were summarised using frequencies and percentages.

A multinomial logistic regression model was performed for the primary outcome of SSI; SSI was categorised as no, yes (superficial) and yes (deep/organ). Binary logistic regression models were performed for the secondary outcomes of re-admission, return to theatre, and wound dehiscence; the secondary outcomes were all categorised as yes or no. For each analysis the adjusted odds ratios (aORs) and 95% confidence intervals (CI) were obtained to estimate the effects of dressing, whilst adjusting for the potential confounding due to demographic, oncologic and surgical characteristics. Potential explanatory variables were selected for the logistic regression models if they demonstrated a statistical difference between the dressing groups in the bivariate analyses using a threshold of $p < 0.25$; the threshold was considered sufficient to indicate potential confounding between the dressing groups in outcome. The assumption of linearity between continuous explanatory variables and the logit was tested using the Box-Tidwell transformation. The assumption of linearity could not be assumed for BMI and for the purpose of the logistic regression was categorised as $>$18.5, $\leq$24.9; $\geq$25.0, $\leq$29.9; $\geq$30.0, $\leq$34.9; $\geq$35.0, $\leq$39.9; $\geq$40 kg/m^2.

The critical level of statistical significance was set to 0.05 (5%). For the bivariate statistical hypothesis tests, adjustment to the critical level of significance was made using Bonferroni's correction factor to account for multiple hypothesis testing and potential type I errors. All statistical analyses were performed using SPSS Version 28 (IBM Corp., Chicago, IL, USA).

3. Results

A total of 170 patients underwent laparotomy for endometrial carcinoma between 1st January 2018 and 31st December 2019. There were 129 patients in the standard dressing group and 41 patients in the ciNPWT group. Of the 41 patients who had a ciNPWT dressing, 29 (70.7%) had a PICO© dressing whilst 12 (29.3%) had a PREVENA© dressing. Patient demographics and characteristics between the two groups are presented in Table 1.

Patients in the ciNPWT group tended to be younger (53.2 *vs.* 62.7 years; $p < 0.001$), had a higher BMI (49.6 *vs.* 34.6 kg/m^2; $p < 0.001$), and were more likely to smoke (26.8% *vs.* 5.4%; $p < 0.001$). There was a significant difference between the dressing groups in terms of ethnicity ($p < 0.001$): a greater proportion of the ciNPWT group were of Māori/Pacific Island ethnicity (82.9% *vs.* 41.9%) whilst that of the standard dressing group were more likely to be of New Zealand or European descent (45.0% *vs.* 14.6%). There was no significant difference between the groups in the type of abdominal incision.

Table 2 displays the oncological and surgical variables for each of the two dressing groups. Operative factors in the ciNPWT group showed a significant difference in the type of operation with the control group having a higher percentage of total abdominal hysterectomy (TAH), bilateral salpingo-oophorectomy (BSO) and lymph node excision compared to the ciNPWT group (36.4% *vs.* 31.7%; $p = 0.011$), but when split into categories of similar operations, this difference no longer existed ($p = 0.544$). There was no significant difference between the groups of transfusion, type of sutures used, grade or stage at operation, estimated blood loss (EBL) or operative time. Postoperative hospital stay was also significantly longer in the ciNPWT group by over a day (5.0 *vs.* 3.6 days; $p = 0.003$).

WHO infection prevention measures were not documented. Preoperative shaving, treatment of *S. aureus*, bathing prior to surgery, surgical hand preparation, levels of oxygen and use of warming devices or iodine irrigation prior to closure were not accurately documented in the theatre or ward notes, and therefore were not included. Closure suture information was also screened for triclosan-coating information but this was not available for data capture. All patients were given preoperative antibiotics within 120 minutes of knife to skin except for one patient, whilst alcohol-based skin preparation was used at the same frequency.

Table 3 shows the occurrence of SSI and that of the secondary outcomes (wound dehiscence, readmission, return to theatre, overall adverse wound outcome and other postoperative infections). The percentage of patients that experienced SSI was greater in the ciNPWT group, although the difference was not statistically significant ($p = 0.159$). The most frequently occurring SSI in both dressing groups were superficial incisional type infections (ciNPWT: 29.3% *vs.* standard dressings: 17.8%). Deep SSI occurred more frequently in the ciNPWT group (4.9% *vs.* 3.1%).

