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A Comparison of Frailty Measures as Predictors of Outcomes After Orthopedic Surgery

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Abstract

Background/Objectives—Preoperative frailty has been associated with poor postoperative outcomes after orthopedic surgery; however frailty measures have not been compared in this population. We applied the Frailty Phenotype (FP) and Frailty Index (FI) before major elective orthopedic surgery to categorize frailty status and assessed association with postoperative outcomes.

Design—Prospective cohort study.

Setting—Two tertiary hospitals in Boston, MA.

Participants—415 patients aged ≥70 years undergoing scheduled orthopedic surgery enrolled in SAGES: Successful Aging after Elective Surgery (SAGES) Study.

Measurements—Preoperative evaluation included assessment of frailty using the FP and FI. We used the weighted kappa statistic to determine concordance between the 2 frailty measures and multivariable modeling to determine associations between each measure and postoperative complications, postoperative length of stay (LOS) >5 days, discharge to post acute (PAC) institutional care, and 30 day readmission.

Results—Frailty was highly prevalent (FP 35%, FI 41%). There was moderate concordance between the FP and FI (kappa=.42, 95% confidence interval (CI) .36,.49). When using FP, compared to the robust group, being pre-frail predicted higher risk of complications (RR 1.6, 95% CI 1.1,2.1) and PAC (RR 1.8, 95% CI 1.2,2.9); being frail predicted complications (RR 1.7, 95% CI 1.1,2.1), LOS >5 days (RR 3.1, 95% CI 1.1,8.8), and PAC (RR 2.3 95% CI 1.4,3.7). When using FI, being pre-frail predicted LOS > 5 days (RR 2.1, 95% CI 1.0,4.8), and PAC (RR 1.5, 95% CI 1.4,2.1) as did being frail (RR=1.9, 95% CI 1.4,2.5; and RR 3.1, 95% CI 1.4,6.8 respectively).. The other outcomes were not significantly associated with frailty status.

Conclusion—Both FP and FI predict postoperative outcomes after major elective orthopedic surgery, and should be considered for preoperative risk stratification.

Keywords

Pre-operative evaluation; Elderly; Frailty measures; Surgery outcomes; Orthopedic procedures

INTRODUCTION

Half of elective surgeries are performed in older adults¹ and orthopedic procedures are among the most common in this age group.² Reducing medical and surgical complications, and reducing length of stay (LOS), post-acute institutional care, and hospital readmissions are emerging priorities in improving quality and lowering healthcare costs in older patients.^{3,4} Therefore, identifying predictors of these outcomes in older patients undergoing orthopedic surgery is an important step in optimizing care.

Frailty can generally be described as a state of weakness and susceptibility to stress arising from reduced physiologic reserve that is not necessarily defined or constrained by age or

presence of comorbidities.⁵ Measuring frailty before surgery in older patients may confer added risk stratification beyond age and traditional perioperative risk factors. It is therefore increasingly important to use validated measures to appraise frailty preoperatively where potential exists to modify treatment options and adjust expectations for recovery before surgery.

Different studies have shown that frailty predicts key postoperative outcomes including mortality,⁶ delirium,^{7,8} and institutional discharge,⁹ and is becoming increasingly recognized as risk factor for poor outcome after elective general, thoracic, and cardiac surgery.^{6,9,10} Despite orthopedic procedures being among the most common in older patients, studies of the association of frailty with post-orthopedic outcomes have been limited to single measures.^{11,12} Given the general lack of consensus about the best preoperative frailty assessment it is important to assess frailty's utility as a predictor of adverse outcomes using the most commonly used assessment tools. In this study we evaluate and compare Frailty Phenotype (FP) and the Frailty Index (FI). Each have been widely cited in aging research and represent different conceptualizations of frailty.^{13,14} The FP is based on the energy depletion model of frailty and examines five phenotypic criteria:^{13,15} slow gait, reduced activity, weakness, involuntary weight loss, and exhaustion. The FI is conceptualized as an accumulation of deficits across a broad array of domains (i.e., functional status, health and social status, medical problems, mental health problems, brain and body measures). In this conceptualization, frailty is measured as the proportion of deficits relative to the total number of deficits evaluated, expressed as a value from 0-1, with higher scores indicating increasing frailty.^{15, 17} Few studies have compared these measures in terms of their agreement in assessing the frailty status of individual surgical patients, and examined their relationship with demographic and functional factors, or with post-surgical outcomes. To address these knowledge gaps, we conducted a prospective study in a cohort of older patients scheduled for major elective orthopedic procedures: 1) to examine the relationship of the FP and FI measures with baseline demographic and functional measures, and 2) to examine and compare the predictive ability of these two measures with respect to postoperative complications, postoperative length of stay, post acute (PAC) institutional care, and 30-day hospital readmissions.

