ORIGINAL ARTICLE

A new surgical approach of direct perineal wound full-thick closure for perineal wound of abdominoperineal resection for rectal carcinoma: A prospective cohort trial

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Abstract

Perineal wound complications after APR have high morbidity in the colorectal surgical department. Although some approaches have been figured out to solve this clinical focus, the outcomes are still not satisfied. Herein, this prospective comparative clinical trial has been designed to evaluate a new surgical procedure of direct perineal wound full-thick closure (DPWC), compared with conventional perineal wound closure (CPWC), with hopes of making wound healing with less complications. In addition, an evaluation of an incision negative wound pressure therapy, as another focus in this field, was also analysed in the DPWC group. A total of 44 participants in our department were recruited from March 2018 to March 2020, divided into two groups randomly, CPWC group and DPWC group. The patients' characteristics, such as age, gender, BMI, smoking, alcohol consumption, comorbidities, CEA level, and high-risk of invasion, were recorded without statistical significance between the CPWC group and DPWC group. After the same standard abdominal phase, these two groups were performed in different perineal phases. And then, operative and postoperative outcomes were analysed with different statistical methods. Data on wound healing time and length of stay in the DPWC group were shorter than those in the CPWC group ($P < .05$). Furthermore, cases of wound infection within 30 days in the DPWC group were also less than that in the CPWC group ($P < .05$). However, no difference was found between the incisional negative pressure wound therapy assisted group (NPA group) and non- incisional negative pressure wound therapy assisted group (non-NPA group). During this study, hypoalbuminemia, as an independent high-risk factor, impacted perineal wound healing. ($P = .0271$) In conclusion, DPWC is a new surgical approach, which can lead to a better outcome than DPWC, and it can be another surgical procedure for clinicians. In addition, hypoalbuminemia should be interfered for avoiding perineal wound complications.

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1 | INTRODUCTION

Since the first description of the abdominoperineal resection for rectal carcinoma (APR),[1] this surgical approach is accepted widely by surgeons. As a result of a non-cylindrical resection without mesorectal removal at the level of the pelvic floor, conventional APR is associated with a high rate of positive resection margins, which has a consequence of being abandoned.[2] As an advanced surgical method, extralevator APR has been a substitute recently, characterised by en bloc resection of the anal levator muscles covering the distal mesorectum. Recent studies show that extralevator APR has better oncological outcomes, including local recurrence rate and overall survival.[3,4] However, with the removal of rectum, levator muscles, anus, and its surrounding perineal skin, leaving a pelvic cavity and perineal skin defect, a high incidence of wound complications exists, reported with a rate of 14%–80%.[5-9] Consequently, perineal wound complications have been a surgery-associated and high morbidity postoperative issue.

Owing to the high incidence of perineal wound complications, reconstruction of the perineal defect with rapid wound healing could be one of the major challenges for surgeons. However, wound tissue infection, remains of liquid beneath incision, and sometimes-high surface tension between sutured tissues could increase the risk of wound complications, which are of high-frequency and have to be faced by surgeons. This risk would be higher if neoadjuvant radiotherapy is administered.[6,10] Meanwhile, diabetes mellitus, smoking, lack of nutrition, and hypercholesterolemia have been considered to be the risk factors for wound healing complications, which are also for the perineal wound following APR.[8,10,11]

So far, some methods have been applied, such as perioperative prophylaxis with antibiotics and drainage device involvement.[12,13] A reduction of wound complications, to some extent, has been made. However, the incidence rate of perineal wound complications is still high and dissatisfied by patients and surgeons. Furthermore, in recent decades, few studies have been designed to evaluate the clinical outcomes of different surgical suture techniques with or without incisional drainage devices. Because of these mentioned reasons, this present clinical trial was designed with two groups, conventional perineal wound closure (CPWC) and direct perineal wound full-thick closure (DPWC), in order to analyse effects of

Key Messages

- a new procedure of direct perineal wound full-thick closure is verified to be a better choice compared with conventional perineal wound closure
- incisional negative pressure wound therapy could not be an essential procedure for patients in the DPWC group
- hypoalbuminemia is an independent high-risk factor impacting perineal wound healing

different approaches towards the perineal wound healing. In addition, we have explored the necessity and essential of incisional negative pressure device towards perineal wound healing as a kind of incisional negative pressure wound therapy (i-NPWT).

2 | METHODS

2.1 | Patients

This single centre prospective random clinical trial conducted from March 2018 to March 2020. A total of 44 patients were recruited and followed up for 3 months in the Second Hospital of Jilin University without anyone withdrawn. For the safety of the surgical approach chosen, before abdominoperineal resection for rectal carcinoma involved, all the participants were accessed by the following indications strictly: (a) the diagnosis evidence of rectal carcinoma were obtained, such as pathological results of colonoscopy biopsy; (b) the distance from the lowest edge of tumour to the anal edge was within 5 cm, confirmed by both the examination of colonoscopy and rectal physical examination; (c) no evidences were found to support distant metastasis, such as the liver and/or lung, after CT scan and MRI examination; (d) preoperative assessment was performed for every patient, with the purpose that this surgery could be safe enough to undergo. These 44 participants were divided into two groups: CPWC group 20 cases, DPWC group 24 cases. In addition, two subgroups in DPWC group were formed up according to whether to use an incisional negative

TABLE 1 Clinical characteristics of 44 patients in this study

	Total (n=44)	CPWC group (n=20)	DPWC group (n=24)	*P*-value
Age (years old)				
Mean±SD	71.59±8.79	71.85±9.09	71.38±8.72	.8622
Range	45-89	45-89	56-87	
Gender (n, %)				
Male	28(63.64%)	13(65%)	15(62.5%)	.557
Female	16(36.36%)	7(35%)	9(37.5%)	
BMI (kg/m^2)				
Mean±SD	23.68±3.39	23.15±3.38	24.12±3.41	.3509
Range	17.54-31.57	18.43-29.53	17.54-31.57	
Smoking (n, %)	14(31.82%)	7(35%)	7(29.17%)	.4633
Alcohol consumption (n, %)	2(4.55%)	1(5%)	1(4.17%)	.7082
Comorbidity:				
Hypertension (n, %)	5(11.36%)	2(10%)	3(12.5%)	.5889
Diabetics (n, %)	6(13.64%)	3(15%)	3(12.5%)	.5745
Hypoalbuminemia(<3.5 g/dl) (n, %)	10(22.73%)	5(25%)	5(20.83%)	.5105
COPD (n, %)	3(6.82%)	1(5%)	2(8.33%)	.5696
Congestive heart disease (n, %)	1(2.27%)	0(0%)	1(4.17%)	.5455
Blood and imaging examination:				
Elevated CEA level (n, %)	29(65.91%)	13(65%)	16(66.67%)	.5791
High-risk of invasion (n, %):				
EMVI (+)	15(34.09%)	7(35%)	8(33.33%)	.5791
MRF (+)	20(45.45%)	10(50%)	10(41.67%)	.4017

