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Cost of Major Surgery in the Sarcopenic Patient

Kyle H Sheetz, BS, **Seth A Waits, MD**, **Michael N Terjimanian, MS**, **June Sullivan, MBA**, **Darrell A Campbell, MD, FACS**, **Stewart C Wang, MD, PhD, FACS**, and **Michael J Englesbe, MD, FACS**
Morphomic Analysis Group, University of Michigan, Ann Arbor, MI

Abstract

Background—Sarcopenia is associated with poor outcomes after major surgery. There are currently no data regarding the financial implications of providing care for these high-risk patients.

Study Design—We identified 1,593 patients within the Michigan Surgical Quality Collaborative (MSQC) who underwent elective major general/vascular surgery at a single institution between 2006–2011. Patient sarcopenia, determined by lean psoas area (LPA), was derived from preoperative CT scans using validated analytic morphomic methods. Financial data including hospital revenue and direct costs was acquired for each patient through the hospital's finance department. Financial data was adjusted for patient and procedural factors using multiple linear regression methods and Mann-Whitney U test was employed for significance testing.

Results—After controlling for patient and procedural factors, decreasing LPA was independently associated with increasing payer costs ($6,989.17 per 1000mm^2 LPA, $p<0.001$). The influence of LPA on payer costs increased to $26,988.41 per 1000mm^2 decrease in LPA ($p<0.001$) in patients who experienced a postoperative complication. Further, the covariate adjusted hospital margin decreased by $2,620 per 1000mm^2 decrease in LPA ($p<0.001$) such that average negative margins were observed in the third of patients with the smallest LPA.

Conclusions—Sarcopenia is associated with high payer costs and negative margins after major surgery. While postoperative complications are universally expensive to payers and providers, sarcopenic patients represent a uniquely costly patient demographic. Given that sarcopenia may be remediable, efforts to attenuate costs associated with major surgery should focus on targeted preoperative interventions to optimize these high risk patients for surgery.

Introduction

Sarcopenia is associated with poor outcomes in both surgical and non-surgical patients with serious illness.[1, 2] The relationship between sarcopenia and perioperative morbidity and mortality has been established in several major surgical populations.[3, 4] There is also evidence to suggest a significant correlation with long-term outcomes after cancer resection.

Correspondence address: Michael J Englesbe, M.D., Department of Surgery, University of Michigan Medical School, 2926A Taubman Center, 1500 East Medical Center Drive, Ann Arbor, MI 48109-5331, Tel: 734-936-9623, Fax: 734-936-5830, englesbe@med.umich.edu.

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[5, 6] Importantly, sarcopenia increases with advanced age, where the propensity for poor surgical outcomes is well-established. Nonetheless, there is evidence to suggest that sarcopenia may be at least partially independent from age and comorbid disease burden as a domain of surgical risk.[7] Sarcopenia, as a potentially remediable risk factor, may represent a novel target for quality improvement and cost control efforts at the patient-level.

Despite this, the financial implications of sarcopenia in surgical patients are poorly understood. High individual patient costs are attributed in part to advanced age and comorbid disease burden, which predispose patients to adverse perioperative events.[8, 9] Current efforts to attenuate costs at the hospital-level have leveraged the outcomes-driven nature of surgical care, with initiatives such as pay for performance, centers of excellence, and pay for participation (surgical collaborative) gaining recent momentum.[10] Cost containment measures for individual surgeons at the point-of-care have lagged behind and focus on preoperatively mitigating risks associated with comorbid conditions (e.g. diabetes and heart disease).[11–13] These efforts have resulted in questionable benefits.[14] Investment in addressing potentially remediable risks such as sarcopenia may improve cost control efforts.

Within this context, we used data from the Michigan Surgical Quality Collaborative (MSQC) to characterize the independent financial impact of sarcopenia in major surgical patients. Using validated analytic morphometric measures, we studied the relationship between lean core muscle size, as a metric for sarcopenia, and surgical costs to payers and providers at a single institution.