METHODS

Study population

The Successful Aging after Elective Surgery (SAGES) study is an ongoing prospective cohort study of older adults undergoing major elective surgery. The study design and methods have been described in detail previously.¹⁶ In brief, eligible participants were age 70 years and older, English speaking, scheduled to undergo elective surgery at one of two Harvard-affiliated academic medical centers and with an anticipated length of stay of at least 3 days. Eligible orthopedic procedures were: total hip or knee replacement, lumbar, cervical, or sacral laminectomy. Exclusion criteria assessed during the screening process included evidence of dementia, delirium, hospitalization within 3 months, terminal condition, legal blindness, and severe deafness, history of schizophrenia or psychosis, and history of alcohol abuse or withdrawal. A total of 566 patients met all eligibility criteria and were enrolled

between June 18, 2010 and August 8, 2013. Written informed consent for study participation was obtained from all participants according to procedures approved by the institutional review boards of Beth Israel Deaconess Medical Center and Brigham and Women's Hospital, the two study hospitals, and Hebrew SeniorLife, the study coordinating center, all located in Boston, Massachusetts. The current study focused on the 415 patients who underwent orthopedic surgery and who had baseline (preoperative) FP and FI measures.

Data source

Baseline comorbidities and hospital complications were collected from the medical record, whereas baseline functional and cognitive testing occurred during a 90-minute assessment in the patient's home or the hospital outpatient setting according to patient preference. Data collection methods included electronic data capture and paper data collection when appropriate.

Frailty measures and their operationalization

Frailty measures were added to the cohort in October 2010 after the first 45 participants undergoing orthopedic surgery were already enrolled. Our FP criteria were adapted from the original approach used by Fried in the Cardiovascular Health Study (CHS) and Women's Health and Aging studies (WHAS)^{17,18} and were based on the presence or absence of the following 5 phenotypic criteria:

1. Slow gait (3-meter Timed Walk)—The average of two 3-meter walking trials was used. Assistive devices are allowed. The cutoff for slow gait is based on published normative data stratified by gender and height.¹⁷ We used this distance because it was more feasible in patients' home setting than the 4 meter distance used in WHAS.

2. Weakness (Grip Strength)—Grip strength was measured twice in each hand with a Jamar dynamometer with the participant seated with the arm held against the side and the elbow at a 90-degree position. The score is an average of the maximum pressure recorded from two trials in the stronger hand selected by the participant. Impairment is based on normative data by gender and body mass index.¹⁷

3. Reduced activity (Energy Expenditure)—Participants completed the shortened 6-item version of the Minnesota Leisure Time Activities Questionnaire.^{18,19} Survey items are converted to kcal/week and patients are categorized as reported previously.¹⁹

4. Involuntary Weight Loss—We collected self-reported weight loss of 10 lbs. or more in the past 6 months.¹⁷

5. Exhaustion—Exhaustion was captured with the following question from the Medical Outcomes Study Short Form 12 (SF-12), which was similar to the questions in the CHS and WHAS: "How much of the time did you have a lot of energy?" answered "little or none of the time."

Individuals without any of these phenotypic criteria are considered robust while pre-frail and frail populations are defined by the presence of 1-2 and 3 criteria, respectively.

To operationalize the FI in SAGES, we convened a panel of seven experts in geriatric assessment (2 geriatricians, 2 epidemiologists, 1 cognitive neurologist, 1 neuropsychologist, and 1 biostatistician), to consider elements from two previously used frailty indices (FIs) from the Canadian Study of Health and Aging²⁰ and the Precipitating Events Project.²¹ Through discussion and consensus we created a composite measure of 42 individual deficit measures that were part of the baseline study evaluation. A description of this measure can be found in the Appendix. For each participant, we then determined the presence or absence of each of the 42 deficits using data from the SAGES baseline assessment. Individuals with FI scores of ≥ 0.25 were considered frail, while scores of 0.15-0.24 and <0.15 indicate pre-frail and robust populations, respectively.^{22,23}

Outcomes

The outcomes of interest were postoperative medical and surgical complications (complications), hospital LOS >5 days (all eligible procedures had expected LOS of 5 days or less), discharge to post-acute institutional care (PAC), and readmission in <30 days. We chose 30-day readmissions because this measure is used by the Center for Medicare Services to compare quality between hospitals.²⁴ The first 3 outcomes were assessed by medical record review (blinded to baseline frailty status) and the final outcome was assessed by participant report (see below for details). Complications were both major and minor complications adjudicated by an expert panel (including 2 geriatricians (EM, LG) and a surgeon (ZC)), and included cardiac arrhythmia, cardiac ischemia, stroke, seizure, infection (sepsis, pneumonia, urinary tract infection, wound infection, deep surgical site infection, infectious colitis), anemia, bleeding, respiratory insufficiency or failure, analgesic overdose, neuralgia, cerebrospinal fluid leak, or motor deficit after spine surgery, unplanned reoperation, bowel obstruction or ileus, rash, electrolyte abnormality, and urinary retention. LOS was defined as number of days from surgery to hospital discharge. Thirty-day readmissions were determined from the date of discharge by patient self-report in 410 patients. Information on hospital readmissions was collected during patient follow-up interviews and verified by medical record review. Overall agreement on the total count of admissions and timing of admissions was substantial (90% (kappa=.79, 95% Confidence Interval, CI, .71-.87); and, 99% (kappa=.78, 95% CI, .72-.85) respectively).²⁵

