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Sarcopenia Best Predicts Complications in Free Flap Breast Reconstruction

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Background: Breast reconstruction remains a major component of the plastic surgeon's repertoire, especially free-flap breast reconstruction (FFBR), though this is a high-risk surgery in which patient selection is paramount. Preoperative predictors of complication remain mixed in their utility. We sought to determine whether the sarcopenia score, a validated measure of physiologic health, outperforms the body mass index (BMI) and modified frailty index (mFI) in terms of predicting outcomes.

Methods: All patients with at least 6-months follow-up and imaging of the abdomen who underwent FFBR from 2013 to 2022 were included in this study. Appropriate preoperative and postoperative data were included, and sarcopenia scores were extracted from imaging. Complications were defined as any unexpected outcome that required a return to the operating room or readmission. Statistical analysis and regression were performed.

Results: In total, 299 patients were included. Patients were split into groups, based on sarcopenia scores. Patients with lower sarcopenia had significantly more complications than those with higher scores. BMI and mFI both did not correlate with complication rates. Sarcopenia was the only independent predictor of complication severity when other factors were controlled for in a multivariate regression model.

Conclusions: Sarcopenia correlates with the presence of severe complications in patients who undergo FFBR in a stronger fashion to BMI and the mFI. Thus, sarcopenia should be considered in the preoperative evaluation in patients undergoing FFBR. *(Plast Reconstr Surg Glob Open 2023; 11:e5125; doi: 10.1097/GOX.0000000000005125; Published online 18 July 2023.)*

INTRODUCTION

Breast cancer remains among the most common cancers in women in the United States, with over 300,000 cases diagnosed each year.[1,2] Given the immense physical, social, and emotional burden of breast cancer treatment, breast reconstruction is a critical phase of overall patient care.[3]

Although reconstruction using a tissue expander and prosthetic implant remains the most common approach, free-flap breast reconstruction (FFBR) can provide ample tissue and natural shape without requiring the implantation of a foreign body in appropriate patients. However, given the length of surgery and donor site morbidity, FFBR is considered a higher risk option, and strategic patient selection is important.[4–6] The categorization of patient risk factors to predict postoperative outcomes is an important counseling tool in advising patients on the potential risks and benefits of FFBR.

Consistent with well-established surgical risk factors, patient comorbidities such as obesity, diabetes, vascular disease, and tobacco use are associated with increased complications after autologous breast reconstruction.[7–10] However, there is increasing interest in assessing risk for postoperative complications beyond these comorbidities. Particularly, some patients without the aforementioned risk factors may still have an increased degree of physiologic frailty that may be difficult to quantify with traditional metrics.

Although our group and others have established the modified frailty index (mFI), which is a global picture of

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health from preoperative comorbidities as a predictor of short-term complications in FFBR,[11,12] it has been demonstrated to be inferior to sarcopenia in other fields in the long term.[13–15] Sarcopenia is the progressive and generalized depletion of skeletal muscle mass and strength associated with aging of physiologic decline.[16] Fortunately, sarcopenia can be assessed with routine preoperative abdominal computed tomography (CT), which is often already obtained for preoperative cancer staging or surgical planning in FFBR. The sarcopenia score has already gained significant recognition as a prognostic factor for complications in surgical oncology procedures, and in patients undergoing transplant, abdominal, and vascular surgery.[17–20]

More recently, an emerging body of literature has suggested a relationship between preoperative sarcopenia and complication rates among reconstructive surgery patients, though the information is conflicted in FFBR patients.[21] Further, sarcopenia has not been compared directly with mFI to assess if one measurement is superior. Therefore, we performed a retrospective review of our patients to determine if (1) sarcopenia was a predictor of postoperative complications and (2) if sarcopenia was a superior predictor of complications when compared with traditional risk factors, such as comorbid conditions like diabetes and obesity, as well as the mFI.

Takeaways

Question: How do various measurements of overall health, such as the sarcopenia score, the body mass index, and the modified frailty index, compare when looking at outcomes after free flap breast reconstruction?

