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Reconstructive

Sarcopenia Is a Risk Factor for Infection for Patients Undergoing Abdominoperineal Resection and Flap-based Reconstruction

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Background: Abdominoperineal resection (APR) carries a high risk of morbidity. Preoperative risk assessment can help with patient counseling, minimize adverse outcomes, and guide surgeons in their choice of reconstruction. This study examined the impact of sarcopenia (low lean muscle mass) on postoperative complications after APR.

Methods: One hundred seventy-eight patients who underwent APR between May 2000 and July 2017 were retrospectively analyzed. Sarcopenia was identified on preoperative computed tomography scans using the Hounsfield Unit Average Calculation. Two cohorts were compared (group 1: primary perineal closure; group 2: flap-based perineal reconstruction). Multivariable analysis evaluated predictors of complications.

Results: Sarcopenia was an independent risk factor for postoperative surgical site infection in patients undergoing APR (odds ratio [OR] = 2.9, $P = 0.04$). The risk for sarcopenic patients who underwent flap-based perineal reconstruction was even higher (OR = 8.9, $P < 0.01$). Male sex was also found to be a risk factor for infection (OR = 3.5, $P < 0.01$). Perineal flap-based reconstruction was a risk factor for delayed wound healing (OR = 3.2, $P < 0.01$).

Conclusions: Sarcopenia was an independent risk factor for infection in patients undergoing APR. This risk was even greater in patients undergoing flap-based perineal reconstruction. Sarcopenia can be identified on preoperative imaging and inform surgeons on risk stratification and surgical plan. *(Plast Reconstr Surg Glob Open 2019;7:e2343; doi: 10.1097/GOX.0000000000002343; Published online 26 July 2019.)*

The occurrence of a complication after major surgery has significant ramifications for both individual patients and society. The occurrence of a complication doubles the cost of care for surgical patients, leading to substantial economic burden on the healthcare system.[1] There is theoretical benefit in categorizing patient risk factors to predict postoperative outcomes and identify potentially reversible risk factors.[2] One particular risk factor, sarcopenia (low lean muscle mass), is the subject of many recent studies. Sarcopenia is reported to correlate highly with frailty, and computed tomography (CT) provides 1 avenue to estimate sarcopenia level.[3,4] Its predictive value for complications has been demonstrated for surgical oncology procedures and ventral hernia repair.[5–7] The impact of sarcopenia on clinical outcomes in colorectal surgery patients has also been examined,[8–11] though a study examining the effect of sarcopenia on abdominoperineal resection (APR) and perineal reconstruction has not been performed to date.

First described over 100 years ago, APR is the established treatment for colorectal disease involving the distal colon, rectum, and sphincter complex.[12] APR is a complex

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procedure consisting of both anterior and perineal incisions and carries significant risk of morbidity but is still the procedure of choice for advanced cancer and severe inflammatory bowel disease. Plastic surgeons are often consulted to assist in reconstruction after APR to both close the perineal wound and assist in obliterating pelvic dead space. The beneficial effects of flap-based reconstruction on clinical outcomes following APR has been demonstrated, especially in irradiated patients.[13–19] However, there is little clinical evidence to guide flap choice or to inform surgeons when flap-based reconstruction has maximum benefit compared with primary perineal closure. Evaluation of patient risk factors, such as sarcopenia, may assist surgeons preoperatively in identifying high-risk patients and provide objective guidelines in managing perineal defects.

This present study investigates whether sarcopenia is an independent risk factor for complications after APR. We hypothesized that sarcopenia would be associated with poorer outcomes. We also hypothesized that patients undergoing flap-based reconstruction may have different risk profiles, and we performed subgroup analysis to investigate if sarcopenia was predictive of complications in both patient cohorts, that is, those who underwent primary perineal closure (group 1) versus those who underwent flap-based reconstruction (group 2).

MATERIALS AND METHODS

Study Design

The study reported in this manuscript was approved by the Stanford University Institutional Review Board (Protocol #41869). The Stanford Translational Research Integrated Database Environment, an informatics platform supporting clinical research at Stanford University,[20] was utilized to identify patients who underwent APR between May 2000 to July 2017. Patients were identified by relevant Current Procedural Terminology codes. Patients were then screened to identify those who had a CT scan of the abdomen and pelvis within 1 year before surgery.

