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Complete List of Authors:	Cohen, Seth; Duke University Medical Center, Porter Starr, Kathryn; Duke University, Center for the Study of Aging and Human Development; Durham VA Medical Center, Geriatric Research, Education, and Clinical Center Risoli, Thomas; Duke CTSI Biostatistics, Epidemiology and Research Design Methods Core LEE, HUI-JIE; Duke University, Misono, Stephania; , Department of Otolaryngology/Head and Neck Surgery, University of Minnesota Jones, Harrison; Duke University Medical Center Raman, Sudha; Duke University School of Medicine, Population Health Sciences
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Association of Dysphagia on Surgical Outcomes across the Continuum of Frailty

Seth M. Cohen, MD, MPH[1], Kathryn Starr, PhD[2], Thomas Risoli, Jr, MS[3], Hui-Jie Lee, PhD[3], Stephanie Misono, MD, MPH[4], Harrison Jones, PhD[5], Sudha Raman, PhD[6]

[1] Duke Voice Care Center, Department of Head and Neck Surgery & Communication Sciences, Duke University Medical Center, Durham, NC

[2] Center for the Study of Aging, Department of Medicine, Duke University Medical Center, Durham, NC and Geriatric Research, Education, and Clinical Center, Durham VA Medical Center, Durham, NC

[3] Duke CTSI Biostatistics, Epidemiology and Research Design Methods Core, Duke University Medical Center, Durham, NC

[4] Lions Voice Clinic, Department of Otolaryngology/Head and Neck Surgery, University of Minnesota

[5] Department of Head and Neck Surgery & Communication Sciences, Duke University School of Medicine, Durham, NC

[6] Department of Population Health Sciences, Duke University School of Medicine, Durham, NC

Corresponding Author: Seth Cohen, MD, MPH

DUMC Box 3805

Durham, NC, 27710

seth.cohen@duke.edu

919-681-7350 phone; 919-668-6036 fax

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Impact Statement

We certify that this work examining the independent relationship between dysphagia and adverse patient outcomes while adjusting for frailty in middle aged and older surgical population level is novel and necessary. Additionally, our manuscript focuses on a surgical subset of intermediate/high risk surgery not involving the swallowing mechanism, and thus, where dysphagia may be underappreciated. Our findings suggest that dysphagia is not simply a marker of disease severity or frailty but a potentially modifiable independent risk factor for poor outcomes among surgical inpatients ≥ 50 years of age across frailty conditions. Dysphagia evaluation and treatment is an important consideration in perioperative patient care.

Abstract

Background/Objective: Perioperative dysphagia is an important consideration for providers seeking to reduce risk in vulnerable surgical populations. This study examines the relationship between dysphagia and adverse health outcomes across frailty conditions among surgical patients ≥ 50 years of age.

Design: Retrospective cohort analysis of the Healthcare Cost and Utilization Project's National Inpatient Sample from 2014 through the first 3 quarters of 2015.

Setting: Population-based.

Participants: Surgical hospitalizations among patients ≥ 50 years of age undergoing intermediate/high risk surgery not involving the larynx, pharynx, or esophagus.

Measurements: Dysphagia was the primary exposure determined by ICD-9-CM codes. Frailty was the secondary exposure and defined as: (a) ≥ 1 condition in the 10-item Johns Hopkins Adjusted Clinical Groups (ACG) frailty measure or (b) a frailty index for the 19-item Frailty Risk Score (FRS) categorized as non-frail, pre-frail, and frail. Adverse outcomes included length of stay (LOS), hospital costs, discharge status, and medical and surgical complications. Weighted generalized linear models for complex survey designs using generalized estimating equations were performed.

Results: Of 3,298,835 weighted surgical hospitalizations, 1.2% had dysphagia. Dysphagia occurred in 31,440 (1.0%) and 7,465 (5.4%) of ACG non-frail and ACG frail surgical hospitalizations, respectively ($p<0.001$), and 27,720 (0.9%), 10,700 (3.4%), and 485 (11.7%) of non-frail, pre-frail and frail hospitalizations, respectively ($p<0.001$). Dysphagia was associated with greater LOS, higher total costs, increased non-routine discharges, and increased medical/surgical complications among both frail and non-frail patients. ORs ranged from 1.24

(1.06 to 1.45) for surgical complications among dysphagic versus non-dysphagic ACG frail patients to 3.08 (1.20 to 7.89) for non-routine discharge among dysphagic versus non-dysphagia frail patients defined by the FRS.

