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The Effect of Closed Incision Negative Pressure Therapy on Groin Wounds after Vascular Surgery: A Prospective Randomized Trial

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Abstract

Postoperative Wound Healing Complications (WHCs) are often responsible for prolonged hospital stay, patient dissatisfaction, and high treatment costs. Many clinical studies and case reports have reported a reduction of surgical site infections for various wound types after using closed incision Negative Pressure Therapy (ciNPT). Apart from a randomized study published in 2020, data regarding the effect of ciNPT (PICO™ system) on groin incision wounds are scarce. The aim of this prospective, randomized, single-institution study was to investigate the effectiveness of ciNPT (using the PICO™ system) on groin incisions after vascular surgery and compare it with that of conventional therapy. A total of 100 patients with 120 groin incisions were analyzed. Patients were randomized and treated with either PICO™ (n=62 groins) or a conventional wound dressing (n=58 groins). PICO™ was applied intraoperatively and removed on day 5 to 7 postoperatively. Wounds were evaluated 5 to 7 days and 30 days postoperatively. Compared with the control group, the PICO™ group showed a significant reduction in WHCs ($p<0.0005$). There was no significant effect of PICO™ in preventing revision surgeries ($p=0.087$) was not confirmed. Subgroup analysis revealed a significant effect of PICO™ for almost all wound healing risk factors. In comparison to the conventional adhesive dressing, ciNPT (PICO™ system) significantly reduced the incidence of WHCs in the groin after vascular surgery up until 30 days postoperatively.

Keywords: Closed incision negative pressure therapy; Postoperative wound complications; Wound healing; Surgical site infections

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Introduction

Despite the highly skilled knowledge and achievements of modern medicine Wound Healing Complications (WHCs) in the groin after vascular surgery are still a considerable problem. Prolonged hospital stay, unplanned readmissions, morbidity, and death are mainly attributed to Surgical Site Infections (SSIs), resulting in an increased financial burden for the health care system [1,2]. The groin is a leading access point for the majority of vascular surgeries and interventions, and iatrogenic injury of the lymphatic vessels can result in lymphatic leaks and lymphocele, which, in combination with bacterial contamination originating from the urogenital area, can lead to bacterial wound infection. The most common WHCs in the groin after vascular procedures are wound dehiscence, skin necrosis, lymphatic leaks, seroma, hematoma, and wound infection [3-9]. The incidence of WHCs after vascular surgery is reportedly as high as 45% [5,6,9-12]. Since the first publication by Morykwas in 1997 [14], negative pressure wound therapy has proved to be an increasingly successful treatment for a wide range of surgical wounds [15-20]. Since 2010, several reports have been published on the use of closed incision Negative Pressure Therapy (ciNPT), documenting a decrease in SSIs in traumatic, orthopedic, abdominal, sternal and plastic surgery incision wounds [21-32]. The success of ciNPT can be attributed to its mode of action, which decreases the lateral tension around the incision wound, strengthens the cohesiveness of the edges, enhances oxygen saturation and blood/microcirculation within the incision area, removes fluids and infectious materials from the wound, and protects the incision wound from external contamination [6,33-35]. Currently, the leading ciNPT systems are PICO™ Single Use Negative Pressure Wound Therapy System (Smith & Nephew, London, UK) and Prevena™ Incision Management Therapy System (KCI, an ACELITY

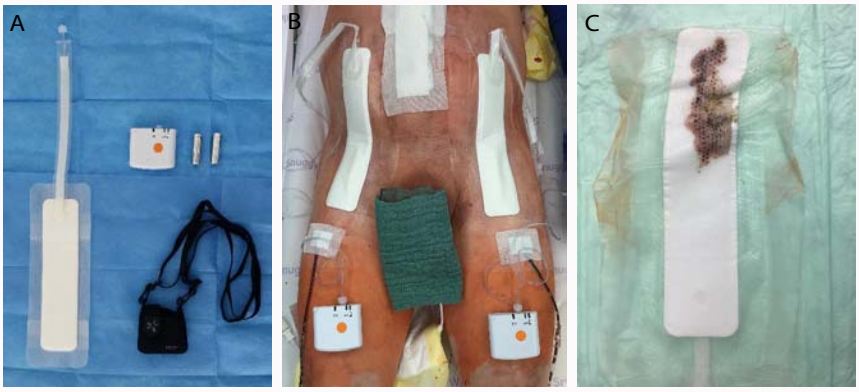

Figure 1: A) Components of PICO™; B) PICO™ after aortobifemoral bypass; C) Inner side of the PICO™ multi-function dressing with absorbed fluid.

Company, San Antonio, Texas, USA). PICO™ consists of a battery-powered vacuum unit that delivers a negative pressure of -80 mmHg (Figure 1) [31]. Prevena™ consists of a vacuum unit with a battery and a preset negative pressure of -125 mmHg [5,6,9,10,35]. Study data published in the last few years demonstrated a significant reduction of SSIs and other WHCs for groin wounds after vascular surgery using these two ciNPT systems [5-7,9,10,12,13,38-41]. Almost all data in the literature concern the effect of Prevena™ on groin wounds. Thus far, there is only one Randomized Clinical Trial (RCT) examining the effectiveness of PICO™ [40]. Therefore, we initiated the present RCT to investigate the effectiveness of PICO™ and compare it with that of conventional wound dressing with regard to the incidence of groin WHCs on postoperative days 5 to 7 and 30 and the incidence of surgery revisions at 30 days. Furthermore, subgroup analyses of primary wound healing risk factors and perioperative risk factors were carried out to examine the effect of PICO™ on patients with a specific risk profile for postoperative WHC in the groin.