Other study variables

We included the following self-reported functional measures: Activities of Daily Living (ADLs) scale,²⁶ Instrumental Activities of Daily Living (IADLs) scale,²⁷ physical summary score and the mental summary score of the Medical Outcomes Study (MOS) Short Form Health Survey (SF-12).²⁸ The ADL scale measures the ability to perform basic care activities (feeding, bathing, dressing, grooming, toileting, transferring, and walking), whereas the IADL scale measures more complex skills (grocery shopping, taking medications, using the telephone, cooking, housekeeping, using transportation, and managing finances). The physical and mental function subscale summary scores were used from the MOS SF-12, which is a 12-item multidimensional survey tool designed to assess social functioning, role-emotional, and physical and mental health.²⁹ As a summary cognitive score, we used the previously developed General Cognitive Performance (GCP) composite, which synthesizes results from a battery of neuropsychological tests,³⁰ including

attention, executive functioning, memory, naming, and visual-spatial function. The GCP scores were standardized to have a mean of 50 and standard deviation of 10 for the age-matched U.S. population; higher scores are better.

Other collected variables included patient age, gender, procedure type, and American Society of Anesthesiologists (ASA) Physical Status score. The ASA score represents a preoperative assessment of the patient's physiologic fitness for surgery (range 1-5, 5 is worst), and is predictive of postoperative mortality.³¹ The ASA was abstracted from the medical record as determined by the anesthesiologist during routine care. Comorbidities were also abstracted from the medical record. Co-morbidity burden was calculated using the Charlson index.³²

Analysis

We first examined the level of agreement between FP and FI in determining each individual's frailty status by measuring the following: 1) distribution of relative frequencies of frail, pre-frail and robust; 2) percent agreement of individual patient categorization; and 3) kappa coefficient. Analyses were performed based on the 3-category classification (robust, pre-frail, frail); analyses 2) and 3) were also performed using a simplified, 2-category classification according to frail and robust categories (where robust includes pre-frail and robust from the 3-category model).

We report the distribution among the cohort across the 3 frailty categories (robust, pre-frail, and frail) for both FP and FI. Since these analyses are meant to be descriptive rather than tests of association, no p-values are reported.

We performed bivariable analyses to test the association between different frailty measures and the outcomes of interest (postoperative medical and surgical complications, hospital LOS > 5 days, post-acute institutional discharge and 30-day hospital readmissions). Ordinal logistic regression was used to test frailty's association with complications. We considered a 3-level complication variable: 1) No complications, 2) At least one minor complication, no major complications and 3) At least one major complication. Odds Ratios were then converted to Relative risk using the methods of Zhang et al.³³ We used a Poisson regression model with log link and robust variance estimates while controlling for age and gender, to assess the effect of frailty on hospital LOS > 5 days, PAC, and 30-day readmission. Due to concerns about its subjective nature,³⁴ ASA class was not included in the adjusted model. The Charlson score was also excluded from the adjusted model because the FI shares multiple variables with the Charlson score, and would introduce collinearity. Continuous variables were reported as means (plus associated ranges) and standard deviations; categorical variables were reported as percentages. All of the analyses were performed using SAS Version 9.3 software. A value of $p < 0.05$ was considered as the threshold for statistical significance.

RESULTS

Patient characteristics

Among the 556 patients enrolled in the SAGES study, 460 underwent orthopedic procedures and of these 415 had frailty measures as part of their baseline evaluation. All patients missing frailty measures were enrolled prior to the incorporation of frailty into the cohort; thus, the 415 patients included in this analysis represent a consecutive cohort with no missing frailty measures. These patients had a mean age of 77 (SD 5.2) years and 60% were female (Table 1). Almost a quarter (23%) had a Charlson comorbidity score ≥ 2 and almost one third (30%) had impairments in IADLs. The mean GCP score was 57 [range: 34-77]. MOS SF-12 Physical and Mental Summary Scores were available for 412 patients and their mean values were 34 (Standard deviation (SD) 9.3) and 50 (SD 8.7) respectively. Almost all patients had ASA scores of 2 (mild systemic disease, 40%) or 3 (severe systemic disease, 60%).