Conclusion: Dysphagia is an independent risk factor for poor inpatient outcomes among surgical patients ≥ 50 years of age across frailty conditions, justifying future efforts to improve the identification and treatment of perioperative dysphagia.

Key words: dysphagia, frailty, surgery, outcomes

Introduction: The US surgical population will involve a greater number of older patients who present additional challenges for perioperative care.[1] This cohort may have less physiologic reserve to respond to surgical stress with associated poor outcomes in addition to higher costs, longer length of stay, and increased morbidity, and mortality.[2, 3] Thus, understanding the factors that influence postoperative outcomes is essential to optimize care for the aging surgical population.

Increased risk of poor surgical outcomes among older surgical patients can likely be attributed to many factors including chronic comorbidity burden, functional status, cognition and falls.[4, 5] Additionally, adverse outcomes, loss of independence, disability, and mortality are especially common in surgical patients with sarcopenia and frailty, a clinical state of vulnerability with reduced resilience and ability to cope with health stressors.[6-8] Frailty also has important clinical implications, such as mortality risk, even among middle aged adults around age 50.[9, 10]

Dysphagia (difficulty swallowing) represents another potentially important risk factor for poor inpatient outcomes.[11] Dysphagia prevalence begins to increase in middle aged adults at around age 50 and occurs in up to 30% of independently living adults ≥ 65 years of age.[11, 12] Moreover, dysphagia is associated with greater cost, mortality, and morbidity including poor nutrient or fluid intake predisposing to malnutrition, aspiration, and respiratory infections.[13-16] Swallowing efficiency and safety may become impaired during the aging process, secondary to medical factors, and in patients with frailty and sarcopenia.[17, 18]

Whether dysphagia is independently associated with poor inpatient outcomes among middle aged and older surgical patients, or is simply a marker of frailty or comorbidity burden, is not fully known, as prior studies on dysphagia and outcomes have not assessed frailty.[19-21] Given

the overlap between frailty and dysphagia and presence of both conditions among middle aged and older adults, further investigation is needed in this broad surgical population to assess the independent relationship between dysphagia and adverse outcomes across frailty levels. Such knowledge will provide the foundation for optimizing dysphagia-related care to improve postoperative outcomes, especially among patients undergoing intermediate/high risk surgery.

This study used the Agency for Healthcare Research and Quality (AHRQ) sponsored Healthcare Cost and Utilization Project (HCUP) National Inpatient Sample (NIS) database to examine the association of dysphagia, frailty, and their interaction with adverse inpatient outcomes among a surgical cohort of middle aged and older adults. Our objectives were to: (1) assess the prevalence of dysphagia and frailty in an inpatient cohort of surgical patients ≥ 50 years of age and (2) examine the relationship between dysphagia and adverse outcomes across frailty conditions. We hypothesized that (1) dysphagia is more prevalent among frail surgical patients and that (2) dysphagic patients have longer length of stay (LOS), higher hospitalization cost, more non-routine discharge, and greater medical and surgical complications compared to non-dysphagic patients independent of frailty status.

Methods: This study was considered exempt by the Duke University Medical Center Institutional Review Board. A retrospective analysis of surgical inpatient hospitalizations between 2014 and the first three quarters of 2015 was undertaken with discharge data from the NIS database, the largest publically available, all-payer inpatient health care database developed by the AHRQ-HCUP. It represents a 20% stratified sample of discharges from all inpatient stays in US community hospitals, excluding short-term rehabilitation and long-term acute care hospitals. The NIS includes clinical and nonclinical data such as diagnoses, procedures, patient and hospital characteristics, payment source, LOS, in-hospital death, admission and discharge status, and total charges.[22]

This is a subset analysis of a previous general analysis across all medical and surgical inpatients regardless of surgical procedure.[23] This subset analysis consists of specific surgical hospitalizations that do not involve surgery of the swallowing mechanism (ie larynx, pharynx, or esophagus). Inclusion criteria included (a) inpatient surgical hospital stays of patients ≥ 50 years of age (using SERVICELINE variable in NIS to identify discharges with surgical procedures) with (b) one of the following surgical procedures based on the presence of International Classification of Disease, Ninth Revision Clinical Modification (ICD-9-CM) volume 3 codes: peripheral arterial bypass surgery, cardiac surgery, carotid endarterectomy, abdominal aortic aneurysm repair, total/partial/revision hip replacement, total or revision knee replacement, anterior cervical spinal fusion, large bowel surgery, liver resection, pancreas resection, nephrectomy, cystectomy, pneumonectomy, lobectomy/segmental resection, or general surgery (open/laparoscopic cholecystectomy, inguinal hernia repair, anterior abdominal wall hernia repair) (Supplementary Table 1). These surgical procedures are common in middle aged and older adults and were a focus of studies examining links between frailty and patient outcomes.[8,

[24] Hospitalizations classified as medical, injury, mental health/substance abuse, and maternal/neonatal were excluded.