Methods

Patient Population

We used data from the Michigan Surgical Quality Collaborative (MSQC) clinical registry to identify patients undergoing elective major general or vascular surgery at a single institution between 2006 and 2011. All patients underwent elective operations that required an inpatient hospitalization of at least 24 hours. The MSQC is a provider-led quality improvement organization funded by Blue Cross and Blue Shield of Michigan. Data for this project employed standard data definitions and collection protocols of the American College of Surgeons- National Surgical Quality Improvement Program (ACS-NSQIP) platform as previously described.[15] All available variables were collected for this analysis including patient demographics, preoperative risk factors, laboratory values, perioperative factors, and 30-day postoperative morbidity and mortality. The patient population was limited to those with an available abdominal CT scan within the 90 days prior to operation.

Analytic Morphomics

Using validated analytic morphomic methods, we measured the cross-sectional area and density (Hounsfield Units) of both psoas muscles at the level of the fourth lumbar vertebra (L4).[1, 4, 16] We then adjusted for fatty infiltration of the muscle using a correction factor to generate the lean psoas area (LPA). All measurements were carried out in a semi-automated fashion using custom algorithms programmed in MATLAB v13.0.

Outcomes

We obtained inpatient and outpatient financial data for procedural costs, facility fees, and reimbursements for each patient using the internal cost-accounting database at the study institution. Data was collected from 2 days prior to operation to 90 days postoperatively. Financial data was limited to those costs incurred within the institution's healthcare system. The Transitions Systems Incorporated (TSI) (Shoreview, MN, USA) was used to identify direct and indirect hospital costs in addition to reimbursements. Reimbursements were calculated using a modeled revenue for reimbursements. TSI tracks resource utilization and assigns estimates of cost based on direct acquisition costs for supplies and time-and-motion studies for labor costs. This method of cost accounting is generally accepted as the most accurate means of estimating the true costs of a healthcare encounter.[17] Margin data was calculated based on differences in reimbursements and hospital costs.

We also assessed patient outcomes including 30-day in hospital morbidity and mortality. Morbidity outcomes included surgical site infection (superficial, deep, and organ space defined separately), deep venous thrombosis, urinary tract infection, acute renal failure, postoperative bleeding requiring transfusion, stroke, unplanned intubation, fascial dehiscence, prolonged mechanical ventilation over 48 hours, myocardial infarction, pneumonia, pulmonary embolism, sepsis, vascular graft loss, and renal insufficiency.

Statistical Analysis

Descriptive statistics were generated for the study population. Continuous variables were summarized by mean and standard deviation, while frequency calculations were employed for categorical variables. Differences between continuous variables were evaluated using Student's t-test, while Chi-squared and Fisher's exact tests were employed to assess differences in categorical variables. Simple linear regression was performed to examine the relationship between lean core muscle size and other continuous patient characteristics. Lean psoas measurements were made categorical and patients were grouped based on LPA (accounting for gender differences) in to tertiles- sarcopenic, average, and non-sarcopenic.

The association between patient-level covariates and financial outcomes was assessed using Mann-Whitney U test for continuous variables and Chi-squared test for categorical data. Outlier costs were defined as those exceeding 1.5 times the interquartile range (IQR) for the specific parameter in question. Despite variation in financial data, costs were generally normal in distribution. As a result, transformation was not performed prior to regression analysis. Hospital costs and reimbursements were controlled for patient and procedural factors using multiple linear regression. Final models for adjusted revenue and costs included patient comorbidities, age, sex, ASA Class, and Work RVU for the surgical procedure.

A significance level of $\alpha=0.05$ was used. All statistical analyses were performed using Stata statistical software version12.1 (College Station, Texas). This study was approved by the University of Michigan Institutional Review Board.