Methods

This prospective, randomized clinical study was approved by the ethics committee of the Münster Medical Chamber and the Wilhelms University of Münster, Germany. The study was conducted and fully funded by our own department, without any financial or scientific support from Smith & Nephew, London, UK. From 1 August 2017 to 30 June 2018, 100 patients with 119 groin incisions were evaluated. Inclusion criteria were vascular procedures with access in the common femoral artery with at least a 5 cm longitudinal incision in the groin and at least two of the following wound healing risk factors: Diabetes mellitus, renal insufficiency, hypoalbuminemia, overweight, Chronic Obstructive Pulmonary Disease (COPD), and age >60 years. Patients with appropriate inclusion criteria were divided randomly into either the PICO™ group (n=50) or the conventional dressing (control) group (n=50). The randomization was based on the optimum biased coin design by Atkinson. PICO™ consists of a battery-powered vacuum unit that delivers a negative pressure of -80 mmHg and a four-layer, multi-function dressing design. Each layer of the dressing has a specific function. The silicone adhesive layer the nearest to the wound protects the wound environment and decreases pain during the removal. The airlock layer spreads the negative pressure over the wound surface and enables the movement of secretions through the dressing. The super-absorbent core keeps the secretions away from the wound, and the top-layer film has a high moisture transmission rate (Figure 1) [31]. All patients were prepared in the groin area preoperatively (hair shave and sterile skin disinfection with the antiseptic ECOLAB Skinsept® G [Ecolab GmbH Monheim am Rhein, Germany]), and all received perioperative prophylactic single-dose antibiotic treatment with cefazolin 2 g (HEXAL® AG Holzkirchen, Germany; administrated intravenously). A subfascial drain was placed before reapproximation of the subcutaneous tissue with Vicryl™ 3-0 sutures Ethicon® and the skin with Ethilon™ II 2-0 sutures Ethicon® (Johnson & Johnson Medical GmbH, Norderstedt, Germany). Depending on the randomization, either PICO™ or a conventional adhesive dressing Medipore™ + Pad, (3M Poland Manufacturing Sp. z o.o. 51-416 Wrocław, Poland) was applied to the incision immediately after closure (Figure 1). PICO™ was removed on postoperative days 5 to 7 with subsequent use of the conventional adhesive dressing. The conventional adhesive dressing in the control group was changed daily. The first evaluation took place on postoperative days 5 to 7 during the hospital stay and the second evaluation on postoperative day 30 in the outpatient clinic. The assessment of the incision wounds was based on the Szilagyi classification consisting of 3 grades: Grade I describes superficial infections on the skin surface; grade II comprises an additional infiltration of the subcutaneous layer; and grade III involves an infection of the arterial graft [42]. Since the Szilagyi classification describes only tissue and prosthetic infections, we modified this classification by adding different types of postoperative WHCs of the study to the respective grades. Thus, cutaneous wound dehiscence, skin necrosis, or isolated local signs of infection were classified as grade I, wound dehiscence in the subcutaneous layer, lymphatic fistula, lymphocele, seroma, hematoma, isolated local signs of infection, or systemic infection parameters (leukocytes >13 × 10^9/dL, C-reactive protein >100 mg/L) were classified as grade II, and arterial graft infections were classified as grade III. Subgroup analysis included all risk factors of wound healing and perioperative risk factors. All risk factors were examined with regard to the incidence of groin WHCs on postoperative days 5 to 7 and 30 and the need for surgical revision until postoperative day 30. The primary risk factors were defined as follows: Diabetes mellitus with Hemoglobin A1c (HbA1c) >6.5% and 48 mmol/mol glucose; renal insufficiency with glomerular filtration rate <89 mL/min (stage 2) and creatinine >1.2 mg/dL; overweight with BMI>25 kg/m^2; hypoalbuminemia with albumin <3.4 g/dL; Chronic Obstructive Pulmonary Disease (COPD) with the Global Initiative for Chronic Obstructive Lung Disease (GOLD) grade 1 FEV1 ≥ 80 %, and age >60 years. Perioperative risk factors were defined as wound length >8 cm, hospital stay >15 days, operative time >147 min, perioperative blood transfusion with hemoglobin <8 mg/dL, and previous vascular interventions (percutaneous transluminal

angioplasty). Statistical analysis was carried out using the Student´s t-test, Levene´s test, and Fisher´s exact test. Fisher´s exact test and the Poisson regression were used for subgroup analyses. Logistic regression analysis and Receiver Operating Characteristic (ROC) analysis were applied to investigate the risk of postoperative WHC. Statistical significance was determined by a p-value <0.05.

Results

The study included 100 patients with 120 groin wounds (PICO™ group n=62 groins; control group n=58 groins). The patient cohort consisted of 33 females and 67 males with a median age of 69 ± 8.9 years. One hundred groin wounds resulted from unilateral surgeries and 20 were groin wounds from bilateral surgeries such as endovascular aneurysm repair, fenestrated endovascular aneurysm repair and aortobifemoral bypass. The most frequently reported comorbidities were peripheral artery disease (79%) and abdominal aortic aneurysm (15%) (Table 1). The most frequent types of surgery were femoral endarterectomy (38%), femoral popliteal bypass (20%), and endovascular aneurysm repair (18%) (Table 2). There were a total of 55 groin WHCs (45.8%), including 12 (19.4%) in the PICO™ group and 43 (74.1%) in the control group (Table 3). At the first postoperative wound examination on postoperative days 5 to 7, WHCs in the PICO™ group were significantly (p<0.0005) less frequent than in the control group. Also, the second postoperative examination on postoperative day 30 showed fewer WHCs in the PICO™ group (p=0.362; Table 3 and Figure 2, 3). There were no WHCs in Szilagyi grade III in either group. The overall incidence of postoperative WHCs assessed 30 days postoperatively was lower in the PICO™ device than in the conventional dressing group (PICO™ 19.4% *vs.* control group 74.1%; p<0.0005; Table 3). There were 2 (3.2%) revision surgeries in the PICO™ group and 7 (12.1%) in the control group; although this difference was not statistically significant (p=0.087), a tendency favoring the use of PICO™ was noted (Table 3). The most frequently occurring WHC in the PICO™ group was superficial wound dehiscence (9.7%), and the leading WHCs in the control group were skin necrosis (20.7%), hematoma (17.2%), local infection (13.8%), and wound dehiscence (13.8%) (Table 4). A comparison of the two groups showed an advantage of PICO™ in patients with hematoma (p<0.0005), skin necrosis (p=0.004), and local infection (p=0.014). Two patients died during the first 5 postoperative days in the control group; however, the cause of death was unrelated to surgery. Subgroup analysis based on the primary risk factors and perioperative risk factors for wound healing (Table 5) revealed fewer WHCs in the PICO™-group than in the control group for age (>60 years) (p<0.0005), overweight (p<0.0005), wound length (>8 cm) (p=0.002), operation time (>147 min) (p=0.002), previous interventions (p=0.003), hypoalbuminemia (p=0.005), diabetes mellitus (p=0.006), hospital stay (>15 days) (p=0.007), and renal insufficiency (p=0.009). On postoperative days 5 to 7 there was a significant difference in results for risk all factors between the two groups. The evaluation on postoperative day 30 showed no statistically significant difference between the two groups. There were also no significant differences observed in patients requiring revision surgery on postoperative day 30. There was only a tendency for a lower WHC incidence (p=0.056) in patients >60 years treated with PICO™ (Table 5). All individual risk factors were examined for

Table 1: Patient characteristics.