Exposures

The primary exposure was dysphagia diagnosis defined by ICD-9-CM codes: 787.2, 787.20, 787.21, 787.22, 787.23, 787.24, 787.29 on discharge records.[25] Frailty diagnosis was the secondary exposure and was determined using two previously developed tools. First, the Johns Hopkins Adjusted Clinical Groups (ACG) frailty-defining diagnosis indicator is a binary yes/no variable based on the presence of at least 1 of 10 diagnoses (Supplementary Table 2).[26] This measure is associated with mortality, risk of hospitalization, intensive care stay, non-routine discharge, readmission, LOS, medical complications, and cost and has been validated in administrative databases, such as NIS in patients ≥ 18 years of age.[7,8,27] The Frailty Risk Score (FRS), a 19-item measure (Supplementary Table 2) developed to identify hospitalized frail persons ≥ 55 years of age in electronic health record data, is associated with mortality for specific LOS, readmission, and post-hospitalization institutional discharge.[28,29]

Covariates

Discharge demographics (age, sex, race), hospital characteristics (bed size), geographic region (northeast, Midwest, south, west), insurance (Medicare, Medicaid, private, self-pay), smoking status (ICD-9-CM codes V15.82, 305.1), household income, and admission type (elective, non-elective) were recorded. Comorbid diseases were assessed using the 29 individual Elixhauser comorbidities, coded by the AHRQ comorbidity variables at any time during the hospital stay (Supplementary Table 3).[30] In analyses with the ACG frailty measure, depression and anemia were classified as comorbid disease; weight loss was part of the ACG measure.

Weight loss, depression, and anemia were included in the FRS frailty measure and were not counted as comorbid conditions in analyses with the FRS.

Outcomes

LOS represents the number of days from admission to discharge. HCUP cost-to-charge ratio files were used to convert total hospital charges to costs, adjusting for inflation based on the US Bureau of Labor Statistics indices to 2015 USD.[31] Discharge disposition was categorized as routine (home discharge) or non-routine (discharge to short-term hospital, facility, or home health). Discharged/transferred to court/law enforcement and discharge alive (destination unknown) were considered as missing. Medical and surgical complications were based on having at least one ICD-9-CM diagnosis codes consistent with prior publications using NIS (Supplementary Table 4).[7]

Statistical Analysis

To account for stratification, clustering, and unequal weighting of the NIS survey design, discharge weights, NIS hospital number, and NIS stratum used to sample discharges were used to generate nationally representative estimates. Statistical models for our outcomes used discharge trend weighted generalized linear models (GLMs). Since we combined multiple NIS databases, "year" was added as a stratification variable. Analytic procedures for subpopulation analyses (i.e. domain analyses), as recommended by AHRQ were conducted to yield correct standard errors.[43] For LOS and total cost, we used generalized estimating equations (GEE) with a log link. For our binary outcomes, multivariable logistic regression was used, with the Taylor series linearization method to estimate the covariance matrix for the regression parameters. This is a commonly used approach for complex survey designs.[33, 34]

Frequencies of categorical variables related to patient and hospital characteristics were reported as a weighted number (weighted percentage), while continuous variables were reported as weighted mean (standard error). Comparison among variables was made using Rao-Scott chi-square test and Wald F test for categorical and continuous variables, respectively.[35] Nonzero discharge counts with fewer than 10 observations were masked in accordance with the HCUP data-use agreement. Observations with missing values for the outcomes and covariates were not included in the statistical models, hence the sample size may vary by outcome. Discharges with extreme LOS or cost (less than 1% or greater than 99%) were excluded. For analyses involving surgical complications, only surgical categories with > 1% complication rate were included (total knee revision, total/partial hip revision, anterior cervical spinal fusion were excluded).

