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ARTICLE

Outcomes of perineal wound closure techniques after abdominoperineal resections in rectal cancer: an NSQIP propensity score matched study

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ABSTRACT

Perineal defects following abdominoperineal resections (APRs) for rectal cancer may require myocutaneous or omental flaps depending upon anatomic, clinical and oncologic variables. However, studies comparing their efficacy have shown contradictory results. We aim to compare postoperative complication rates of APR closure techniques in rectal cancer using propensity score-matching. The American College of Surgeons Proctectomy Targeted Data File was queried from 2016 to 2019. The study population was defined using CPT and ICD-10 codes for patients with rectal cancer undergoing APR, stratified by repair technique. Perioperative demographic and oncologic variables were controlled for by propensity-score matching. Multivariate logistic regression analysis was performed for wound and major complications (MCs). Of the 3291 patients included in the study, 85% underwent primary closure (PC), 8.3% rectus abdominis myocutaneous (RAM) flap, 4.9% pedicled omental flap with PC, and 1.9% lower extremity (LE) flap repair. Primary closure rates were significantly higher for patients with stage T1 and T2 tumors ($p < 0.001$). RAM and LE flaps were most used with multi-organ resections, 24% and 25%, respectively ($p < 0.001$). Similarly, cases with T4 tumors used these flaps more frequently, 30% and 40%, respectively ($p < 0.001$). After propensity score matching for comorbidities and oncologic variables, there was no significant difference in 30-day postoperative wound or MC rates between perineal closure techniques. The complication rates of the different closure techniques are comparable when tumor stage is considered. Therefore, tumor staging and concurrent procedures should guide clinical decision making regarding the appropriate use of each technique.

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Abdominoperineal resection; perineal reconstruction; rectal cancer; myocutaneous flap; omental flap

Introduction

Abdominoperineal resection (APR) is a prevalent surgical approach for low-lying rectal tumors when complete en bloc resection or sphincter-sparing resection is not feasible [1]. This technique requires removal of tissue from the sigmoid colon to the anal verge in addition to the surrounding perineal soft tissue through abdominal and perineal incisions [2,3]. Locally advanced rectal cancer is generally treated with neoadjuvant chemotherapy and radiation therapy with subsequent surgical resection [4]. Extensive excision can lead to complex pelvic defects that require advanced closure techniques from colorectal and plastic and reconstructive surgeons. Intra- and extra-abdominal approaches exist within the operative repertoire to aid in wound closure. Omental pedicle flaps and myocutaneous flaps serve to obliterate pelvic dead space and provide well-vascularized tissue to the defect to promote wound healing and mitigate postoperative complications [5].

Myocutaneous flaps include the rectus abdominis myocutaneous (RAM) flap as well as lower extremity (LE) flaps such as the gracilis or gluteal pedicle flaps. Intraabdominally, a pedicled omental flap can aid in large pelvic defects as it provides a well-vascularized buttress and obliterates dead space with a supplemental lymphatic system to the perineal defect promoting wound healing. Anticipated wound complications (WCs) following an APR include dehiscence and surgical site infections (SSIs), resulting from closure under tension, weight-bearing in the region, or insufficient blood supply from the surrounding irradiated tissue. Pelvic dead space can also persist following primary repair, predisposing the patient to bowel obstruction from firm adhesions to the denuded structures of the pelvic side wall and abscess, hematoma, or lymphocele formation [5]. The success of myocutaneous and omental flaps has been individually evaluated in national datasets and single-center studies [1,5,6]. Previous NSQIP analyses from cohorts of 2005 to 2013 showed superiority of primary repair compared to myocutaneous flap in wound dehiscence and overall morbidity [7–9], which is in stark contrast to more recent single-center retrospective analysis and a randomized controlled trial reporting myocutaneous flaps with more successful obliteration of

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pelvic dead space and less morbidity compared to primary closure (PC) or omental flap [6,10–13]. Additionally, a subsequent NSQIP study analyzing solely omental flaps associated these with a higher likelihood for organ space infection [14]. Contradictory results may be due to a lack of standardization in preoperative variables and patient demographics between the techniques in comparison, as well as the inherent limitations of large databases.

The purpose of this study is to revisit this question using the most recent and extensive dataset available. We sought to do this by comparing complication rates between immediate closure techniques after an APR using a national proctectomy database. By using propensity score matching, we can retrospectively control for preoperative demographic and oncological variables to isolate the effect of the closure techniques on 30-day postoperative complication rates. Comparative analysis may help guide clinical decision making regarding appropriate use of myocutaneous and omental pedicle flaps.

Materials and methods

Database

The American College of Surgeons/National Surgical Quality Improvement Program (ACS/NSQIP) Proctectomy Targeted Participant Use Data Files (PUF) was queried from 2016 to 2019. The PUF is a Health Insurance Portability and Accountability Act (HIPAA)-compliant data file containing cases submitted to ACS NSQIP from participant sites. The file includes deidentified patient-level, aggregate data collected by a trained surgical clinical reviewer through a 30-day postoperative period. As of 2019, there are a total of 719 participating sites. The procedure targeted files supplement the annual NSQIP database with surgical and oncologic variables for a specific study population [15]. This analysis is exempt from Institutional Review Board due to deidentified HIPAA compliant clinical information. This study adhered to STROBE Guidelines.

Study groups

The targeted population was isolated by Current Procedural Terminology (CPT) and International Classification of Disease, Tenth Revision (ICD-10) codes (Appendix 1). The study population consisted of rectal and rectosigmoid cancers undergoing APRs with oncologic data available. The study groups were divided into RAM flap (CPT code for trunk flap), LE flap, omental pedicled flap with PC, and PC alone (Appendix 1). Disseminated cancer and multiple flaps on the same patients were excluded to isolate individual effects of each repair technique (Figure 1).