Agreement between measures and prevalence of frailty

The mean FP score was 2.0 (SD 1.2) and frequencies of robust, pre-frail and frail patients as determined by this measure were 11%, 54% and 35%, respectively (Figure 1a). The mean FI was 0.2 (SD 0.1) and percentages of robust, pre-frail and frail patients were 21%, 38% and 41%, respectively (Figure 1b). Table 2 shows that FP and FI resulted in assignment to the same 3-level frailty category in 241 patients (58% agreement, kappa = .42, 95% CI .36, .49). In cases where disagreement was present (42%), the FP category was worse than FI in 23%, and FI category was worse in 19%. In the analysis based on a simplified 2-category model in which the pre-frail and robust categories from the traditional 3-category model were merged, the agreement between FP and FI was improved with percent agreement increased to 78% (N=322) and kappa=.53 (95% CI .44,.61).

Correlation of frailty with baseline patient characteristics

Baseline patient characteristics by frailty category were generally similar in both measures (Table 3). A higher percentage of females were classified as frail by FP than by FI (76% vs. 68%). By both measures, frail patients had higher Charlson scores, more impairments in ADLs and IADLs and worse mean MOS SF-12 Physical Summary Scores compared with robust and pre-frail patients. There was a greater observed trend toward higher Charlson comorbidity scores and functional dependence across the FI categories than in the FP categories, which may be due to the fact that functional deficits and comorbidities are included as “deficits” in the FI. The GCP score, showed only a slight but consistent decrease from robust to frail by both FP and FI categories. More frail patients had ASA scores ≥ 3 , and scores were similarly distributed between measures.

The association of frailty with outcomes

Complications, hospital LOS >5 days, PAC discharge, and 30-day readmissions were experienced by 53%, 18%, 63%, and 10% of patients respectively (Table 4). Patients categorized as pre-frail and frail in both measures had higher risk of at least one adverse outcome. Using the FP, pre-frailty was associated with higher risk of PAC and

complications, and frailty was associated with higher risk of hospital LOS >5 days, PAC, and complications; Whereas, using FI, pre-frailty conferred higher risk of PAC, and frailty conferred higher risk of both LOS >5 days and PAC.

DISCUSSION

This study adds to the growing body of evidence documenting the importance of frailty measurement in older surgical patients. In this study we found a high burden of frailty among elderly individuals undergoing elective major orthopedic surgery, using two well-established frailty measures, and that preoperative frailty as identified by these measures predicts worse outcomes.

Although previous studies have demonstrated a strong association between preoperative frailty and adverse postoperative outcomes in general surgery patients, current approaches to identifying high risk patients before surgery do not routinely include frailty measures.³⁵ Most current surgical risk measures, including the American Society of Anesthesiologists physical status classification system, are based on the presence of comorbidities. Complementary indices have been developed to assess cardiac³⁶ and pulmonary risk.³⁷ However, these methods do not consider important factors which are captured by frailty measures such as strength and functional status, that may not be apparent by examining a patient's list of medical problems. Nor, do they measure the patient's overall physiologic vulnerability to stress which is more comprehensively assessed by frailty measures.^{22,38,39}

Although there has been in general a lack of consensus as to how best to identify and categorize frailty, it is increasingly used in clinical risk assessment strategies.⁴⁰ The ability to predict relevant outcomes (e.g., predictive validity) is perhaps the most important characteristic of any risk stratification variable or system. In a study of 594 elective general surgical patients aged 65 and older, FP predicted LOS, medical and surgical complications, and institutional discharge, but other frailty measures were not assessed.⁴¹ A study in patients undergoing major surgery requiring postoperative intensive care unit admission used a broad number of domains and comorbidities as frailty markers including advanced age, impaired cognition, weight loss, low body mass index, low serum albumin, falls, depression, low hematocrit counts, and demonstrated that frailty predicted discharge to skilled nursing facilities (SNFs) and higher 6-month mortality.^{9,42} However, the investigators in this study created a clinical composite measure, similar to the approach in the FI, which has not been validated in non-surgical populations and included factors such as cognition and depression that are often considered outside of the frailty construct. In another study where the majority of the population underwent orthopedic surgery interventions (including lower limb and spine surgery), increased frailty as measured using the Edmonton Frail Scale, which includes both measures of physical and cognitive function, was associated with a higher rate of medical and surgical complications, prolonged LOS, and discharge to SNFs.⁴³ Our work extends their findings by demonstrating the two frailty measures with the strongest evidence base in the literature,⁴¹ are associated with similarly poor outcomes after orthopedic surgery. Given the variability in approaches to measuring frailty in the literature, it is beneficial to demonstrate that very different conceptualizations and constructs of frailty may be useful in preoperative risk assessment.

The present study reveals incomplete agreement between frailty status of individual patients as determined by the FP and FI. This would be expected because these measures are derived from entirely different theoretical models of frailty, and include highly disparate domains. From an operational standpoint, FP includes only 5 criteria, but most, if not all, of these need to be collected specifically for this purpose, and some (grip strength, gait speed) require special equipment and training to collect. On the other hand, FI as defined in the SAGES study included 42 variables, which would require development of an index and algorithm to abstract information from individual electronic medical records, administrative databases, or other existing data sources. As both approaches are useful in identifying frailty before surgery, selection of the optimal measure of preoperative frailty will depend on feasibility considerations, such as the available data, logistical constraints and preference.