Abbreviations: BMI, body mass index; CEA, carcinoembryonic antigen; COPD, chronic obstructive pulmonary disease; CPWC group, conventional perineal wound closure group; DPWC group, direct perineal wound full-thick closure group; EMVI, extramural vascular invasion; MRF, mesorectal fascia.
Statistically significant: *P* < .05.

pressure device or not, 13 cases without such device (non-negative pressure-assisted group, non-NPA group) and 11 cases with such device (incisional negative pressure wound therapy assisted group, NPA group).

All the patients' characteristics are listed in Table 1, in which patients were divided into two groups, CPWC group and DPWC group. In addition, for the DPWC group, Table 2 was tabulated to record these cases' characteristics, with the non-NPA group and NPA group. In both Tables 1 and 2, basic data of patients were collected, such as age (years), gender, and body mass index (BMI, kg/m^2). Smoking history was analysed in this study since there was a common sense of smoking affecting wound healing. Some comorbidities, such as hypertension and diabetics, were also recorded. CEA (carcinoembryonic antigen) level was monitored pre-surgery, as a result of its indication of recurrence (>5 ng/mL was considered to be elevated). EMVI (extramural vascular invasion) and MRF (mesorectal fascia), as high risks of invasion, which

were examined by MRI, were collected, with a consideration of whether there would be a relationship between them and wound healing or not.

All the recruited cases in this study did not receive any neoadjuvant therapy preoperatively. All of them followed a protocol of the workup, which is shown in Figure 1.

2.2 | Surgical procedure

In this study, a surgical procedure of APR was performed with two phases: abdominal phase and perineal phase.

For both the CPWC and DPWC group, a common abdominal phase was performed. This surgical procedure followed principles below: (a) isolated and cut off the inferior mesenteric artery (preserve the left colon artery) meanwhile cut off the inferior mesenteric vein; (b) sharply separated the mesorectum in presacral space

TABLE 2 Clinical characteristics of 24 patients in the DPWC group

	Total (n=24)	Non-NPA group (n=13)	NPA group (n=11)	*P*-value
Age (years old)				
Mean ± SD	71.38±8.72	69.85±6.73	73.18±10.67	.3627
Range	56-87	59-79	56-87	
Gender				
Male	15(62.5%)	8(61.54%)	7(63.64%)	.4153
Female	9(37.5%)	5(38.46%)	4(36.36%)	
BMI (kg/m^2)				
Mean ± SD	24.12±3.41	24.31±3.82	23.90±3.01	.7761
Range	17.54-31.57	18.43-31.53	17.54-27.01	
Smoking (n, %)	7(29.17%)	4(30.77%)	3(27.27%)	.6049
Alcohol consumption (n, %)	1(4.17%)	1(7.69%)	0(0%)	.5417
Comorbidity:				
Hypertension (n, %)	3(12.5%)	2(15.38%)	1(9.09%)	.5652
Diabetics (n, %)	3(12.5%)	2(15.38%)	1(9.09%)	.5652
Hypoalbuminemia (<3.5 g/dl) (n, %)	5(20.83%)	3(23.08%)	2(18.18%)	.5854
COPD (n, %)	2(8.33%)	1(5%)	2(8.33%)	.4348
Congestive heart disease (n, %)	1(4.17%)	0(0%)	1(4.17%)	.4583
Blood and imaging examination:				
Elevated CEA level (n, %)	16(66.67%)	8(61.54%)	8(72.73%)	.4445
High-risk of invasion (n, %)				
EMVI (+)	8(33.33%)	5(38.46%)	3(27.27%)	.4445
MRF (+)	10(41.67%)	6(46.15%)	4(36.36%)	.4733

Abbreviations: BMI, body mass index; CEA, carcinoembryonic antigen;DPWC group, direct perineal wound full-thick closure group; EMVI, extramural vascular invasion; MRF, mesorectal fascia; non-NPA group, non-negative pressure-assisted group; NPA group, incisional negative pressure wound therapy assisted group.
Statistically significant: *P* <.05.

under direct vision; (c) maintained the visceral layer of pelvic fascia integrated; (d) left hemi-colostomy was performed under enough blood supply to the intestinal mucosa.

A perineal phase was different between these two groups. For the CPWC group, a classic Mile's procedure for anal resection was performed. After removal of the specimen through the abdominal wound, such protocols for perineal closure were followed: (a) sutured the muscle layer at the pelvic floor with multiple tight single-knot by using absorbable line (thickness "0"); (b) closed the ischiorectal fat layer with multiple tight single-knot by using absorbable line (thickness "2–0"); and (c) closed the epidermal layer. However, a strategy for closing the perineal wound situs was different in DPWC group: directly closed the perineal wound situs by suturing the ischiorectal fat and epidermal lay as an entire layer, with multiple tight single-knot by using absorbable line (thickness "0"), without suturing muscle layer. (Figure 2)

Furthermore, in NPA group as a subgroup of DPWC, a tube was placed through the ischiorectal fat layer, into the pelvic cavity, with a connection to an incisional negative pressure device outside the skin, meanwhile, for the non-NPA group, surgery was finished without any negative pressure device placing inside the wound.