Preoperative variables

Demographic variables were extracted including sex, race/ethnicity, age, body mass index (BMI), history of hypertension (HTN), chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), current smoking status, steroid use, ACS/NSQIP probability of morbidity, and modified frailty index (mFI-5) score. Probability of morbidity is a variable provided within the PUF and is derived using hierarchical regression analysis that a patient will experience the event based on pre-existing conditions. The mFI score is created by adding each positive comorbidity of diabetes mellitus (DM), HTN on medication, dependent functional status, COPD and CHF. Relevant pre-operative variables include laboratory results and oncologic data such as chemotherapy and radiation therapy within 90 days prior to surgery, chemotherapy with radiation therapy within 90 days prior to surgery, T status, N status and American Joint Committee on Cancer (AJCC) stage $\geq$ II. AJCC stage $\geq$ II refers to T status >2 or any T status with positive N status. Operative variables of interest include American Society of Anesthesiologists (ASA) classification, surgical approach, margin status, concurrent organ resection and free flap use. Multiorgan resection refers to a binary variable for any additional male or female urologic, gynecologic or musculoskeletal organ resected (one or more) from the standard APR. This is not an additive variable for each additional organ.

Outcome variables

The outcome analysis was separated by WCs and major complications (MCs). The WCs variable consists of superficial incisional SSI, deep incisional SSI, organ/space SSI and wound dehiscence. In addition to WCs, MCs include return to OR, readmission or ileus within 30 days of the procedure.

Statistical analysis

Statistical analysis was conducted using Stata 14.1 (StataCorp., College Station, TX). Continuous variables were tested for normality with a Shapiro–Wilk test. Based on normality, the variables were described as mean with standard deviation (SD) or median with interquartile range (IQR) and compared with one-way ANOVA or the Kruskal–Wallis test, respectively. Categorical variables were defined as frequencies and compared with Fisher's exact or Chi-squared test where indicated. Multivariate logistic regression analysis (MLRA) was used to estimate effect size of risk factors. Risk factors for increased postoperative complications were selected *a priori* based on known individual impact from previously reported data and univariate analysis. The preoperative variables include chemotherapy, tumor stage, obesity, mFI-5 score, morbidity probability, concurrent multiorgan resection, hypoalbuminemia and operative approach. Specific variables were dichotomized for the logistic regression model for interpretability. A Bonferroni correction for the multivariate analysis was established for the 10 covariates placed in the model leading to a significance cutoff of 0.005 (0.05/10) for the independent variables. Alpha error for univariate analysis was established at 0.05. No imputation was done for missing values. A 'total' column is present on all descriptive tables to illustrate the observations used in the analysis.

To homogenize our population by demographic, oncologic and perioperative variables beyond the limitations of the aforementioned model, a propensity score match was performed using a greedy one-to-one matching without replacement. Predicting the probability to have a flap closure (RAM, omental or LE) was done through an initial logistic regression model using age, sex, smoking status, race/ethnicity, chemotherapy in 90 days, radiation therapy within 90 days, T status, N status, AJCC stage, operative approach, vaginectomy, hysterectomy, cystectomy, prostatectomy, sacrectomy, hypoalbuminemia, mFI-5 score and morbidity probability. The one-to-one (flap vs. primary repair) without replacement methods was used for equal comparative groups. The nearest neighbor caliper was established at 0.02. A final multivariate regression model was performed with wound and MCs as the dependent variables and the three flap groups as the independent variables.

Results

Preoperative variables

A total of 3291 patients were included in the study. Primary closure of all layers comprised the largest cohort with 2792 patients