Electronic medical records were queried for sociodemographic and preoperative and postoperative clinicopathologic data. CT imaging files were cataloged to the matching patient. Patient records were then deidentified for subsequent analysis. Baseline characteristics included age, sex, body mass index (BMI), and past medical history. Smoking status and history of neoadjuvant chemotherapy and/or radiotherapy were noted. For patients in group 2, the flap type was recorded. The decision to pursue flap-based reconstruction (and subsequent flap choice) was at the discretion of the colorectal and consulting reconstructive surgeon and was not predetermined. The date of the last clinic visit determined the length of follow-up.

The primary outcome measure was the occurrence of a complication. Complications included delayed wound healing, infection, seroma, bleeding that required intervention, stroke, deep venous thrombosis, pulmonary embolism, ileus, fistula formation, hernia, erectile dysfunction, and iatrogenic injury to significant structures. Delayed wound healing was defined as dehiscence or wound breakdown that required wound care for greater than 1 month or reoperation. In group 2, this included both abdominal and perineal sites. Infection was defined as clinically evident infection (cellulitis or abscess) that required procedural intervention or readmission. For patients in group 2, complications were further categorized as perineal versus donor site complications. Readmission events within 30 days after discharge were also noted.

CT Scan Analysis and Determination of Sarcopenia

Preoperative abdominal CT scans were analyzed to determine the presence of sarcopenia. Using OsiriX imaging software (Pixmeo SARL; Bernex, Geneva, Switzerland), the cross-sectional psoas area was measured in a semiautomated manner. The outline of the left and right psoas muscles at the superior border of the L4 vertebrae was performed manually, and the cross-sectional area was measured as previously described in the literature.[7,21–23] The Hounsfield Unit Calculation, a measure of psoas muscle density, was determined for the left and right psoas muscles. The measurements were averaged to determine the Hounsfield Unit Average Calculation (HUAC).[6,7] A representative example is seen in Figure 1.

The HUAC for each patient was then used to determine the presence or absence of sarcopenia. As previously reported, patients in the bottom quartile of the HUAC data set were defined as sarcopenic.[5,8,9,19]

Statistical Analysis

Tests of significance were performed using 2-tailed tests with $\alpha = 0.05$. Analysis between cohorts was performed with Student's *t* test for continuous variables and chi-square test for categorical variables. Multivariable logistic regression was performed utilizing the following as dependent variables: >70 years of age, obesity, sarcopenic status, use of flap-based reconstruction, active smoking, sex, neoadjuvant chemo/radiotherapy, hypertension, history of cardiovascular or cerebrovascular event, diabetes, chronic kidney disease, liver disease, lung disease/chronic obstructive pulmonary disease, inflammatory bowel disease as the surgical indication, and recurrent rectal cancer as the surgical indication. All complications, perineal-specific complications, delayed wound healing, infection, and readmission <30 days after discharge were chosen as outcome variables. Ileus, seroma formation, bleeding requiring repeat surgery, fistula or hernia, iatrogenic injury, portal vein thrombosis, stroke, and pulmonary embolism were also observed complications but not independently analyzed. Data preparation and analysis was performed in SPSS (IBM, Armonk, New York).

RESULTS

Baseline Patient Characteristics

Two hundred twenty-four patients were identified who underwent APR in the study period. Forty-six patients did not have CT scans that were sufficient for HUAC assessment and were not included in the study. The study pop-

