Inpatient costs and blood transfusion rates of sarcopenic patients following thoracolumbar spine surgery

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OBJECTIVE Sarcopenia, the muscle atrophy associated with aging and disease progression, accounts for nearly \$18.5 billion in health care expenditures annually. Given the high prevalence of sarcopenia in patients undergoing orthopedic surgery, the goal of this study was to assess the impact of sarcopenia on inpatient costs following thoracolumbar spine surgery.

METHODS Patients older than 55 years undergoing thoracolumbar spine surgery from 2003 to 2015 were retrospectively analyzed. Sarcopenia was measured using total psoas area at the L-4 vertebra on perioperative CT scans. Hospital billing data were used to compare inpatient costs, transfusion rate, and rate of advanced imaging utilization.

RESULTS Of the 50 patients assessed, 16 were sarcopenic. Mean total hospital costs were 1.75-fold greater for sarcopenic patients compared with nonsarcopenic patients (\$53,128 vs \$30,292, $p = 0.04$). Sarcopenic patients were 2.1 times as likely to require a blood transfusion (43.8% vs 20.6%, $p = 0.04$). Sarcopenic patients had a 2.6-fold greater usage of advanced imaging (68.8% vs 26.5%, $p = 0.002$) with associated higher diagnostic imaging costs (\$2452 vs \$801, $p = 0.01$). Sarcopenic patients also had greater pharmacy, laboratory, respiratory care, and emergency department costs.

CONCLUSIONS This study is the first to show that sarcopenia is associated with higher postoperative costs and rates of blood transfusion following thoracolumbar spine surgery. Measuring the psoas area may represent a strategy for predicting perioperative costs in spine surgery patients.

<https://thejns.org/doi/abs/10.3171/2017.5.SPINE17171>

KEY WORDS sarcopenia; frailty; thoracolumbar spine surgery; inpatient costs; lumbar; thoracic

SARCOPENIA is the muscle atrophy associated with aging and disease progression.⁶ This condition is highly prevalent in the elderly population, with older adults losing up to 15% of their total muscle mass during their 7th decade of life.¹⁹ In addition to being an independent predictor of fall risk, hospital-acquired infection, and all-cause mortality,^{1,5,16} sarcopenia has been shown to significantly increase inpatient costs following elective general surgery.¹⁴

Over the last 2 decades, Medicare spending on lumbar spine surgery has risen nearly 500%, reaching a cost of

\$482 million annually.²⁸ As these costs have continued to grow, so too has the need for cost-effective surgical practices and appropriate patient selection.²⁶ The assessment of sarcopenia prior to surgery may represent one such risk stratification tool. To put the impact of sarcopenia in perspective, it has been estimated that a 10% decrease in the prevalence of sarcopenia nationally could amount to health care cost savings of \$1.1 billion annually in the US.¹¹

While sarcopenia has been identified as an independent predictor of higher postoperative costs and poorer outcomes following general surgery,^{7,8,14,24,27} few studies have

ABBREVIATIONS CCI = Charlson Comorbidity Index; ICU = intensive care unit; TPA = total psoas area.

SUBMITTED February 5, 2017. **ACCEPTED** May 12, 2017.

INCLUDE WHEN CITING Published online October 6, 2017; DOI: 10.3171/2017.5.SPINE17171.

measured the impact of sarcopenia on inpatient surgical costs following orthopedic surgery, despite the fact that as many as 44% of orthopedic patients may meet the criteria for sarcopenia.¹³

In this investigation, we examined the effect of sarcopenia on inpatient surgical costs following thoracolumbar spine surgery. In addition to the total inpatient cost, a sub-analysis was performed to examine which aspects of the hospitalization were costlier for sarcopenic patients. We hypothesized that sarcopenia would be associated with a greater overall cost of hospitalization following thoracolumbar spine surgery.

Methods

Study Design

Institutional review board approval from Rhode Island Hospital was obtained prior to initiating this investigation. All patients undergoing thoracolumbar decompression or decompression with fusion at a single institution from 2003 to 2015 were analyzed. All surgical indications were considered for inclusion. Patients were included if they were older than 55 years, if there was a perioperative CT scan available for measuring psoas muscle cross-sectional area (performed an average of 4.3 months prior to date of surgery; range 0–21.4 months), and if inpatient cost data were available from the hospital's billing department. Patients were excluded if a CT scan had been performed more than 2 years prior to a patient's surgery date, or if the patient's inpatient cost data were unavailable.