Findings: Sarcopenia outperforms the body mass index and the modified frailty index in predicting complications.

Meaning: Sarcopenia may be superior for preoperative risk stratification and, if available, should be discussed with patients.

METHODS

Patient Selection and Data Extraction

All patients who underwent an FFBR at our institution from 2013 to 2022 were eligible for screening for inclusion in the study. Patients were found by querying the operating room records for any patient with CPT code 19364. Over 1000 patients were found.

Once patients were identified, a corresponding CT scan of the abdomen was then identified. If the CT scan was performed at most 6 months before the surgery or 1 month after, the patient was selected for inclusion (n = 299). All forms of CT imagery (including CT angiography, CT with or without contrast, and positron emission tomography with associated CT scan) were included. The sarcopenia measurement requires only muscular outline and can be equally determined in each of these types of CT scans.

Once the patients were identified, they were screened to ensure at least 6-months follow-up was done before inclusion in the study (n = 299). Selected patients were then reviewed, and preoperative characteristics, including comorbidities, cancer stage, cancer care, and surgical history and body mass index (BMI), were extracted. The mFI was calculated based on history of hypertension, heart failure, diabetes, functional status, and chronic obstructive pulmonary disease. Intraoperative data (including operative time, vein size, artery size, and ischemia time) were collected. Postoperative complications were defined by any complication that required operative intervention or readmission. These complications included infection, hematoma, fat necrosis requiring debridement, flap failure, wound dehiscence, bulge deformity, seroma requiring evacuation, and delayed wound healing.

Additionally, preoperative and postoperative characteristics measured as a continuous variable were normalized for statistical analysis, based on the average. This

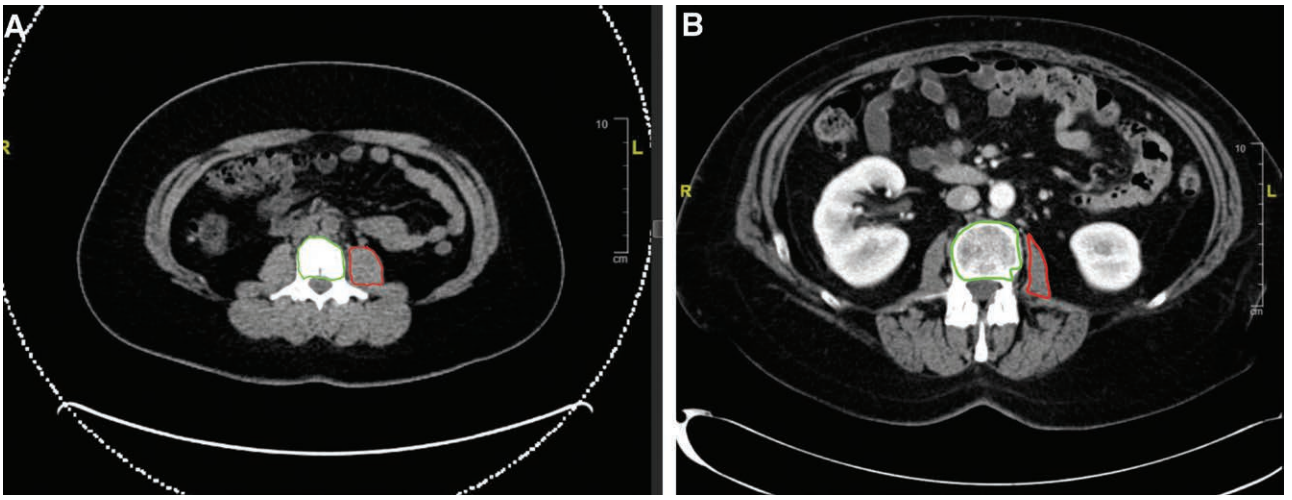

Fig. 1. CT scans showing measurement of Sarcopenia. A, Sarcopenia measurements in a patient with an average sarcopenia score with cross-sectional area of the psoas muscle in red and the L3 vertebral body in green. The ratio of red to green, as measured by our PACS softtware, is used to calculate the sarcopenia score. B, Patient with poor sarcopenia score.

included a BMI split at 30 kg per m^2, age at 50 years, and operative time at 500 minutes.