2.3 | Data collection during the surgical and post-surgical period

For the surgical period, American society of anesthesiologists physical status classification (ASA classification) scores were collected for all participants. Meanwhile, operation time, estimated blood loss during surgery, and intra-operative perforation were also recorded. After surgery, pathological examination reports, including the T stage, N stage, and M stage were recorded.
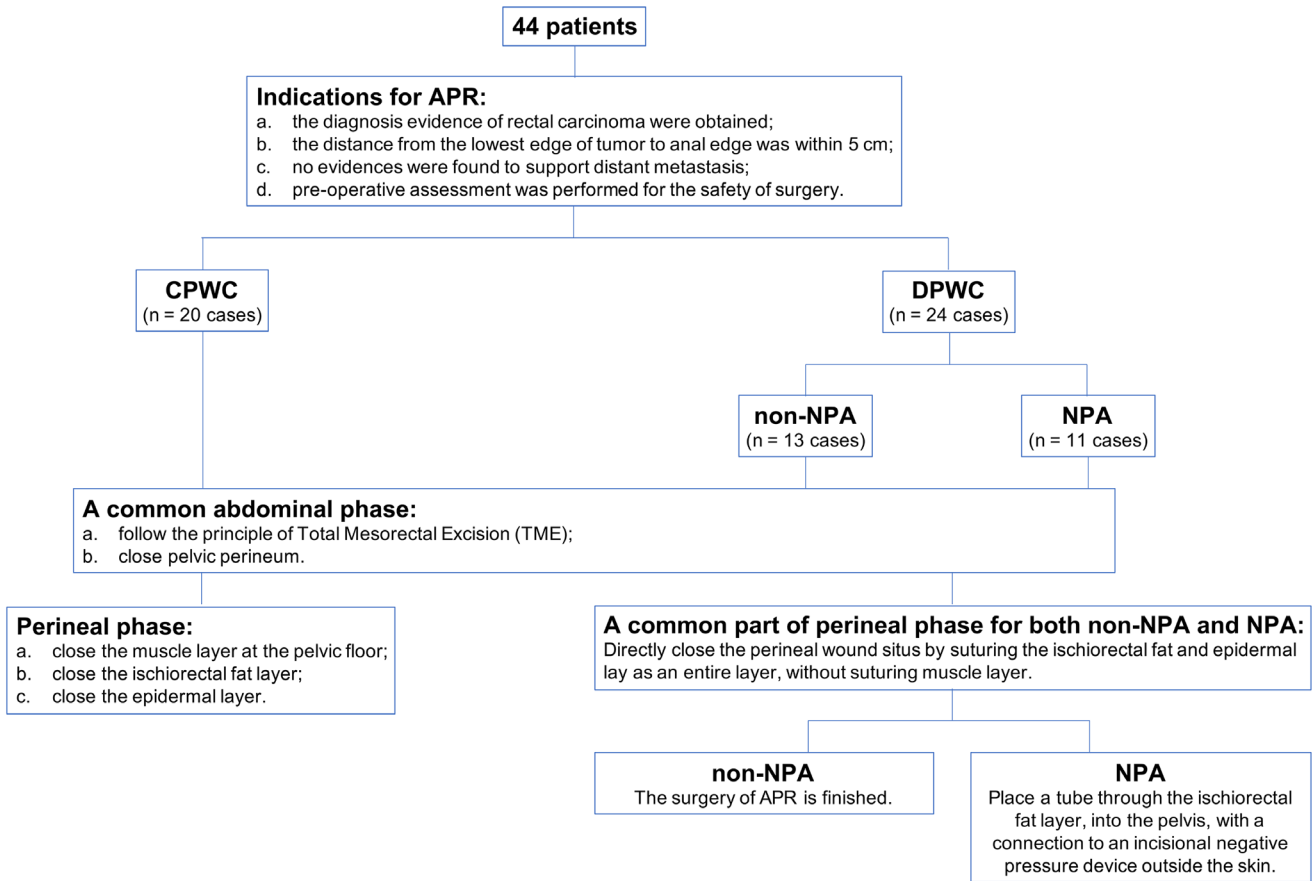
44 patients

Indications for APR:
a. the diagnosis evidence of rectal carcinoma were obtained;
b. the distance from the lowest edge of tumor to anal edge was within 5 cm;
c. no evidences were found to support distant metastasis;
d. pre-operative assessment was performed for the safety of surgery.

CPWC
(n = 20 cases)

DPWC
(n = 24 cases)

non-NPA
(n = 13 cases)

NPA
(n = 11 cases)

A common abdominal phase:
a. follow the principle of Total Mesorectal Excision (TME);
b. close pelvic perineum.

Perineal phase:
a. close the muscle layer at the pelvic floor;
b. close the ischiorectal fat layer;
c. close the epidermal layer.

A common part of perineal phase for both non-NPA and NPA:
Directly close the perineal wound situs by suturing the ischiorectal fat and epidermal lay as an entire layer, without suturing muscle layer.

non-NPA
The surgery of APR is finished.

NPA
Place a tube through the ischiorectal fat layer, into the pelvis, with a connection to an incisional negative pressure device outside the skin.

FIGURE 1 Algorithm of the workup of APR in this study. APR, abdominoperineal resection for rectal carcinoma; CPWC, conventional perineal wound closure; DPWC, direct perineal wound full-thick closure; NPA, incisional negative pressure wound therapy assisted group; non-NPA, non-negative pressure-assisted group

FIGURE 2 Schematic diagram of DPWC. A and B, showed directly closed the perineal wound situs by suturing the ischiorectal fat and epidermal lay as an entire layer, with multiple tight single-knot by using absorbable line (thickness "0"), without suturing muscle layer; C, showed the distance between each two suture knots is >1 cm; D, showed epidermal layer sutures was added with a purpose of a better skin healing (with white arrows)
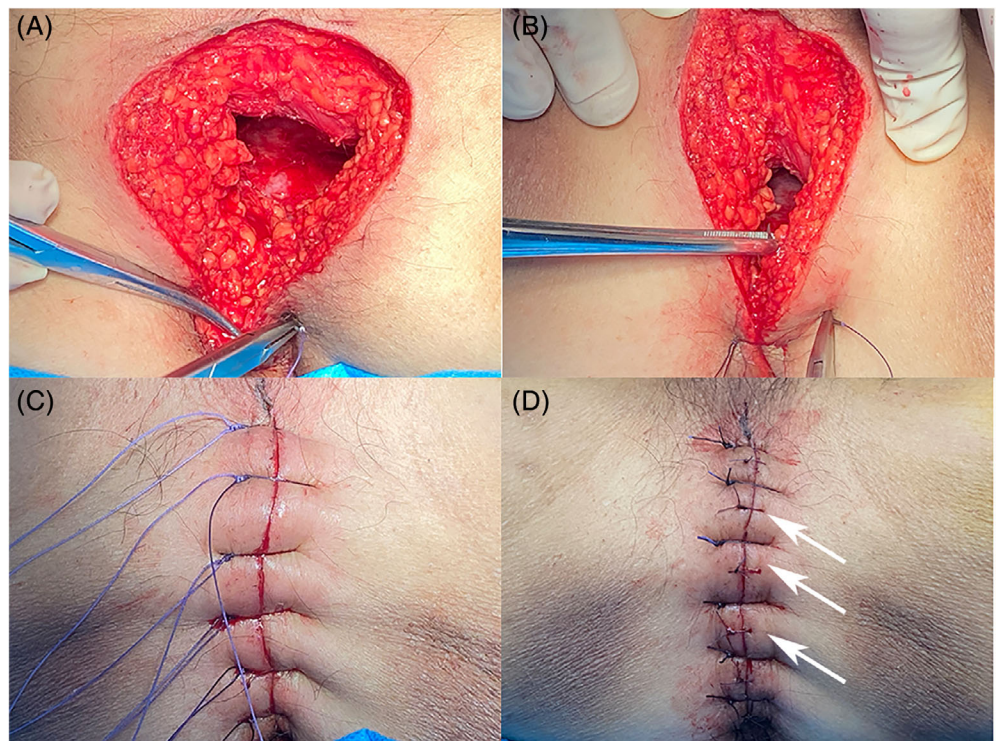
TABLE 3 Operative and postoperative outcome