	PICO™ group	Control group	p-value
Number of patients	50	50	
Number of groin incisions	62	58	
Sex			
Male	34 (68%)	33 (66%)	1
Female	16 (32%)	17 (34%)	1
Mean age [years]	70.6 (range 53-90)	70.5 (range 53-93)	0.974
Mean BMI [kg/m^2]	27.9 (range 17.5-37.4)	27.5 (range 17.6-46)	0.638
Hypertension	46 (92%)	43 (86%)	0.535
Coronary artery disease	17 (34%)	14 (28%)	0.666
Diabetes mellitus	16 (32%)	21 (42%)	0.408
Renal insufficiency	16 (32%)	17 (34%)	1
Dialysis	0 (0%)	1 (2%)	1
Hypoalbuminemia	15 (30%)	12 (24%)	0.653
COPD	11 (22%)	9 (18%)	0.803
Smoker	20 (40%)	18 (36%)	0.837
Preoperative anemia	2 (4%)	1 (2%)	1
Postoperative anemia	19 (38%)	15 (30%)	0.531
Postoperative leukocytosis	24 (48%)	25 (50%)	0.842
Peripheral artery disease			
Fontaine classification grade II	27 (54%)	23 (46%)	0.689
Fontaine classification grade III	3 (6%)	6 (12%)	0.313
Fontaine classification grade IV	13 (26%)	7 (14%)	0.213
Infrarenal abdominal aortic aneurysm Thoracic abdominal aortic aneurysm	8 (16%) 0 (0%)	7 (14%) 2 (4%)	1 0.238
Iliac aneurysm Infrarenal aortic stenosis	0 (0%) 0 (0%)	2 (4%) 1 (2%)	0.238 0.490
Artery occlusion (thrombosis/ embolism)	0 (0%)	1 (2%)	0.490
Leriche syndrome	0 (0%)	1(2%)	0.490

BMI: Body Mass Index; COPD: Chronic Obstructive Pulmonary Disease

Table 2: Perioperative characteristics.

	PICO™ group	Control group	p-value
Mean operative time [min]	151.3 (range 48-363)	142.1 (range 42-360)	0.538
Mean hospital stay [days]	15.2 (range 5-61)	15.6 (range 5-56)	0.989
Mean wound length [cm]	8 (range 5-15)	7.8 (range 5-15)	0.430
Perioperative blood transfusion	7 (14%)	11 (22%)	0.304
Procedure types			
EVAR/TEVAR	8 (16%)	10 (20%)	0.608
Revascularization	42 (84%)	40 (80%)	1
Bilateral procedures	13 (26%)	16 (32%)	0.511
Prosthetic material used			
PTFE	6 (12%)	7 (14%)	1
Dacron	5 (10%)	6 (12%)	0.758
Biological patch	25 (50%)	13 (26%)	0.025
Vein	7 (14%)	7 (14%)	1

EVAR: Endovascular Aortic Repair; TEVAR: Thoracic Endovascular Aortic Repair; PTFE: Polytetrafluoroethylene

Table 3: Wound healing complications according to Szilagyi classification.

Szilagyi classification	Total number			5-7 day postoperatively			30 day postoperatively			Revision surgery on 30 day postoperatively		
	PICO™-group n=62	Control-group n=58	p-value	PICO™-group n=62	Control-group n=58	p-value	PICO™-group n=62	Control-group n=58	p-value	PICO™-group n=62	Control-group n=58	p-value
Szilagyi grade I	9 (14.5%)	21 (36.2%)	0.011	1 (1.6%)	13 (22.4%)	<0.0005	8 (12.9%)	8 (13.8%)	1	1 (1.6%)	2 (3.4%)	0.609
Szilagyi grade II	3 (4.8%)	22 (37.9%)	<0.0005	1 (1.6%)	16 (27.6%)	<0.0005	2 (3.2%)	6 (10.3%)	0.154	1 (1.6%)	5 (8.6%)	0.106
Szilagyi grade III	0 (0%)	0 (0%)	-	0 (0%)	0 (0%)	-	0 (0%)	0 (0%)	-	0 (0%)	0 (0%)	-
Total number	12 (19.3%)	43 (74.1%)	<0.0005	2 (3.2%)	29 (50%)	<0.0005	10 (16.1%)	14 (24.1%)	0.362	2 (3.2%)	7 (12%)	0.087

Number of complications shown as a percentage of the total number of groin incisions for wound evaluation 5-7 days and 30 days postoperatively. Number of revision surgeries carried out as of 30 days postoperative

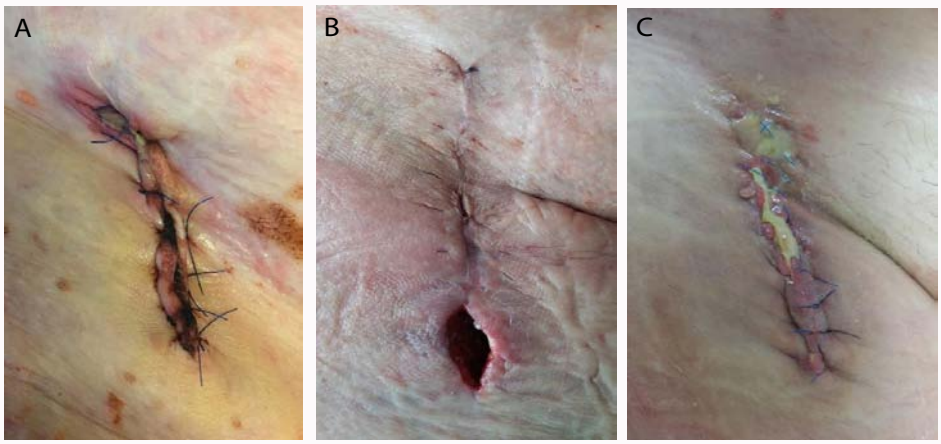

Figure 2: Wound complications of study patients based on Szilagyi classification. A) Szilagyi I: Skin necrosis on 5 to 7 days postoperatively; B) Szilagyi II: Superficial and deep wound dehiscence on 30 day postoperatively; C) Szilagyi II: Superficial wound dehiscence and local infection on 5 to 7 days postoperatively.

Table 4: Types of wound complications within the three grades of Szilagyi classification.

