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Analytic Morphomics Corresponds to Functional Status in Older Patients

Ashley L. Miller, BS[^], Lillian C. Min, MD, MSHS^{^*}, Kathleen M. Diehl, MD[^], David C. Cron, BS[^], Chiao-Li Chan, MSW[^], Kyle H. Sheetz, MS[^], Michael N. Terjimanian, MS[^], June A. Sullivan, MBA[^], William C. Palazzolo, MS, PA-C[^], Stewart C. Wang, MD, Ph.D.[^], Karen E. Hall, MD^{^*}, and Michael J. Englesbe, MD.[^]

[^]University of Michigan, Ann Arbor, MI, Departments of Surgery, and Medicine, Division of Geriatric and Palliative Medicine

^{*}VA Ann Arbor Healthcare System and the Geriatric Research Education Clinical Center (GRECC)

Abstract

Background—Older patients account for nearly half of U.S. surgical volume and age alone is insufficient to predict surgical fitness. Various metrics exist for risk stratification, but little work has been done to describe the association between measures. We aimed to determine whether analytic morphomics, a novel objective risk assessment tool, correlates with functional measures currently recommended in the preoperative evaluation of older patients.

Materials and Methods—We retrospectively identified 184 elective general surgery patients over age 70 with both a preoperative CT scan and Vulnerable Elderly Surgical Pathways and outcomes Assessment (VESPA) within 90 days of surgery. We used analytic morphomics to calculate trunk muscle size (total psoas area, or TPA) and univariate logistic regression to assess the relationship between TPA and domains of geriatric function – mobility, *basic* and *instrumental* activities of daily living (ADL), and cognitive ability.

Results—Greater TPA was inversely correlated with impaired mobility (OR=0.46, 95% C.I. 0.25–0.85, P=0.013). Greater TPA was associated with decreased odds of deficit in any *basic* ADLs (OR=0.36 per SD unit increase in TPA, 95% C.I. 0.15–0.87, P<0.03) and any *instrumental*

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Corresponding author: Ashley L. Miller, BS, Medical Student (MS3), University of Michigan Health Systems, 1500 E. Medical Center Drive, 2926A Taubman Health Center, Ann Arbor, MI 48109-5331, Cell: (513) 403-2282, FAX: (734) 763-3187 (MJE) ashmil@med.umich.edu.

All 12 authors included on this manuscript participated in study design, development of methodology, data collection, and analysis of the VESPA and/or analytic morphomics studies as well as the design, data analysis, and creation of the manuscript for this study. Work was done within a student career development program. All students added substantial value, and with mentorship, this significantly added to the number of authors.

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ADLs (OR=0.53, 95% C.I. 0.34–0.81; $P<0.005$). Finally, patients with larger TPA were less likely to have cognitive difficulty assessed by Mini-Cog scale (OR=0.55, 95% C.I. 0.35–0.86, $P<0.01$). Controlling for age did not change results.

Conclusions—Older surgical candidates with greater trunk muscle size, or greater TPA, are less likely to have physical impairment, cognitive difficulty, or decreased ability to perform daily self-care. Further research linking these assessments to clinical outcomes is needed.

Keywords

Analytic morphomics; Trunk muscle size; Risk assessment Geriatric assessment; Activities of daily living; Mobility; Functional status

INTRODUCTION

Advances in surgical technology, increased life expectancy, and high demand have resulted in surgeons performing more operations on patients of advanced age.(1–3) Patients aged 65 years and older undergo surgical procedures at a rate two to three times that of the general population and account for almost 40% of operations performed in the United States.(1, 4) Given the heterogeneous presentation of these older patients,(5) it has become evident that age alone is insufficient to risk-stratify these patients for surgery.(6) Some variation in apparent physical fitness is appreciable by history and physical examination, but there exists a need for objective, time-efficient measures of physical fitness in the preoperative setting. Our recent work described the use of existing preoperative cross-sectional imaging to define surgical risk and has identified central sarcopenia as a strong marker of poor surgical outcomes in the general population.(7) In response, we have become interested in potential approaches to identify remediable surgical risk in older patients with the goal of optimizing high-risk patients for surgical procedures. The potential clinical application would be to optimize sarcopenic patients for surgery by prescribing physical exercise to increase muscle mass.