	CPWC group (n=20)	DPWC group (n=24)	*P*-value
ASA classification (n, %)			
Score II	15(75%)	19(79.17%)	.5105
Score III	5(15%)	5(20.83%)	
Operation time (min, mean ± SD)	104.05±10.26	99.54±9.29	.1337
Estimated blood loss (mL, mean ± SD)	99.25±14.89	102.08±12.76	.5008
Intra-operative perforation (n, %)	1(5%)	0(0%)	.4545
Wound healing time (days, mean ± SD)	28.95±9.50	22.13±7.16	*.0096
Prolonged wound healing (>30 days, n, %)	6(30%)	4(16.67%)	.2449
Length of stay (days, mean ± SD)	24.4±4.13	21.88±4.00	*.0466
Pathological examination: (n, %)			
T stage			
T0-T2	4(20%)	5(20.83%)	.6233
T3-T4	16(80%)	19(79.17%)	
N stage			
N0	1(5%)	2(8.33%)	.5696
N1-N2	19(95%)	22(91.67%)	
M stage			
M0	18(90%)	21(87.5%)	.5889
M1	2(10%)	3(12.5%)	

Abbreviation: ASA, American Society of Anesthesiologists physical status classification; CPWC group, conventional perineal wound closure group; DPWC group, direct perineal wound full-thick closure group.
*Statistically significant, *P*<.05.

TABLE 4 Perineal wound complications postoperatively for all 44 cases (n, %)

	CPWC group (total n=20)	DPWC group (total n=24)	*P*-value
Short term (< 30 days):	n=9/14	n=6/20	
Wound infection	7(50%)	2(10%)	*.0136
Wound dehiscence	2(14.29%)	3(15%)	.6723
Perineal abscess	0(0%)	1(5%)	.3650
Perineal hernia	0(0%)	0(0%)	1.0000
Long term (> 30 days):	n=6/6	n=4/4	
Wound infection	3(50%)	1(25%)	.4524
Wound dehiscence	1(16.67%)	2(50%)	.3333
Persistent perineal sinus	2(33.33%)	0(0%)	.3333
Perineal hernia	0(0%)	1(25%)	.4000
Total cases with wound complications	15	10	*.0267
Surgical intervention for wound complication:			
Suture	2(10%)	3(12.5%)	.5889
Percutaneous drainage	2(10%)	0(0%)	.2008

Abbreviation: CPWC group, conventional perineal wound closure group; DPWC group, direct perineal wound full-thick closure group.
*Statistically significant, *P*<.05.

Some data about perineal wound healing were collected, including wound healing time, prolonged wound healing (>30 days), length of stay in the hospital. Furthermore, perineal wound complications in this study were grouped into short term (<30 days) and long term (>30 days) according to healing time postoperatively.

TABLE 5 Perineal wound complications postoperatively for non-NPA group and NPA group (n, %)

	Non-NPA group (n=13)	NPA group (n=11)	P-value
Wound healing time (days, mean ± SD)	21.62±7.77	22.73±6.68	
Prolonged wound healing (>30 days)	2(15.38%)	2(18.18%)	.6366
Short term (< 30 days):			
Wound infection	2(15.38%)	2(18.18%)	.6366
Wound dehiscence	0(0%)	1(9.09%)	.4583
Perineal abscess	1(7.69%)	0(0%)	.5417
Perineal hernia	0(0%)	0(0%)	1.0000
Long term (> 30 days):			
Wound infection	1(7.69%)	0(0%)	.5417
Wound dehiscence	1(7.69%)	1(9.09%)	.7174
Persistent perineal sinus	0(0%)	0(0%)	1.0000
Perineal hernia	0(0%)	1(9.09%)	.4583
Surgical intervention for wound complication:			
Suture	2(15.38%)	1(9.09%)	.5652
Percutaneous drainage	0(0%)	0(0%)	1.0000

Abbreviations: non-NPA group, non-negative pressure-assisted group; NPA group, incisional negative pressure wound therapy assisted group.
Statistically significant, $P<.05$.

TABLE 6 Multivariate analysis of risk factors for perineal procedure-related complications in APR of this study

Variables	healing without complications (n=19)	healing with complications (n=25)	Multivariate OR(95% CI)	P-value
Age > 65 (years old)	15	20	0.9375 (0.2143-4.101)	1.0000
Gender			1.444 (0.4115-5.070)	.7530
Male	13	15		
Female	6	10		
BMI > 25 (kg/m^2)	7	9	1.037 (0.3002-3.582)	1.0000
Smoking	5	9	0.6349 (0.1717-2.348)	.5340
Comorbidity:				
Hypertension	3	2	2.156 (0.3225-14.42)	.6378
Diabetics	2	4	0.6176 (0.1006-3.790)	.6843
Hypoalbuminemia (<3.5 g/dl)	1	9	0.09877 (0.01124-0.8681)	*.0271
Elevated CEA level	12	17	0.8067 (0.2299-2.831)	.7589
High-risk of invasion:				
EMVI (+)	7	8	1.240 (0.3533-4.350)	.7589
MRF (+)	8	12	0.7879 (0.2367-2.622)	.7662
Operation time > 100 minutes	7	14	0.4583 (0.1350-1.556)	.2387
Estimated blood loss > 100 mL	8	10	1.091 (0.3245 > 3.668)	1.0000
Intra-operative perforation	0	1	0.4188 (0.01614-10.87)	1.0000