Results

Patient Characteristics

We identified 1,593 patients undergoing major elective general or vascular surgery at a single institution between 2006–2011. Descriptive statistics for the patient population are included in Table 1. Lean psoas area (LPA) was normally distributed for both men (mean area, 2150.56 ± 670.32 mm^2) and women (1371.96 ± 421.14 mm^2) in our patient population. Decreasing LPA was correlated with increasing age in both men ($r= -0.485$) and women ($r= -0.492$). As has been described before, there was significant variation in LPA among patients of similar age. For example, in patients over 65, the observed range of LPA spanned 2730.90mm^2 (SD=469.03) for men and 2286.92mm^2 (SD=326.44) for women. Based on multiple linear regression modeling, LPA was independently associated with age ($p<0.001$), sex ($p<0.001$), BMI ($p<0.001$), COPD ($p=0.040$), congestive heart failure ($p=0.030$) and disseminated cancer ($p=0.017$). The overall complication rate in the study population was 21.6%. Sarcopenic (patients within the smallest tertile of LPA) patients experienced higher rates of postoperative events (30.3%) when compared to non-sarcopenic patients (16.4%, $p<0.001$). Overall median length of stay was 5 days, which was higher in sarcopenic patients (7 days) in contrast to non-sarcopenic patients (4 days, $p<0.001$). While patients included in this study underwent a wide variety of procedures, we found no differences in the overall case mix between sarcopenic, average, and non-sarcopenic patients.

Payer Cost (Reimbursements)

Mean unadjusted payer costs were significantly higher in sarcopenic ($34,796.37) when compared to average ($27,115.84) and non-sarcopenic ($21,380.07; $p<0.001$) patients. Significant differences remained when comparing patients with no complications or any postoperative complication. (Table 2) Further, 60% of outlier payer costs (>1.5 IQR) were contained in the sarcopenic cohort, with average (24 %) and non-sarcopenic (16%) patients contributing to substantially fewer. After controlling for patient and procedural factors, LPA was independently associated with increased payer costs ($6,989.17 per 1000mm^2 LPA, $p<0.001$). The independent contribution of LPA to payer costs was significantly higher when patients incurred any postoperative complication ($26,988.41 per 1000mm^2 LPA, $p<0.001$). Linear regression models also indicated that covariate adjusted payer costs decreased significantly across percentiles of lean psoas area. (Figure 1) The relationship between sarcopenia and payer costs in subsets of patients with none, one, or multiple postoperative complications was also assessed. (Figure 2) It was determined that significant differences between sarcopenic and non-sarcopenic patients persisted across all subsets of patients, such that mean costs in non-sarcopenic patients experiencing multiple complications ($29,665) are similar to mean costs in sarcopenic patients who do no experience any complications ($29,554).

Hospital Margin

The unadjusted total costs incurred by the hospital were concentrated in sarcopenic patients. (Figure 3) Hospital margin (payer costs minus hospital costs) was adjusted for patient and procedural factors. The treatment of sarcopenic patients resulted in an average negative margin for the hospital (−$873), in contrast to average ($1,806) and non-sarcopenic ($3,170) patients. Based on the regression model, covariate adjusted hospital margin decreased by $2,620 for each per 1000mm^2 decrease in LPA ($p<0.001$). Figure 4 illustrates that the hospital begins to appreciate a positive margin in patients with a LPA between the 20th and 40th percentile.

Discussion

Given the widespread interest in healthcare costs, it is important that surgeons understand drivers of expensive care, particularly in the setting of novel patient risk factors. We have shown that sarcopenia is an independent predictor of both payer- and hospital costs. Importantly, the financial burden of treating these patients is appreciated by both parties. The relationship between sarcopenia and high costs is most relevant in the setting of postoperative complications, of which sarcopenic patients are more susceptible. While many efforts to control costs address hospital-level processes of care, our data suggest that leveraging clinician efforts at the patient-level may provide novel targets for quality improvement and cost containment.