Measurement of Sarcopenia

All sarcopenia measurements were performed using axial views of the psoas muscle at the L-4 vertebra on CT. The cross-sectional areas of the left and right psoas muscles at the level of the transverse process of L-4 were measured manually using OsiriX imaging software (Pixmeo), with fat stranding observed on CT used to exclude fat tissue from psoas muscle measurement. Measurements were made using the axial image in which both transverse processes were fully visualized to improve objectivity and reproducibility of the measurement, as previously described.²¹ The cross-sectional areas were then added to calculate the L-4 total psoas area (TPA).⁹ A single investigator blinded to patient diagnosis and outcomes calculated the TPA two separate times for each patient, in a random order on two different occasions, with the two values subsequently averaged. Patients were diagnosed with sarcopenia if they fell into the lowest tertile for their sex-specific TPA.

Outcome Variables

The primary outcome variable was the total inpatient hospitalization cost, which included the cost of the surgical procedure and all costs incurred during the inpatient postoperative period. Secondary outcomes measures included the following individual costs: surgical cost (cost of operating room time, instrumentation, and perioperative nursing care), cost of occupying a hospital bed (nursing care for a routine bed, step-down bed, or intensive care unit [ICU] bed), blood bank, laboratory studies, diagnos-

tic imaging, pharmacy costs, respiratory care, endoscopy, emergency department cost, rehabilitation services (both physical and occupational therapists), intravenous therapy (cost of fluid resuscitation, venous access), and central supply (cost of all medical-grade equipment not routinely available on the hospital floor). Costs were obtained from the hospital charge center prior to being negotiated by insurance, with cost data adjusted for year-to-year inflation by the cost center. All costs were based on a standardized hospital registrar, completely independent of insurance type or reimbursement rates. Additional secondary outcomes included requirements for blood transfusions and advanced imaging (defined as CT, MRI, or ultrasonography).

Preoperative health and comorbidity burden was measured using the Charlson Comorbidity Index (CCI), a well-validated index used to account for complex medical comorbidities such as end-organ disease (e.g., end-stage renal disease) and presence of malignancy (localized and metastatic).²⁵ Patient charts were reviewed in detail to identify medical comorbidities based on ICD-10 codes, which were subsequently used for calculation of the CCI as previously described.^{4,22}

Statistical Analysis

A Student t-test was used to compare mean differences in total hospital costs and for each individual department cost between sarcopenic and nonsarcopenic patients. A z-score was used to assess for differences in the proportion of patients receiving blood transfusion or advanced imaging for sarcopenic versus nonsarcopenic patients. A cutoff of $p = 0.05$ was used to determine significance for all tests (SPSS version 21, IBM Corp.).

Results

Fifty patients met inclusion criteria for the study, with 16 (8 men and 8 women) falling into the lowest tertile for sex-specific L-4 TPA and thus diagnosed with sarcopenia. Follow-up duration ranged from 6 days (died in hospital) to 12.7 years, with an average of 4.6 years. Indications for surgery were spinal stenosis in 35 patients (4 secondary to metastasis), degenerative scoliosis in 4 patients, epidural abscess or discitis in 5, acute fracture requiring operative fixation in 4 (1 secondary to metastasis), and radiculopathy in 2 (Table 1). All 5 patients requiring an operation for spinal metastasis were sarcopenic. However, there was no significant difference between the proportion of sarcopenic and nonsarcopenic patients with any diagnosed malignancy (8 vs 9 patients, respectively; $p = 0.1$). Sarcopenic patients were significantly older than nonsarcopenic patients with a mean age of 76.6 years compared with 70.8 years, respectively ($p = 0.027$). There was no statistically significant difference in mean CCI (3.6 vs 3.2, $p = 0.59$) for sarcopenic patients compared with nonsarcopenic patients.