	PICO™ group	Control group	p-value
Superficial wound dehiscence	6 (9.7%)	8 (13.8%)	0.570
Skin necrosis	2 (3.2%)	12 (20.7%)	0.004
Deep wound dehiscence with fat necrosis	0 (0%)	1 (1.7%)	0.483
Hematoma	0 (0%)	10 (17.2%)	<0.0005
Seroma	1 (1.6%)	1 (1.7%)	1
Lymphatic fistula	2 (3.2%)	3 (5.2%)	0.672
Arterial graft infection	0 (0%)	0 (0%)	-
Local infection	1 (1.6%)	8 (13.8%)	0.014

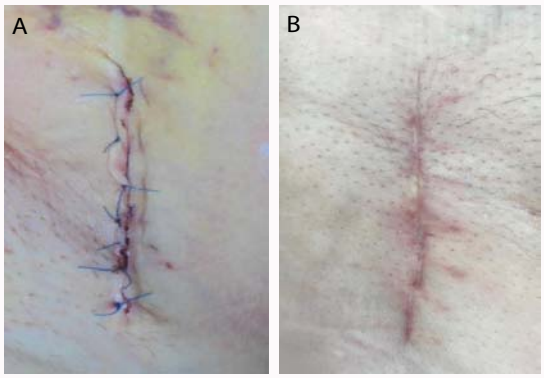

Figure 3: Wound results after removing PICO™ on A) 5 to 7 days and B) 30 days postoperatively.

postoperative WHCs in the logistic regression, where the strongest predictor of developing WHCs was the primary wound healing factor age (>60 years) (p=0.048, odds ratio =0.951). In the ROC analysis, only the perioperative risk factor age (>60 years) with an Area under the Curve (AUC) of 0.623 (p=0.047) was shown to be predictive of postoperative WHCs (Figure 4).

Discussion

Over the last few decades ciNPT has manifested as a powerful therapeutic method in the treatment of postoperative incision wounds in various surgical disciplines [21-29]. In recent years many publications have also revealed the potential of the two ciNPT systems Prevena™ and PICO™ to avoid postoperative WHCs after vascular surgeries [5-7,9-13,38-41]. Matatov et al. [5] first investigated Prevena™ in comparison with either a skin adhesive or absorbent dressing and documented a reduction of wound infections in the groin (p=0.011). Several years later Pleger et al. [6] showed a reduction in WHCs (p<0.0005) and revision surgeries (p=0.022) in incision groin after using Prevena™ wounds using in comparison to a conventional wound dressing. Further significant effects of Prevena™ *vs.* standard wound dressing were documented by Gombert et al. [10] who reported a decrease in SSI prevalence (p=0.015) in groin incisions, and by Kwon et al. [39] who demonstrated a reduction in wound complications (p<0.001) and reoperation (p<0.05). A reduction in major wound complications, including SSIs (p<0.001) and reoperation (p<0.05), in groin incisions treated by Prevena™ was also reported by DiMuzio [13]. Several studies have been published concerning PICO™, including one by Hasselmann et al. [40] who first reported a reduction of SSIs in patients with unilateral and bilateral groin incisions after vascular surgery using PICO™ versus standard

Table 5: Analyses of subgroups of patients based on primary wound healing risk factors and perioperative risk factors with regard to WHCs and revision surgeries.

Patient Subgroups	Analysis Intervals											
	Total Number of WHCs			Number of WHCs at Postoperative Days 5-7			Number of WHCs at Postoperative Day 30			Patients Requiring Revision Surgery 30 days postoperatively		
	PICO™-group	Control-group	p-value	PICO™-group	Control-group	p-value	PICO™-group	Control-group	p-value	PICO™-group	Control-group	p-value
Age (>60 years)	n=47 10 (21.3%)	n=46 36 (78.3%)	<0.0005	n=47 2 (4.3%)	n=46 25 (54.3%)	<0.0005	n=47 8 (17%)	n=46 11 (23.9%)	0.357	n=47 1 (2.1%)	n=46 7 (15.2%)	0.056
Diabetes mellitus	n=16 4 (25%)	n=20 21 (105%)	0 .006	n=16 1 (6,3%)	n=20 13 (65%)	0.020	n=16 3 (18.6%)	n=20 8 (40%)	0.218	n=16 1 (6.3%)	n=20 5 (25%)	0.182
Renal insufficiency	n=16 2 (12.5%)	n=17 13 (76.5%)	0.009	n=16 0 (0%)	n=17 9 (53%)	0.001	n=16 2 (12.5%)	n=17 4 (23.5%)	0.360	n=16 0 (0%)	n=17 2 (11.8%)	0.485
Hypoalbuminemia	n=15 1 (6.7%)	n=12 15 (125%)	0.005	n=15 0 (0%)	n=12 9 (75%)	<0.0005	n=15 1 (6.7%)	n=12 6 (50%)	0.068	n=15 0 (0%)	n=12 2 (16.7%)	0.188
Overweight	n=42 11 (26.2%)	n=36 37 (103%)	<0.0005	n=42 2 (4.8%)	n=36 24 (66.7%)	<0.0005	n=42 9 (21.4%)	n=36 13 (36.1%)	0.214	n=42 2 (4.8%)	n=36 5 (13.8%)	0.194
COPD	n=11 1 (9.1%)	n=9 4 (44.4%)	0.09	n=11 0 (0%)	n=9 4 (44.4%)	0.026	n=11 1 (9.1%)	n=9 0 (0%)	1	n=11 0 (0%)	n=9 1 (11.1%)	0.450
Wound length (>8 cm)	n=39 9 (23.1%)	n=31 24 (77.4%)	0.002	n=39 2 (5.1%)	n=31 15 (48.4%)	0.002	n=39 7 (17.9%)	n=31 9 (29%)	0.559	n=39 2 (5.1%)	n=31 5 (16.1%)	0.142
Hospital stay (> 15 days)	n=18 5 (27.8%)	n=13 18 (138%)	0.007	n=18 2 (11.1%)	n=13 12 (92.3%)	0.022	n=18 3 (16.7%)	n=13 6 (46.2%)	0.165	n=18 0 (0%)	n=13 4 (30.8%)	0.165
Operation time (> 147 minutes)	n=24 9 (37.5%)	n=19 28 (147%)	0.002	n=24 2 (8.3%)	n=19 17 (89.5%)	0.005	n=24 7 (29.2%)	n=19 11 (57.9%)	0.231	n=24 2 (8.3%)	n=19 1 (5.3%)	0.614
Previous interventions	n=3 0 (0%)	n=6 11 (183%)	0.003	n=3 0 (0%)	n=6 7 (116%)	0.008	n=3 0 (0%)	n=6 4 (66.7%)	0.176	n=3 0 (0%)	n=6 1 (16.7%)	1
Perioperative blood transfusion	n=7 2 (28.6%)	n=11 14 (127%)	0.087	n=7 0 (0%)	n=11 8 (72.7%)	0.004	n=7 2 (28.6%)	n=11 6 (54.5%)	0.811	n=7 0 (0%)	n=11 2 (18.1%)	0.497

COPD: Chronic Obstructive Pulmonary Disease

Table 6: Scoring system for PICO™ based on the significant risk factors for groin WHCs.