Sarcopenia Measurement

Sarcopenia scores were assessed using the ImageJ platform (National Institutes of Health, Madison, Wis.). All measurements were done by the lead author. CT scans were taken at the L3 body, and the cross-sectional area of the left psoas major muscle was normalized to the cross section of the vertebral body at L3 (Fig. 1). This is an accepted measurement of sarcopenia if cross-sectional area (in cm^2) is not available in the image source program, as muscle degradation is more prominent when compared with bone degradation in patients with sarcopenia.[18] The left side is chosen by convention. This ratio was then recorded for each patient. Ratios were then divided into groups as less than 0.2, 0.2–0.4, 0.4–0.6, 0.6–0.8, and more than 0.8. This further allows us to normalize sarcopenia scores against the population being studied rather than a healthy standard.

Statistical Analysis

All analysis was performed on SPSS (IBM, Armonk, N.Y.). ANOVA tests were performed to compare continuous variables and chi-squared test for discrete variables. Multivariate regression was also performed to control for covariates. All preoperative and intraoperative characteristics (including age, BMI, sarcopenia score, ischemia time, mFI, tracked comorbidities, vein size, and artery size) were included and controlled for during analysis. BMI, mFI, and sarcopenia score were run independently with the others as covariates. All additional factors found to be correlates with outcomes were also run to test for independence.

RESULTS

Demographic Data

A total of 299 patients were included in this study. The average age of these patients was 52 years, with an average BMI of 27.8 kg per m^2 and average sarcopenia score of 0.544. Sixty-four patients experienced complications (21%). Neoadjuvant chemotherapy was required in 127 patients (43%), and 184 patients (62%) required preoperative radiation. Sixty-two patients (21%) had an mFI of 1, and 13 (4%) had a score of 2. An estimated 172 patients (58%) had delayed reconstruction, and 20 (7%) had nipple sparing mastectomy. The high number of delayed reconstruction patients is due to the broad time period of our study, including patients from when immediate reconstruction was less popular. One hundred sixty patients had bilateral reconstruction (54%). The average ischemia time was 61 minutes, artery size was 2.6 mm, and operative time was 498 minutes. The average vein size was 2.8 mm. Full preoperative characteristics are summarized in Table 1, and complications are included in Table 2.

Sarcopenia Scores Predicting Postoperative Complications

Sarcopenia scores were split into five groups: less than 0.2, 0.2–0.4, 0.4–0.6, 0.6–0.8, and more than 0.8. A higher sarcopenia score correlates with less muscle wasting and signifies healthier physiology. Preoperative and postoperative characteristics are also summarized in Table 1. All groups were statistically equivalent, except for age (higher scores had younger patients), BMI (higher scores had heavier patients), laterality (higher scores have bilateral reconstruction), and ASA score (higher scores had worse ASA scores).

When comparing the complication rate across different sarcopenia groups, the rate of complications decreases as the sarcopenia score increases ($P = 0.002$). Furthermore, when examining the sarcopenia score based on complication, the patients with no complications had a score of 0.556 compared with 0.499 for those with complications ($P = 0.005$).

Other Predictors of Complications

Secondary outcomes in this study included comparing the performance of the sarcopenia score with the performance of the traditional risk stratification measures, BMI and mFI, to determine superiority of one method over the others. As demonstrated in Table 1, sarcopenia does have a positive correlation with BMI; specifically, patients with a higher sarcopenia score have a higher BMI, and a negative correlation with age (lower age in higher sarcopenia), but the mFI score is equivalent across all sarcopenia groups. When investigating the average sarcopenia score in each mFI group, the values were statistically insignificant (0.5 for mFI of 0, 0.54 for mFI 1, 0.54 for mFI 2; $P = 0.921$). In contrast, patients with a BMI less than 30 kg per m^2 had a sarcopenia score of 0.515 when compared with higher BMIs with a score of 0.603 ($P < 0.001$), and patients younger than 50 years of age had a score of 0.584 when compared with a score of 0.510 for older patients ($P < 0.001$).