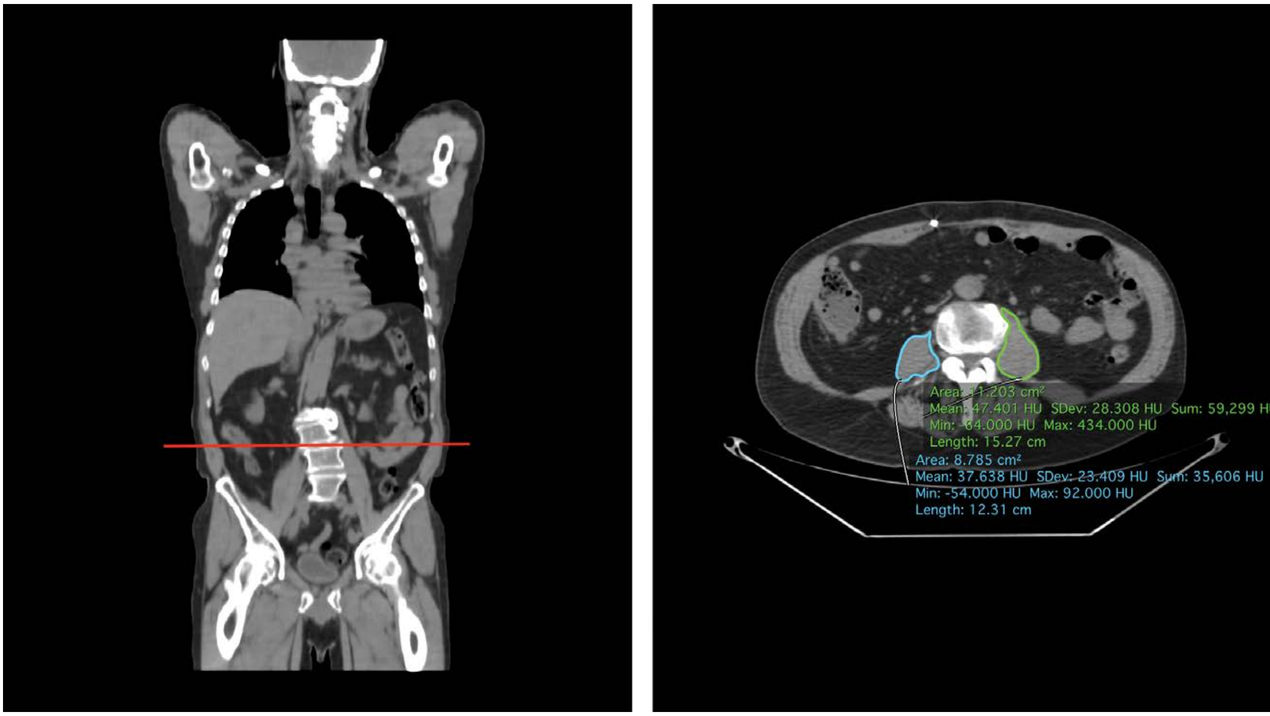

Fig. 1. Representative example of HU and psoas dimension acquisition. The psoas muscle was examined on the axial cuts at the top of the L4 vertebral level. The psoas muscles were outlined, allowing for HU and psoas area acquisition. Calculations to obtain HUAC: LHUC = (Left Hounsfield Unit × Left Psoas Area)/Total Psoas Area; RHUC = (Right Hounsfield Unit × Right Psoas Area)/Total Psoas Area; HUAC = (LHUC + RHUC)/2. LHUC, Left Hounsfield Unit Calculation; Max, maximum; Min, minimum; RHUC, Right Hounsfield Unit Calculation.

ulation consisted of 178 patients (109 males [61.2%]; 69 females [38.8%]) with a median age of 58.5 years. Most patients were overweight or obese (mean BMI = 27.1 kg/m^2). Twenty-two patients (12.4%) were current regular smokers. One hundred thirty-four patients (75.3%) had a history of neoadjuvant chemotherapy and radiotherapy. Only 2 patients received neoadjuvant chemotherapy alone. On average, CT scan acquisition was obtained 65 days before surgery. One hundred forty-eight scans (83.1%) were obtained within 3 months before surgery. The average HUAC score was 23.3. The bottom quartile cutoff for HUAC was 18.9, and this was the threshold under which patients were declared to be sarcopenic (N = 45). Group 2 consisted of a total of 65 patients who underwent reconstruction with pedicled flaps. Flap types included vertical rectus abdominis musculocutaneous flap (N = 37; 56.9%), gracilis flap (N = 18; 27.7%), and gluteal fasciocutaneous flaps (N = 10; 15.4%). Mean postoperative length of stay and follow-up was 9.6 days and 23.8 months, respectively (Tables 1 and 2).