Risk Factors	p-value	Points
Patient age (>60 years)	(p<0.0005)	2
Overweight	(p<0.0005)	2
Wound length	(p=0.002)	2
Operation time	(p=0.002)	2
Previous interventions	(p=0.003)	1
Hypoalbuminemia	(p=0.005)	1
Diabetes mellitus Renal insufficiency	(p=0.006) (p=0.009)	1 1

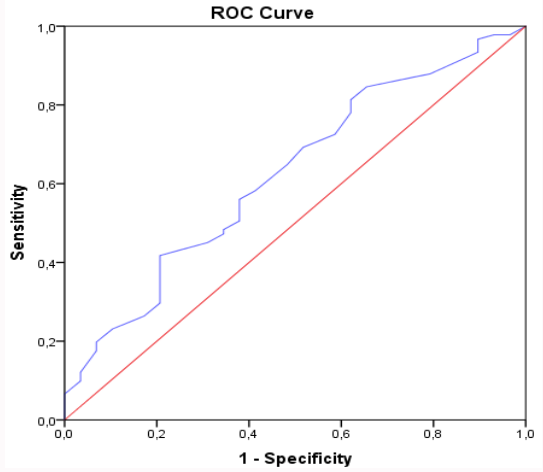

Figure 4: ROC Curve of the primary risk faktor age (>60 years).

wound dressing (p=0.02). In addition, several meta-analyses confirmed the effectiveness of ciNPT [7,12,41]. After analyzing seven RCTs of vascular surgery patients Svensson et al. [7] showed a decrease in SSIs in groin incision wounds after using Prevena™ and PICO™ (OR: 0.35, 95% CI [0.24-0.50], p<0.001). Singh et al. investigated 17 articles reporting the effectiveness of Prevena™ and PICO™ versus standard dressing, with the result that Prevena™ shows a more effective prevention of SSIs (Prevena™ OR: 3.17, 95% CI [2.17-4.65], p<0.0001; PICO™ OR: 1.70, 95% CI [0-94-3.08], p=0.008) [41]. Based on an analysis of six RCTs, Gombert et al. [12] reported a reduced incidence of SSIs in groin incisions treated with Prevena™ over standard dressing (Odds Ratio [OR] 3.06, 95% Confidence Intervals [CI] [2.05-4.58]; p<0.05). The potential of ciNPT can also be observed not only in primary incision wounds but also in groin incision wounds after revision vascular surgeries. In this regard, Gombert et al. [10] reported significantly less SSIs in the ciNPT group (n=5 [10.8%]) than in the control group (n=13 [33.3 %]) in 85 patients with a previous incision in the groin treated by Prevena™ (p=0.016). Recently, Pleger et al. [9] published data from an RCT of 94 patients with 100 groin incisions undergoing revision surgeries treated either by Prevena™ or conventional adhesive dressing. The results showed a significant decrease in the incidence of postoperative WHCs in cases employing ciNPT (n=6 [12.8%] *vs.* n=39 [73.6%], p<0.0005). Several studies, however, have yielded equivocal results concerning the value of ciNPT. After applying Prevena™ or standard wound dressing in 30 of 102 high-risk vascular surgery patients with a previous cut down in the groin, Lee et al. [38] showed nominally lower 30 day SSI rate in the ciNPT group (n=6 [11%] *vs.* n=9 [18%]) without demonstrating significance (p=0.24). Sabat et al. also did not observe a significant difference despite fewer infections in the ciNPT group (Prevena™) in comparison to the control group (n=2 [6.7%] *vs.* n=7 [21.2%], respectively; p=0.09) and less frequent wound occurrence (n=3[10%] *vs.* n=8 [24.2%], respectively; p=0.14) [11]. A similar lack of significant results was also reported by Engelhardt et al. [33] in comparing ciNPT (Prevena™) with conventional dressing (n=9 [14%] *vs.* n=19 [28%], respectively; p=0.055) as well as by Koetje et al. [37] who found even more SSIs in patients treated by ciNPT (n=5 [12.5%] *vs.* n=3 [6%], respectively; p=0.458) and wound healing disorders (n=7 [17.5%] *vs.* n=6 [12%], respectively; p=0.552). With these published results as a backdrop, our data supports the positive tendency of ciNPT to prevent WHCs in the groin after vascular surgeries. Our results clearly reveal that PICO™ reduced the overall incidence of postoperative WHCs compared with the conventional dressing after a follow up of 30 days (p<0.0005; Table 3). Although PICO™ showed no significant advantage in preventing groin wound revisions during the 30-day postoperative period (p=0.087), there was a tendency for PICO™ to be beneficial as evidenced by 8.8% fewer necessary revision surgeries being performed (Table 3). Both our data and the results of