Frailty is now increasingly recognized as a set of actionable and modifiable risk factors. Increasing gait speed over a period of 12 months was shown to be associated with improved survival,⁴⁴ and several studies in older patients with hip fractures have shown that frail patients benefit from a comprehensive geriatric assessment and specialized processes of care.⁴⁵⁻⁴⁹ From a financial perspective, patients having orthopedic procedures and complex medical problems are of high priority for the Centers for Medicare & Medicaid Services,¹⁴ which highlights the importance of improved coordination of transitions of care and geriatric follow-up in these patients. Patients recognized as frail before surgery can be targeted for interventions to improve outcomes and reduce costs.

Several limitations are worthy of mention. We have evaluated only two of the many indices that are currently available for assessment of frailty. Nonetheless, FP and FI are generally considered the most studied and robust measures based on the available evidence as they have shown strong predictive value in other studies.⁵⁰ Although we examined a large prospective cohort of patients undergoing orthopedic procedures, the generalizability of our results will need to be examined in future studies since the study only involved two academic centers in a single metropolitan region and excluded patients with recent hospitalizations and with dementia. The selection criteria may have excluded patients with severe frailty. Nonetheless, the less obviously impaired patients, who constitute our population, may be the ones in whom frailty measures are most likely to identify those most amenable to intervention.

In summary, in this large prospective study of older patients undergoing major elective orthopedic surgery, we found that preoperative frailty, as measured by both FP and FI, is highly prevalent. The two measures showed only moderate agreement with each other. Yet, both frailty measures are strong and independent predictors of surgical outcomes. This work is highly significant for demonstrating the importance of frailty to identify patients at high risk for poor surgical outcomes, and highlighting the need for future studies to develop interventions, such as preoperative prehabilitation to mitigate this risk.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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REFERENCES

- Centers for Medicare and Medicaid Services (CMS). [June 1, 2013] Healthcare Expenditures. Centers for Medicare and Medicaid Services (online). Available at: <http://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/NationalHealthExpendData/index.html?redirect=/nationalhealthexpenddata/>.
- Centers for Disease Prevention and Control (CDC). Fast Stats: Inpatient Surgery. Centers for Disease Control and Prevention; (online). Available at: <http://www.cdc.gov/nchs/fastats/insurg.htm>. [June 1, 2013]
- U.S. Department of Health & Human Services - Administration of Aging. [November 28, 2013] Aging Statistics. (online). Available at: [http://www.aoa.gov/AoARoot/\(S\(2ch3qw55k1qylo45dbihar2u\)\)/Aging_Statistics/index.aspx](http://www.aoa.gov/AoARoot/(S(2ch3qw55k1qylo45dbihar2u))/Aging_Statistics/index.aspx).
- Department of Health and Human Services of the Centers for Medicare & Medicaid Services. CFR Parts 412, 482, 485, and 489, RIN 0938-AR53. 2013
- Xue QL. The frailty syndrome: definition and natural history. Clin Geriatr Med. 2011; 27:1–15. [PubMed: 21093718]
- Robinson TN, Wu DS, Sauaia A, et al. Slower walking speed forecasts increased postoperative morbidity and one-year mortality across surgical specialties. Ann Surg. 2013; 258:582. [PubMed: 23979272]
- Leung JM, Tsai TL, Sands LP. Preoperative frailty in older surgical patients is associated with early postoperative delirium. Anesth Analg. 2011; 112:1199–1201. [PubMed: 21372278]
- Pol R, van Leeuwen B, Visser L, et al. Standardised frailty indicator as predictor for postoperative delirium after vascular surgery: A prospective cohort study. Eur J Vasc Endovasc Surg. 2011; 42:824–830. [PubMed: 21810543]
- Robinson TN, Wallace JI, Wu DS, et al. Accumulated frailty characteristics predict postoperative discharge institutionalization in the geriatric patient. J Am Coll Surg. 2011; 213:37–42. discussion 42-34. [PubMed: 21435921]
- Makary MA, Segev DL, Pronovost PJ, et al. Frailty as a predictor of surgical outcomes in older patients. J Am Coll Surg. 2010; 210:901–908. [PubMed: 20510798]
- Velanovich V, Antoine H, Swartz A, et al. Accumulating deficits model of frailty and postoperative mortality and morbidity: Its application to a national database. J Surg Res. 2013; 183:104–110. [PubMed: 23415494]
- Dasgupta M, Rolfson DB, Stolee P, et al. Frailty is associated with postoperative complications in older adults with medical problems. Arch Gerontol Geriatr. 2009; 48:78–83. [PubMed: 18068828]