However, surgeons must appreciate a complex milieu of risk among older patients, especially those in the upper end of this age range (i.e. age 70 and older). Older patients are more likely to have complex risk factors such as functional impairment and cognitive decline, which also impact surgical course.(5, 8–12) This marked variation in preoperative functional capacity has prompted a strong recommendation to employ geriatric assessment prior to surgery, for example in recent guidelines on the pre-operative care of the older surgical patient written by the American College of Surgeons.(5, 6, 13) The landscape of tests includes not only physical screens, such as ability to perform self-care(14, 15) and observed gait speed,(16) but also assessment of cognitive ability.(17, 18) Great enthusiasm has been shown for identifying various domains of risk, yet little work has been performed to describe the association between the various metrics in the older patient population.(19–21) We also do not fully understand how sarcopenia relates to the geriatric screening tests, and how they might overlap in these complex patients.(22, 23)

Therefore, we proposed this cross-sectional study of the relationship between central sarcopenia and risk factors identifiable by a comprehensive geriatric assessment in older

patients planning to undergo elective general surgical procedures in the Vulnerable Elderly Surgical Pathways and outcomes Assessment (VESPA) study.(18) We aimed to determine the extent to which radiographic quantification of trunk muscle size is correlated with risk stratification measures currently used to assess fitness in older patients. We hypothesized that muscle size would be associated most closely with measures of physical function in older patients. However, because decline in cognition can precede or concur with diminished physical and functional capacity,(24, 25) we also anticipated correlation between trunk muscle size and self-care / cognitive measures.

METHODS

Study Design

We conducted an observational cross-sectional study of a subsample of patients in the VESPA study. The original VESPA study was a quality improvement intervention developed in 2008 as a collaborative effort between the Departments of Surgery and Medicine at the University of Michigan Health System (UMHS), an academic, tertiary referral center.(18) Briefly, the VESPA initiative implemented a brief geriatric assessment that could be administered by surgery physician assistants as part of preoperative evaluation for patients aged 70 and older with planned general surgery. In 2012, we formally evaluated the VESPA effort from 2008–11, obtained approval by appropriate institutional review boards at UMHS as human research, and described cross-sectional relationships between the risk factors.(18) Relevant to this study, the VESPA evaluation measured functional status (through performance of activities of daily living (ADLs), 6 *basic* ADLs and 8 *instrumental* ADLs, mobility (through a Timed Up and Go test (3-meter walk), gait evaluation (normal or unsteady), and any self-reported falls within the past year) and cognitive status (using a clock composition test and three item recall).(14–17)

Data

Among the 736 patients in the VESPA study, we retrospectively identified an analytic sample who also received a preoperative computed tomography (CT) scan of the thoracolumbar area within the UMHS health system within 90 days *prior to* their elective general surgery. The CT scan had to include the psoas muscle at L4. We did not exclude any CT scans based on clinical indication. No additional CT scans, other than those already clinically indicated and performed, were conducted for this study.

Measures (dependent variables)

The original VESPA study collected functional status as a series of self-reported questions regarding difficulty with ADLs. The questions modified the *basic* ADL and *instrumental* ADL items from the original severity scales(14, 15) to dichotomous responses, difficulty versus no difficulty, for each task. VESPA allowed for either self- or proxy-reporting. The surgery physician's assistant performed both the interview and the physical examination to evaluate gait, balance, and cognition.

One challenge for the present analysis was to describe how TPA relates to the many VESPA items in broad domains. While some VESPA measures are physical (e.g., gait speed) and

others are cognitive (e.g., the Mini-cog), ADLs require both cognitive and physical ability. Therefore we considered the individual VESPA items as three types: self-care (ADLs), mobility, and cognitive (Figure 1). Of the three domains, mobility measures depend more highly on physical reserve, and therefore we expected the mobility deficits to be strongly and inversely-correlated with TPA (i.e. increased muscle size would be associated with decreased difficulty in mobility).

For this study, we considered each of the ADL difficulties as a separate measure as well as part of one or more composite measures. The *basic* ADLs were bathing, dressing, transferring, feeding, grooming, and toileting; the *instrumental* ADLs were medication administration, meal preparation, telephone use, transportation, shopping, housekeeping, laundry, and finances. For composite measures, we considered a categorical variable indicating any basic ADL difficulty (versus no difficulty on any basic ADL) and another separate indicator for any *instrumental* ADL difficulty (versus no difficulty on any instrumental ADL). Last, we considered a final composite measure of any functional difficulty in either basic or instrumental ADLs versus no functional difficulty.

We categorized patients requiring greater than 20 seconds to walk 3 meters in the Timed Up and Go test(16) as having slow gait speed. We used the single-item physical evaluation of steady versus unsteady gait to classify patients with unsteady gait. Mobility deficit was defined as having either slow or unsteady gait. Fall history, while related to mobility, was a self-reported rather than performance measure, so was considered separately.

The Mini-Cog includes the clock composition test and three-item recall.(17) Although the Mini-cog uses a cut-off of 3 or less to classify as positive for impairment, there were only 3 patients below this cutoff (2.2%), thus we classified all patients with a score of 4 or less as having a cognitive deficit.