Hasselmann et al. demonstrate significant effectiveness of PICO™ versus standard wound dressing in groin wounds after vascular surgeries (p<0.0005 *vs.* p=0.02; respectively). This is consistent with the Prevena™ data from the studies mentioned above: Our results show a similar significant advantage of ciNPT over conventional wound dressing, and both ciNPT systems appear to have an equivalent effect on incision wounds in the groin. Notably, in our study we observed an increase in WHCs in the PICO™ group within the period between the removal of PICO™ and the second wound evaluation at 30 days (n=2 [3.2%] *vs.* n=10 [16.1%], respectively), which finally resulted in a loss of significant difference between the groups on postoperative day 30 (p<0.0005 *vs.* p=0.362, respectively; Table 3). A similar observation made by Engelhardt et al. [36] who showed an 8% increase in the frequency of SSIs in incision wounds between postoperative days 5 and 42 after treatment with Prevena™ (n=4 [6%] *vs.* n=9 [14%], respectively), although on both days there was no significant difference between the two groups (p=0.125 *vs.* p=0.055, respectively). Moreover, Pleger et al. [6] reported that the number of WHCs in the Prevena™ group between both evaluation periods showed a clear difference of 8.6% (n=0 [0%] *vs.* n=5 [-8.6%], respectively) with a loss of significance on the 30th postoperative day (p<0.0005 *vs.* p=0.023, respectively). The reason for the two ciNPT systems showing an increased number of WHCs on postoperative day 30 is unclear. One possible explanation might be the difference in the negative pressure applied (PICO™ -80 mmHg *vs.* Prevena™ -125 mmHg) in the two ciNPT systems; it might be that the difference of -45 mmHg has a negative impact on skin adhesion, skin vascularization, and removal of fluids out of the subcutaneous layer. When comparing our data with that of Pleger et al. [6] this explanation is consistent with the occurrence of more cases of superficial wound dehiscence (n=6 [9.7%] *vs.* n=3 [7%]) using PICO™ *vs.* Prevena™. However, it must be taken into account that the loss of effectiveness between days 5 to 7 and 30 postoperatively that resulted in more WHCs also occurred in incision wounds in the groin after revision vascular surgery using Prevena™ *vs.* conventional wound dressing (n=1 [2.1%] *vs.* n=5 [-10.6%], respectively), resulting in a lack of significance on postoperative day 30 (p<0.0005 *vs.* p=0.116, respectively) [9]. All of these studies of PICO™ and Prevena™ show a lack of effectiveness after their removal on days 5 to 7 postoperatively; thus, the difference in negative pressure is not a sufficient explanation, especially as the optimum negative pressure in accordance with literature is -80 mmHg [35,43]. It is more likely, that the duration of application is the primary cause of the increase of WHCs in the groin. To confirm this hypothesis, more detailed information for individual evaluation days is needed. Unfortunately, not all published RCTs contain data about different evaluation periods, so that a far-reaching comparison is not possible. The above mentioned RCTs, with detailed information about primary and revision incision wounds in the groin documented on individual evaluation days, are consistent with this hypothesis [6,9,36]. In view of the limited data, further studies should be performed to explore the most effective period of application of ciNPT. In addition to the significant results regarding the reduction of WHCs in the groin our subgroup analysis revealed a significant effect of PICO™ in reducing groin WHCs for all risk factors except COPD or perioperative blood transfusion (Table 5). These results reveal a high effectiveness of PICO™ in patients with a variety of decisive wound healing risk and, thus, an important treatment benefit in patients with exactly this profile of risk factors. To confirm the clinical relevance of our results a comparison with study data concerning the use of ciNPT, especially PICO™, on postoperative incision wounds in the groin after vascular surgery would be helpful. Due to limited data from subgroup analyses, a comparison can only be made with Prevena™. Gombert et al. [7] reported peripheral artery disease stage ≥ 3 (p<0.001) and BMI>25 kg/m² (p<0.001) as relevant risk factors responsible for higher rates of SSIs, and Pleger et al. [6] detected a benefit for patients with respect to age (>50 years) (p<0.0005), overweight (p<0.0005), diabetes mellitus (p<0.0005), renal insufficiency (p<0.0005), malnutrition (p=0.043), operation time (>142 min) (p<0.0005), wound length (>8 cm) (p=0.003), hospital stay (>8 days) (p=0.001), and perioperative blood transfusion (p=0.004), emphasizing the importance of ciNPT with regard to these risk factors. Additionally, Lee et al. [38] observed a shorter duration of hospital stay (p=0.02) in ciNPT patients, showing a high relevance for this risk factor. Another study by Pleger et al. [9] observed similar relevant risk factors in ciNPT patients after revision vascular surgery, including age (>60 years) (p<0.0005), overweight (p<0.0005), diabetes mellitus (p<0.0005), renal insufficiency (p=0.007), hypoproteinemia (p=0.003), operation time (>168 min) (p<0.0005), wound length (10 cm) (p<0.0005), hospital stay (18 days) (p=0.006), and perioperative blood transfusion (p=0.003). In summary, these subgroup analysis data show a significant effect of both ciNPT systems on clearly defined risk factors, not only in primary incision wounds but also in revision wounds in the groin after vascular surgery. In our investigation the most frequent WHCs were hematoma (PICO™ n=0 *vs.* control group n=10; p=0.0005), skin necrosis (PICO™ n=2 *vs.* control group n=12; p=0.004), and local infection (PICO™ n=1 *vs.* control group n=8; p=0.014), and these were the WHCs with the most significant effect of PICO™ *vs.* the conventional dressing (Table 4). In comparison to our data, Kwon et al. [39] observed significantly fewer infections in incision wounds in patients treated with ciNPT (Prevena™ n=6 *vs.* standard dressing n=12; p=0.001) and fewer hematomas, with no significant differences between the two groups (Prevena™ n=0 *vs.* standard dressing n=1). Pleger et al. [6] reported significantly lower number of hematomas (Prevena™ n=0 *vs.* control group n=8; p=0.020), and local infection (Prevena™ n=1 *vs.* control group n=10; p=0.022). These data suggest that ciNPT is able to largely prevent hematomas and local infections that can result in SSIs and revision surgeries, longer hospital stays and higher treatment costs. The costs of treating postoperative WHCs in the groin after vascular surgery is a highly relevant topic, but unfortunately it has not been examined with valid study data. Apart from Kwon et al. [39] who reported a variable hospital savings of more than $6000 per patient without proof of significance (p=0.11), there is a lack of cost analyses with regard to the use of ciNPT for incision wounds in the groin. Our logistic regression revealed age (p=0.048, odds ratio =0.951) as the strongest predictor of developing WHCs in the groin. In comparison, Pleger et al. detected wound length (p=0.003, odds ratio 4.800) and operation time (p=0.046, odds ratio 2.571) as the leading predictors when using Prevena™, which indicates that for these primary risk factors attention should be given to the application of ciNPT. Presently, the indication for the use of ciNPT is still mostly random, despite significant results pointing out crucial risk factors for postoperative WHCs in the groin. Scoring systems that estimate a risk of WHCs as an indication for ciNPT (Prevena™) have been published: that of Karl and Woeste is based on various diseases as risk factors, with a score limit at 4 points [44], and that of Pleger et al. [6] uses significant primary - and perioperative risk factors from the study, with a score cutoff of 8 points. Based on the present data, we constructed a comparable scoring system by assigning the risk factors with the highest significance a value of 2 points and the risk factors