13. Fried LP, Tangen CM, Walston J, et al. Frailty in older adults: evidence for a phenotype. *J Gerontol A Biol Sci Med Sci*. 2001; 56:M146–156. [PubMed: 11253156]
14. Collard RM, Boter H, Schoevers RA, et al. Prevalence of frailty in community-dwelling older persons: A systematic review. *J Am Geriatr Soc*. 2012; 60:1487–1492. [PubMed: 22881367]
15. Fried, L.; Walston, J.; Ferrucci, L., et al. *Hazzard's geriatric medicine and gerontology*. 6th ed.. Ouslander, JG.; Tinetti, ME.; Studenski, S., et al., editors. McGraw-Hill Companies; New York: 2009.
16. Schmitt EM, Marcantonio ER, Alsop DC, et al. Novel risk markers and long-term outcomes of delirium: The successful aging after elective surgery (SAGES) study design and methods. *J Am Med Dir Assoc*. 2012; 13:818, e811–810.
17. Fried LP, Tangen CM, Walston J, et al. Frailty in Older Adults: Evidence for a phenotype. *J Gerontol A: Bio Sci Med Sci*. 2001; 56:M146–M157. [PubMed: 11253156]
18. Bandeen-Roche K, Xue QL, Ferrucci L, et al. Phenotype of frailty: characterization in the women's health and aging studies. *J Gerontol A Biol Sci Med Sci*. 2006; 61:262–266. [PubMed: 16567375]
19. Richardson MT, Leon AS, Jacobs DR Jr. et al. Comprehensive evaluation of the Minnesota leisure time physical activity questionnaire. *J Clin Epidemiol*. 1994; 47:271–281. [PubMed: 8138837]
20. McDowell I, Hill G, Lindsay J, et al. Canadian study of health and aging-study methods and prevalence of dementia. *CMAJ*. 1994; 150:899–913. [PubMed: 8131123]
21. Searle SD, Mitnitski A, Gahbauer EA, et al. A standard procedure for creating a frailty index. *BMC Geriatr*. 2008; 8:24. [PubMed: 18826625]
22. Rockwood K, Mitnitski A. Frailty in relation to the accumulation of deficits. *J Gerontol A Biol Sci Med Sci*. 2007; 62:722–727. [PubMed: 17634318]
23. Rockwood K, Mitnitski A. Frailty defined by deficit accumulation and geriatric medicine defined by frailty. *Clin Geriatr Med*. 2011; 27:17–26. [PubMed: 21093719]
24. Centers for Medicare and Medicaid Services. [June 21, 2015] 30-day unplanned readmission and death measures. (online). Available at: <http://www.medicare.gov/hospitalcompare/Data/30-day-measures.html>. 2015
25. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics*. 1977; 33:159–174. [PubMed: 843571]
26. Katz S, Ford A, Moskowitz R, et al. Studies of illness in the aged. The Index of ADL: A standardized measure of biological and psychosocial function. *JAMA*. 1963; 185:941–949.
27. Lawton MP, Brody EM. Assessment of older people: Self-maintaining and Instrumental activities of daily living. *Gerontologist*. 1969; 9:179–186. [PubMed: 5349366]
28. Ware J Jr, Kosinski M, Keller SD. A 12-Item short-form health survey: construction of scales and preliminary tests of reliability and validity. *Med Care*. 1996; 34:220–233. [PubMed: 8628042]
29. Ware, J.; Kosinski, M.; Keller, S. *How to score the SF-12 physical and mental health summaries: A user's manual*. The Health Institute, New England Medical Centre, Boston, MA; Boston: 1995.
30. Schmitt EM, Marcantonio ER, Alsop DC, et al. Novel risk markers and long-term outcomes of delirium: The successful aging after elective surgery (SAGES) study design and methods. *J Am Med Dir Assoc*. 2012; 13:818, e811–810.
31. Davenport DL, Bowe EA, Henderson WG, et al. National Surgical Quality Improvement Program (NSQIP) risk factors can be used to validate American Society of Anesthesiologists Physical Status Classification (ASA PS) levels. *Ann Surg*. 2006; 243:636–641. discussion 641–634. [PubMed: 16632998]
32. Charlson ME, Pompei P, Ales KL, et al. A new method of classifying prognostic comorbidity in longitudinal studies: Development and validation. *J Chronic Dis*. 1987; 40:373–383. [PubMed: 3558716]
33. Zhang J, Yu KF. What's the relative risk? A method of correcting the odds ratio in cohort studies of common outcomes. *JAMA*. 1998; 280:1690–1691. [PubMed: 9832001]
34. Haynes SR, Lawler PGP. An assessment of the consistency of ASA physical status classification allocation. *Anaesthesia*. 1995; 50:195–199. [PubMed: 7717481]
35. Makary MA, Segev DL, Pronovost PJ, et al. Frailty as a predictor of surgical outcomes in older patients. *J Am Coll Surg*. 2010; 210:901–908. [PubMed: 20510798]