For all models, explanatory variables included age category (50-64, 65-80, > 80), sex, race, insurance, hospital bed-size, hospital geographic region, median household income, admission type, smoking status, surgical category, and the individual Elixhauser comorbidities. Because smoking status capture may be particularly incomplete in administrative data, analyses were run with and without smoking status with no change in results, and thus, smoking status remained in the models. Separate models were constructed by including dysphagia, frailty, and their interaction for the two definitions of frailty: (1) binary ACG and (2) non-frail, pre-frail, frail cut-offs using the 19-item FRS index score. Although the frailty literature suggests that deficit accumulation frailty measures should have at least 30 items, we used published cut-points for non-frail (≤ 0.08), pre-frail (> 0.08 but < 0.25), frail (≥ 0.25) as a means of measuring dysphagia's impact while controlling for increasing number of frailty deficits.[36-38] The statistical analyses were conducted using GENMOD and SURVEYs procedures in SAS 9.4 (SAS Institute, Cary, NC, USA).

Results: There were 659,767 raw discharges in adults ≥ 50 years of age with surgical hospitalizations involving our surgical procedures of interest in 2014 and first 3 quarters of 2015, giving a weighted estimate of 3,298,835 discharges. 52.5% were female and 47.5% male with a mean age of 67.2 years (SE: 0.03 years). The demographic characteristics of the study cohort are displayed in Table 1.

Overall, 38,905 (1.2%) of surgical inpatients ≥ 50 years of age had perioperative dysphagia. Based on the binary ACG, the prevalence of frailty was 138,385 (4.2%). Dysphagia presented in 31,440 (1.0%) and 7,465 (5.4%) of ACG non-frail and ACG frail surgical hospitalizations, respectively ($p<0.001$). Using the FRS, the prevalence of non-frail, pre-frail, and frail inpatient surgical stays was 2,981,035 (90.4%), 313,645 (9.5%), and 4,155 (0.1%), respectively. Dysphagia presented in 27,720 (0.9%), 10,700 (3.4%), and 485 (11.7%) of non-frail, pre-frail and frail surgical hospitalizations, respectively ($p<0.001$) based on the indexed FRS. The top 5 positive frailty categories for the ACG were: weight loss (93,790; 2.8%), malnutrition (60,540; 1.8%), difficulty walking (29,050; 0.9%), decubitis ulcer (14,215; 0.4%), and severe vision impairment (2,580; 0.1%). The top 5 positive frailty categories for the FRS were: anemia (415,300; 12.6%), depression (389,045; 11.8%), chronic pain (134,370; 4.1%), high white blood cell count 129,725; 3.9%), and severe vision impairment (119,415; 3.6%).

Dysphagia prevalence increased across age groups: 11,770 (0.9%) in 50 – 64 years of age, 19,135 (1.2%) in 65 – 80 years of age, and 8,000 (2.5%) in surgical patients > 80 years of age. As assessed by the ACG frailty definition, frailty alone and dysphagia + frailty prevalence increased across age groups: 42,805 (3.3%) and 1,715 (0.1%) in 50 – 64 years of age, 63,265 (3.9%) and 3,695 (0.2%) in 65-80 years of age, and 24,850 (7.6%) and 2,055 (0.6%) in > 80 years of age, respectively. Table 2 demonstrates a greater dysphagia prevalence among ACG

frail versus non-frail patients for all surgical procedures with similar results among FRS frailty categories for all surgical procedures.

After removing outliers, total hospital charges adjusted to 2015 inflation were a mean $19,907 (SE $93.9); median LOS was 2.6 days (interquartile range 1.6 to 4.7 days) and mean LOS was 4.3 days (SD 0.02 days). In the entire cohort, excluding missing discharge dispositions, 1,515,255 (46.0%) discharges were routine, and 948,825 (28.8%) had at least one medical complication. The most common medical complications were: acute cardiac event (739,945; 22.4%), acute renal failure (229,825; 7.0%), urinary tract infection (126,680; 3.8%), acute pulmonary edema/failure (99,340; 3.0%), and pneumonia (48,385; 1.5%). 96,215 (6.6%) had at least one surgical complication. The most common surgical complications included: hemorrhage, hematoma, or seroma (40,145; 2.8%), postoperative infection (19,300; 1.33%), and shock (16,210; 1.12%).

Figure 1 and 2 summarize the univariate analysis of frailty, dysphagia, and their interaction on adverse health outcomes using the ACG and FRS frailty definitions, respectively. The exposures of dysphagia and frailty consistently corresponded to increased prevalence of adverse outcomes.