Abbreviations: APR, abdominoperineal resection for rectal carcinoma; BMI, body mass index; CEA, carcinoembryonic antigen; EMVI, extra-mural vascular invasion; MRF, mesorectal fascia.
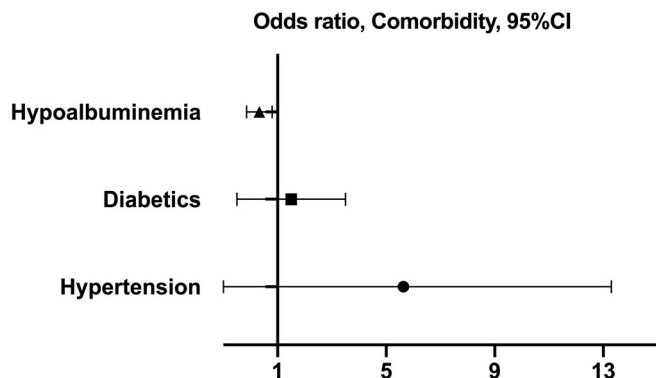*Statistically significant: $P <.05$.

Odds ratio, Comorbidity, 95%CI

FIGURE 3 Forrest plot of high-risk factors for perineal wound complications for all 44 cases

These complications totally included wound infection, wound dehiscence, perineal abscess, perineal hernia, and perineal sinus. Some complications, such as wound infection and wound dehiscence, were diagnosed by clinical physical examination and laboratory tests. Other complications, such as perineal abscess, perineal hernia, and perineal sinus, were diagnosed by clinical physical examination, ultrasonic examination, and/or pelvic MRI scan. Surgical interventions for wound complications were also recorded, such as suture and percutaneous drainage. (Tables 3, 4, and 5).

In order to value risk factors for perineal procedure-related complications, multivariate analysis was performed in Table 6, with the data of age, gender, BMI, smoking, comorbidity, elevated CEA level, high-risk of invasion, operation time, estimated blood loss, and intra-operative perforation. A further Forrest Plot analysis was also undergoing with the purpose of more direct description. (Figure 3).

2.4 | Data analysis

SPSS for MAC, version 26.0.0.0. was implied for data analysis. The Mann–Whitney U test was used for continuous variables (eg, age, BMI, operation time, estimated blood loss, wound healing time, length of stay). Chi-square test or Fisher exact test was used for comparing categorical data (eg, gender, smoking, alcohol consumption, hypertension, diabetics, hypoalbuminemia, COPD, congestive heart disease, etc). Variate analysis was used for potential risk factors of perineal procedure-related complications in APR of this study by using the chi-square test or Fisher's exact test. $P < .05$ was statistically significant. In Forrest Plot analysis, it was considered statistically significant only when both minimal and maximal value was under 1.

2.5 | Ethical considerations

The Institutional Ethics Committee of the Second Hospital of Jilin University has approved this study. Written informed consent was provided by every patient in this study.

3 | RESULTS

A total of 44 patients were enrolled, of which clinicopathological characteristics were listed in Table 1. The age of all enrolled cases was 71.59 ± 8.79 (range was 45–89), of which the age of CPWC group was 71.85 ± 9.09 (range was 45–89), and the age of DPWC group was 71.38 ± 8.72 (range was 56–87). The male proportion of all cases was 63.64%, of which the male proportion in the CPWC group was 65%, and that in the DPWC group was 62.5%. The total BMI was 23.68 ± 3.39 (range was 17.54–31.57), with 23.15 ± 3.38 in the CPWC group and 24.12 ± 3.41 in the CPWC group. The record of smoking (CPWC group vs DPWC group was 35% vs 29.17%) and alcohol consumption (CPWC group vs DPWC group was 5% vs 4.17%) was also tabulated in this table. Comorbidities, such as hypertension (CPWC group vs DPWC group was 10% vs 12.5%), diabetics (CPWC group vs DPWC group was 15% vs 12.5%), hypoalbuminemia (CPWC group vs DPWC group was 25% vs 20.83%), COPD (CPWC group vs DPWC group was 5% vs 8.33%), and congestive heart disease (CPWC group vs DPWC group was 0% vs 4.17%) were also included in Table 1. Among these comorbidities, hypoalbuminemia was the most common one. The proportion of elevated CEA levels in the CPWC group was 65%, meanwhile, that proportion in DPWC was 66.67%. To evaluate the high-risk of invasion, EMVI (+) (CPWC group vs DPWC group was 35% vs 33.33%) and MRF (+) (CPWC group vs DPWC group was 50% vs 41.67%) were also recorded. From these results, no statistical significance was found between the two groups.

In addition, we have analysed the data in the DPWC group, which was divided into two subgroups according to whether an incisional negative pressure wound device was placed or not. The collected items shown in Table 2 were as same as these in Table 1. From the data shown to us in Table 2, such as age, gender, BMI, the proportion of smoking, the proportion of alcohol consumption, comorbidities, the proportion of elevated CEA level and proportion of the high-risk of invasion, no statistical significance was found between NPA group and non-NPA group. Hypoalbuminemia was still the main comorbidity (20.83%), which still had no statistical difference between these two subgroups.

The operative and postoperative outcomes were tabulated in Table 3. As shown in this table, the distribution of ASA classification in both the CPWC group and DPWC group had no statistical difference

(P = .5105). The operation time was 104.05 ± 10.26 minutes vs 99.54 ± 9.2 minutes (P = .1337). The estimated blood loss in both groups was also almost the same. One intra-operative perforation occurred in the CPWC group; however, it took no statistical significance. We found that the wound healing time in the CPWC group was longer than that in the DPWC group (28.95 ± 9.50 days vs 22.13 ± 7.16 days, P = .0096). As a result, the length of stay in the hospital in the CPWC group was also longer than that in the DPWC group (24.4 ± 4.13 days vs 21.88 ± 4.00 days, P = .0466). However, for the cases proportion of prolonged wound healing, no statistical difference was found (P = .2449). Pathological classification distributions were further analysed in both the CPWC group and DPWC group, without any differences found.