Sarcopenia is an independent predictor of morbidity and mortality after major surgery. [1, 4, 7] Further, surgical care is particularly expensive in the setting of postoperative morbidity, where longer hospital stays and high resource utilization are common.[18, 19] Previous work using national survey data indicated high costs attributed to treating sarcopenic elderly patients, though analyses lacked objective metrics for assessing musculature.[20] Methods for controlling cost in surgery (e.g. pay-for-performance) vary significantly both in scope and target audience, and there is currently little empirical evidence support one method over another.[10] Regardless of the means, surgeons will be expected to understand and address patient factors that predispose to poor (and expensive) outcomes. Within this context, there is evidence to suggest that sarcopenia may be remediable. Studies have shown that aerobic and resistance exercises can lead to skeletal muscle hypertrophy in elderly patients.[21, 22]

Analytic morphomics may provide a novel and unique means of forecasting surgical costs. First, many patients receive CT scans for operative planning purposes. Previous work has already shown that objective data from these imaging studies is informative within the context of surgical outcomes. However, surgeons and hospitals may also be able to utilize this information to inform financial decisions. While no studies have directly shown that remediating sarcopenia preoperatively reduces postoperative complications, there is evidence to suggest that surgeons could utilize waiting times for elective surgery to optimize their patients physiologically, thereby ultimately reducing costs. Identifying which patients are most in need of preoperative optimization is a critical question. Addressing this question scientifically requires prospective study design with randomization of subjects to intervention and control. While most all patients would benefit from some level of “pre-habilitation” prior to surgery, we believe that those patients in represented in the lowest third of LPA (gender adjusted) may be most beneficial to target preoperatively.

This study has several key limitations. First, only patients with preoperative CT imaging were included, which may select for patients more susceptible to complications and high costs. The application of novel imaging techniques to obtain morphomic measures may improve generalizability of results. It is important to note that financial data is institution specific and cost accounting methods can vary significantly between centers. Further, specific payer reimbursements are unique to the center’s negotiations with insurers. Estimations in reimbursements are biased according to these limitations. The scope of this analysis is additionally limited by the fact that opportunity costs were not quantified. A patient experiencing a complicated hospital stay may be utilizing an inpatient bed that could potentially be occupied by a more “profitable” patient. This study also focuses only on costs incurred within a single healthcare system. It is possible that certain patients sought care at other medical centers related to their procedure within the 90-days after operation. Finally, the study is limited by the fact that this is a single institution retrospective study.

Understanding the mechanisms for high surgical costs is critical as healthcare payment structures continue to evolve rapidly. Using preoperative cross-sectional imaging and analytic morphomics, we describe the independent relationship between sarcopenia and costs associated with major surgery. These methods offer novel opportunities to preoperatively identify patients with the potential for high resource utilization and costs to payers and providers. Further, as sarcopenia may be remediable, efforts to address this risk factor may result in novel targets for cost containment. Given that these evaluations occur at the point-of-care, analytic morphomics can engage surgeons in broader institution-level efforts that reduce healthcare costs.

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Abbreviations and Acronyms

LPA	Lean psoas area

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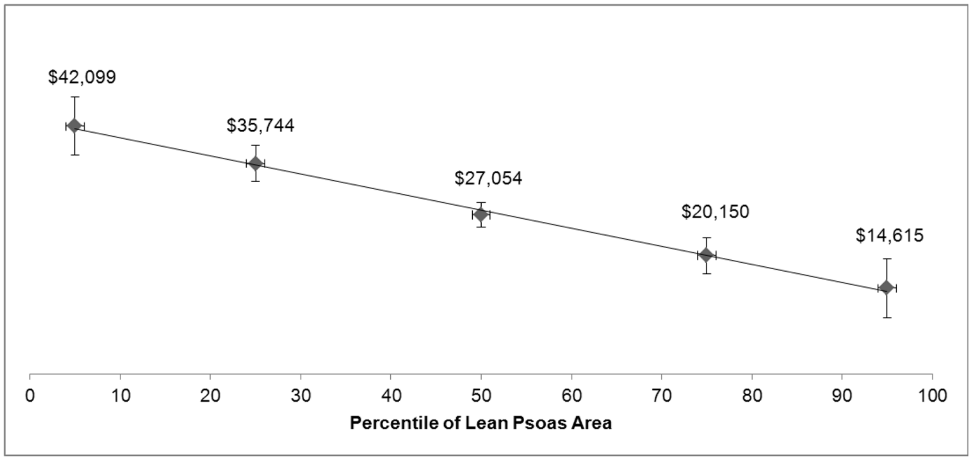

Figure 1.