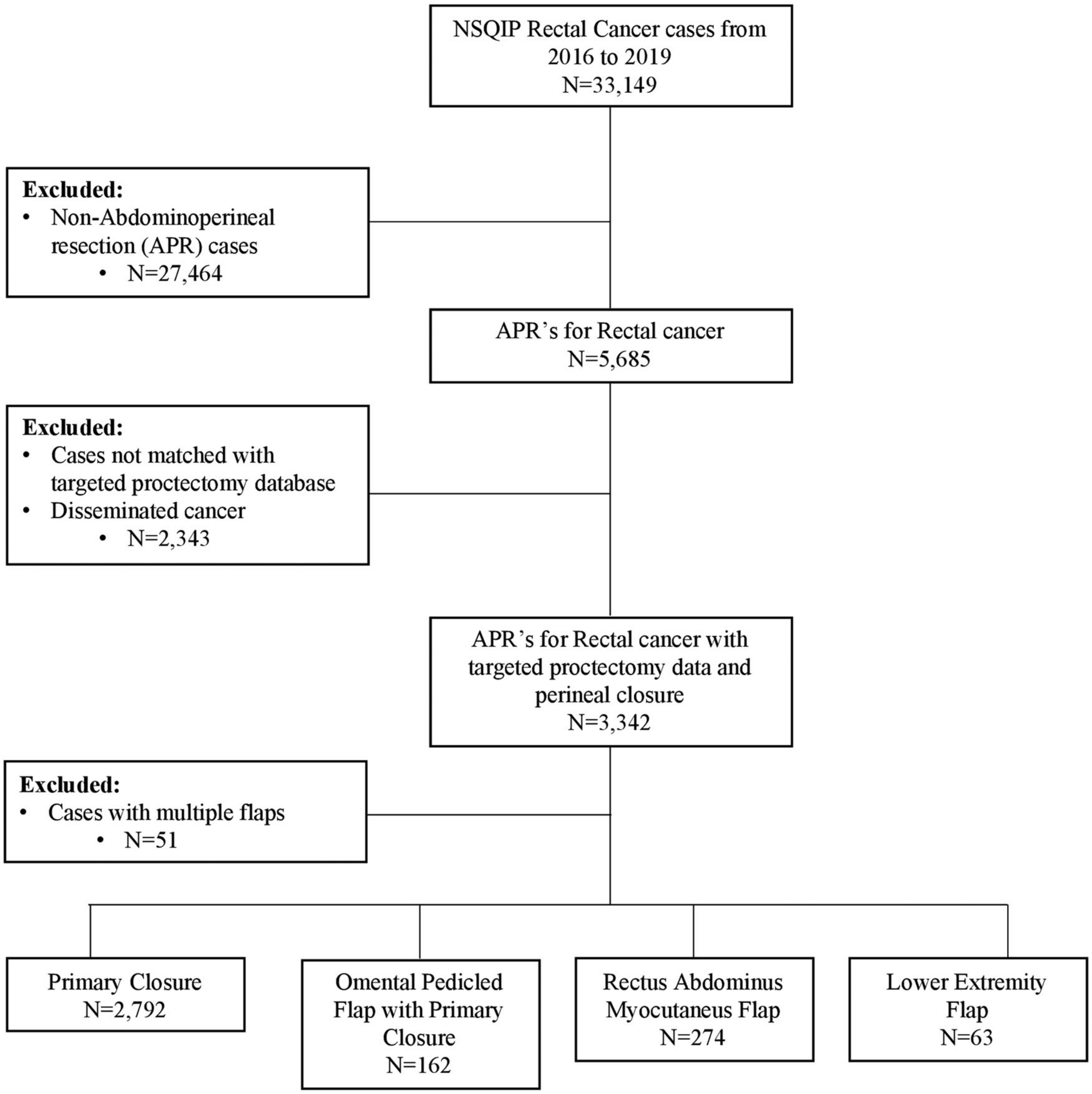

Figure 1. Flow diagram. NSQIP: National Surgical Quality Improvement Program.

(85%), followed by RAM flap with 274 patients (8.3%), OP with 162 (4.9%) and LE flaps with 63 patients (1.9%). The greatest median age was present in the PC group, 65 years (56–74 IQR; $p = 0.001$). Other demographics including BMI, DM, HTN, COPD, CHF, current smoking status, steroid use and functional status were similar between the groups (Table 1). Calculated mFI scores between groups were also similar. However, the estimated probability of morbidity was highest in the RAM group at 20% ($p < 0.001$). Preoperative laboratory results highlighted a higher creatinine level in the omental pedicle flap group (0.89 mg/dL, 0.8–1; $p = 0.006$) while albumin and hematocrit were lowest in the RAM group with 3.8 g/dL (3.5–4.1; $p = 0.05$) and 38% (34–41; $p < 0.001$), respectively; the rest of the laboratory values were similar between groups (Table 2).

Neoadjuvant therapy

Proportions of patients undergoing neoadjuvant chemotherapy and/or radiation therapy within 90 days prior to the procedure were statistically similar between the groups (Table 2). Advanced T-stage was highest in the LE flaps and RAM groups, 40% and 30%, respectively. Primary closure was more commonly performed with T1 and T2 tumors ($p < 0.001$). Dichotomizing AJCC stage into ≥ stage II and < stage II, LE flaps had the highest proportion with stage II or greater at 94%. However, this was not statistically significant ($p = 0.06$). Margin negativity was similar between the groups ($p = 0.8$).

Surgical approach and concurrent procedures

Those who received a RAM or LE flap were more likely to have an open approach to the APR (75%, 57%), while PC was most commonly performed for laparoscopic APRs (33%) (Table 3). Patient who received a RAM or LE flap were also more likely to have undergone a multiorgan resection. Twenty-four percent of patients who had a RAM flap closure and 25% of patients with a LE flap closure underwent concurrent multiorgan resection compared to only 4.8% of patients with a PC and 14% of patients with an omental pedicle flap (Table 3).

Postoperative outcomes and complication analysis

Major and WCs were more frequent in the RAM cohort in univariate analysis (38% MC, 6.6% WC; $p = 0.02$, 0.004, respectively). For overall WCs, dehiscence had the highest rate of occurrence in RAM flap group. Of note, distinction from donor or recipient

Table 1. Baseline demographics.

Patient characteristics	Total (*N* = 3291)	Primary closure (*N* = 2792)	Omental + primary closure (*N* = 162)	RAM (*N* = 274)	Lower extremity (*N* = 63)	*p* Value
Sex	3291					<0.001
Female (*N*/%)		1018 (37%)	57 (36%)	134 (49%)	37 (59%)	
Male (*N*/%)		1773 (64%)	105 (65%)	140 (51%)	26 (41%)	
Race/ethnicity	2682					<0.001
White (*N*/%)		1773 (80%)	136 (90%)	176 (73%)	51 (85%)	
Black (*N*/%)		138 (6.2%)	8 (5.3%)	30 (12%)	4 (6.7%)	
Asian (*N*/%)		161 (7.2%)	1 (0.7%)	9 (3.7%)	0 (0%)	
Hispanic (*N*/%)		139 (6.2%)	6 (4.0%)	25 (10%)	4 (6.7%)	
Other (*N*/%)		17 (0.8%)	1 (0.6%)	2 (0.8%)	1 (1.7%)	
Age (median/IQR)	3268	65 (56–74)	64 (55–72)	60 (52–69)	62 (56–70)	0.001
BMI (median/IQR)	3273	27.7 (23.7–31.8)	27.8 (24.7–30.8)	26.9 (23.9–31.2)	25.8 (22.3–30.7)	0.06
DM	3291					0.41
NIDDM (*N*/%)		339 (12%)	17 (11%)	33 (12%)	5 (7.9%)	
IDDM (*N*/%)		156 (5.6%)	15 (9.3%)	19 (6.9%)	2 (3.2%)	
Hypertension (*N*/%)	3291	1345 (48%)	79 (49%)	119 (43%)	23 (36%)	0.14
COPD (*N*/%)	3291	122 (4.4%)	8 (4.9%)	10 (3.7%)	4 (6.4%)	0.71
CHF in 30 days (*N*/%)	3291	16 (0.6%)	0 (0%)	3 (1.1%)	0 (0%)	0.56
Current smoker (*N*/%)	3291	498 (18%)	29 (18%)	55 (20%)	15 (24%)	0.53
Steroid use (*N*/%)	3291	68 (2.4%)	5 (3.1%)	11 (4.0%)	2 (3.2%)	0.32
Functional status	3285					0.95
Independent (*N*/%)		2743 (98.2)	270 (99%)	62 (98%)	159 (98%)	
Partial dependent (*N*/%)		39 (1.4)	4 (1.5%)	1 (1.6%)	3 (1.9)	
Total dependent (*N*/%)		4(0.1)	0 (0%)	0 (0%)	0 (0%)	
Morbidity (median/IQR)	3291	17.5 (14–23)	19.3 (15–25)	20.2 (16–25)	19.9 (15–24)	<0.001
5-mFI-score	3291					0.218
Zero (*N*/%)		1279 (46%)	71 (44%)	138 (50%)	38 (60%)	
One (*N*/%)		1052 (38%)	65 (40%)	90 (33%)	17 (27%)	
≥Two (*N*/%)		461 (17%)	26 (16%)	46 (17%)	8 (13%)	