When assessing the predictive ability of mFI and BMI for complications, an mFI of 0 had 23% of patients with complications, an mFI of 1 with 19%, and an mFI of 2 with 0% ($P = 0.127$). Similarly, a BMI of less than 30 kg per m^2 had 23% with unexpected complications, and a BMI more than 30 kg per m^2, 17% ($P = 0.217$). Patients with complications had mean BMI of 27.1 kg per m^2, and those without complications, a BMI of 28.3 kg/m^2 ($P = 0.136$). Additionally, patients without complications had an average age of 52 years, whereas those with complications had an average age of 50 years ($P = 0.043$). However, those with an age younger than 50 had a complication rate of 24%, whereas those who were older had a rate of 18% ($P = 0.108$). Of all other preoperative characteristics, a history of abdominal surgery correlated with more complications, mainly wound dehiscence and bulge deformity, but a history of breast surgery correlated with lower rates of complication (Table 3).

Multivariate Regression

Multivariate regression was also performed to identify factors that were significant when controlling for all preoperative variables collected. This was performed for preoperative factors identified as statistically significant (age, sarcopenia score, breast surgery, abdominal surgery). Only sarcopenia score was found to be significant (odds ratio, 0.52; $P = 0.010$) when controlling for other variables (Table 4).

DISCUSSION

Breast reconstruction is a critical component of comprehensive breast cancer care. FFBR is an increasingly

Table 1. Demographics of Included Patients, Divided by Sarcopenia Score

Factor	Overall (n = 299)	<0.2 (n = 3)	0.2–0.4 (n = 47)	0.4–0.6 (n = 157)	0.6–0.8 (n = 72)	>0.8 (n = 20)	*P*
Age (y)	52	53	55	53	48	47	<0.001
BMI (kg/m^2)	27.8	25.3	26.5	26.9	29.2	32.2	<0.001
Chemotherapy (%)							0.924
Preoperative	42.5	33	30	28	24	20	
Postoperative	30.8	33	36	43	42	55	
None	26.8	33	34	29	35	25	
Radiation (%)	61.5	0	70	62	56	70	0.092
Diabetes (%)	6	0	6	5	8	5	0.885
Hypertension (%)	23	33	26	24	18	25	0.824
Poor function (%)	0	0	0	0	0	0	—
COPD (%)	0	0	0	0	0	0	—
Heart failure (%)	0.3	0	0	0	1	0	0.531
mFI (%)							0.989
0	75	67	72	75	78	75	
1	21	33	23	22	17	20	
2	4	0	5	3	5	5	
Steroid use (%)	16	0	9	15	21	20	0.390
Delayed reconstruction (%)	58	33	62	57	58	55	0.883
Nipple sparing (%)	7	0	9	6	10	0	0.527
Bilateral reconstruction (%)	54	33	55	46	69	65	0.007
Axillary dissection (%)	32	33	30	36	25	35	0.596
Stage (%)							0.500
0	13	33	6	15	11	20	
1	22	0	9	25	19	15	
2	43	0	36	28	42	25	
3	30	67	36	28	25	40	
4	3	0	2	4	3	0	
ASA score (%)							0.011
1	2	33	0	3	0	0	
2	64	33	68	62	68	60	
3	33	33	32	34	31	40	
Abdominal surgery (%)	63	33	66	62	67	55	0.668
Breast surgery hx (%)	46	33	45	50	43	25	0.267
Operative time (min)	497	559	490	484	523	528	0.131
Ischemia time (min)	61	61	61	59	65	62	0.453
Vein size (mm)	2.8	2.8	2.8	2.8	2.7	2.9	0.379
Artery size (mm)	2.6	2.7	2.6	2.6	2.6	2.6	0.911
Complications (%)	21	100	32	20	14	20	0.002

Table 2. Complication Categories Studied, with Percentage of Total Complications and Percentage of Total Patients Included