Table 1. Descriptive Statistics of Patient Cohort

Characteristics	
Sex (N [%])	
Male	109 (61.2)
Female	69 (38.8)
Age, y	
Mean	58.8
Range	28–89
BMI, kg/m^2	
Mean	27.1
Range	15.1–52.8
Smoker (N [%])	22 (12.4)
Neoadjuvant chemo/radiotherapy (N [%])	134 (75.3)
Timing of CT scan (days before surgery)	
Mean	65
Range	1–354
HUAC	
Mean	27.7
Range	1.4–41.8
Length of stay, d	
Mean	9.6
Range	2–40
Follow-up, mo	
Mean	23.8
Range	1–153

Cohort Analysis

The majority of patients (N = 140; 78.7%) had at least 1 medical comorbidity with hypertension being most common (N = 64; 36.0%). The overall complication rate was 61.2%. In addition to a 4.6% rate of partial flap necrosis, a 25% rate of donor site complication was noted in group 2. No total flap losses were noted in this study (Table 3).

Table 4 displays the results of a comparative analysis of sarcopenic versus nonsarcopenic cohorts and group 1 versus group 2. No significant difference in complication rate was noted.

Comparative analysis of group 1 versus group 2 demonstrated a higher rate of perineal complications in group 2 (36.9% versus 17.7%; P = 0.01). The overall complication rate, however, was not significantly different. No further statistical differences were noted between group 1 and group 2 (Table 4).

Table 2. Flaps Used for Perineal Reconstruction in Patients in Group 2 (N = 65)

Flap Type	N (%)
VRAM flap	37 (56.9)
Gracilis flap	18 (27.7)
Gluteal fasciocutaneous flap	10 (15.4)

VRAM, vertical rectus abdominis musculocutaneous.

Multivariable Analysis

Logistic regression was performed to analyze risk factors for complications as outlined in Materials and Methods. All patients undergoing APR were analyzed (Table 5). Patients in group 2 were found to be at higher risk of delayed wound healing complications (OR = 3.2, $P < 0.01$). Male sex (OR = 3.5, $P < 0.01$) and sarcopenia (OR = 2.9, $P = 0.04$) were found to be risk factors for infection.

Subgroup analysis was then performed on patients who underwent primary perineal closure and patients who received flaps. Variables analyzed were those that appeared most predictive for complications on regression for the overall APR cohort. Multivariable analysis was performed on the primary closure group (N = 113). Age, sex, history of coronary artery disease/stroke, recurrent rectal cancer, and sarcopenia were not found to be significant risk factors in this cohort (Table 6). For the patients who underwent flap reconstruction (N = 55), recurrent rectal cancer was found to be a risk factor for perineal complications (OR = 5.6, $P = 0.03$), and sarcopenia was found to be a risk factor for infection (OR = 8.9, $P < 0.01$) (Table 7). Postregression prediction analysis was performed for all patients undergoing APR comparing individual patient HUAC score and adjusted infection risk (Fig. 2).

DISCUSSION

Sarcopenia has previously been linked to frailty and adverse outcomes and, as a metric, has been useful alongside other patient variables such as age and BMI.[24] Measuring sarcopenia allows physicians to identify patients who may have higher risk of surgery, but sarcopenia is not always evident on simple physical exam. Indeed, patients who appear overnourished (ie, high BMI) may have low lean muscle mass, a concept known as "sarcopenic obe-

Table 3. Comorbidity and Complication Profiles

Comorbidities (N [%])		Complications (N [%])	
Any comorbidity present	140 (78.7)	Any complication	109 (61.2)
Hypertension	64 (36.0)	Perineal complications	64 (36.0)
Hyperlipidemia	39 (21.9)	Infection/abscess	60 (33.7)
History of CAD/stroke	21 (11.8)	Delayed wound healing	44 (24.7)
Diabetes	18 (10.1)	Readmission	77 (43.3)
History of mental disorder	25 (14.2)	Ileus	16 (9.0)
Obstructive sleep apnea	9 (5.1)	Seroma	4 (2.2)
History of other endocrine disease	20 (11.2)	Bleeding	4 (2.2)
Chronic kidney disease	5 (2.8)	Fistula or hernia	6 (3.4)
Chronic liver disease	7 (3.9)	Iatrogenic injury	4 (2.2)
History of COPD or emphysema	16 (9.0)	Portal vein thrombosis	1 (0.6)
History of gastrointestinal disease	21 (11.8)	Stroke	1 (0.6)
History of hematologic disease	24 (13.5)	Pulmonary embolism	1 (0.6)
History of neurological disease or seizure	6 (3.4)		
History of nonrectal cancer	14 (7.9)	Flap based reconstruction (group 2)	
		Donor site complication	16 (25.0)
		Partial flap necrosis	3 (4.6)