36. Lee TH, Marcantonio ER, Mangione CM, et al. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. *Circulation*. 1999; 100:1043–1049. [PubMed: 10477528]
37. Canet J, Gallart L, Gomar C, et al. Prediction of postoperative pulmonary complications in a population-based surgical cohort. *Anesthesiology*. 2010; 113:1338–1350. [PubMed: 21045639]
38. Deiner S, Silverstein JH. Long-term outcomes in elderly surgical patients. *Mt Sinai J Med*. 2012; 79:95–106. [PubMed: 22238042]
39. Finlayson, E.; Birkmeyer, J. Surgical outcomes.. In: Halter, J.; Ouslander, J.; Tinetti, M., et al., editors. *Hazzard's geriatric medicine and gerontology*. 6th edn. McGraw Hill; New York: 2009.
40. Rodriguez-Manas L, Feart C, Mann G, et al. Searching for an operational definition of frailty: A delphi method based consensus statement. The frailty operative definition-consensus conference project. *J Gerontol A Biol Sci Med Sci*. 2013; 68:62–67. [PubMed: 22511289]
41. Makary MA, Segev DL, Pronovost PJ, et al. Frailty as a predictor of surgical outcomes in older patients. *J Am Coll Surg*. 2010; 210:901–908. [PubMed: 20510798]
42. Robinson TN, Eiseman B, Wallace JI, et al. Redefining geriatric preoperative assessment using frailty, disability and co-morbidity. *Ann Surg*. 2009; 250:449–455. [PubMed: 19730176]
43. Dasgupta M, Rolfson DB, Stolee P, et al. Frailty is associated with postoperative complications in older adults with medical problems. *Arch Gerontol Geriatr*. 2009; 48:78–83. [PubMed: 18068828]
44. Hardy SE, Perera S, Roumani YF, et al. Improvement in usual gait speed predicts better survival in older adults. *J Am Geriatr Soc*. 2007; 55:1727–1734. [PubMed: 17916121]
45. Barone A, Giusti A, Pizzonia M, et al. A comprehensive geriatric intervention reduces short- and long-term mortality in older people with hip fracture. *J Am Geriatr Soc*. 2006; 54:1145–1147.
46. Deschodt M, Braes T, Broos P, et al. Effect of an inpatient geriatric consultation team on functional outcome, mortality, institutionalization, and readmission rate in older adults with hip fracture: A controlled trial. *J Am Geriatr Soc*. 2011; 59:1299–1308. [PubMed: 21718273]
47. Folbert EC, Smit RS, van der Velde D, et al. Geriatric fracture center: A multidisciplinary treatment approach for older patients with a hip fracture improved quality of clinical care and short-term treatment outcomes. *Geriatr Orthop Surg Rehabil*. 2012; 3:59–67. [PubMed: 23569698]
48. Gregersen M, Mørch MM, Hougaard K, et al. Geriatric intervention in elderly patients with hip fracture in an orthopedic ward. *J Inj Violence Res*. 2012; 4:45–51. [PubMed: 21502786]
49. Polanczyk CA, Marcantonio E, Goldman L, et al. Impact of age on perioperative complications and length of stay in patients undergoing noncardiac surgery. *Ann Intern Med*. 2001; 134:637–643. [PubMed: 11304103]
50. Theou O, Brothers TD, Mitnitski A, et al. Operationalization of frailty using eight commonly used scales and comparison of their ability to predict all-cause mortality. *J Am Geriatr Soc*. 2013; 61:1537–1551. [PubMed: 24028357]

a) Frailty Phenotype, Score 0-5, 5 worst:

b) Frailty Index, Score 0-1, 1 worst (N=415):

Figure 1. Distribution of the Frailty Measures (N=415)

Legend Figure 1a and 1b: Distribution of categories of frailty (robust, pre-frail, and frail) (N,%) among SAGES cohort undergoing orthopedic procedures and with frailty measures using a) the Frailty Phenotype and b) the Frailty Index. Y axis represents the percent of the cohort in each category; the x axis is the score in each measure.

Table 1

Characteristics of the study populations (N=415)

Characteristic	Mean Value (Standard deviation) or N (%)
Age	76.8 (5.2)
Female Gender	250 (60%)
Charlson Comorbidity Score ^a	
0	209 (50.4)
1	112 (27.0)
2	56 (13.5)
3+	38 (9.1%)
Activities of Daily Living ^b (any impairment)	35 (8%)
Instrumental Activities of Daily Living ^c (any impairment)	124 (30%)
Short form health survey (SF) –12 Physical Summary Score ^d	34 (9.3)
SF-12 Mental Summary Score ^d	50 (8.7)
General Cognitive Performance Score ^e	58 (7.4)
ASA Physical Status ^f	
1 – Normal/Healthy	1 (0%)
2 – Mild Systemic Disease	164 (40%)
3 – Severe Systemic Disease	249 (60%)
4 - Severe Systemic Disease	1 (0%)
Orthopedic Surgery, type	
Total Hip Replacement	110 (27%)
Total Knee Replacement	183 (44%)
Lumbar Laminectomy	105 (25%)
Cervical Laminectomy	17 (4%)

^aCharlson comorbidity index predicts the ten-year mortality by assigning points to each comorbid condition in participants, higher score is worse.