Complication Category	Percentage of Total Complications	Percentage of Total Patients
Wound healing issue	39.1	8.4
Hematoma	17.2	3.7
Infection/abscess	17.2	3.7
Diastasis requiring mesh	7.8	1.7
Flap failure	10.9	2.3
Other medical issues	3.1	0.7
Death	4.7	1.0

popular modality of breast reconstruction due to use of autologous tissues and avoidance of chronically implanted devices. However, FFBR is a complex procedure with increased perioperative risk when compared with implant-based reconstruction due to the extent of surgery involved. Many attempts have been made at identifying preoperative risk factors for FFBR, including BMI, history of diabetes, laterality of surgery, and the mFI. Sarcopenia is a relatively newer modality for measuring preoperative risk in FFBR. We sought to assess its utility in risk stratification and to determine whether it outperforms other preoperative characteristics such as age, BMI, and mFI.

As demonstrated by our data, the sarcopenia score was the only independent predictor of complications in our patient cohort. Although the absolute difference of the sarcopenia score between the patients with and without complications is small, when splitting the patients by sarcopenia score it is obvious that patients with lower scores had a higher rate of complications than patients with higher sarcopenia scores. Importantly, BMI and mFI showed no significant correlation with complications in this dataset and thus, had no predictive power for complications. Factors such as age, history of breast surgery, and history of abdominal surgery did have correlations

Table 3. Preoperative Characteristics Categorized by Complications

Factor	Overall (n = 299)	No Complication (n = 235)	Complication (n = 64)	*P*
Age (y)	52	52	50	0.043
BMI (kg/m^2)	27.8	28	27	0.136
Chemotherapy (%)				0.554
Preoperative	42.5	27	27	
Postoperative	30.8	44	38	
None	26.8	29	36	
Radiation (%)	61.5	64	52	0.064
Diabetes (%)	6	7	3	0.272
Hypertension (%)	23	25	16	0.110
Poor function (%)	0	0	0	—
COPD (%)	0	0	0	—
Heart failure (%)	0.3	0.4	0	0.601
mFI (%)				0.127
0	75	73	81	
1	21	22	19	
2	4	6	0	
Steroid use (%)	16	17	13	0.425
Delayed reconstruction (%)	58	57	58	0.958
Nipple sparing (%)	7	6	9	0.332
Bilateral reconstruction (%)	54	54	50	0.525
Axillary dissection (%)	32	33	18	0.442
Stage (%)				0.406
0	13	11	18	
1	22	23	17	
2	43	31	34	
3	30	31	25	
4	3	3	5	
ASA score (%)				0.723
1	2	2	3	
2	64	64	66	
3	33	34	31	
Abdominal surgery (%)	63	60	73	0.049
Breast surgery hx (%)	46	49	33	0.018
Operative time (min)	497	503	478	0.079
Ischemia time (min)	61	61	59	0.228
Vein size (mm)	2.8	2.8	2.8	0.472
Artery size (mm)	2.6	2.6	2.6	0.352
Sarcopenia ratio	0.544	0.556	0.499	0.005

Table 4. Multivariate Regression outcomes

Parameter	Odds Ratio	*P*
Age	1.49	0.300
Sarcopenia	0.52	0.010
History of abdominal surgery	1.56	0.776
History of breast surgery	0.67	0.653

with complications that disappeared when controlling for other variables.

This finding related to sarcopenia is supported by several studies in the literature, though it does stand in contrast to those of others. Kim et al[22] described a series of patients who underwent FFBR, with preoperative sarcopenia associated with significantly higher rates of complication and BMI not associated with complications, though they did not include the mFI. This was also supported by the findings of Pittelkow et al, who found similar results in 103 patients, again not including the mFI.[23] On the other hand, Broyles et al, Yoshino et al, and Sadok et al found that sarcopenia was not a strong predictor of complications and that BMI outperformed sarcopenia.[24–26]