Table 4. Comparison of Cohorts

	Not Sarcopenic	Sarcopenic	*P*		Group 1	Group 2	*P*
Mean age, y	57.4	61.9	0.05	Mean age, y	58.2	59.0	0.73
Mean BMI, kg/m^2	27.28	26.97	0.766	Mean BMI, kg/m^2	28.2	28.36	0.65
Smoker	11.3%	15.6%	0.441	Smoker	14.1%	9.2%	0.48
Any complication	61.7%	60.0%	0.844	Neoadjuvant chemo/radiotherapy	70.8%	83.1%	0.07
Neoadjuvant chemo/radiotherapy	77.4%	68.9%	0.252	Cancer indication	76.1%	81.5%	0.40
Cancer indication	79.7%	73.3%	0.374	IBD indication	13.3%	7.7%	0.25
IBD indication	9.8%	15.6%	0.29	Sarcopenic	23.0%	29.2%	0.36
Flapped	34.6%	42.2%	0.359	Any comorbidity	78.8%	78.5%	0.96
Any comorbidity	75.2%	88.9%	0.06	Any complication	61.1%	61.5%	1.00
Any complication	61.7%	60.0%	0.861	Perineal complication	31.9%	43.1%	0.15
Perineal complication	35.3%	37.8%	0.858	Infection	37.2%	27.7%	0.25
Infection	30.1%	44.4%	0.10	Delayed wound healing	17.7%*	36.9%*	0.01*
Delayed wound healing	26.3%	20.0%	0.43	Readmission	45.1%	40.0%	0.53
Readmission	42.9%	44.4%	0.864				

Group 1: Primary perineal closure. Group 2: Flap-based perineal reconstruction.
*Statistically significant differences ($P \leq 0.05$).
CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; IBD, inflammatory bowel disease.