Morphomics (independent variable)

As a measure of trunk muscle size, we calculated the total psoas area (TPA) from preoperative CT scans. We have previously described methods used to measure TPA.(7, 26) Briefly, vertebral levels were identified on each patient's CT scan to be used as anatomical landmarks. Using the transverse image at the L4 vertebral level, the left and right psoas muscles were outlined and the total area was calculated in centimeters. All image processing was performed using semi-automated algorithms programmed in MATLAB v13.0 (MathWorks, Natick, Mass). The population distribution of TPA in mm² is depicted for males and females in Figure 2A and 2B, respectively. In order to analyze the TPA as a measure of sarcopenia in this study, we normalized the cross section by gender (because men have larger psoas muscles so naturally the cross-section is also larger for the same degree of sarcopenia). Therefore, we expressed our units of TPA in standard deviation units, for each patient's psoas muscle size compared to the mean within their own gender (Figure 2C). This additional calculation also obviated the need to additionally control for gender.

Last, we also expressed TPA in tertiles in order to more easily display the results in terms of patients with small, medium, and large psoas muscle size.

Statistical Analysis

Descriptive statistics were calculated for the study cohort: continuous variables were described using mean and standard deviation, and categorical variables were summarized using proportions. To correlate TPA with individual VESPA components, we used univariate logistic regression. We determined the effect of each standard deviation increase in TPA on the likelihood of impairment in each dichotomous VESPA component. Next, we used univariate ordered logistic regression to assess the relationship between TPA and number of total deficits in basic and instrumental ADLs. We adjusted additionally for age in sensitivity analyses. A significance level of $\alpha=0.05$ was used. All statistical analysis was performed using STATA v.12.

RESULTS

Patient Demographic and Clinical Characteristics

Of the 736 VESPA patients, 184 patients fulfilled study inclusion criteria (had an eligible preoperative CT scan). Patient demographic and clinical characteristics are detailed in Table 1A. The average age of our study cohort was 77.7 ± 5.4 years, and the majority of patients were male (61.4%). The average hospital stay for this cohort was 6.7 days. Gastrointestinal procedures comprised the largest fraction of the case mix (42%), followed by urologic (29%), and oncologic (13%) operations.

Preoperative Geriatric Screening Results

Preoperative VESPA results for the items used in our study are described in Table 1B. With regard to physical function, 62 out of 147 patients in our analytic sample (42.2%) were recorded as having a deficit in one or more items (fall, unsteady gait, or slow 'up and go' test). Few patients ($n=6$, 4.0%) reported difficulty with any *basic* ADL. One-fifth of our sample had an *instrumental* ADL difficulty on one or more tasks ($n=32$, 21.8%). Finally, 29 of 131 (22.1%) patients who participated in the Mini-cog exam scored 4 points or less.

Relationship between Total Psoas Area (TPA) and Individual Measures of Mobility

Figure 3 shows the relationship between increasing trunk muscle size (TPA) and the odds of impairment in mobility measures. Increasing TPA was inversely correlated with slow gait speed (OR=0.52 per SD unit increase in TPA, 95% C.I. 0.31–0.88, $P=0.015$). Patients with greater TPA were less likely to have unsteady gait (OR=0.39, 95% C.I. 0.23–0.65, $P<0.001$). The effect of TPA on both measures remains unchanged after adjusting for age. TPA was not related to positive screen for history of falling (OR=0.81, 95% C.I. 0.54–1.21, $P=0.294$). There was a significant effect of TPA as tertiles on gait speed and steadiness, but not on positive history of falls.

Relationship between TPA and Individual Activities of Daily Living

Greater TPA (i.e., larger trunk muscle size) was associated with decreased incidence of any deficit in *basic* ADLs (OR=0.36 per SD unit increase in TPA, 95% C.I. 0.15–0.87, $P=0.023$). We did not find a significant relationship between TPA and odds of difficulty performing any individual *basic* ADL with the exception of transferring (OR=0.22, 95% C.I.

0.12–0.85; $P=0.022$; Figure 4A). Regarding overall number of *basic* ADL difficulties, increased TPA was associated with a decreased count of impairments in *basic* ADLs (OR=0.35 per additional difficulty, 95% C.I. 0.14–0.85; $P=0.022$).

There was an inverse relationship between increased TPA and reported difficulties performing any *instrumental* ADL (OR=0.53, 95% C.I. 0.34–0.81; $P=0.004$) (i.e. patients with larger TPA were less likely to report difficulties performing *instrumental* ADLs). We found a significant relationship between TPA and six of the eight individual *instrumental* ADLs (Figure 4B). Concerning overall burden of disability, increased TPA was associated with a decreased burden of impairments in *instrumental* ADLs (OR=0.48 per additional impairment, 95% C.I. 0.31–0.74; $P=0.001$).