The data of perineal wound complications postoperatively were collected and analysed for all 44 cases, in terms of two groups. As shown in Table 4, as short term complications, wound infection, wound dehiscence, perineal abscess, and the perineal hernia was recorded. In the CPWC group, 9 in 14 participants suffered from short term complications, meanwhile, 6 in 20 of the DPWC group suffered. Among these short term complications, the CPWC group had more wound infection cases than the DPWC group (7 vs 2, P = 0.0136). The distribution of the cases suffering from wound dehiscence and perineal abscess between these two groups were without statistical significance. No perineal hernia was observed in both groups within 30 days postoperatively. As long term complications wound infection, wound dehiscence persistent perineal sinus, and the perineal hernia was observed. There were six cases in the CPWC group and four cases in DPWC group having long term complications. However, the distribution of these complications between the two groups had no statistical significance. As a summary of both short and long term postoperatively, the number of cases with complications in the CPWC group was more than that in the DPWC group (15 vs 10, P = .0267). For further surgical interventions, two cases in the CPWC group and three cases in the DPWC group received suture (P = .5889), while two cases in the CPWC group performed percutaneous drainage (P = .2008).

In order to evaluate the effect of incisional negative pressure wound therapy, we further investigated the cases in the DPWC group with the same observation items as Table 4, which were shown in Table 5. No significant differences were found for each comparison.

We further analysed risk factors for perineal procedure-related complications in APR of this study,

including age, gender, BMI, smoking, comorbidities, elevated CEA level, high risks of invasion, operation time, estimated blood loss, and intra-operative perforation. (Table 6) Multivariable logistic regression analysis was performed, with a result showing that hypoalbuminemia had an independent risk factor for delayed wound healing (OR = 0.09877, 95% CI = 0.01124–0.8681, P = .0271). A Forrest plot analysis also manifested as a same trend as shown in Table 6. (Figure 3) In Figure 3, with the data of hypoalbuminemia, the data of hypertension and diabetics, as other comorbidities, were also described (hypertension OR = 2.156, 95% CI = 0.3225–14.42, P = .6378, diabetics OR = 0.6176, 95% CI = 0.1006–3.790, P = .6843). In this figure, hypoalbuminemia, as an independent risk factor, can be observed more directly.

4 | DISCUSSION

Wound complications during perineal incision healing have high morbidity after APR.[6] Wound complications are a complicated issue, which surgeons have to confront. For decades, some interventions have been figured out to deal with such situations; however, the outcomes can hardly be well accepted. Our study was designed to investigate the morbidity of perineal wound complications after the surgical intervention of direct perineal wound full-thick closure, with a comparison with CPWC, hoping to confirm the advantages of DPWC.

Conventional closure of the perineal wound, reported by some surgical groups recently, is always associated with high morbidity of wound healing complications.[6,14-17] Reasons for this situation have been widely debated. First, surgical tissue dissociation and removal of tumour, partial rectum, anus, and tissue surrounding result in a large empty space, where abdominal space remaining liquid tend to accumulate because of the lowest anatomical position. Whereupon bacteria implanting and reproduction leading to infection would be a high possible issue after APR. Second, debris and fragments of damaged tissue can also be bacteria medium for its growth. Third, micro-ischaemic area after incision, separation, ligation, and haemostasis during surgery could be an inevitable issue, which can be another high-risk factor or predisposing factor for bacteria implanting for infection. Finally, high superficial tension between suturing tissues cannot be ignored when a large coloboma exists. In addition, some researchers argued that[6,18] preoperative radiotherapy can increase the risk of perineal procedure-related wound complications, which was regarded as an independent predictor.[19]

In this study, we performed a surgical procedure of direct perineal wound full-thick suture as a whole layer in the DPWC group, with hopes of less wound-related

complications. The outcomes from Tables 4 and 5 are positive. We analysed the reasons for these outcomes, holding conclusions are following, First, a full-thick suture as an entire layer can avoid micro-ischaemia area happening by less needle puncturing, less separation and ligation practice, less haemostasis procedure, and less tissue fragments remaining beneath the incision. Furthermore, closure of pelvic peritoneum after removal specimen could prevent liquid accumulation around the perineal wound to some extent; and then, the distance between each two suture knots can be another key point for decreasing local ischaemia and wound complications in advance. The distance of full-thick closure between each two suture knots is more than 1 cm in our DPWC group. However, some epidermal layer sutures can be added before surgical procedure finishing, with the purpose of better skin healing, as shown in Figure 2d. Finally, thorough sanitation in and around perineal wound could also have contributed to a relatively lower incidence of wound complications, compared with other groups reported. To our group point view, less changes or destructions of perineal local hemodynamics play an intensive significant role in this wound incision procedure.

Recently, some studies argued that incisional negative pressure wound therapy can have an impact on the reduction of wound complications.[20-22] However, in our study, such an outcome has not been observed. (Table 5) The number of participants of prolonged wound healing with or without negative pressure device has no statistical significance. The reasons for this, as we analysed, are (a) no tension between each healing tissues, no medium accumulated potential for bacterium reproduction and sufficient blood flow are the key issues, which could make an intensive impact on incision healing. What we did during this clinical trial, such as suture technology, can make a similar clinical outcome, which may be a substitution of negative pressure device implantation; (b) in our institute, negative pressure device tubes are made of plastic-like material, which would be recognised as a foreign body by body immune system. Furthermore, a channel would be left when this tube retracted, which could take several days to recovery with liquid secretion for those hypoalbuminemia patients. Comparing with tubes, absorbable lines are thought to be more compatible with the immune system. Herein, the application of absorbable lines during the surgical procedure is a better choice than a plastic-like tube.