Table 2. Preoperative data and oncologic variables.

Patient characteristics	Total (*N* = 3291)	Primary closure (*N* = 2792)	Omental + primary closure (*N* = 162)	RAM (*N* = 274)	Lower extremity (*N* = 63)	*p* Value
Creatinine (median/IQR)	3099	0.85 (0.7–1.0)	0.89 (0.8–1.0)	0.80 (0.7–1.0)	0.80 (0.7–1.0)	0.006
Albumin (median/IQR)	2378	3.9 (3.6–4.2)	3.9 (3.6–4.2)	3.8 (3.5–4.1)	4 (3.7–4.2)	0.05
Hematocrit (median/IQR)	3160	39 (36–42)	39 (36–42)	38 (34–41)	39 (35–41)	<0.001
Platelets (median/IQR)	3138	185 (227–278)	218 (175–277)	231 (189–295)	230 (191–270)	0.24
INR (median/IQR)	1349	1 (1–1.1)	1 (1–1.1)	1 (1–1.1)	1 (1–1.1)	0.17
Chemotherapy in 90 d (*N*/%)	3251	1618 (59%)	93 (60%)	164 (61%)	41 (65%)	0.7
Radiation in 90 d (*N*/%)	3251	1589 (58%)	85 (54%)	155 (57%)	35 (56%)	0.82
Chemotherapy and radiation in 90 d (*N*/%)	2851	1432 (59%)	79 (58%)	143 (60%)	35 (61%)	0.97
T stage	2580					<0.001
Tis (*N*/%)		2 (0.1%)	0 (0%)	1 (0.5%)	0 (0%)	
T1 (*N*/%)		95 (4.3%)	5 (4.1%)	6 (2.9%)	0 (0%)	
T2 (*N*/%)		407 (19%)	14 (12%)	19 (9.2%)	7 (14%)	
T3 (*N*/%)		1390 (63%)	74 (61%)	119 (58%)	23 (46%)	
T4 (*N*/%)		308 (14%)	28 (23%)	44 (30%)	20 (40%)	
N Stage	2679					0.25
N0 (*N*/%)		1340 (58%)	66 (35%)	137 (63%)	27 (60%)	
N1 (*N*/%)		690 (30%)	45 (35%)	50 (23%)	12 (27%)	
N2 (*N*/%)		260 (11%)	17 (13%)	29 (13%)	6 (13%)	
AJCC stage > II (*N*/%)	2494	1827 (86%)	108 (91%)	184 (91%)	45 (94%)	0.06

wound is unable to be assessed within this dataset. However, rates of superficial, deep and organ/space SSIs were similar between the groups (Table 4). Additionally, return to OR and debridement in OR frequencies were higher for the RAM group, 10% and 4.4%, respectively (return to OR: PC 5.1%, OP 4.3%, LE: 7.9%; debridement in OR: PC 0.8%, OP 2.5%, LE: 1.6%). Nevertheless, incision and drainage in OR, readmission rates, ileus and post-op acute renal failure were comparable between the groups (Table 4). In the WC multivariate regression model, RAM showed a higher tendency to have WCs (OR: 2.13, 95%CI 1.14–3.97; *p*: 0.02), however with Bonferroni's correction, this was not statistically significant (Figure 2). There was no difference in complication rates between the closure techniques. The controlling variable 'morbidity probability' was the single statistically significant variable to increase the likelihood of complications (Figure 3).

Table 3. Operative variables.

Patient characteristics	Total (*N* = 3291)	Primary closure (*N* = 2792)	Omental + primary closure (*N* = 162)	RAM (*N* = 274)	Lower extremity (*N* = 63)	*p* Value
ASA >2 (*N*/%)	3289	1857 (67%)	111 (69%)	196 (72%)	52 (83%)	0.02
Approach	3210					<0.001
Open (*N*/%)		891 (33%)	91 (58%)	203 (75%)	34 (57%)	
Laparoscopic (*N*/%)		902 (33%)	32 (12%)	6 (10%)	22 (14%)	
Robotic (*N*/%)		787 (29%)	32 (20%)	27 (10%)	19 (32%)	
MIS converted to open (*N*/%)		141 (5.2%)	9 (3.3%)	1 (1.7%)	113 (8.2%)	
Negative distal margin (*N*/%)	2891	2438 (99%)	134 (99%)	234 (98%)	51 (98%)	0.8
Sacrectomy (*N*/%)	3291	5 (0.2%)	1 (0.62%)	11 (4.0%)	0 (0%)	<0.001
Vaginectomy (*N*/%)	3291	57 (2.0%)	6 (3.7%)	39 (14%)	12 (19%)	<0.001
Hysterectomy (*N*/%)	3291	51 (1.8%)	9 (5.6%)	23 (8.4%)	8 (13%)	<0.001
Prostatectomy (*N*/%)	3291	27 (1.0%)	7 (4.3%)	2 (0.7%)	1 (1.6%)	0.007
Cystectomy (*N*/%)	3291	9 (0.3%)	3 (1.8%)	2 (0.7%)	1 (1.6%)	0.01
Multiorgan Resection (*N*/%)	3291	135 (4.8%)	22 (14%)	66 (24%)	16 (25%)	<0.001
Free flap						
Myocutaneous (*N*/%)	3291	3 (0.1%)	0 (0%)	4 (1.5%)	0 (0%)	0.007
Fasciocutaneous (*N*/%)	3291	1 (0.04%)	0 (0%)	0 (0%)	0 (0%)	1