There was a significant effect of TPA as tertiles on difficulty performing both *basic* and *instrumental* ADLs. Age did not significantly predict impairment in *basic* ($P=0.689$) or *instrumental* ($P=0.085$) ADLs. As a sensitivity analysis, age was added to each model with TPA, and no significant changes to the results were found.

Relationship between TPA and Cognitive Function

Patients with greater TPA were less likely to have a cognitive deficit as assessed by the Mini-Cog scale (4 of 5 or worse on Mini-Cog versus 5 of 5 points, OR=0.55 per SD unit increase in TPA, 95% C.I. 0.35–0.86, $P=0.008$) (Figure 5A). Age alone did not significantly predict the presence of cognitive deficit ($P=0.074$). The effect of the Mini-Cog remained significant after adjusting for age (OR=0.58, 95% C.I. 0.37–0.92, $P=0.019$). When TPA was stratified into tertiles, patients in the lowest tertile of TPA had odds of cognitive deficit that were three-fold higher than patients in the highest tertile of TPA (Figure 5B).

Relationship between TPA and Broader Functional Status Domains

Greater TPA was also inversely associated with deficits in the summary VESPA measures, summarized in Figure 6: any mobility impairment (OR = 0.41, 95% C.I. 0.25–0.67, $P<0.001$), any ADL impairment (OR=0.53 per SD unit increase in TPA, 95% C.I. 0.36–0.85), and any cognitive impairment (OR=0.55, 95% C.I. 0.35–0.86, $P=0.008$). As a final sensitivity analysis, all three composite measures were adjusted for age, which did not change the results.

DISCUSSION

In this work, we describe the association of trunk muscle size, as measured by total psoas area, with three domains of ability (mobility, functional status, and cognition) in older elective surgical patients (Figure 6). Patients with larger TPA were less likely to have deficits in all three domains. Mobility and cognitive status were assessed through either direct observation (e.g. gait speed and cognitive testing) or through self-reported difficulty with *basic* and *instrumental* ADLs(24), whereas TPA was measured quantitatively by calculation of psoas area on preexisting computerized tomography images obtained previously during clinical care.

These results have implications relevant to both clinical care of geriatric surgery patients and future research in surgical risk prediction. TPA, a novel radiologic measure of sarcopenia, has been shown to identify risk for post-operative complications among younger patients. (27) We anticipate future testing of how TPA might predict risk in older patient populations. However, prior to this future research, it is important to understand what TPA means in context of the geriatric patient, through cross-sectional analysis with other measures of preoperative ability. To better understand the relationships between TPA and the many VESPA measures, we used underlying geriatric principles to group the measures into three broader domains (Figure 1). While some measures were purely physical (e.g., gait speed) or cognitive (e.g., the Mini-cog), ADLs require both cognitive and physical ability. Furthermore, among the ADLs, BADLs require more physical contribution than cognitive, (28) while the opposite is likely for IADLs. (29–31) Contrary to our expectations, we found a more robust association between TPA with the cognitive testing and cognitively intense *instrumental* ADLs than the physical measures (mobility and BADLs). Frailty, or its various components including grip strength and gait speed, have been found to be correlated with cognitive impairment, possibly due to shared causes such as inflammation and cardiovascular risk (32). We posit that TPA is associated with frailty, therefore explaining the association we found in our sample. Due to the cross-sectional study design, the association should not be interpreted as causal.

The multi-dimensional relationship of TPA with function poses important implications for future interventions. Measuring TPA has been proposed as a way to identify patients who would most benefit from preoperative optimization of physical health, for example through more intensive “prehabilitation” prior to surgery. These results suggest that efforts to optimize *older* sarcopenic patients for elective surgery may be more complicated than for younger patients. Purely physical interventions recommended to younger elective surgery patients (which focus solely on increasing muscle strength and endurance) may need to be adapted to older patients, especially those with cognitive difficulty. This might include tailoring the “one size fits all” approach in current research to less-intense regimens and providing patient educational materials to accommodate patients with cognitive, sensory or physical impairments, or those who have caregivers as coaches.

Assessments such as those employed by the VESPA study have become mainstream, recommended surgical care processes in the evaluation for older patients. (13) Though formal research on geriatric risk indices in surgery is still in its infancy, there is evidence of their association with in-hospital occurrences, total length of stay, post-discharge institutionalization, and mortality. (9, 33–36) One concern is that *comprehensive* geriatric assessment (e.g., performing all domains of assessment) is not feasible in a busy surgical preoperative practice and the assessments are likely performed with less reliability in this setting compared to prior formal research studies. (6, 33, 37, 38) TPA is also correlated with postoperative outcomes, including length of stay, payer costs, surgical complication rate, and mortality. (7, 26, 27, 39) As a quantitative measure, TPA would be a more precise index than the geriatric assessments. Because TPA is computerized, it could also be more objective than geriatric assessment. Once incorporated into a sophisticated medical record system, analytic morphomics technology would not require any new imaging nor additional

valuable face-to-face clinical time, potentially resulting in an efficient new risk-prediction tool in older patients. More work is needed to develop clinically relevant protocols using analytic morphomics for real-time assessment of surgical fitness, and to determine how well it performs in comparison to traditional preoperative cardiac evaluation and the geriatric assessments.(7, 26)