To date, several surgical procedures have been implied during clinical practice. To deal with wound superficial pressure after specimen removal away, different biological mesh-assisted closures have been performed, such as cross-link or non-cross-linked porcine meshes and human dermal meshes.[23-29] Most groups reported relatively low morbidity of wound complications, compared with conventional perineal technique. Partial omentum tissue, it is reported as omentoplasty, reserved with gastroepiploic artery supplying, delivered to the pelvis, with a purpose of being sewn to the subcutaneous fatty tissue and elimination of pelvic remaining space after specimen removal out.[23,25,30] Dijkstra EA et al reported a biological mesh implement after extralevator abdominoperineal excision can have a low incidence of incisional hernia, comparing with other cases in literature reporting.[31]

In addition, we analysed the data about risk factors of perineal wound complications for all the participants in our study, shown in Table 6. Among age, gender, BMI, smoking, some comorbidities with high incidence, high risks of invasion, and some intra-operative data, hypoalbuminemia was an independent risk factor for delayed perineal wound healing, as a result of statistical analysis of estimated pooled OR and corresponding 95% CI. This pooled data result is also confirmed by other groups.[32,33] Furthermore, an animal trial was performed by Kobayashi N et al, with a finding that an early albumin administration can enhance wound healing ability in burned rats.[34] It is now common that serum albumin levels can reflect the patient's gross nutritional level. As a result of hypoalbuminemia, low collagen formation and high morbidity of wound dehiscence may occur. Besides glucose and fatty acids, albuminemia is regarded as an essential material for body re-healing. However, a low gross nutritional level and postoperative high exudate loss can lead to hypoalbuminemia existing. As a result, avoiding the morbidity of hypoalbuminemia can be a key part of wound healing. Meanwhile, some studies also argued that neoadjuvant radiotherapy may increase perineal wound complications, as a consequent outcome of DNA and protein damages.[35,36] Intra-operative perforation is also a high-risk factor for incision healing.[7] Nevertheless, such outcomes corresponding with neoadjuvant radiotherapy or intra-operative perforation have not been observed in our clinical trial with statistical analysis.

Although a relationship between intra-operative perforation and postoperative wound complications has not been observed during this clinical trial, such consequent outcome is confirmed by some other researches.[7,19] Tumour tissue involvement and contamination of bowel contents during surgeries are considered as the main factors of increasing postoperative wound complications for the intra-operative perforation cases.

However, there are some limitations to this clinical study. First, it is a single centre analysis with a limited quantity of observed participants. Second, the postoperative follow-up period is also limited because of the

restriction of technology-related factors. In the future study, with more cases involved and longer follow-up period practice, some more reliable outcomes may come to a conclusion for helping analysing postoperative wound complication related factors.

5 | CONCLUSION

Managements towards perineal wound complications after APR are a long-lasting and frequently discussed problem for decades, especially after a wide intervention of extralevator APR. This current study has illustrated this clinical focus by short- and long term data, coming to an outcome of hypoalbuminemia as an independent risk factor for wound healing. A new surgical procedure of direct perineal wound full-thick closure has been described, with statistical data evidence supporting, as a better choice for quicker perineal wound healing. However, an incision negative pressure device placement seems not to be an essential choice for reducing wound complications.

CONFLICT OF INTEREST
The authors declare no potential conflict of interest.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

1. Miles WE. A method of performing abdomino-perineal excision for carcinoma of the rectum and of the terminal portion of the pelvic colon (1908). *CA Cancer J Clin*. 1971;21(6):361-364. https://doi.org/10.3322/canjclin.21.6.361.

2. den Dulk M, Putter H, Collette L, et al. The abdominoperineal resection itself is associated with an adverse outcome: the European experience based on a pooled analysis of five European randomised clinical trials on rectal cancer. *Eur J Cancer*. 2009;45(7):1175-1183. https://doi.org/10.1016/j.ejca.2008.11.039.

3. De Nardi P, Summo V, Vignali A, Capretti G. Standard versus Extralevator abdominoperineal low rectal cancer excision outcomes: a systematic review and meta-analysis. *Ann Surg Oncol*. 2015;22(9):2997-3006. https://doi.org/10.1245/s10434-015-4368-8.

4. Zhang Y, Wang D, Zhu L, et al. Standard versus extralevator abdominoperineal excision and oncologic outcomes for patients with distal rectal cancer: A meta-analysis. *Medicine (Baltimore)*. 2017;96(52):e9150. https://doi.org/10.1097/MD.0000000000009150.

5. Wiatrek RL, Thomas JS, Papaconstantinou HT. Perineal wound complications after abdominoperineal resection. *Clin Colon Rectal Surg*. 2008;21(1):76-85. https://doi.org/10.1055/s-2008-1055325.

6. Bullard KM, Trudel JL, Baxter NN, Rothenberger DA. Primary perineal wound closure after preoperative radiotherapy and abdominoperineal resection has a high incidence of wound failure. *Dis Colon Rectum*. 2005;48(3):438-443. https://doi.org/10.1007/s10350-004-0827-1.

7. Musters GD, Sloothaak DAM, Roodbeen S, van Geloven AAW, Bemelman WA, Tanis PJ. Perineal wound healing after abdominoperineal resection for rectal cancer: a two-centre experience in the era of intensified oncological treatment. *Int J Color Dis*. 2014;29(9):1151-1157. https://doi.org/10.1007/s00384-014-1967-y.

8. Althumairi AA, Canner JK, Gearhart SL, Safar B, Sacks J, Efron JE. Predictors of perineal wound complications and prolonged time to perineal wound healing after abdominoperineal resection. *World J Surg*. 2016;40(7):1755-1762. https://doi.org/10.1007/s00268-016-3450-0.

9. Kokosis G, Sun Z, Avashia YJ, et al. V-Y fasciocutaneous flap closure technique is a safe and efficacious alternative to primary closure of the perineal wound following abdominoperineal resection. *Am J Surg*. 2017;213(2):371-376. https://doi.org/10.1016/j.amjsurg.2016.04.018.

10. Artioukh DY, Smith RA, Gokul K. Risk factors for impaired healing of the perineal wound after abdominoperineal resection of rectum for carcinoma. *Color Dis*. 2007;9(4):362-367. https://doi.org/10.1111/j.1463-1318.2006.01159.x.

11. Christian CK, Kwaan MR, Betensky RA, Breen EM, Zinner MJ, Bleday R. Risk factors for perineal wound complications following abdominoperineal resection. *Dis Colon Rectum*. 2005;48(1):43-48. https://doi.org/10.1007/s10350-004-0855-x.

12. Gorbach SL. Antimicrobial prophylaxis for appendectomy and colorectal surgery. *Rev Infect Dis*. 1991;13(Suppl 10):S815-S820.

13. Hyldig N, Birke-Sorensen H, Kruse M, et al. Meta-analysis of negative-pressure wound therapy for closed surgical incisions. *Br J Surg*. 2016;103(5):477-486. https://doi.org/10.1002/bjs.10084.