Multiple multi-variable models were constructed to further examine the relationship between dysphagia and adverse outcomes in patients with varied frailty status (Table 3). Dysphagia was associated with adverse outcomes (higher LOS, greater hospital costs, more non-routine discharges, medical complications, and surgical complications) across frailty level with odds ratios (ORs) above 1.2 except hospital costs and surgical complications in FRS frail index category (Table 3). Results were similar, regardless of how frailty was measured. For LOS,

hospital costs, and surgical complications, the ORs tended to be higher in the non-frail population, compared to frail or pre-frail patients.

Discussion: The aim of this investigation was to measure the relationship between dysphagia, and inpatient outcomes across frailty condition in a subset of patients ≥ 50 years of age having surgically-related inpatient hospitalizations. Dysphagia is present among various surgical populations: 54% in older hip fracture surgery patients, 16% of non-emergent, non-transplant cardiac surgery patients, and 15.6% of anterior cervical fusion patients.[21, 39, 40] The method for determining dysphagia (patient report, instrumental swallow evaluations) can affect prevalence estimates but could not be ascertained in our study. However, our estimated dysphagia prevalence of 1.2% is comparable to estimates of 0.35% to 5.7% documented in administrative datasets.[14, 16, 41] While dysphagia diagnoses are typically under-coded, making our dysphagia prevalence of 1.2% almost certainly an underestimate, a diagnosis of dysphagia has high specificity (i.e. low false positive rate).[25] Similarly, our ACG frailty prevalence of 4.2% is similar to rates of 3.1% to 11.5% measured in administrative studies of non-cardiac surgical cohorts.[7, 8, 42] Our data show increasing frequency of dysphagia, frailty, and combined dysphagia and frailty across age groups and more frequent dysphagia among frail versus non-frail patients across all surgical categories which has important clinical implications for middle aged and older surgical inpatients. (Table 2).

Perioperative dysphagia was associated with adverse inpatient outcomes across frailty level. In both frailty model analyses, dysphagia was significantly associated with higher LOS, more non-routine discharges, medical complications, and was significantly associated with greater hospital costs and more surgical complications, except among FRS frail patients (Table 3). Furthermore, these analyses adjusted for covariates including surgical category, which is important as anterior cervical fusion patients might be expected to have more dysphagia due to the proximity of the surgical approach to the innervation of the larynx/pharynx. Mechanisms for

the link between our adverse inpatient outcomes and dysphagia may be mediated by dysphagia-related complications, such as aspiration pneumonia, dehydration, and malnutrition, and potential interventions like gastrostomy tubes.[13, 15, 41] Dysphagia may also inhibit the full potential of perioperative nutrition interventions, by limiting the use of oral nutrition supplements.[43] Furthermore, consequences of dysphagia include increased inflammation, altered immune function, muscle breakdown and reduced functional capacity setting up a vicious cycle between dysphagia, frailty, sarcopenia, and malnutrition leading to worse outcomes.[17, 18] Pre-frail patients may be particular targets for dysphagia screening and treatment in an effort to reduce the synergy between dysphagia and frailty exacerbation.

Through a multidisciplinary assessment of dysphagia, including specialties such as otolaryngology, gastroenterology, speech-language pathology, registered dietician nutritionists, and respiratory therapy, a variety of interventions may improve outcomes in patients with dysphagia. Non-invasive treatments emphasize swallowing compensation strategies, exercise-based rehabilitation, and dietary modifications which improve swallowing function and reduce pneumonia risk.[44, 45] With 24% of hospitalized older patients with dysphagia not receiving nutritional intervention, increased use of nutritional therapy may represent an opportunity to reduce dysphagia-related complications.[46] Oral hygiene protocols may also improve dysphagia management. While frail dysphagic patients have higher oral bacterial colonization, perioperative oral care in lung cancer resection patients was associated with lower rates of postoperative pneumonia.[47] Dysphagia may also benefit from surgical intervention, and thus, shared decision making and patient focused care considering patient age, prognosis, and functional status are necessary to determine the most appropriate steps.[17] Given that dysphagia is a modifiable risk factor for poor inpatient outcomes in middle aged and older surgical patients,

examining the relationship between preoperatively identified dysphagia and postoperative outcomes is worthy of investigation as preoperative optimization of risk factors can improve postoperative outcomes. [24]