These three studies that found negative results in sarcopenia also suffered from smaller sample sizes than used in our study. Furthermore, each of these studies evaluated specific subsets of patients, not the overall breast reconstruction population. In the study by Broyles, only patients who underwent delayed reconstruction after radiation (those classified as "high risk" by the authors) were analyzed. These patients are predisposed to complications, which may explain the equivalent rates. Broyles and Yoshino also defined sarcopenia as a static value, describing sarcopenia as a present or absent state based on an arbitrary value. In our study, we describe sarcopenia as a continuum; sarcopenia values are not necessarily translatable on a present/absent scale due to variance in patients due to ethnicity, height, and weight. Thus, a simple binary compared with a "standard" value is not

necessarily reliable; comparing the sarcopenia score with the population standard, as we did with the quintile division, is a more reliable form of analysis. Sadok et al did not even study sarcopenia as an independent variable; they studied sarcopenic obesity, looking at sarcopenic patients with an elevated BMI, which again evaluates different factors than those in our study.

Importantly, our study also demonstrates that BMI and mFI are not reliable predictors of complications. BMI has been demonstrated frequently as an unreliable predictor of complications across various surgical disciplines[27–29]; this study fits in with the prevailing trend in the literature. In our study, we demonstrate that the BMI in patients with complications and without complications are approximately the same, suggesting that having a high BMI alone does not result in having more complications. This is because BMI has been repeatedly demonstrated as a poor measure of overall physical health leading to complications,[29] though it does correlate with specific complication types such as bulges and hernias. However, this is also true of abdominal surgical history, due to multiple violations of fascia, suggesting that BMI is not physiologically reliable. A more comprehensive measurement of overall health, such as the sarcopenia score, is more applicable.

The mFI aspect, however, is more interesting. Again, mFI does have detractors in the literature due to the lack of strength of prediction, but recent studies have demonstrated that the mFI has predictive value.[30–33] Interestingly, many of the mFI articles are database studies, which are limited in the scope and the assessment of individual complications, only presenting recent complications as well as the presence, not the severity. Our study was able to review longer term outcomes to assess procedure-associated complication rates more accurately, providing more granular and clinically meaningful data.

With sarcopenia being identified as a risk factor, the question remains as to why sarcopenia is a predictor of complications and how it can be utilized in clinical practice. The physiologic relationship of sarcopenia and complications has not been elucidated. Sarcopenia is considered a global measure of physical health. Muscular catabolism is a sign of declining physiologic reserve, regenerative capacity, and impaired immunologic competence, all of which predispose patients to poor wound healing and complications.[34] However, recent studies have demonstrated that regular exercise can boost sarcopenia scores.[35] It is possible that improvements in preoperative nutrition and exercise may improve psoas mass and sarcopenia scores, and thus, outcomes.

This study does have limitations. The sarcopenia measurements were taken by hand on individual scans, introducing error. Patients were followed up for a minimum of only 6 months after surgery in a retrospective fashion; this limits the detail that can be obtained regarding postoperative complications and preoperative characteristics. Specific complications that arise in the long term, such as bulges and hernias, could not be addressed. Complications were also grouped into general groups; flap takebacks and admissions for infections were treated equivalently, which limits the specificity of analysis. Further, CT scans were not reliably performed on the day of surgery, which would provide the optimal assessment of perioperative health. We attempted to control for this by performing our scans within a certain preoperative time period to best limit variability between scan and surgery. Various changes in health between date of scan and date of surgery could affect the relationship between sarcopenia score and complications. Neoadjuvant chemotherapy can also affect the sarcopenia score measured and the complications that occur postoperatively. Although the broad nature of the dataset is an asset in many fashions, allowing us to capture aspects of all types of patients, it can also limit subgroup analysis and more specific outcomes.

CONCLUSIONS

Breast cancer remains a common condition, and breast reconstruction is an important component of a comprehensive treatment strategy. Autologous breast reconstruction with free flaps is an increasingly popular form of reconstruction. Using CT scans obtained for surgical planning and/or cancer staging, we demonstrated that the sarcopenia score, a measure of muscle mass at the L3 vertebra, was a superior predictor of complications when compared with both the BMI and the mFI.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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