This study has several important limitations. First, it was conducted at a single academic, tertiary-referral center, which potentially may limit the results to patients of similar centers. To improve generalizability, future studies should include patients receiving surgery at community centers, and centers across US regions with differing utilization of elective surgery. Second, the majority of patients in this study were male. Given the significant difference in muscle mass between males and females, future prospective trials should enroll both genders in equal numbers. Third, only patients with a preoperative CT of the thoracolumbar area and a planned surgical procedure were included in this study. Patients requiring thoracolumbar CT scans (e.g., to evaluate malignancies) are more likely to have organ-based disease, and these patients are therefore likely to be sicker than those not requiring CT scans. Also, we expect that patients who receive preoperative evaluation would naturally differ from patients who prefer no surgery, who would not be in this study. Therefore, our results only generalize to those patients with similar need for preoperative imaging and desire for preoperative evaluation. Fourth, we tested many risk factors across several domains of function in older surgical patients. It is possible that testing many risk factors results in a few positive findings due to chance. However, we observed consistent relationships across broad categories of risk factors, making this error less likely. One potential direction would be to test the composite domains (cognition, self-care, or mobility) as the primary research question in further research. Fourth, we had too few patients with abnormal Mini-Cog Assessment to use the traditional cutoff of 3 or fewer points, and therefore had ceiling effects. Other groups have also increased the conventional dementia-screening threshold of the Mini-Cog in order to maximize sensitivity(40) and capture patients with more mild cognitive impairment. In this population, future work should utilize more robust cognitive assessments to increase sensitivity for mild cognitive impairment. One direction would be to add more sensitive tests of multi-tasking (e.g., alternating Trails B test to better test concentration, executive function, and mental processing(41)) that could be more clinically relevant than the Mini-cog for patients seeking to return home with complex post-operative instructions after surgery. Similarly, we were able to detect an association between *basic* ADLs and TPA, but not between TPA and individual items due to the small numbers of patients within each ADL. The association was not detectable until we used the composite measure. Future studies should enroll a larger patient sample, which would also permit testing of confounding variables beyond age. Last, we used a novel radiologic definition (loss of muscle mass) to classify sarcopenic patients. The consensus diagnostic definition of sarcopenia is relatively new and work to delineate a universal operational definition of sarcopenia that is clinically relevant to surgeons remains ongoing.(42–44)

Designing clinically relevant preoperative training programs in older patients requires an enhanced understanding of the relationship between low muscle mass and other determinants of preoperative risk, which include both physical and cognitive abilities. We

found that our morphometric measure, TPA, had broad associations across functional domains in older patients. In patients with preoperative imaging, morphomic measures may be an efficient and complementary preoperative assessment. Further work is needed to elucidate how morphometric measures, age, and functional impairment predict clinical outcomes in older patients as well as its utility in selecting patients for targeted prehabilitation programs.