^bADL scale measures the ability to perform basic care activities (feeding, bathing, dressing, grooming, toileting, transferring, and walking).

^cIADL scale measures more complex skills (grocery shopping, taking medications, using the telephone, cooking, housekeeping, using transportation, and managing finances).

^dMedical Outcomes Study (MOS). MOS SF-12= Medical Outcomes Study SF-12 which is a 12-item multidimensional survey tool designed to assess social functioning, role-emotional, and physical and mental health. Both SF-12 mental and physical summary scores present in 412.

^eGeneral Cognitive Performance (GCP) composite score synthesizes neuropsychological tests including attention, executive functioning, memory, naming, and visual-spatial function. Higher scores are better.

^fAmerican Society of Anesthesiologists (ASA) Physical Status is a subjective measure of fitness for surgery, higher worse.

Table 2

Agreement among Frailty Measures in SAGES

N=415	Frailty Index (N)			
Frailty Phenotype (N)	Robust	Pre-Frail	Frail	Total
Robust	24	21	2	47
Pre-Frail	60	106	57	223
Frail	2	32	111	145
Total	86	159	170	415

3 Category measures N=241: 58% agreement; Weighted kappa 0.42. 95% confidence interval [.36, .49]

2 Category measures (pre-frail and robust) N=322: 78% agreement; Weighted kappa 0.53. 95% CI [.44, .61]

Table 3

Baseline Characteristics of SAGES Participants by Frailty Category

Characteristic (Mean±SD or Percent)	Frailty Phenotype			Frailty Index		
	Robust (N=47)	Pre-Frail (N=223)	Frail (N=145)	Robust (N=86)	Pre-Frail (N=159)	Frail (N=170)
Age	74 ± 4	77 ± 5	78 ± 6	76 ± 5	76 ± 5	78 ± 6
Female Gender	21 (45%)	118 (53%)	111 (76%)	42 (49%)	93 (58%)	115 (68%)
Charlson comorbidity score ^a (2 points or higher)	10 (21%)	46 (21%)	39 (27%)	10 (12%)	27 (17%)	58 (34%)
ADL ^b (any impairment)	0 (0%)	15 (7%)	20 (14%)	0 (0%)	2 (2%)	33 (19%)
IADL ^c (any impairment)	4 (8%)	47 (21%)	73 (50%)	1 (1%)	33 (21%)	90 (53%)
SF-12 Physical Summary Score ^d (higher better)	40± 8	36 ± 9	29.1 ± 8.3	44.0 ± 5.8	35.7 ± 7.4	27.5 ± 7.1
SF-12 Mental Summary Score ^d (higher better)	52± 6	52 ± 7	45 ± 9	55 ± 5	51 ± 8	46 ± 9
GPC Score ^e	60 ± 7	55	54.9 ± 8	60 ± 7	58± 7	55± 8
ASA Class ^f 3	24 (51%)	123 (55%)	103 (71%)	33 (38%)	90 (57%)	127 (75%)

^aCharlson comorbidity index predicts the ten-year mortality by assigning points to each comorbid condition in participants, higher score is worse.

^bADL scale measures the ability to perform basic care activities (feeding, bathing, dressing, grooming, toileting, transferring, and walking).

^cIADL scale measures more complex skills (grocery shopping, taking medications, using the telephone, cooking, housekeeping, using transportation, and managing finances).

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Table 4

Associations of Preoperative Frailty Status with In-hospital Outcomes.

	Frailty Phenotype				Frailty Index	
	Overall	Robust	Pre-Frail	Frail	Robust	Frail
Total (N=415)						
Medical Complications						
Major Complications (%)	7	0	8	8	5	16
Minor Complications (%)	46	34	47	50	42	47
Relative Risk [‡] (95% CI)			1.6 (1.1,2.1)	1.7 (1.1,2.1)		1.2 (0.9,1.6)
Hospital LOS > 5 days (%)	18	9	17	22	8	24
Relative Risk (95% CI)			2.2 (0.8,5.9)	3.1 (1.1,8.8)		3.1 (1.4,6.8)
Post Acute Care (PAC) (%)	63	28	57	83	36	79
Relative Risk (95% CI)			1.8 (1.2,2.9)	2.3 (1.4,3.7)		1.9 (1.4,2.5)
30 Day Readmission (%) [*]	10	4	12	10	11	11
Relative Risk (95% CI)			2.6 (0.6,10.9)	2.4 (0.5,11.7)		1.1 (0.5,2.4)

Relative risks obtained from a Poisson regression model with log link and robust variance estimates while controlling for age and gender

[‡] Odds ratios from an ordinal logistic regression model converted to relative risks based on Zhang³³

^{*} N=410