Certain methodologic limitations are important to acknowledge. As previously discussed, dysphagia and frailty-related diagnoses are likely under-coded, and therefore our prevalence rates are conservative. Coding errors and misclassification bias could similarly impact our medical and surgical complication and Elixhauser comorbid disease rates. Because dysphagia may present similarly to feeding difficulties and globus pharyngis, there is some inherent imprecision in diagnosing dysphagia.[48] Additionally, we were unable to differentiate between those with oropharyngeal and/or esophageal involvement which may be important for future research. Due to the nature of the database, we also could not determine if patients were admitted from a nursing home or readmitted, whether dysphagia was present pre or postoperatively, and if medical complication diagnoses were pre-existing prior to hospitalization. The selected frailty measures were used because one alternative includes comorbid disease and demographic variables preventing separate adjustment for the concepts of comorbidity and frailty, and another includes variables and claims for durable medical equipment which are not available in NIS.[49, 50] Nonetheless, using these two frailty measures produced consistent findings of an independent relationship between perioperative dysphagia and adverse inpatient outcomes in surgical patients ≥ 50 years of age across frailty levels.

Conclusion: Among surgical patients ≥ 50 years of age, dysphagia was more common in frail patients and associated with increased LOS, hospital cost, non-routine discharge, and medical and surgical complications, independent of frailty status, suggesting that dysphagia is not simply a proxy or surrogate for poor overall health status. Our findings support efforts aimed at improving dysphagia diagnosis and appropriate treatment of middle aged and older dysphagic surgical inpatients regardless of frailty level. Future studies are needed to corroborate our findings in different datasets and with different frailty measures. Investigations are also needed to examine the temporal relationship between dysphagia, frailty, and outcomes and to assess if preoperatively identified dysphagia is independently associated with adverse postoperative outcomes as there may be opportunities for prehabilitation or improved rehabilitation.

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We assure this work is original and has not been submitted elsewhere.

Informed consent: This study used de-identified data and informed consent from study participants was not possible nor required.

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Authorship: Seth Cohen: study concept and design, acquisition of subjects and/or data, analysis and interpretation of data, drafting, editing, and final approval of manuscript. Kathryn Starr: study concept and design, acquisition of subjects and/or data, analysis and interpretation of data, drafting, editing, and final approval of manuscript. Thomas Risoli Jr: study design, acquisition of subjects and/or data, analysis and interpretation of data, editing and final approval of manuscript. Hui-Jie Lee: study design, acquisition of subjects and/or data, analysis and interpretation of data, editing and final approval of manuscript. Stephanie Misono: study design, acquisition of subjects and/or data, analysis and interpretation of data, editing and final approval

of manuscript. Harrison Jones: study design, acquisition of subjects and/or data, analysis and interpretation of data, editing and final approval of manuscript. Sudha Raman: study design, acquisition of subjects and/or data, analysis and interpretation of data, editing and final approval of manuscript.

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499 **Figure Title and Legend**

500 Figure 1. Distribution of outcomes by dysphagia and binary 10-item Johns Hopkins Adjusted
501 Clinical Groups (ACG) frailty-defining diagnosis indicators frailty measure. D = dysphagia. F =
502 frailty. For length of stay and total cost of discharge, the point represents the median and the bars
503 represent the Q1 and Q3, respectively.
504
505 Figure 2. Distribution of outcomes by dysphagia and 19-item Frailty Risk Score indexed and
506 categorized by non-frail, pre-frail, frail. The non-frail, pre-frail, frail cut-points were ≤ 0.08, >
507 0.08 but < 0.25, and ≥ 0.25, respectively. D = dysphagia. F = frailty. Pre-F = pre-frail. For length
508 of stay and total cost of discharge, the point represents the median and the bars represent the Q1
509 and Q3, respectively.