The average total hospital cost was 1.75-fold greater for sarcopenic versus nonsarcopenic patients (\$53,128 vs \$30,292, $p = 0.04$; Table 2). There was no significant difference in total surgical costs (inclusive of operating room time, instrumentation cost, and cost of perioperative care) for sarcopenic versus nonsarcopenic patients (\$23,515 vs

TABLE 1. Baseline patient characteristics by sarcopenic status

Variable	Sarcopenic	Nonsarcopenic	p Value
Sex			
Male	8	18	
Female	8	16	
Mean age $\pm$ SD (yrs)	76.6 $\pm$ 2.2	70.8 $\pm$ 1.4	0.027
Mean L-4 TPA $\pm$ SD (mm ²)	1297.6 $\pm$ 105.2	2283.4 $\pm$ 123.5	<0.001
Mean CCI $\pm$ SD	3.6 $\pm$ 0.7	3.2 $\pm$ 0.4	0.59
Preop diagnosis			
Spinal stenosis (metastasis)	11 (4)	24	
Degenerative scoliosis	0	4	
Epidural abscess/discitis	2	3	
Acute fracture (metastasis)	3 (1)	1	
Radiculopathy	0	2	

All data given as number of patients unless otherwise indicated.

\$19,140, $p = 0.31$). While the cost of occupying a routine hospital bed was greater for sarcopenic patients (\$10,522 vs \$4934, $p = 0.002$), there was no significant difference in cost for step down–level beds (\$2831 vs \$714, $p = 0.11$) or ICU-level beds (\$6520 vs \$2442, $p = 0.12$) for sarcopenic patients compared with nonsarcopenic patients.

Blood bank cost was significantly higher for sarcopenic patients compared with nonsarcopenic patients (\$960 vs \$167, $p = 0.01$). Sarcopenic patients were 2.1 times as likely to require blood transfusion (43.8% vs 20.6%, $p = 0.04$), with a significantly greater number of units transfused than nonsarcopenic patients (1.4 vs 0.3 units, $p = 0.02$). Similarly, diagnostic imaging costs were significantly greater for sarcopenic patients (\$2452 vs \$801, $p = 0.01$), with a 2.6-fold greater usage of advanced imaging (68.8% vs 26.5%, $p = 0.002$).

With regard to the remaining aspects of hospitalization, sarcopenia was associated with a higher cost for pharmacy (\$2128 vs \$609, $p < 0.001$), laboratory studies (\$1128 vs \$274, $p = 0.004$), respiratory care (\$649 vs \$225, $p = 0.04$), and the emergency department (\$375 vs \$147, $p = 0.04$). However, there were nonsignificant differences in costs for rehabilitation services (\$123 vs \$55, $p = 0.08$), intravenous therapy (\$249 vs \$104, $p = 0.14$), central supply (\$111 vs \$6, $p = 0.18$), and endoscopy (\$123 vs \$55, $p = 0.31$) between sarcopenic and nonsarcopenic patients.

Discussion

Sarcopenia is a common condition in older age and may account for an additional \$18.5 billion in health care expenditures annually.²⁵ Our previous study of sarcopenia in patients who underwent thoracolumbar spine surgery demonstrated that sarcopenic patients had a significantly increased risk of death, in-hospital complications, and discharge to rehabilitation facilities, as well as longer length of hospital stay.² While previous studies have shown that sarcopenia increases the cost of elective general surgery by nearly \$10,000 per cm² of psoas area, this study is the

TABLE 2. Cost comparison for sarcopenic patients compared to nonsarcopenic patients

Cost Variable	Sarcopenic (\$)*	Nonsarcopenic (\$)*	p Value
Total inpatient cost	53,128 $\pm$ 10,612	30,292 $\pm$ 6535	0.04†
Routine hospital bed	10,522 $\pm$ 1618	4934 $\pm$ 760	0.002†
Blood bank	960 $\pm$ 311	167 $\pm$ 54	0.01†
Diagnostic imaging‡	2452 $\pm$ 529	801 $\pm$ 262	0.01†
Pharmacy	2128 $\pm$ 356	609 $\pm$ 93	<0.001†
Laboratory studies	1128 $\pm$ 281	274 $\pm$ 78	0.004†
Respiratory care	649 $\pm$ 205	225 $\pm$ 110	0.04†
Emergency department	375 $\pm$ 114	147 $\pm$ 57	0.04†
Surgery	23,515 $\pm$ 7193	19,140 $\pm$ 4901	0.31
ICU bed	6520 $\pm$ 3129	2442 $\pm$ 1314	0.12
Step-down bed	2831 $\pm$ 1648	714 $\pm$ 404	0.11

* Data given as mean $\pm$ SEM.