Covariate adjusted payer costs. Sarcopenia is significantly associated with higher payer costs. After adjusting for patient and procedural covariates, patient costs varied nearly 3-fold across the observed range of lean psoas area.

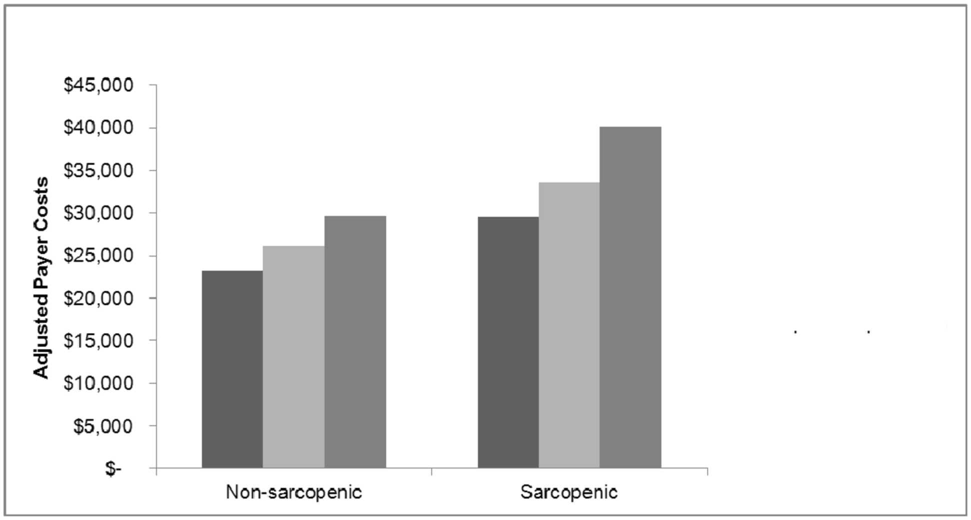

Figure 2.
Covariate adjusted payer costs. Patients were grouped in to tertiles of lean psoas area. Payer costs in sarcopenic patients were significantly higher that non-sarcopenic patients in those with zero, one, and multiple complications (*denotes significance, p<0.001 for all). Black bar, no complications; light gray bar, 1 complication; dark gray bar, multiple complications.

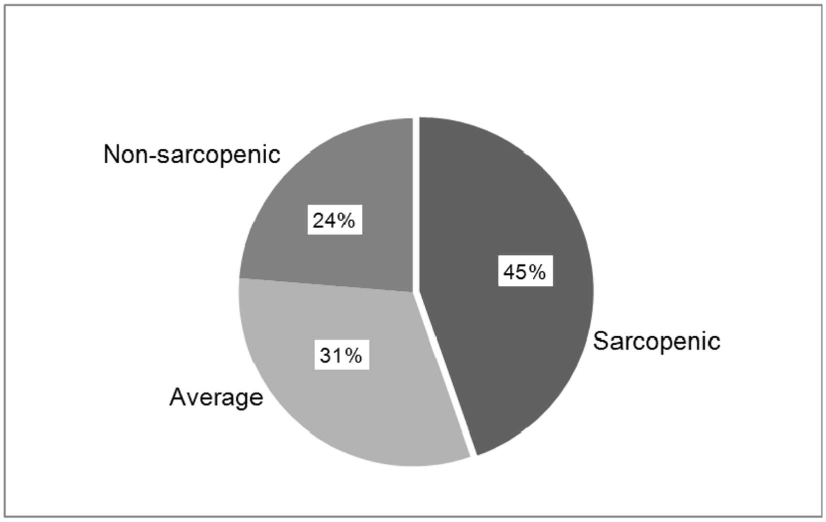

Figure 3.
Distribution of total hospital costs. The percentage of hospital costs attributed to the sarcopenic tertile of patients is significantly higher than those incurred by average and non-sarcopenic patients.