References

1. Elixhauser A, Andrews RM. Profile of Inpatient Operating Room Procedures in US Hospitals in 2007. *Archives of surgery*. 2010; 145:1201–1208. [PubMed: 21173295]
2. Vincent, GK.; Velkoff, VA. U.S. Census Bureau. The next four decades : the older population in the United States : 2010 to 2050. Washington, D.C: U.S. Dept. of Commerce, Economics and Statistics Administration, U.S. Census Bureau; 2010.
3. Etzioni DA, Liu JH, O'Connell JB, Maggard MA, Ko CY. Elderly patients in surgical workloads: a population-based analysis. *The American surgeon*. 2003; 69:961–965. [PubMed: 14627256]
4. Cullen, KA.; Hall, MJ. Golosinskiy A Natl Health Statistics Reports--Ambulatory Surg in US. 2009.
5. Malani PN. Functional status assessment in the preoperative evaluation of older adults. *JAMA*. 2009; 302:1582–1583. [PubMed: 19826029]
6. Cheema FN, Abraham NS, Berger DH, Albo D, Taffet GE, et al. Novel approaches to perioperative assessment and intervention may improve long-term outcomes after colorectal cancer resection in older adults. *Annals of surgery*. 2011; 253:867–874. [PubMed: 21183846]
7. Englesbe MJ, Lee JS, He K, Fan L, Schaubel DE, et al. Analytic morphomics, core muscle size, and surgical outcomes. *Annals of surgery*. 2012; 256:255–261. [PubMed: 22791101]
8. Ansaloni L, Catena F, Chattat R, Fortuna D, Franceschi C, et al. Risk factors and incidence of postoperative delirium in elderly patients after elective and emergency surgery. *The British journal of surgery*. 2010; 97:273–280. [PubMed: 20069607]
9. Robinson TN, Raeburn CD, Tran ZV, Angles EM, Brenner LA, et al. Postoperative delirium in the elderly: risk factors and outcomes. *Annals of surgery*. 2009; 249:173–178. [PubMed: 19106695]
10. Hamel MB, Henderson WG, Khuri SF, Daley J. Surgical outcomes for patients aged 80 and older: morbidity and mortality from major noncardiac surgery. *Journal of the American Geriatrics Society*. 2005; 53:424–429. [PubMed: 15743284]
11. Robinson TN, Wallace JI, Wu DS, Wiktor A, Pointer LF, et al. Accumulated frailty characteristics predict postoperative discharge institutionalization in the geriatric patient. *Journal of the American College of Surgeons*. 2011; 213:37–42. discussion 42–34. [PubMed: 21435921]
12. Lawrence VA, Hazuda HP, Cornell JE, Pederson T, Bradshaw PT, et al. Functional independence after major abdominal surgery in the elderly. *Journal of the American College of Surgeons*. 2004; 199:762–772. [PubMed: 15501119]
13. American College of Surgeons and American Geriatrics Society ACS NSQIP/AGS. Best Practice Guidelines: Optimal Pre-operative Assessment of the Geriatric Surgical Patient. 2012.
14. Lawton MP, Brody EM. Assessment of older people: self-maintaining and instrumental activities of daily living. *The Gerontologist*. 1969; 9:179–186. [PubMed: 5349366]
15. Katz S. Assessing self-maintenance: activities of daily living, mobility, and instrumental activities of daily living. *Journal of the American Geriatrics Society*. 1983; 31:721–727. [PubMed: 6418786]
16. Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *Journal of the American Geriatrics Society*. 1991; 39:142–148. [PubMed: 1991946]
17. Borson S, Scanlan J, Brush M, Vitaliano P, Dokmak A. The mini-cog: a cognitive 'vital signs' measure for dementia screening in multi-lingual elderly. *International journal of geriatric psychiatry*. 2000; 15:1021–1027. [PubMed: 11113982]

18. Min L, Hall K, Finlayson E, Engelsbe M, Diehl K. Pre-operative function, mobility, and home environment risk among older elective general surgery patients. *Journal of the American Geriatrics Society*. 2013; 61(S4):S72.
19. Robinson TN, Wu DS, Pointer L, Dunn CL, Cleveland JC Jr, et al. Simple frailty score predicts postoperative complications across surgical specialties. *American journal of surgery*. 2013; 206:544–550. [PubMed: 23880071]
20. Kwon SMDMPH, Symons RMPH, Yukawa MMDMPH, Dasher NBA, Legner VMDMS, et al. Evaluating the Association of Preoperative Functional Status and Postoperative Functional Decline in Older Patients Undergoing Major Surgery. *The American surgeon*. 2012; 78:1336–1344. [PubMed: 23265122]
21. Robinson TN, Wu DS, Sauaia A, Dunn CL, Stevens-Lapsley JE, et al. Slower walking speed forecasts increased postoperative morbidity and 1-year mortality across surgical specialties. *Annals of surgery*. 2013; 258:582–588. discussion 588–590. [PubMed: 23979272]
22. Fried LP, Tangen CM, Walston J, Newman AB, Hirsch C, et al. Frailty in older adults: evidence for a phenotype. *The journals of gerontology Series A, Biological sciences and medical sciences*. 2001; 56:M146–156.
23. Tanimoto Y, Watanabe M, Sun W, Sugiura Y, Tsuda Y, et al. Association between sarcopenia and higher-level functional capacity in daily living in community-dwelling elderly subjects in Japan. *Archives of gerontology and geriatrics*. 2012; 55:e9–13. [PubMed: 22795189]
24. Rajan KB, Hebert LE, Scherr PA, Mendes de Leon CF, Evans DA. Disability in Basic and Instrumental Activities of Daily Living is Associated with Faster Rate of Decline in Cognitive Function of Older Adults. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*. 2013; 68:624–630.
25. Mitnitski A, Fallah N, Rockwood MR, Rockwood K. Transitions in cognitive status in relation to frailty in older adults: a comparison of three frailty measures. *The journal of nutrition, health & aging*. 2011; 15:863–867.
26. Lee JS, He K, Harbaugh CM, Schaubel DE, Sonnenday CJ, et al. Frailty, core muscle size, and mortality in patients undergoing open abdominal aortic aneurysm repair. *Journal of vascular surgery*. 2011; 53:912–917. [PubMed: 21215580]
27. Englesbe MJ, Terjimanian MN, Lee JS, Sheetz KH, Harbaugh CM, et al. Morphometric age and surgical risk. *Journal of the American College of Surgeons*. 2013; 216:976–985. [PubMed: 23522786]
28. Kingston A, Collerton J, Davies K, Bond J, Robinson L, et al. Losing the ability in activities of daily living in the oldest old: a hierarchic disability scale from the Newcastle 85+ study. *PloS one*. 2012; 7:e31665. [PubMed: 22355385]
29. Park B, Jun JK, Park J. Cognitive impairment and depression in the early 60s: which is more problematic in terms of instrumental activities of daily living? *Geriatrics & Gerontology International*. 2014; 14:62–70. [PubMed: 23560396]
30. Gold DA. An examination of instrumental activities of daily living assessment in older adults and mild cognitive impairment. *Journal of clinical and experimental neuropsychology*. 2012; 34:11–34. [PubMed: 22053873]
31. Burton CL, Strauss E, Bunce D, Hunter MA, Hultsch DF. Functional abilities in older adults with mild cognitive impairment. *Gerontology*. 2009; 55:570–581. [PubMed: 19602873]
32. Robertson DA, Savva GM, Kenny RA. Frailty and cognitive impairment-A review of the evidence and causal mechanisms. *Ageing research reviews*. 2013; 12:840–851. [PubMed: 23831959]
33. Puts MTE, Hardt J, Monette J, Girre V, Springall E, et al. Use of Geriatric Assessment for Older Adults in the Oncology Setting: A Systematic Review. *Journal of the National Cancer Institute*. 2012; 104:1134–1164.
34. Savva GM, Donoghue OA, Horgan F, O'Regan C, Cronin H, et al. Using timed up-and-go to identify frail members of the older population. *The journals of gerontology Series A, Biological sciences and medical sciences*. 2013; 68:441–446.
35. Donoghue OA, Horgan NF, Savva GM, Cronin H, O'Regan C, et al. Association between timed up-and-go and memory, executive function, and processing speed. *Journal of the American Geriatrics Society*. 2012; 60:1681–1686. [PubMed: 22985141]