† Statistically significant cost differences.

‡ MRI, CT, or ultrasonography.

first to demonstrate that sarcopenia is associated with significantly higher costs following thoracolumbar spine surgery.⁸ Specifically, the total hospitalization cost for sarcopenic patients was nearly \$23,000 greater per patient. This finding is particularly salient given that sarcopenia rates are as high as 44.1% in certain orthopedic populations.¹³

Interestingly, there was no significant difference in the total operative cost; the biggest differences in costs were in occupying a routine hospital bed, receiving blood, laboratory testing, advanced diagnostic imaging, and respiratory care. Therefore, it appears that the largest cost drivers during hospitalization are the need for closer monitoring and the interventions for blood loss and other surgical complications. These nonsurgical costs accounted for more than 50% of the total cost in sarcopenic patients but less than 35% in nonsarcopenic patients (Fig. 1). These findings are consistent with numerous previous investigations demonstrating that sarcopenia is an independent predictor of postoperative complications following abdominal and emergency surgery.^{7,14,15} Likewise, sarcopenia has also been associated with reduced left ventricular ejection fractions and respiratory failure.^{12,20}

It is especially important that sarcopenic patients were 2.1 times more likely to receive a blood transfusion compared with nonsarcopenic patients. Not only has blood transfusion been shown to increase the potential for postoperative infection and the average length of ICU stay following spine surgery, but it also exposes patients to transfusion-related acute lung injury and transfusion-associated circulatory overload, both of which may be fatal to the sarcopenic patient.¹⁰

This study had several potential limitations. One limitation is that only the L-4 TPA was used to define sarcopenia. Other investigations have used Hounsfield units on CT scan, quadriceps area, dual energy x-ray absorptiometry, or bioelectrical impedance analysis in combination with measures of muscle strength (handgrip) and physical performance (gait speed).^{3,17,23} L-4 TPA was used in this

FIG. 1. Percentage of total cost for the 7 largest cost drivers during hospitalization for thoracolumbar spine surgery. A star denotes statistically significant differences. Figure is available in color online only.

study given the wide availability of CT scans in spine surgery patients, as well as the strong objectivity and reproducibility of this measure.⁹ In addition, because CT scans were obtained perioperatively, we could not exclude the possibility that patients may have developed sarcopenia due to the operation itself. Furthermore, due to a lack of data regarding patient body mass index, we were not able to identify patients with sarcopenic obesity, which has been associated with worse outcomes.¹⁸ Another potential limitation is that sarcopenic patients in our study were significantly older than nonsarcopenic patients, and that all 5 patients with spinal metastasis were sarcopenic. This may have contributed to the higher cost of care associated with sarcopenia, although it should be noted that sarcopenic and nonsarcopenic patients in our study did not significantly differ in mean CCI score, which adjusts for age and accounts for comorbidities including metastasis. Finally, our study retrospectively analyzed a patient cohort from a single institution, and accounted for only direct patient costs. Future studies would be strengthened by analyzing indirect costs in addition to prospectively studying a larger sample size derived from multiple centers.

Conclusions

This study demonstrates that sarcopenia is associated with higher total postoperative costs following thoracolumbar surgery, in addition to higher costs for both routine laboratory tests and advanced diagnostic imaging. Given the growing importance of cost containment and an in-

creasingly outcomes-based surgical climate, measuring sarcopenia represents one potential strategy for screening spine surgery patients and predicting surgical cost, especially considering the widespread use of lumbar CT scans in this setting.

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Disclosures

Dr. Daniels reports being a paid consultant for DePuy, Globus Medical, Orthofix, SpineArt, and Stryker, and an unpaid consultant for Osseus; receiving research support for the study from Orthofix; and receiving financial or material support from DePuy, Medtronic Sofamor Danek, and Stryker.

Author Contributions

Conception and design: all authors. Acquisition of data: all authors. Analysis and interpretation of data: all authors. Drafting the article: all authors. Critically revising the article: all authors. Reviewed submitted version of manuscript: Daniels, Bokshan, DePasse, Eltorai. Statistical analysis: Bokshan.

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