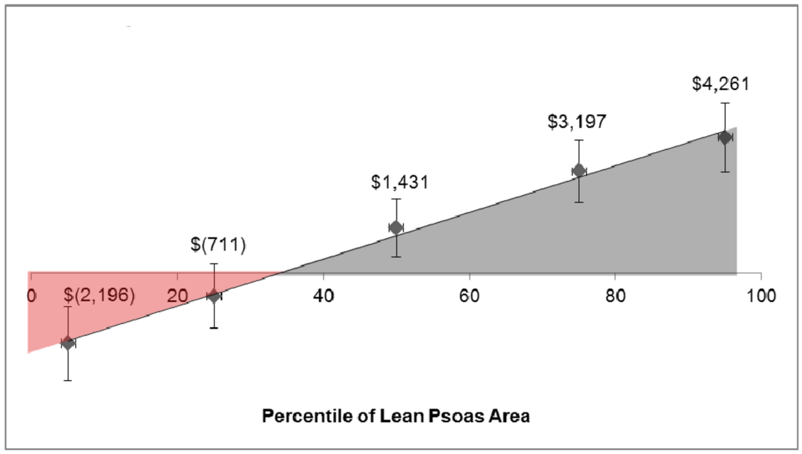

Figure 4.
Covariate adjusted hospital margin. Lean psoas area is associated with overall hospital margin. Sarcopenic patients represented an overall negative margin for the hospital.

Table 1

Patient Demographic and Clinical Factors across Tertiles of Lean Psoas Area

Patient characteristics	Sarcopenic, mean ± SD or %	Non-sarcopenic, mean ± SD or %	p Value
Demographics			
Age, y	66.4 ± 14.4	48.5 ± 14.8	<0.001
Male sex	52.3%	52.4%	0.998
Body mass index, kg/m^2	26.2 ± 6.1	31.1 ± 8.4	<0.001
Public insurance	70.9%	30.2%	<0.001
Work-RVU	21.6 ± 14.4	16.5 ± 14.0	<0.001
Clinical			
Diabetes mellitus	21.2%	13.6%	0.001
Chronic obstructive pulmonary disease	10.3%	2.5%	<0.001
Dialysis	4.7%	1.1%	0.001
Disseminated cancer	8.5%	5.7%	0.075
Hypertension	62.2%	34.2%	<0.001
Preoperative serum albumin, g/dL	3.77 ± 0.7	4.21 ± 0.6	<0.001
Independent function status	91.7	98.1	<0.001
Smoker	17.3%	17.5%	0.913
Peripheral vascular disease	6.3%	1.5%	<0.001
Congestive heart failure	1.5%	0.3%	0.057

Table 2

Unadjusted Costs Across Tertiles of Lean Psoas Area

Unadjusted financial parameters	Sarcopenic	Non-sarcopenic	p Value
Payer costs (reimbursements)			
Overall	$ 34,796.37	$ 21,380.07	<0.001
No complications	$ 23,857.95	$ 18,751.21	<0.002
Any complication	$ 60,002.31	$ 34,766.10	0.002
Hospital Costs			
Overall	$ 35,056.30	$ 18,488.48	<0.001
No complications	$ 23,133.24	$ 15,865.96	<0.001
Any complication	$ 62,531.17	$ 31,842.23	<0.001
Hospital Margin			
Overall	$ (259.93)	$ 2,891.59	<0.001
No complications	$ 724.71	$ 2,885.25	0.108
Any complication	$ (2,528.86)	$ 2,923.87	<0.001