36. Kim, K-i; Park, K-H.; Koo, K-H.; Han, H-S.; Kim, C-H. Comprehensive geriatric assessment can predict postoperative morbidity and mortality in elderly patients undergoing elective surgery. *Archives of gerontology and geriatrics*. 2013; 56:507–512. [PubMed: 23246499]
37. Makary MA, Segev DL, Pronovost PJ, Syin D, Bandeen-Roche K, et al. Frailty as a predictor of surgical outcomes in older patients. *Journal of the American College of Surgeons*. 2010; 210:901–908. [PubMed: 20510798]
38. Robinson TN, Eiseman B, Wallace JI, Church SD, McFann KK, et al. Redefining geriatric preoperative assessment using frailty, disability and co-morbidity. *Annals of surgery*. 2009; 250:449–455. [PubMed: 19730176]
39. Sheetz KH, Waits SA, Terjimanian MN, Sullivan J, Campbell DA, et al. Cost of Major Surgery in the Sarcopenic Patient. *Journal of the American College of Surgeons*. 2013; 217:813–818. [PubMed: 24119996]
40. McCarten JR, Anderson P, Kuskowski MA, McPherson SE, Borson S. Screening for cognitive impairment in an elderly veteran population: acceptability and results using different versions of the Mini-Cog. *Journal of the American Geriatrics Society*. 2011; 59:309–313. [PubMed: 21314650]
41. Nasreddine ZS, Phillips NA, Bedirian V, Charbonneau S, Whitehead V, et al. The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society*. 2005; 53:695–699. [PubMed: 15817019]
42. Fielding RA, Vellas B, Evans WJ, Bhasin S, Morley JE, et al. Sarcopenia: an undiagnosed condition in older adults. Current consensus definition: prevalence, etiology, and consequences. International working group on sarcopenia. *Journal of the American Medical Directors Association*. 2011; 12:249–256. [PubMed: 21527165]
43. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, et al. Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. *Age and ageing*. 2010; 39:412–423. [PubMed: 20392703]
44. Cederholm TE, Bauer JM, Boirie Y, Schneider SM, Sieber CC, et al. Toward a definition of sarcopenia. *Clinics in geriatric medicine*. 2011; 27:341–353. [PubMed: 21824551]

FIGURE 1.

Assessment measures and broad domains of geriatric function. Individual VESPA items were considered as one of three types: self-care (ADLs), mobility, and cognitive. Some measures included in the VESPA were purely physical (e.g., gait speed) or cognitive (e.g., the Mini-cog); however, ADLs require both cognitive and physical ability. Furthermore, among the ADLs, BADLs require more physical contribution than cognitive(28) while the opposite is likely for IADLs.(29–31)

FIGURE 2.