Table 4. Post-operative complications.

Post-operative complications	Total (*N* = 3291)	Primary closure (*N* = 2792)	Omental + primary closure (*N* = 162)	RAM (*N* = 274)	Lower extremity (*N* = 63)	*p* Value
Major complications (*N*/%)	3291	800 (29%)	48 (30%)	103 (38%)	20 (32%)	0.02
Wound complication (*N*/%)	3291	75 (2.7%)	4 (2.5%)	18 (6.6%)	2 (3.2%)	0.004
Wound dehiscence (*N*/%)	3291	59 (2.1%)	4 (2.5%)	14 (5.1%)	2 (3.2%)	0.03
Superficial SSI (*N*/%)	3291	3 (0.1%)	0 (0%)	1 (0.4%)	0 (0%)	0.48
Deep SSI (*N*/%)	3291	4 (0.1%)	0 (0%)	0 (0%)	0 (0%)	1
Organ/space SSI (*N*/%)	3291	10 (0.4%)	0 (0%)	3 (1.1%)	0 (0%)	0.28
Return to OR (*N*/%)	3291	143 (5.1%)	7 (4.3%)	30 (10%)	5 (7.9%)	0.001
Incision and drainage in OR (*N*/%)	3291	4 (0.1%)	0 (0%)	1 (0.4%)	0 (0%)	0.56
Debridement in OR (*N*/%)	3291	21 (0.8%)	4 (2.5%)	12 (4.4%)	1 (1.6%)	<0.001
Readmission (*N*/%)	3291	413 (15%)	23 (14%)	44 (16%)	12 (19%)	0.74
Readmission related to procedure (*N*/%)	491	390 (95%)	22 (96%)	42 (96%)	11 (92%)	0.95
Ileus (*N*/%)	3291	474 (17%)	30 (19%)	61 (22%)	10 (16%)	0.16
Acute renal failure (*N*/%)	3291	4 (0.1%)	0 (0%)	1 (0.4%)	0 (0%)	0.57

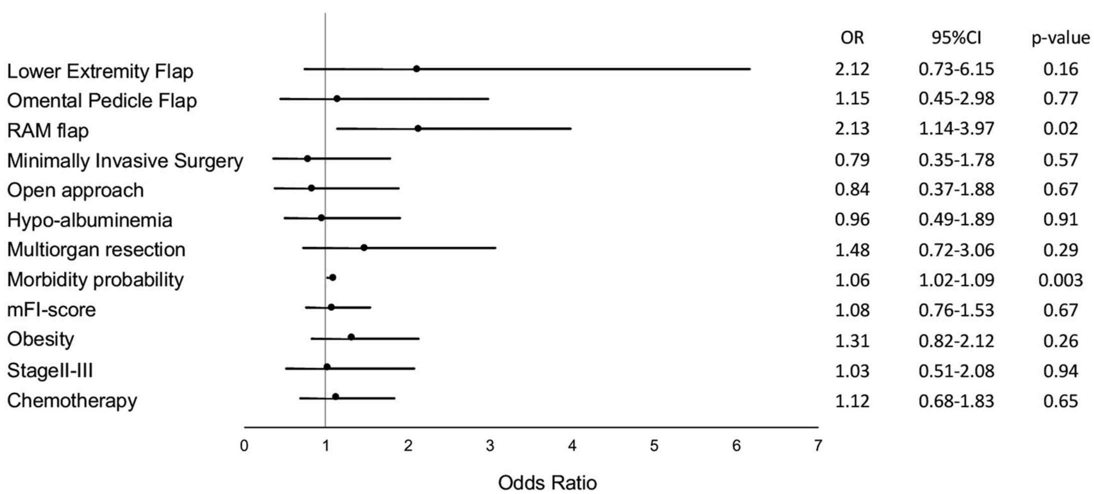

Figure 2. Wound complication multivariate regression analysis. RAM: rectus abdominis myocutaneous; mFI: five factor modified frailty index.

Propensity score matching

After propensity score matching, a total of 437 patients were analyzed. The groups were divided into 284 patients with PC, 145 with RAM flaps, 90 with omental flaps and 32 with LE flaps. There was no difference in demographic, perioperative and oncologic factors between the groups (Table 5). The final logistic regression models for MC and WC, did not show any flap to increase or decrease the likelihood of major or WCs (Figures 4 and 5).