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514 **Tables**

515 Table 1. Characteristics of the study cohort. Weighted N = 3,298,835.

ACG Frailty[a] and Dysphagia Group	Dysphagia Only	Frailty Only	Frailty + Dysphagia	Neither	Total	P value
Weighted N	N=31,440	N=130,920	N=7,465	N=3,129,010	N=3,298,835	
Elective versus non-elective admission						<0.001[1]
Missing	135	405	30	8,815	9,385	
Elective admission	20,120 (64.3%)	61,455 (47.1%)	2,790 (37.5%)	2,449,725 (78.5%)	2,534,090 (77.0%)	
Non-elective admission	11,185 (35.7%)	69,060 (52.9%)	4,645 (62.5%)	670,470 (21.5%)	755,360 (23.0%)	
Age						<0.001[1]
50 – 64	10,055 (32.0%)	42,805 (32.7%)	1,715 (23.0%)	1,297,075 (41.5%)	1,351,650 (41.0%)	
65 – 80	15,440 (49.1%)	63,265 (48.3%)	3,695 (49.5%)	1,539,160 (49.2%)	1,621,560 (49.2%)	
> 80	5,945 (18.9%)	24,850 (19.0%)	2,055 (27.5%)	292,775 (9.4%)	325,625 (9.9%)	
Race						<0.001[1]
Missing	2,025	7,285	475	197,580	207,365	
White	23,345 (79.4%)	97,045 (78.5%)	5,305 (75.9%)	2,392,860 (81.6%)	2,518,555 (81.5%)	
Black	3,005 (10.2%)	12,735 (10.3%)	730 (10.4%)	236,010 (8.1%)	252,480 (8.2%)	
Other	3,065 (10.4%)	13,855 (11.2%)	955 (13.7%)	302,560 (10.3%)	320,435 (10.4%)	
Sex						<0.001[1]
Missing	10	25	0	310	345	
Female	14,615 (46.5%)	66,235 (50.6%)	2,985 (40.0%)	1,646,970 (52.6%)	1,730,805 (52.5%)	
Male	16,815 (53.5%)	64,660 (49.4%)	4,480 (60.0%)	1,481,730 (47.4%)	1,567,685 (47.5%)	
Median household income for patient's ZIP Code						<0.001[1]
Missing	630	2,420	135	54,935	58,120	
0-25th percentile	8,395 (27.2%)	36,945 (28.8%)	2,060 (28.1%)	730,570 (23.8%)	777,970 (24.0%)	
26th to 50th percentile (median)	8,170 (26.5%)	35,425 (27.6%)	1,995 (27.2%)	832,255 (27.1%)	877,845 (27.1%)	
51st to 75th percentile	7,625 (24.7%)	30,250 (23.5%)	1,750 (23.9%)	795,430 (25.9%)	835,055 (25.8%)	
76th to 100th percentile	6,620 (21.5%)	25,880 (20.1%)	1,525 (20.8%)	715,820 (23.3%)	749,845 (23.1%)	
Primary expected payer						<0.001[1]
Missing	50	155	0	4,195	4,400	
Medicare	21,510 (68.5%)	89,050 (68.1%)	5,720 (76.6%)	1,791,050 (57.3%)	1,907,330 (57.9%)	
Medicaid	1,620 (5.2%)	9,155 (7.0%)	450 (6.0%)	155,140 (5.0%)	166,365 (5.0%)	
Private insurance	6,815 (21.7%)	27,520 (21.0%)	1,030 (13.8%)	1,051,420 (33.6%)	1,086,785 (33.0%)	
Self-pay/No charge/Other	1,445 (4.6%)	5,040 (3.9%)	265 (3.5%)	127,205 (4.1%)	133,955 (4.1%)	
Bed size of hospital						<0.001[1]
Large	17,690 (56.3%)	72,625 (55.5%)	4,500 (60.3%)	1,545,565 (49.4%)	1,640,380 (49.7%)	
Medium	8,765 (27.9%)	37,505 (28.6%)	1,950 (26.1%)	903,185 (28.9%)	951,405 (28.8%)	
Small	4,985 (15.9%)	20,790 (15.9%)	1,015 (13.6%)	680,260 (21.7%)	707,050 (21.4%)	
Geographic region						<0.001[1]
Northeast	4,390 (14.0%)	22,400 (17.1%)	930 (12.5%)	581,195 (18.6%)	608,915 (18.5%)	
Midwest	8,080 (25.7%)	34,105 (26.1%)	2,285 (30.6%)	791,850 (25.3%)	836,320 (25.4%)	
South	12,970 (41.3%)	54,250 (41.4%)	2,965 (39.7%)	1,205,175 (38.5%)	1,275,360 (38.7%)	
West	6,000 (19.1%)	20,165 (15.4%)	1,285 (17.2%)	550,790 (17.6%)	578,240 (17.5%)	

516 [a] The 10-item ACG is the Johns Hopkins Adjusted Clinical Groups (ACG) frailty-
517 defining diagnosis indicators and is a binary frail yes/no variable.