3.1 Primary Outcome

A multinomial logistic regression model was performed for the primary outcome of SSI. The results are shown in Table 4. The following variables were selected as potential confounders as they demonstrated a statistical difference between the dressing groups using a threshold of $p < 0.25$: age, categorised BMI, smoking status, ethnicity, type of incision, and length of stay. The use of ciNPWT did not increase the occurrence of superficial SSI (relative to no SSI) when compared to standard dressings (aOR 1.27; 95% CI 0.41–3.90). However, the ciNPWT group had a statistically significant increased risk of deep organ SSI (relative to no SSI) when compared to the standard dressing group (aOR 7.19; 95% CI 1.15–337.18). There was no statistical evidence that age, smoking, ethnicity or length of stay in this model had any difference on rates of superficial SSI. A Pfannenstiel incision was found to be protective compared

Table 4. Results of multinomial logistic regression to estimate the effect upon surgical site infection (SSI) (primary outcome) by dressing applied, and selected patient demographics and clinical characteristics.

			Odds ratio (95% confidence interval)
Surgical Site Infection: Superficial	Dressing Applied	Standard	(1)
		ciNPWT	1.27 (0.41, 3.90)
	Age (years)		0.99 (0.95, 1.03)
	Length of Stay (days)		1.08 (0.87, 1.32)
	Categorised BMI	>18.5, ≤24.9	(1)
		≥25, ≤29.9	Not Estimable
		≥30, ≤35	Not Estimable
		≥35, ≤39.9	Not Estimable
		≥40	Not Estimable
	Smoking Status	Non-smoker	(1)
		Smoker	0.74 (0.20, 2.69)
	Ethnicity	Māori/Pacific Island	(1)
		White	0.53 (0.18, 1.56)
		Other	0.53 (0.05, 5.43)
	Type of Incision	Midline	(1)
		Pfannenstiel	0.17 (0.04, 0.66)
Surgical Site Infection: Deep Organ	Dressing Applied	Standard	(1)
		NPWT	7.19 (1.15, 337.18)
	Age (years)		1.07 (0.93, 1.24)
	Length of Stay (days)		1.50 (1.09, 2.06)
	Categorised BMI	>18.5, ≤24.9	(1)
		≥25, ≤29.9	Not Estimable
		≥30, ≤35	Not Estimable
		≥35, ≤39.9	Not Estimable
		≥40	Not Estimable
	Smoking Status	Non-smoker	(1)
		Smoker	34.54 (0.48, 2503.08)
	Ethnicity	Māori/Pacific Island	(1)
		NZ European	84.29 (0.19, 37,431.88)
		Other	544.51 (0.45, 659,049.57)
	Type of Incision	Midline	(1)
		Pfannenstiel	1.91 (0.14, 25.48)

The OR for each type of SSI and 95% CI are shown. For each explanatory variable, the reference category is shown by (1). For a given type of SSI, the OR is the odds of the SSI if risk factors are present, relative to the reference category. Each type of SSI is compared against no SSI.

BMI, Body mass index; ciNPWT, Closed incision negative pressure wound therapy; OR, Odds ratio; SSI, Surgical site infection; CI, Confidence interval; NZ, New Zealand.

to a midline incision in the superficial rates of SSI (aOR 0.17, CI 0.04–0.66). There was no statistical evidence that age, smoking, ethnicity, or type of incision affected the occurrence of deep organ SSI. ciNPWT patients with deep SSI had a longer length of stay (aOR 1.50, CI 95% 1.09–2.06). The effect of BMI was not able to be estimated due to small numbers for either superficial or deep organ SSI.

3.2 Secondary Outcomes

Binary logistic regression models were performed to estimate the effect of the dressing upon the outcomes of wound dehiscence, readmission to hospital and return to theatre whilst controlling for the potential confounding of demographic and clinical characteristics in Tables 5,6,7. The following variables were selected as potential confounders as they demonstrated a statistical difference between the dressing groups using a threshold of $p < 0.25$: age, categorised BMI, smoking status, ethnicity, type of incision, and length of stay. A statistically significant difference existed between the dressing groups in type of operation. However, for several types of operation there were none or only one person observed and therefore the equa-

Table 5. Results of binary logistic regression to estimate the effect upon wound dehiscence (secondary outcome) by dressing applied, and selected patient demographics and clinical characteristics.