Discussion

Abdominoperineal resections for colorectal malignancy result in considerable defects with an average 30-day postoperative MC rate of 30%. Abdominal myocutaneous flaps continue to be the most prevalent flap closure technique when PC is not feasible following APR. However, our multivariate analysis highlighted no significant difference in post-operative complication rates between any of the repair techniques evaluated in this study when

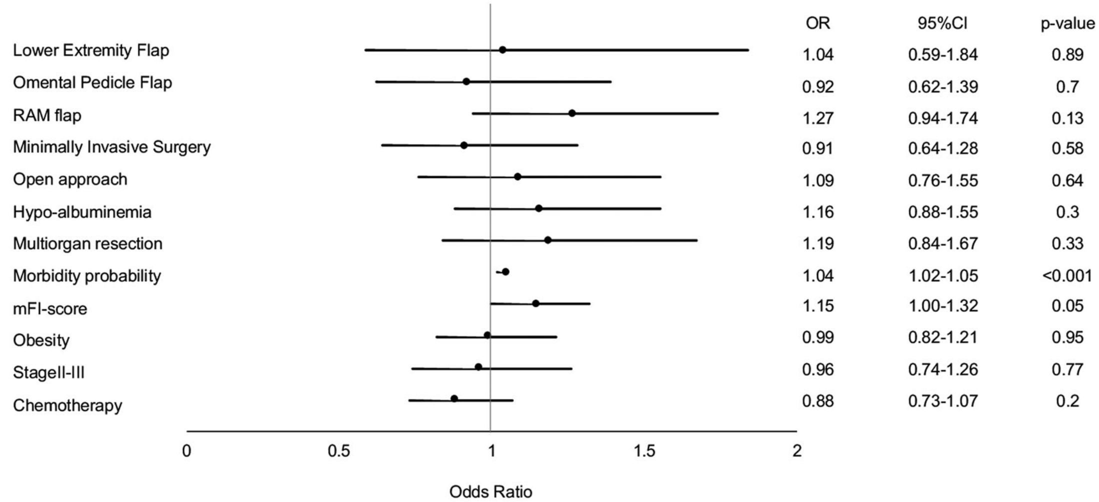

Figure 3. Major complication multivariate regression analysis. RAM: rectus abdominis myocutaneous; mFI: five factor modified frailty index.

Table 5. Propensity score-matched population.

Patient characteristics	Primary closure (*N* = 284)	Omental + primary closure (*N* = 90)	RAM (*N* = 145)	Lower extremity (*N* = 32)	*p* Value
Age (Mean/SD)	60.6 (12)	61.5 (13.2)	62.1 (11.8)	60.2 (12.3)	0.7
Male (*N*/%)	170 (60%)	55 (61%)	85 (59%)	16 (50%)	0.72
Race					0.1
White (*N*/%)	218 (77%)	80 (89%)	104 (72%)	27 (84%)	
Black (*N*/%)	33 (12%)	6 (7%)	18 (12%)	1 (3%)	
Asian (*N*/%)	12 (4%)	0 (0%)	5 (3%)	0 (0%)	
Hispanic (*N*/%)	18 (6%)	3 (3.0%)	17 (12%)	4 (13%)	
Morbidity probability (median/IQR)	19 (15–24)	19 (15–25)	20 (16–24)	18 (14–23)	0.25
MFI					0.09
5-mFI 0 (*N*/%)	148 (52%)	37 (41%)	68 (47%)	22 (69%)	
5-mFI 1 (*N*/%)	96 (34%)	39 (43%)	48 (33%)	6 (19%)	
5-mFI ≥2 (*N*/%)	40 (14%)	14 (16%)	29 (20%)	4 (13%)	
Chemotherapy (*N*/%)	199 (70%)	62 (69%)	95 (66%)	23 (72%)	0.78
Radiation therapy (*N*/%)	173 (60%)	57 (63%)	85 (59%)	20 (63%)	0.9
AJCC stage > II (*N*/%)	255 (90%)	82 (91%)	130 (90%)	29 (91%)	0.99
Open (*N*/%)	170 (60%)	46 (51%)	97(67%)	16 (50%)	0.07
MIS (*N*/%)	98 (35%)	36 (40%)	43 (30%)	15 (47%)	0.19
Multiorgan resection (*N*/%)	35 (12%)	12 (13%)	4 (9.7%)	5 (16%)	0.72

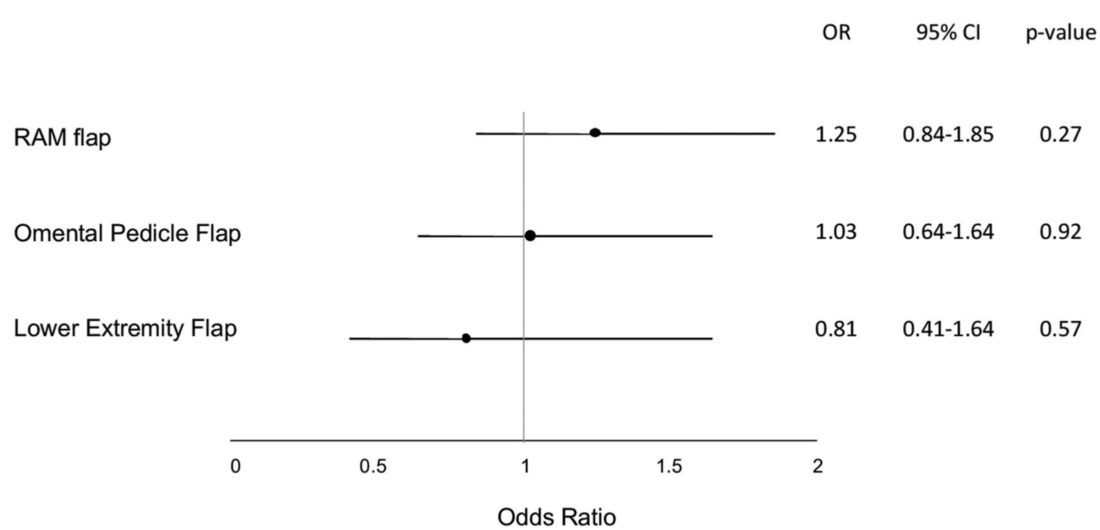

Figure 4. Major complication multivariate regression analysis after propensity score matching. RAM: rectus abdominis myocutaneous.

controlling for pre-operative variables. Therefore, selection of an appropriate flap technique is influenced by a myriad of individual patient characteristics such as, volume or surface area required, adjacent organ resection, comorbidities, surgical approach, i.e. minimally invasive vs. open in addition to surgeon preference.