with lower significance 1 point (Table 6). The average score for all patients treated with PICO™ was calculated to be 7 points. For patients with a score over 7 points, 17.3% of those in the PICO™ group had WHCs and 31.3% in the control group. In contrast, in patients with a score below 7 points, 3.8% of those with PICO™ developed WHCs and 25% with conventional wound dressing. Thus, the use of PICO™ in patients with a score below 7 points would result in a lower rate of WHCs. In our opinion, this scoring system provides a promising opportunity to select the right group of patients for the use of ciNPT. Despite the significance of the data in favor of ciNPT, one cannot assume that this therapy is a panacea to avoid postoperative WHCs in the groin after vascular surgery. It is necessary to be mindful of the causes of potential postoperative WHCs. In addition to the many risk factors investigated in our subgroup analysis, attention should be given to hygiene during the hospital stay and of the follow-up care. The realities of hospital- and outpatient care may give rise to additional potential risk factors. Thus, a low level of patient personal hygiene or incorrectly performed wound dressing changes by the nurses and physicians on the wards, premature removal of stitches, or delayed detection of potential WHCs in outpatient care may foster the development of wound infections. Finally, one must not ignore the iatrogenic impact on postoperative WHCs, which includes a correct preparation of the anatomical structures in the groin and correct wound closure that encompasses all tissue layers. The results of our study reveal a significant reduction in the frequency of WHCs and suggest that ciNPT is an effective therapeutic tool in the treatment of incision wounds in the groin after vascular surgery. Despite these promising results, ciNPT cannot yet be generally recommended as standard of care, and further randomized studies on incision wounds in other clinical situations are needed to substantiate our data.

Limitations

As a potential limitation, the evaluation of the incision wounds that was carried out by the investigators of the study has to be mentioned. In addition, the lack of blinding in the evaluation procedure presents a possible assessment bias, which could have been avoided by a double-blinded study design. As the evaluation time period was restricted to 30 days, the development of further WHCs in the groin during the following days was not documented. To resolve this question, a longer observation period might have revealed new, long-term effects of ciNPT.

Conclusion

In comparison to conventional adhesive dressing, the PICO™ Single Use Negative Pressure Wound Therapy System showed a significant reduction of WHCs in the groin up until 30 days postoperatively for several types of vascular surgeries. In addition, there was tendency for fewer revision surgeries during the postoperative period. The results of the subgroup analysis revealed a significant effect of PICO™ for almost all risk factors examined; therefore, use of the ciNPT system is indicated for patients with a corresponding risk profile.

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References

1. Magill, SS, Edwards JR, Bamberg W, Beldavs ZG, Dumyati G, Kainer MA, et al. Multistate point-prevalence survey of health care-associated infections. N Engl J Med. 2014;370(13):1198-1208.
2. National Healthcare Safety Network (HSN) 2019 Surgical Site Infection (SSI) Protocol.
3. Ploeg AJ, Lardenoye JW, Peeters MP, Hamming JF, Breslau PJ. Wound complications at the groin after peripheral arterial surgery sparing the lymphatic tissue: A double-blind randomized clinical trial. Am J Surg. 2009;197(6):747-51.
4. Stewart AH, Eyers PS, Earnshaw JJ. Prevention of infection in peripheral arterial reconstruction: A systematic review and meta-analysis. J Vasc Surg. 2007;46(1):148-55.
5. Matatov T, Reddy KN, Doucet LD, Zhao CX, Zhang WW. Experience with a new negative pressure incision management system in prevention of groin wound infection in vascular surgery patients. J Vasc Surg. 2013;57(3):791-5.
6. Pleger SP, Nink N, Elzien M, Kunold A, Koshty A, Böning A. Reduction of groin wound complications in vascular surgery patients using closed incision Negative Pressure Therapy (ciNPT): A prospective, randomised, single-institution study. Int Wound J. 2018;15(1):75-83.
7. Svensson-Björk R, Zarrouk M, Asciutto G, Hasselmann J, Acosta S. Meta-analysis of negative pressure wound therapy of closed groin incisions in arterial surgery. BJS. 2019;106(4):310-8.
8. Engin C, Posacioglu H, Ayik F, Apaydin AZ. Management of vascular infection in the groin. Tex Heart Inst J. 2005;32(4):529-34.
9. Pleger SP, Fuhrmann L, Al Tattan M, Kunold A, Elzien M, Böning A, et al. Closed incision negative pressure therapy for management of incision wounds in the groin after revision vascular surgery: A randomized controlled trial. J Surg. 2021;9(1):36-44.
10. Gombert A, Babilon M, Barbati ME, Keszei A, von Trotha KT, Jalaie H, et al. Closed incision negative pressure therapy reduces surgical site infections in vascular surgery: A prospective randomised trial (AIMS Trial). Eur J Vasc Endovasc Surg. 2018;56(3):442-8.
11. Sabat J, Tyagi S, Srouji A, Pechman D, Gupta AM, Lucido D, et al. Prophylactic negative pressure therapy for femoral incision in vascular surgery: preliminary results of a prospective randomised trial. J Vasc Surg. 2016;63(6):94S-95S.
12. Gombert A, Dillavou E, D´Agostino R, Griffin L, Robertson JM, Eells M. A systematic review and meta-analysis of randomized controlled trials for the reduction of surgical site infection in closed incision management versus standard of care dressings over closed vascular groin incisions. Vascular. 2020;28(3):274-84.
13. DiMuzio P, Staley C, Reiter D, McCullough M, Goss S, Arosemena M, et al. A randomized study evaluating negative-pressure therapy to decrease vascular groin wound complications. J Vasc Surg. 2017;65:133S.
14. Morykwas MJ, Argenta LC, Shelton-Brown EI, McGuirt W. Vacuum-assisted closure: A new method for wound control and treatment: Animal studies and basic foundation. Ann Plast Surg. 1997;38(6):553-62.
15. Stannard JP, Robinson JT, Anderson ER, McGwin G, Volgas DA, Alonso JE. Negative pressure wound therapy to treat hematomas and surgical incisions following high-energy trauma. J Trauma. 2006;60(6):1301-6.
16. Meara JG, Guo L, Smith JD, Pribaz JJ, Breuing KH, Orgill DP. Vacuum-assisted closure in the treatment of degloving injuries. Ann Plast Surg. 1999;42(6):589-94.
17. Gustafsson R, Johnsson P, Algotsson L, Blomquist S, Ingemansson R. Vacuum-assisted closure therapy guided by C-reactive protein level in patients with deep sternal wound infection. J Thorac Cardiovasc Surg. 2002;123(5):895-900.
18. Wongworawat MD, Schnall SB, Holtom PD, Moon C, Schiller F. Negative pressure dressings as an alternative technique for the treatment of infected wounds. Clin Orthop. 2003;414:45-8.