Table 5. Multivariable Analysis of Risk Factors for Given Complications

Risk Factor	Any Complication Odds Ratio (95% Interval)	P	Perineal Complications Odds Ratio (95% Interval)	P	Delayed Wound Healing Odds Ratio (95% Interval)	P	Infection Odds Ratio (95% Interval)	P	Readmission Odds Ratio (95% Interval)	P
Age >70	1.3 (0.5–1.9)	0.62	0.8 (0.4–1.9)	0.66	0.5 (0.2–1.5)	0.22	0.9 (0.3–2.4)	0.83	2.1 (1.1–4.5)	0.05
Obese	0.8 (0.4–2.0)	0.69	1.4 (0.6–3.0)	0.41	1.1 (0.4–2.6)	0.91	1.8 (0.8–4.4)	0.17	1.3 (0.6–2.8)	0.47
Flap-based reconstruction	1.6 (0.7–3.7)	0.28	2.0 (1.0–4.1)	0.05	3.2 (1.5–7.0)*	<0.01*	0.6 (0.3–1.5)	0.31	1.0 (0.5–2.0)	0.97
Active smoker	0.3 (0.1–1.2)	0.09	1.2 (0.4–3.5)	0.68	0.8 (0.2–3.0)	0.78	0.5 (0.1–1.6)	0.21	1.8 (0.7–5.0)	0.24
Sex (Male)	1.6 (0.7–3.6)	0.27	1.1 (0.5–2.1)	0.89	0.6 (0.3–1.3)	0.18	3.5 (1.5–8.4)*	<0.01*	0.9 (0.4–1.7)	0.66
Neoadjuvant chemo/radiotherapy	0.4 (0.1–1.2)	0.10	0.4 (0.1–1.1)	0.08	0.6 (0.2–2.1)	0.42	0.8 (0.2–2.7)	0.69	1.9 (0.6–5.3)	0.26
Hypertension	0.4 (0.2–1.2)	0.16	0.4 (0.2–1.2)	0.16	0.6 (0.3–1.5)	0.31	0.6 (0.2–1.5)	0.25	0.5 (0.2–1.1)	0.15
History of CAD or stroke	3.7 (1.1–14.2)	0.05	2.4 (0.8–7.3)	0.13	1.3 (0.4–5.0)	0.66	3.8 (0.8–13.4)	0.08	0.8 (0.2–2.4)	0.62
Diabetes	2.8 (0.7–11.6)	0.16	1.6 (0.5–5.3)	0.46	1.1 (0.3–4.5)	0.90	0.9 (0.2–3.5)	0.90	0.9 (0.3–2.9)	0.86
Chronic kidney disease	0.3 (0.0–4.2)	0.38	0.3 (0.0–5.4)	0.44	0.0 (0.0–0.0)	1.00	2.1 (0.2–25.4)	0.57	6.9 (0.6–76.9)	0.12
Chronic liver disease	0.3 (0.0–2.4)	0.25	1.8 (0.3–9.2)	0.50	0.0 (0.0–0.0)	1.00	0.8 (0.1–6.0)	0.84	1.4 (0.3–7.5)	0.71
History of COPD or emphysema	0.5 (0.1–2.0)	0.32	0.6 (0.2–2.0)	0.41	0.6 (0.1–2.4)	0.45	0.7 (0.2–2.8)	0.66	2.2 (0.7–7.2)	0.20
IBD indication	1.6 (0.2–10.4)	0.63	1.6 (0.3–7.4)	0.56	2.1 (0.4–12.5)	0.40	0.9 (0.2–5.0)	0.91	1.6 (0.3–7.2)	0.56
Recurrent rectal cancer	1.6 (0.5–4.6)	0.40	2.1 (0.9–5.1)	0.09	1.1 (0.4–3.0)	0.92	3.1 (1.0–8.5)	0.05	1.3 (0.5–3.0)	0.60
Sarcopenic	0.7 (0.3–1.8)	0.45	1.0 (0.5–2.3)	0.94	0.6 (0.3–1.6)	0.33	2.9 (1.2–5.4)*	0.04*	1.1 (0.5–2.4)	0.79

*Statistically significant risk factors.
CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; IBD, inflammatory bowel disease.

sity."[24,25] Numerous clinical tests and diagnostic studies are considered valid for assessing sarcopenia, but not all are available or practical in surgical practices.[26]

CT scans of the abdomen and pelvis are a component of the routine workup in patients undergoing APR and are typically reviewed by both colorectal and reconstructive surgeons preoperatively. Assessment of psoas HUAC is simple to perform and could easily be integrated into surgeon or radiologist workflow; thus, HUAC interrogation presents a strategy for risk stratification without additional financial or procedural burden. Numerous other studies have also shown a correlation between core muscle size and adverse outcomes after major abdominal surgery.[6,7,10,27,28] In terms of predictive value, there is evidence to support that sarcopenia, as defined by a low HUAC score, may outperform clinical predictors of frailty such as the Charlson Comorbidity Index.[29]

It is crucial to note that although HUAC has been demonstrated as a useful tool to assess sarcopenia, the definition for the sarcopenic patient via CT imaging has not been standardized. Joglekar et al[5] noted that most studies in the surgical oncology literature defined the bottom quartile of their patient cohort to be sarcopenic, which was mirrored in this study. A previous study by Barnes et al[7] used receiver operating curves on their study cohort to define their cutoff. Our cutoff of 18.9 Hounsfield Unit is comparable to previous studies,[6,7,29] though large demographic studies are lacking to determine the cutoff HUAC that has maximum external validity and if this value is uniform across different regions and populations.

A recent systematic review by Han et al[30] notes that sarcopenia is relatively understudied in the surgical literature. There has been work analyzing the role of sarcopenia in outcomes for patients with colorectal cancer suggesting that sarcopenic patients have lower disease-free survival, higher recurrence rates, increased readmission rate, and higher mortality overall.[8,31,32] There is also evidence suggesting that sarcopenic patients have an increased need for surgery and worse postoperative outcomes for inflammatory bowel disease.[33–36] This study sampled both oncologic and inflammatory bowel disease patients undergoing APR.