14. Marshall MJ, Smart NJ, Daniels IR. Biologic meshes in perineal reconstruction following extra-levator abdominoperineal excision (elAPE). *Color Dis*. 2012;14:12-18. https://doi.org/10.1111/codi.12044.

15. Sinna R, Alharbi M, Assaf N, et al. Management of the perineal wound after abdominoperineal resection. *J Visc Surg*. 2013;150(1):9-18. https://doi.org/10.1016/j.jviscsurg.2013.02.001.

16. Lefevre JH, Parc Y, Kerneis S, et al. Abdomino-perineal resection for anal cancer impact of a vertical rectus abdominis myocutaneus flap on survival, recurrence, morbidity, and wound healing. *Ann Surg*. 2009;250(5):707-711. https://doi.org/10.1097/SLA.0b013e3181bce334.

17. Matsuda K, Hotta T, Takifuji K, et al. Long-term comorbidity of diabetes mellitus is a risk factor for perineal wound complications after an abdominoperineal resection. *Langenbeck's Arch Surg*. 2009;394(1):65-70. https://doi.org/10.1007/s00423-008-0381-8.

18. Musters GD, Buskens CJ, Bemelman WA, Tanis PJ. Perineal wound healing after abdominoperineal resection for rectal cancer:

a systematic review and meta-analysis. *Dis Colon Rectum*. 2014;57 (9):1129-1139. https://doi.org/10.1097/dcr.0000000000000182.

19. Han JG, Wang ZJ, Gao ZG, et al. Perineal wound complications after Extralevator abdominoperineal excision for low rectal cancer. *Dis Colon Rectum*. 2019;62(12):1477-1484. https://doi.org/10.1097/dcr.0000000000001495.

20. Horch RE. Incisional negative pressure wound therapy for high-risk wounds. *J Wound Care*. 2015;24(4):21-28. https://doi.org/10.12968/jowc.2015.24.Sup4b.21.

21. Willy C, Agarwal A, Andersen CA, et al. Closed incision negative pressure therapy: international multidisciplinary consensus recommendations. *Int Wound J*. 2017;14(2):385-398. https://doi.org/10.1111/iwj.12612.

22. 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. https://doi.org/10.1097/prs.0000000000001519.

23. Dalton RSJ, Smart NJ, Edwards TJ, Chandler I, Daniels IR. Short-term outcomes of the prone perineal approach for extralevator abdomino-perineal excision (elAPE). *Surg-J R Coll Surg E*. 2012;10(6):342-346. https://doi.org/10.1016/j.surge.2011.10.001.

24. Bhalla A, Peacock O, Javanmard-emamghissi H, et al. Long term outcomes after biological mesh reconstruction of the pelvic floor following extra-levator abdominoperineal excision of rectum (APER). *Gut*. 2015;64:A337-A338. https://doi.org/10.1136/gutjnl-2015-309861.733.

25. Vaughan-Shaw PG, King AT, Cheung T, et al. Early experience with laparoscopic extralevator abdominoperineal excision within an enhanced recovery setting: analysis of short-term outcomes and quality of life. *Ann R Coll Surg Engl*. 2011;93(6):451-459. https://doi.org/10.1308/003588411x588621.

26. Han JG, Wang ZJ, Wei GH, Gao ZG, Yang Y, Zhao BC. Randomized clinical trial of conventional versus cylindrical abdominoperineal resection for locally advanced lower rectal cancer. *Am J Surg*. 2012;204(3):274-282. https://doi.org/10.1016/j.amjsurg.2012.05.001.

27. Han JG, Wang ZJ, Gao ZG, Xu HM, Yang ZH, Jin ML. Pelvic floor reconstruction using human acellular dermal matrix after cylindrical abdominoperineal resection. *Dis Colon Rectum*. 2010;53(2):219-223. https://doi.org/10.1007/DCR.0b013e3181b715b5.

28. Barker T, Branagan G, Wright E, Crick A, McGuiness C, Chave H. Vertical rectus abdominis myocutaneous flap reconstruction of the perineal defect after abdominoperineal excision is associated with low morbidity. *Color Dis*. 2013;15(9):1177-1183. https://doi.org/10.1111/codi.12286.

29. Christensen HK, Nerstrom P, Tei T, Laurberg S. Perineal repair after Extralevator abdominoperineal excision for low rectal cancer. *Dis Colon Rectum*. 2011;54(6):711-717. https://doi.org/10.1007/DCR.0b013e3182163c89.

30. De Broux E, Parc Y, Rondelli F, Dehni N, Tiret E, Parc R. Sutured perineal omentoplasty after abdominoperineal resection for adenocarcinoma of the lower rectum. *Dis Colon Rectum*. 2005;48(3):476-481. https://doi.org/10.1007/s10350-004-0784-8.

31. Dijkstra EA, Kahmann NLE, Hemmer PHJ, Havenga K, van Etten B. A low incidence of perineal hernia when using a biological mesh after extralevator abdominoperineal excision with or without pelvic exenteration or distal sacral resection in locally advanced rectal cancer patients. *Tech Coloproctol*. 2020;24(8):855–861. https://doi.org/10.1007/s10151-020-02248-z.

32. Chang CC, Lan YT, Jiang JK, et al. Risk factors for delayed perineal wound healing and its impact on prolonged hospital stay after abdominoperineal resection. *World J Surg Oncol*. 2019;17(1):226. https://doi.org/10.1186/s12957-019-1768-4

33. Russell L. The importance of patients' nutritional status in wound healing. *British J Nurs*. 2001;10(6 Suppl):S44-S49.

34. Kobayashi N, Nagai H, Yasuda Y, Kanazawa K. The early influence of albumin administration on protein metabolism and wound healing in burned rats. *Wound Repair Regen*. 2004;12(1):109-114. https://doi.org/10.1111/j.1524-475X.2004.tb00002.x.

35. Devalia HL, Mansfield L. Radiotherapy and wound healing. *Int Wound J*. 2008;5(1):40-44. https://doi.org/10.1111/j.1742-481X.2007.00351.x.

36. Haubner F, Ohmann E, Pohl F, Strutz J, Gassner HG. Wound healing after radiation therapy: Review of the literature. *Radiat Oncol*. 2012;7:162.