The most commonly performed closure technique was PC of all layers. This approach is preferred when treating small perineal defects [12]. Furthermore, patients with T1 and T2 tumors are likely suitable candidates for primary repair, as patients from this group are more likely to have a smaller defect [4,16]. Larger

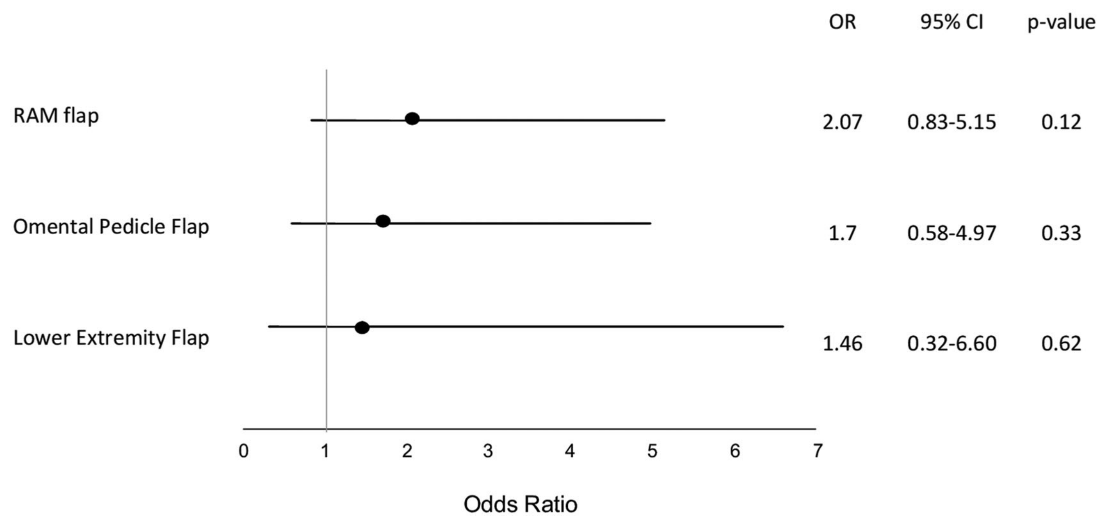

Figure 5. Wound complication multivariate regression analysis after propensity score matching. RAM: rectus abdominis myocutaneous.

perineal defects benefit from flap closure. Devulapalli et al. have shown that the use of flap reconstruction for complex defects decreases complications by more than 50% [13]. Nevertheless, every prior study utilizing the NSQIP database has shown myocutaneous flaps leading to higher morbidity, particularly, wound dehiscence, where single institution studies have found otherwise [6–11]. Our results are consistent with Devulapalli et al. as patients with advanced stage tumors and larger defects, were most likely to have APR closure with LE and RAM flaps, with no subsequent increase in postoperative complications [13]. Neoadjuvant therapy was not shown to predispose a patient to a particular closure technique following APR. Myocutaneous flaps were also more commonly used in cases with multiorgan resection. The role of biologic mesh closure following conventional APR's has also been studied [17,18]. A randomized control trial demonstrated similar rates of uncomplicated perineal wound healing at 30 days with a statistically significant lower one-year perineal hernia rate in the biologic mesh group. The five-year follow up demonstrated significantly lower rates of symptomatic perineal hernia in the biologic mesh group without a difference in chronic perineal wound morbidity, locoregional recurrence and overall survival [18].

Our univariate analysis of complications initially demonstrated a higher incidence of major and WCs with RAM flaps compared to PC. However, this difference was nonsignificant after propensity score matching, and therefore our data support the conclusions made in institutional reviews of RAM and PC postoperative complications [1,6,13,19]. It is important to note, the NSQIP variables used for WCs do not specify location of the SSIs or dehiscence. In addition, the database we utilized lacks multiple variables that significantly influence the selection for closure or reconstruction; for instance, perineal defect size, detailed description of the flap used and variations, and multiple flaps/mesh used at the same time. Myocutaneous flaps result in a perineal, or recipient wound as well as an abdominal or LE donor site wound, which may explain the increase in WCs reported for this group [7]. Multivariate regression analysis controlling for tumor size, multiorgan resection and stage, among the other demographic variables, demonstrate no increase in 30-day postoperative complications with flap closure.

To control for preoperative variables, we used the ACS/NSQIP morbidity probability and frailty index scores which mitigate the effects of potential confounding variables and allows for a direct comparison of complex patients. Recently, efforts have been made to analyze the impact of patients' frailty on surgical outcomes [20,21]. These studies have shown frailty to be associated with postoperative morbidity and mortality. The most commonly used scoring system has been the mFI which has evolved into a five-factor index based on history of DM, HTN on medication, dependent functional status, COPD and CHF [22]. Al-Khamis et al. used ACS/NSQIP data to validate the mFI-5 as a predictor for 30-day outcomes, after colorectal surgery [23]. They found that the frailest patients (mFI $\geq$2) had greater odds of postoperative overall morbidity, mortality, prolonged hospital stay and unplanned readmission. In our study, patients in the RAM group had the highest preoperative mFI scores, with no subsequent increase in postoperative complication rates, indicating this flap closure technique may be clinically preferred for the most complex APR reconstructions.

We believe important cross-specialty variables and outcomes are essential to consider to generate the most pragmatic results. Althumairi et al. utilized the NSQIP database from 2005 to 2013 to analyze the risk factors for perineal WCs following APR. In contrast to our findings, they reported a higher incidence of infection and wound dehiscence in patients treated with myocutaneous flaps compared to primary repair. This difference could be due to the fact that our study differentiated between flap techniques, and we also demonstrated that WCs were associated with oncologic variables (T4 and multiorgan resection) [8].