		Odds ratio (95% confidence interval)	Statistics
		Wound Dehiscence	
Dressing Applied	Standard	(1)	$p = 0.030$
	ciNPWT	4.09 (1.15, 14.58)	
Age (years)		1.01 (0.96, 1.05)	$p = 0.780$
Length of Stay (days)		1.14 (0.99, 1.30)	$p = 0.055$
Categorised BMI (Type 1)	>18.5, ≤24.9	(1)	$p = 0.360$
	≥25, ≤29.9	1.68 (0.06, 44.71)	
	≥30, ≤35	6.21 (0.38, 100.46)	
	≥35, ≤39.9	4.75 (0.26, 88.40)	
	≥40	9.83 (0.59, 164.02)	
Smoking Status	Non-smoker	(1)	$p = 0.767$
	Smoker	1.23 (0.32, 4.71)	
Ethnicity	Māori/Pacific Island	(1)	$p = 0.017$
	NZ European	2.70 (0.83, 8.81)	
	Other	15.58 (2.26, 107.51)	
Type of Incision	Midline	(1)	$p = 0.005$
	Pfannenstiel	0.15 (0.04, 0.57)	

The odds ratio of wound dehiscence and 95% confidence interval are shown. For each explanatory variable, the reference category is shown by (1). The odds ratio is the odds of the outcome if risk factors are present relative to the reference category. The *p*-values are for the statistical test of significance for the variable across all categories. BMI, Body mass index; ciNPWT, Closed incision negative pressure wound therapy; NZ, New Zealand.

tion would not resolve for this potential confounder. The challenge was not overcome following combination of the categories of type of operation, whilst no statistically significant difference was observed between the dressing groups.

The binary logistic regression model identified that wound dehiscence rates are worse with ciNPWT compared to standard dressings (aOR 4.09; 95% CI 1.15–14.58; $p = 0.030$). Neither age, smoking, length of stay, or BMI were found to have a significant effect on wound dehiscence. A Pfannenstiel incision was found to be protective compared to a midline incision (aOR 0.15; 95% CI 0.04–0.57; $p = 0.005$). Compared to Māori/Pacific Island ethnicity, other ethnicities were at higher risk of wound dehiscence (aOR 15.58; 95% CI 2.26–107.51; $p = 0.017$).

The binary logistic regression model identified that when compared to standard dressing ciNPWT did not significantly affect the occurrence of return to theatre (aOR 3.42; 95% CI 0.29–40.58; $p = 0.330$). There was no evidence of a statistically significant effect of BMI or ethnicity on readmission. Being a smoker made a return to theatre more likely (aOR 15.45; 95% CI 1.35–177.35; $p = 0.028$).

The binary logistic regression model identified no difference between the dressing groups (ciNPWT compared to standard dressings) in the occurrence of a readmission (aOR 0.56; 95% CI 0.09–3.46; $p = 0.531$). Neither age, smoking, length of stay, BMI, ethnicity, or type of incision were found to have a statistically significant effect upon the occurrence of readmission.

4. Discussion

This study did not demonstrate a significant difference in superficial SSI, readmission or return to theatre between standard dressings and non-selective use of two different types of ciNPWT. However, wound dehiscence and deep/organ space SSI were worse when ciNPWT was utilized. Evidence regarding the use of ciNPWT remains mixed in gynaecological oncology, with very few prospective randomised trials [12,14,20]. The Cochrane review appraising the evidence across all surgical specialities has found a reduction in SSI incidence rates when ciNPWT was used from 11.75% to 8.7%, but with only moderate certainty due to the risk of bias [21]. In a recent retrospective paper by Chambers *et al.* [12] looking specifically at gynaecology oncology patients in a single centre, they were able to show a significant improvement in both superficial and deep SSIs, along with other adverse wound outcomes by use of ciNPWT. Superficial SSI was reduced from 29.7% in the standard dressing group to 9.4% in the ciNPWT group [12]. The authors do however acknowledge the limitations based on the risk of bias and lack of randomisation. Other studies in obstetric patients have shown either only a small reduction in SSI incidence rates [22] or no difference between standard dressings and ciNPWT [10]. This lack of difference may be accounted for by the infection prevention bundles that are now routinely incorporated into clinical practice (preoperative antibiotics, skin preparation and closing trays). Studies have shown a difference

Table 6. Results of binary logistic regression to estimate the effect upon return to theatre (secondary outcome) by dressing applied, and selected patient demographics and clinical characteristics.