To date, this is the first study to investigate the effect of sarcopenia on postoperative outcomes following APR in 2 patient cohorts, namely those undergoing primary perineal closure (group 1) versus reconstruction with pedicled flaps (group 2). Notably, sarcopenia proved to be a risk factor specifically for postoperative infection. When comparing groups 1 and 2, the effect of sarcopenia on infection appeared to be more pronounced in group 2. The reason for this is unclear. There is some evidence that sarcopenia is related to inefficient neutrophil chemotaxis and impairment of the immune system, and sarcopenic patients thus may be more susceptible to infection.[37] Further clinical studies are certainly warranted to identify the underlying mechanism for this observation, particularly in light of its significant implications in reconstructive procedures in other areas of the body.

Notably, male sex was also found to be a risk factor for infection for patients undergoing APR. Previous work has demonstrated that males have a higher risk of infection af-

Table 6. Analysis of Risk Factors for Given Outcomes in Patients Who Underwent Primary Perineal Repair (Group 1)

Risk Factor	Any Complication Odds Ratio (95% Interval)	*P*	Perineal Complications Odds Ratio (95% Interval)	*P*	Delayed Wound Healing Odds Ratio (95% Interval)	*P*	Infection Odds Ratio (95% Interval)	*P*	Readmission Odds Ratio (95% Interval)	*P*
Age >70	0.5 (0.2–1.4)	0.20	0.5 (0.2–1.6)	0.25	0.4 (0.1–2.0)	0.27	0.3 (0.1–1.1)	0.10	1.4 (0.5–3.8)	0.46
Sex (Male)	1.2 (0.5–2.9)	0.60	1.2 (0.5–2.8)	0.69	0.6 (0.2–1.7)	0.37	2.0 (0.9–4.9)	0.86	1.0 (0.5–2.3)	0.91
History of CAD or stroke	1.8 (0.4–7.7)	0.44	2.7 (0.6–11.7)	0.17	0.7 (0.1–7.1)	0.80	3.1 (0.7–14.1)	0.70	0.7 (0.2–2.8)	0.60
Recurrent rectal cancer	1.4 (0.5–4.1)	0.53	1.2 (0.4–3.8)	0.70	0.2 (0.0–1.9)	0.17	2.2 (0.8–6.5)	0.76	0.8 (0.3–2.2)	0.64
Sarcopenic	0.9 (0.4–2.5)	0.89	1.6 (0.6–4.3)	0.33	0.9 (0.3–3.2)	0.87	1.2 (0.5–3.4)	0.46	0.9 (0.4–2.2)	0.80

The analyzed risk factors were not statistically significant in this cohort.
CAD, coronary artery disease.

Table 7. Analysis of Risk Factors for Given Outcomes Who Underwent Perineal Reconstruction with a Flap (Group 2)

Risk Factor	Any Complication Odds Ratio (95% Interval)	*P*	Perineal Complications Odds Ratio (95% Interval)	*P*	Delayed Wound Healing Odds Ratio (95% Interval)	*P*	Infection Odds Ratio (95% Interval)	*P*	Readmission Odds Ratio (95% Interval)	*P*
Age >70	0.4 (0.1–5.1)	0.23	0.4 (0.1–2.3)	0.33	0.3 (0.1–1.4)	0.12	0.2 (0.03–1.3)	0.08	0.4 (0.1–2.1)	0.28
Sex (Male)	1.2 (0.4–3.8)	0.73	1.0 (0.3–3.4)	0.95	1.0 (0.3–3.1)	0.99	2.9 (0.7–11.9)	0.14	0.6 (0.2–1.9)	0.37
History of CAD or stroke	2.6 (0.4–17.5)	0.33	3.1 (0.4–25.6)	0.29	2.2 (0.3–14.9)	0.41	1.8 (0.2–16.2)	0.59	0.5 (0.1–3.4)	0.48
Recurrent rectal cancer	2.0 (0.4–9.1)	0.36	5.6 (1.2–25.9)*	0.03*	2.7 (0.7–11)	0.16	2.4 (0.5–12.7)	0.30	3.4 (0.8–15.3)	0.10
Sarcopenic	1.0 (0.3–3.8)	1.00	0.6 (0.1–2.5)	0.45	0.5 (0.1–2)	0.32	8.9 (1.9–42.1)*	<0.01*	3.0 (0.8–11.2)	0.11

*Statistically significant risk factors.
CAD, coronary artery disease.