Limitations and future directions

This study is not without its limitations. While a national database might provide greater generalizability of results compared to institutional studies, it is not exempt from selection bias and limited internal validity due to a lack of granularity of the variables provided. Particularly regarding perineal wound defect size and multiple flaps or techniques utilized in a single patient. Despite using propensity-score match to control for this indirectly, we believe some variables that are missing should have been taken into consideration as they guide the decision making when choosing to undergo a reconstruction. Additionally, some subjects may have been at risk of overlapping between the study groups which our analysis was unable to assess. Moreover, based on burden of disease certain subjects would not have been amenable to undergo a PC would have been unable to been compared to a simple PC. The substantial size of the cohort available through NSQIP, allowed us to successfully perform a propensity score match that would not be possible with the sample size in a single institution. However, national databases are limited by the clarity of outcome variables and lack of long-term follow up. Targeted data files allowed us to control key oncologic variables otherwise absent from the NSQIP main data file adding to our study's internal validity. Additionally, it is important to consider that smaller series and centers not participating with ACS/NSQIP hospitals are overlooked in our analysis.

Limitations of national databases specifically for retrospective analysis in plastic and reconstructive surgery include the inability to determine the specific flap used based on CPT codes. We assumed all trunk myocutaneous/fasciocutaneous flaps were rectus abdominis; and LE flaps were gracilis or gluteal flaps based on current clinical practice for pelvic reconstruction. Moreover, myocutaneous flaps have multiple modifications that our study is also unable to determine in addition to many other trunks upper or LE flaps that are utilized by the operating plastic surgeon for a myriad of reasons that are not mentioned in the study or database and may affect surgical outcomes of this. In addition, we were unable to specify the location of wound dehiscence in patients who underwent RAM or flaps. Finally, NSQIP has not recognized the 'graft failure' variable since 2010 due to previously reported inaccuracies [15]. This variable would have been particularly useful in highlighting complications specific to the recipient site in pelvic reconstruction.

Conclusions

This study evaluated the efficacy of diverse APR closure techniques through a national database. The results from our study show myocutaneous and omental flaps do not alter wound or MCs after APRs for rectal cancer when appropriately adjusting for demographic, oncologic and perioperative variables. Rectus abdominis myocutaneous, LE and omental pedicle flaps appear to be associated with analogous outcomes regardless of complex multiorgan pelvic resections and advanced stage.

Disclosure statement

The authors report there are no competing interest to declare.

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Appendix 1. CPT codes used for analysis

ICD 10 codes	
C19	Cancer of the rectosigmoid junction
C20	Malignant neoplasm of the rectum
CPT codes abdominoperineal resections	
45110	Proctectomy, complete, combined abdominoperineal resection with colostomy
45395	Laparoscopic proctectomy, complete, combined abdominoperineal resection with colostomy
CPT codes perineal/pelvic reconstruction	
15734	Muscle, myocutaneous or fasciocutaneous flap; trunk
15738	Muscle, myocutaneous or fasciocutaneous flap; lower extremity
49905	Omental flap, abdominal
49906	Free omental flap with microvascular anastomosis
15756	Myocutaneous flap with microvascular anastomosis
15758	Free fascial flap with microvascular anastomosis
CPT codes gynecologic resection	
57106	Vaginectomy, partial
57110	Vaginectomy, total
58150	Total abdominal hysterectomy with/without removal tube(s) or without removal of ovary(s)
58270	Vaginal hysterectomy, for uterus 250 g or less; with repair of enterocele
58210	Radical abdominal hysterectomy with pelvis lymphadenectomy
58541	Laparoscopy, surgical, supracervical hysterectomy, for uterus 250 g or less
58542	Laparoscopy, surgical, supracervical hysterectomy, for uterus 250 g or less with removal of tube(s) and/or ovary(s)
58543	Laparoscopy, surgical, supracervical hysterectomy, for uterus greater than 250 g
58544	Laparoscopy, surgical, supracervical hysterectomy, for uterus greater than 250 g with removal of tube(s) and/or ovary(s)
58548	Laparoscopy, radical abdominal hysterectomy with pelvic lymphadenectomy
58550	Laparoscopy, surgical, with vaginal hysterectomy, for uterus 250 g or less;
58553	Laparoscopy, surgical, with vaginal hysterectomy, for uterus greater than 250 g
58570	Laparoscopy, surgical, with total hysterectomy, for uterus 250 g or less
58571	Laparoscopy, surgical, with total hysterectomy, for uterus 250 g or less; with removal of tube(s) and/or ovary(s)
58572	Laparoscopy, surgical, with total hysterectomy, for uterus greater than 250 g
58573	Laparoscopy, surgical, with total hysterectomy, for uterus greater than 250 g; with removal of tube(s) and/or ovary(s)
CPT codes urologic resection	
51550	Cystectomy partial
51555	Cystectomy partial, complicated
51570	Cystectomy complete
51580	Cystectomy complete with diversion
51590	Cystectomy with ileal conduit or sigmoid
CPT codes prostatectomy	
55840	Prostatectomy, nerve sparing
55821	Prostatectomy suprapubic subtotal
55831	Prostatectomy retropubic
55810	Prostatectomy perineal radical
55815	Prostatectomy radical with bilateral pelvic lymph node excision
55801	Prostatectomy perineal subtotal
CPT codes musculoskeletal resection	
49215	Excision of presacral/sacral tumor
63307	Sacral vertebral corpectomy for intraspinal lesion
63278	Laminectomy, for biopsy of excision of intraspinal neoplasms; extradural, sacral
63011	Laminectomy without facetectomy, foraminotomy, discectomy, one or two vertebral segments. Sacral