19. DeFranzo AJ, Argenta LC, Marks MW, Molnar JA, David LR, Webb LX, et al. The use of vacuum-assisted closure therapy for the treatment of lower-extremity wounds with exposed bone. Plast Reconstr Surg. 2001;108(5):1184-91.

20. Morton N. Use of topical negative pressure therapy in postoperative dehisced or infected wounds. J Wound Care. 2004;13(8):346-8.

21. Grauhan O, Navasardyan A, Tutkun B, Hennig F, Müller P, Hummel M, et al. Effect of surgical incision management on wound infections in a poststernotomy patient population. Int Wound J. 2014;11(Suppl 1):6-9.

22. Pachowsky M, Gusinde J, Klein A, Lehrl S, Schulz-Drost S, Schlechtweg P, et al. Negative pressure wound therapy to prevent seromas and treat surgical incisions after total hip arthroplasty. Int Orthop. 2012;36(4):719-22.

23. Conde-Green A, Chung TL, Holton LH 3rd, Hui-Chou HG, Zhu Y, Wang H, et al. Incisional negative-pressure wound therapy versus conventional dressings following abdominal wall reconstruction. A comparative study. Ann Plast Surg. 2013;71(4):394-7.

24. Altintas B, Biber R, Brem MH. The accelerating effect of negative pressure wound therapy with Prevena™ on the healing of a closed wound with persistent serous secretion. Int Wound J. 2015;12(6):662-3.

25. Stannard JP, Volgas DA, McGwin G 3rd, Stewart RL, Obremsky W, Moore T, et al. Incisional negative pressure wound therapy after high-risk lower extremity fractures. J Orthop Trauma. 2012;26(1):37-42.

26. Scalise A, Tartaglione C, Bolletta E, Calamita R, Nicoletti G, Pierangeli M, et al. The enhanced healing of a high-risk, clean, sutured surgical incision by prophylactic negative pressure wound therapy as delivered by Prevena Customizable: cosmetic and therapeutic results. Int Wound J. 2015;12(2):218-23.

27. Anglim B, O'Connor H, Daly S. Prevena™, negative pressure wound therapy applied to closed Pfannenstiel incisions at time of caesarean section in patients deemed at high risk for wound infection. J Obstet Gynaecol. 2015;35(3):255-8.

28. Fowler AL, Barry MK. Closed incision negative pressure therapy for laparotomy wounds: A review. Clin Surg. 2018;3(1):2123.

29. Karlakki S, Brem M, Giannini S, Khanduja V, Stannard J, Martin R. Negative pressure wound therapy for managementof the surgical incision in orthopaedic surgery: A review of evidence and mechanisms for an emerging indication. Bone Joint Res. 2013;2:276-84.

30. Witt-Majchrzak A, Żelazny P, Snarska J. Preliminary outcome of treatment of postoperative primarily closed sternotomy wounds treated using negative pressure wound therapy. Pol Przegl Chir. 2015;86(10):456-65.

31. O'Leary DP, Peirce C, Anglim B, Burton M, Concannon E, Carter M, et al. Prophylactic negative pressure dressing use in closed laparotomy wounds following abdominal operations: A randomized, controlled, open-label trial: The P.I.C.O. Trial. Ann Surg. 2017;265(6):1082-6.

32. Karlakki SL, Hamad AK, Whittall C, Graham NM, Banerjee RD, Kuiper JH. Incisional Negative Pressure Wound Therapy dressings (iNPWTd) in routine primary hip and knee arthroplasties: A randomised controlled trial. Bone Joint Res. 2016;5(8):328-37.

33. Horch RE. Incisional negative pressure wound therapy for high-risk wounds. J Wound Care. 2015;24(4 Suppl):21-8.

34. Wilkes RP, Kilpadi DV, Zhao Y, Kazala R, McNulty A. Closed incision management with negative pressure wound therapy (CIM): Biomechanics. Surg Innov. 2012;19(1):67-75.

35. Malmsjö M, Huddleston E, Martin R. Biological effects of a disposable, canisterless negative pressure wound therapy system. Eplasty. 2014;14:e15.

36. Engelhardt M, Rashad NA, Wily C, Müller C, Bauer C, Debus S, et al. Closed-incision negative pressure therapy to reduce groin wound infections in vascular surgery: A randomised controlled trial. Int Wound J. 2018;15(3):327-32.

37. Koetje JH, Ottink KD, Feenstra I, Fritschy WM. Negative pressure incision management system in the prevention of groin wound infection in vascular surgery patients. Surg Res Pract. 2015;2015:303560.

38. Lee K, Murphy PB, Ingves MV, Duncan A, DeRose G, Dubois, et al. Randomized clinical trial of negative pressure wound therapy for high-risk groin wounds in lower extremity revascularization. J Vasc Surg. 2017;66(6):1814-9.

39. Kwon J, Staley C, McCullough M, Goss S, Arosemena M, Babak A, et al. A randomized clinical trial evaluating negative pressure therapy to decrease vascular groin incision complications. J Vasc Surg. 2018;68(6):1744-52.

40. Hasselmann J, Björk J, Svensson-Björk R, Acosta S. Inguinal Vascular surgical wound protection by incisional negative pressure wound therapy: A randomized controlled trial-INVIPS trial. Ann Surg. 2020;271(1):48-53.

41. Singh DP, Gabriel A, Silverman RP, Griffin LP, D´Agostino McGowan L, D´Agostino Jr RB. Meta-analysis comparing outcomes of two different negative pressure therapy systems in closed incision management. Plast Reconstr Surg Glob Open. 2019;7(6):e2259.

42. Szilagyi DE, Smith RF, Elliott JP, Vrandecic MP. Infection in arterial reconstruction with synthetic grafts. Ann Surg. 1972;176(3):321-33.

43. Loveluck J, Copeland T, Hill J, Hunt A, Martin R. Biomechanical modeling of the forces applied to closed incisions during single-use negative pressure wound therapy. Eplasty. 2016;16:e20.

44. Karl T, Woeste S. Prevention of inguinal wound healing disorders in vascular surgery. Results of using an epidermal negative pressure system (Prevena). Gefasschirurgie 2013;18:120-5.