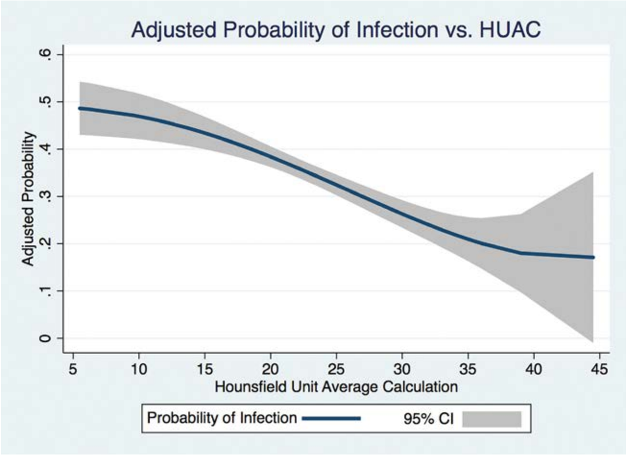

Fig. 2. Predict function providing patient probability of infection based on HUAC score after APR. The function demonstrates an inverse, sigmoidal relationship between infection risk and HUAC.

ter traumatic injury, which is posited from mouse models as an influence of testosterone on the immune and stress responses.[38] This was also somewhat of a surprising finding as one could hypothesize that female patients undergoing APR would have an increased risk of microbial contamination from vaginal manipulation and/or reconstruction; however, this did not appear to be the case in our study population.

A rather surprising observation in this study was that reconstruction with a flap was, by itself, a risk factor for delayed wound healing. This is counterintuitive at first glance, as the purpose of flap transfer is to provide well-vascularized tissue to the pelvis and perineum to improve the soft tissue conditions. An explanation for these observations, however, might be selection bias, as criteria for flap-based reconstruction were not defined a priori, thus, potentially resulting in patients in group 2 having larger soft tissue defects at the outset. Defect dimensions, however, were not recorded, which certainly poses a limitation of the study. Additionally, flap-based reconstruction is associated with a greater wound burden overall, thus, potentially contributing to a higher incidence of wound healing–related complications. Notably, group 2 patients undergoing surgery for a recurrent cancer indication had a higher rate of perineal wound complications, and this relationship was not seen for the total APR group or group 1. Again, this may be due to selection bias, as these patients who are highly likely to have more challenging wounds, and unfavorable soft tissue may be more likely referred for flap reconstruction.

Our findings suggest an inverse relationship between HUAC score and infection (Fig. 2). The appearance of this curve appears sigmoidal with an inflection point near the HUAC cutoff for sarcopenia in this study. Thus, it appears that there is a threshold after which increasing HUAC correlates with a reduction in infection risk. Theoretically, improvement in a patient's sarcopenic status would move them to a lower infection risk on this curve. Prehabilitation aims to optimize patient fitness before surgery to reduce morbidity and mortality. Burgeoning work suggests the merits of this strategy with multiple types of operations.[39,40] Sarcopenia, as measured by HUAC, demonstrates a preoperative assessment tool that could be used for targeting patients who need prehabilitation for APR. Additional investigations are needed to evaluate whether sarcopenia can be reversed in order to decrease the risks of complications.

Limitations of this study include its retrospective study design. As already discussed, the decision to proceed with flap-based reconstruction was left to the discretion of the colorectal and reconstructive surgeons at the time of surgery, rather than established, clearly defined criteria. The same discretion was implemented as it pertained to flap choice. Also, although the majority of CT scans analyzed were within 3 months before surgery, scans up to a year were analyzed, and there is a risk that the sarcopenia level assessed at the time of scan may have changed before surgery.

CONCLUSIONS

Sarcopenia as determined by psoas HUAC calculation is an independent predictor of infectious complications following APR and flap-based reconstruction. CT scans are routinely ordered for patients undergoing APR, and HUAC can be measured with very little additional time or cost with current treatment paradigms. Further investigation is required to determine the reversibility of sarcopenia and preoperative optimization for patients with this risk factor. The link between sarcopenia and infections, especially in patients with flap reconstruction, warrants future study.

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