		Odds ratio (95% confidence interval)	Statistics
		Return to Theatre	
Dressing Applied	Standard	(1)	$p = 0.330$
	ciNPWT	3.42 (0.29, 40.58)	
Age (years)		1.05 (0.97, 1.14)	$p = 0.249$
Length of Stay (days)		1.37 (1.01, 1.86)	$p = 0.045$
Categorised BMI (Type 1)	>18.5, ≤24.9	(1)	$p = 1.000$
	≥25, ≤29.9	15.32 (Not Estimable)	
	≥30, ≤35	Not Estimable	
	≥35, ≤39.9	12.90 (Not Estimable)	
	≥40	Not Estimable	
Smoking Status	Non-Smoker	(1)	$p = 0.028$
	Smoker	15.45 (1.35, 177.35)	
Ethnicity	Māori/Pacific Island	(1)	$p = 0.078$
	White	9.39 (0.89, 98.97)	
	Other	51.54 (1.45, 1831.98)	
Type of Incision	Midline	(1)	$p = 0.862$
	Pfannenstiel	0.84 (1.12, 6.20)	

The odds ratio of return to theatre and 95% confidence intervals are shown. For each explanatory variable, the reference category is shown by (1). The *p*-values are for the statistical test of significance for the variable across all categories.

BMI, Body mass index; ciNPWT, Closed incision negative pressure wound therapy.

in the reduction of SSI rates by using the prevention bundles alone [23], without the need for costly ciNPWT. To date, there have been few randomised control trials on gynaecological oncology patients alone with ciNPWT. Leitao *et al.* [14] ceased their trial early due to futility based on similar SSI rates between the ciNPWT and standard dressing groups (17.3% *vs.* 16.3%, respectively). The majority of the randomised studies have included mixed-speciality patients and operations; Leitao *et al.* [14] also included patients with benign disease [24]. Another small randomised controlled trial also failed to demonstrate an advantage or benefit to ciNPWT [15].

Giannini *et al.* [25] examined the predictive value of obesity, comorbidities and fragility on complication rates. They were able to demonstrate that laparotomy and a modified fragility index of over 3 were independent risk factors for overall complications (OR 7.06, 95% CI 2.52–19.71; $p < 0.001$, OR 7.19, 95% CI 1.43–36.25; $p = 0.021$ respectively [25]. Obesity however was not shown to be an independent risk factor for overall complications after multivariate analysis. A further systematic review by Di Donato *et al.* [26] assessed the impact of frailty on adverse postoperative outcomes and survival in patients undergoing surgery for gynaecological cancer. This review showed that frail patients were more likely to develop 30-day postoperative complications (OR 4.16; 95% CI 1.49–11.65; $p = 0.007$) and worse oncologic outcomes compared to non-frail patients [26]. Fragility scoring is therefore an important preoperative tool to assess those at high risk of postoperative morbidity. Fragility was not assessed in this retrospective study, but would be incorporated in to any future prospective studies.

The cost of one case of an SSI in patients with endometrial cancer has been estimated at NZ$8000 [27]. Deep/organ space SSIs carry high morbidity and mortality rates [28], and so at the risk of ciNPWT leading to higher rates in these categories, this makes it even more imperative that robust randomised trials be carried out to demonstrate whether ciNPWT is justified. A cost analysis by Lewis *et al.* [29] demonstrated that ciNPWT needs to reduce SSI by 33% in order to justify the cost. These authors did not specify which ciNPWT dressing was used. None of the evidence on ciNPWT available to this date has been able to show such a large difference in order to justify its use.