TPA distribution of the study population. A. TPA distribution in mm² for males (n=113). B. TPA distribution in mm² for females (n=71). C. Population distribution of TPA, expressed in standard deviation units. Each patient's psoas muscle size was compared to the mean within his or her own gender. A zero score indicates average.

FIGURE 3.

Relationship between mobility and trunk muscle size (TPA). The effect of a standard deviation unit increase in trunk muscle size on impairment in mobility measures is reported. Trunk muscle size was not correlated with positive screen for fall history. As trunk muscle size increased, patients were less likely to have unsteady gait (OR=0.39, 95% C.I. 0.23–0.65, $P<0.001$) or slow timed ‘up and go’ test results (OR=0.52, 95% C.I. 0.31–0.88, $P=0.015$).

FIGURE 4.

Relationship between Activities of Daily Living (ADL) and TPA. A. Increases in TPA were associated with decreased incidence of any deficit in *basic* ADLs (OR=0.36 per SD unit increase in TPA, 95% C.I. 0.15–0.87, P=0.023). We did not find a significant relationship between TPA and any individual *basic* ADL item with the exception of transferring (OR=0.22, 95% C.I. 0.12–0.85; P=0.022). B. Patients with increased trunk muscle size were less likely to report difficulties performing any *instrumental* ADL (OR=0.53, 95% C.I. 0.34–0.81; P=0.004). We found a significant relationship between increased TPA and decreased odds of deficit in six of the eight individual *instrumental* ADLs (driving, finances, grocery shopping, housekeeping, laundry, and meal preparation). A significant relationship was not found between TPA and ability to administer medication or use a telephone.

FIGURE 5.

Relationship between cognitive function and TPA. A. Patients with larger trunk muscle size were less likely to have cognitive deficits as assessed by the Mini-Cog scale (OR=0.55 per SD unit increase in TPA, 95% C.I. 0.35–0.86, $P=0.008$). B. In order to further evaluate the association between trunk muscle size and preoperative cognitive abilities, we divided patients into tertiles based on their TPA size relative to other patients in our study cohort (highest, middle, lowest). Patients with the smallest core muscle area (lowest tertile) had a complication rate of 32% (15/47), which was higher than the group of patients in the middle tertile of core muscle size (24%, 9/37) and the patients in the highest tertile of core muscle size (11%, 5/47).

FIGURE 6.

Relationship between composite VESPA measures and TPA. We assessed the effect of a standard deviation unit increase in TPA on broad domains of geriatric function. Increased trunk muscle size was associated with decreased incidence of deficits in all three domains (mobility: OR=0.41, 95% C.I. 0.25–0.67, $P=0.0001$; ADLs (self-care): OR=0.53 per SD unit increase in TPA, 95% C.I. 0.36–0.85, $P=0.004$; cognitive: OR=0.55, 95% C.I. 0.35–0.85, $P=0.008$).

Table 1

Patient characteristics (N=184)

A. Demographics	Mean $\pm$ S.D. (or %)
Age (yr)	77.7 $\pm$ 5.4
Male	61.40%
Non-white race	8.70%
Height (in)	66.0 $\pm$ 3.6
Weight (lb)	175.0 $\pm$ 33.9
BMI (kg/m ²)	28.3 $\pm$ 5.0
Total psoas area (mm ²)	1904.7 $\pm$ 557.7
Length of stay (days)	6.7 $\pm$ 5.9

B. Preoperative VESPA Results		N (%)
Mobility	Timed 'up and go' test (N=139)	
	<10 sec	66 (47.5)
	10–20 sec	54 (38.9)
	>20 sec	19 (13.7)
	Unsteady gait (N=140)	27 (19.3)
	Fall in past year (N=141)	32 (22.7)
ADL*	Deficit in 1+ basic ADL (N=147)	6 (4.1)
	feeding	1 (0.7)
	transferring	5 (3.4)
	toileting	3 (2.0)
	dressing	3 (2.0)
	grooming	2 (1.4)
	bathing	4 (2.7)
	Deficit in 1+ instrumental ADL (N=147)	32 (21.8)
	medication	5 (3.4)
	meals	13 (8.8)
	telephone	2 (1.4)
	driving	24 (16.3)
	grocery	16 (10.9)
	housekeeping	17 (11.6)
	laundry	19 (12.9)
	finances	11 (7.5)
Cognitive	Mini Cog score (N=131)	
	5/5 correct	102 (77.9)
	4/5 correct	26 (19.9)
	3/5 correct	1 (0.8)
	2/5 correct	1 (0.8)

B. Preoperative VESPA Results		N (%)
	1/5 correct	1 (0.8)