There was not a statistically significant difference between the type of incisions between the two dressing groups ($p = 0.051$), although there was a trend to a higher proportion of midline incisions in the standard dressing group compared to the ciNPWT group. Pfannenstiel incisions carry a lower intrinsic infection risk [30], so this would give the ciNPWT group an advantage in being able to reduce its' SSI rate in a situation that is already associated with lower risk of infection.

ciNPWT has been introduced but with multiple different pressure settings for separate devices [17,18]. The majority used in this study were PICO© dressings, which

Table 7. Results of binary logistic regression to estimate the effect upon readmission (secondary outcome) by dressing applied, and selected patient demographics and clinical characteristics.

		Odds ratio (95% confidence interval)	Statistics
		Readmission	
Dressing Applied	Standard	(1)	$p = 0.531$
	ciNPWT	0.56 (0.09, 3.46)	
Age (years)		1.00 (0.94, 1.06)	$p = 0.923$
Length of Stay (days)		1.16 (1.00, 1.36)	$p = 0.056$
Categorised BMI (Type 1)	>18.5, ≤24.9	(1)	$p = 0.670$
	≥25, ≤29.9	Not Estimable	
	≥30, ≤35	Not Estimable	
	≥35, ≤39.9	Not Estimable	
	≥40	Not Estimable	
Smoking Status	Non-Smoker	(1)	$p = 0.904$
	Smoker	0.86 (0.08, 9.48)	
Ethnicity	Māori/Pacific Island	(1)	$p = 0.258$
	NZ European	1.28 (0.24, 6.91)	
	Other	5.85 (0.70, 48.90)	
Type of Incision	Midline	(1)	$p = 0.484$
	Pfannenstiel	0.54 (0.10, 3.03)	

The odds ratio of readmission and 95% confidence intervals are shown. For each explanatory variable, the reference category is shown by (1). The *p*-values are for the statistical test of significance for the variable across all categories. BMI, Body mass index; ciNPWT, Closed incision negative pressure wound therapy.

has a lower pressure setting compared to Prevena©. There are few studies directly comparing pressure settings and adverse wound outcomes [31], but none in gynaecological oncology. If higher pressures are hypothesised to result in less SSIs [31], this study with a higher proportion of PICO© dressings would not be able to demonstrate it.

The additional cost of ciNPWT as well as the medical implications of adverse wound outcomes means that more randomised trials are needed in gynaecological oncology patients to help justify the use of ciNPWT in high-risk patients and thus reduce the impact of adverse wound outcomes on this group of patients. Our study also identified how super morbid obesity and ethnicity impact wound outcomes for our study population. In this high-risk group, the small numbers in our study have not been able to demonstrate a difference of outcomes by dressing type. This probably warrants further focused research into the higher-risk group where surgical complications are more common.

Although our study is the first multi-centre study of this type, there are limitations due to its retrospective design, leaving the results subject to bias from surgeon choice. Infection prevention bundles' use was not recorded, so potential confounding factors could not be addressed. We were able to reduce the effect of bias by controlling for some infection contributing factors such as age, BMI, smoking status, and type of incision. The difference in negative pressure between the two types of dressings may also have a differential effect on preventing infection and any future studies will have to focus on a single type of device to accurately measure its benefits. Our study utilized more PICO© dressings which operate at lower pressures than PREVENA©. This may have contributed to the ciNPWT group not showing a benefit in SSI reduction.

5. Conclusions

This study is one of only a few to analyse the effect of ciNPWT on SSI incidence rates in gynaecology oncology patients. This multi-centre retrospective study demonstrated no differences in superficial SSI with ciNPWT compared to standard dressings, but worse rates with deep/organ space SSI. The effect of the WHO SSI prevention bundles means the use of ciNPWT in the post bundle era needs reappraisal with more robust randomised studies, especially for the higher-risk groups, to justify the extra cost of ciNPWT.

Availability of Data and Materials

The data for this manuscript is available on request from the corresponding author.

Author Contributions

CB, AM, LVE and LE designed the research study. AM, LVE, MB, KM, and KDS performed the research. AK and PMS provided help and advice on statistical analysis. PMS analyzed the data. AM, PMS and CB wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This retrospective cohort study was approved by the health and disability ethics committee in New Zealand (Ref: 19/CEN/222). Consent to Participate was waived by the committee due to it using retrospective data. The study was conducted in accordance with the Declaration of Helsinki.

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Conflict of Interest

The authors declare no conflict of interest.

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