518 Table 2: Prevalence of Dysphagia by ACG Frailty[a] and Surgical Procedure.

ACG Frailty and Dysphagia Group	No Frailty	Frailty	Total
Weighted N	N=3,160,450	N=138,385	N=3,298,835
Peripheral arterial bypass			
N	77,785	6,420	84,205
Dysphagia	660 (0.8%)	240 (3.7%)	900 (1.1%)
No Dysphagia	77,125 (99.2%)	6,180 (96.3%)	83,305 (98.9%)
Cardiac surgery			
N	380,260	21,445	401,705
Dysphagia	7,035 (1.9%)	2,040 (9.5%)	9,075 (2.3%)
No Dysphagia	373,225 (98.1%)	19,405 (90.5%)	392,630 (97.7%)
CEA			
N	132,175	2,945	135,120
Dysphagia	3,280 (2.5%)	455 (15.4%)	3,735 (2.8%)
No Dysphagia	128,895 (97.5%)	2,490 (84.6%)	131,385 (97.2%)
AAA			
N	7,320	1,205	8,525
Dysphagia	165 (2.3%)	115 (9.5%)	280 (3.3%)
No Dysphagia	7,155 (97.7%)	1,090 (90.5%)	8,245 (96.7%)
Total/partial/revision hip			
N	559,525	12,350	571,875
Dysphagia	1,745 (0.3%)	345 (2.8%)	2,090 (0.4%)
No Dysphagia	557,780 (99.7%)	12,005 (97.2%)	569,785 (99.6%)
Total/revision knee			
N	1,104,925	15,850	1,120,775
Dysphagia	2,675 (0.2%)	175 (1.1%)	2,850 (0.3%)
No Dysphagia	1,102,250 (99.8%)	15,675 (98.9%)	1,117,925 (99.7%)
Cervical fusion			
N	152,530	4,835	157,365
Dysphagia	9,055 (5.9%)	970 (20.1%)	10,025 (6.4%)
No Dysphagia	143,475 (94.1%)	3,865 (79.9%)	147,340 (93.6%)
Large bowel surgery			
N	157,265	36,250	193,515
Dysphagia	1,700 (1.1%)	1,480 (4.1%)	3,180 (1.6%)
No Dysphagia	155,565 (98.9%)	34,770 (95.9%)	190,335 (98.4%)
Liver resection			
N	11,490	950	12,440
Dysphagia	50 (0.4%)	20 (2.1%)	70 (0.6%)
No Dysphagia	11,440 (99.6%)	930 (97.9%)	12,370 (99.4%)
Pancreas resection			
N	18,465	4,790	23,255
Dysphagia	115 (0.6%)	80 (1.7%)	195 (0.8%)
No Dysphagia	18,350 (99.4%)	4,710 (98.3%)	23,060 (99.2%)
Nephrectomy			
N	79,725	2,760	82,485
Dysphagia	380 (0.5%)	115 (4.2%)	495 (0.6%)
No Dysphagia	79,345 (99.5%)	2,645 (95.8%)	81,990 (99.4%)
Cystectomy			

N	16,350	1,855	18,205
Dysphagia	160 (1.0%)	40 (2.2%)	200 (1.1%)
No Dysphagia	16,190 (99.0%)	1,815 (97.8%)	18,005 (98.9%)
General surgery			
N	406,785	23,470	430,255
Dysphagia	3,690 (0.9%)	1,155 (4.9%)	4,845 (1.1%)
No Dysphagia	403,095 (99.1%)	22,315 (95.1%)	425,410 (98.9%)
Pneumonectomy			
N	2,400	305	2,705
Dysphagia	40 (1.7%)	35 (11.5%)	75 (2.8%)
No Dysphagia	2,360 (98.3%)	270 (88.5%)	2,630 (97.2%)
Lobectomy/segmental resection			
N	53,450	2,955	56,405
Dysphagia	690 (1.3%)	200 (6.8%)	890 (1.6%)
No Dysphagia	52,760 (98.7%)	2,755 (93.2%)	55,515 (98.4%)

[a] The 10-item ACG is the Johns Hopkins Adjusted Clinical Groups (ACG) frailty-defining diagnosis indicators and is a binary frail yes/no variable. Note similar findings of increasing dysphagia prevalence among frail vs prefrail vs non-frail patients based on the Frailty Risk Score were noted across all surgical categories.

Table 3. Multivariable analyses of adverse health outcomes by frailty (F), dysphagia (D), and their interaction.

Model	Length of stay[c] odds ratio (95% CI)	Hospital cost odds ratio (95% CI)
Model 1: ACG binary[a]		
D vs. No D for F	1.51 (1.45, 1.58)	1.27 (1.23, 1.31)
D vs. No D for non-F	1.67 (1.63, 1.70)	1.30 (1.28, 1.32)
Model 2: FRS index categories[b]		
D vs. No D for F	1.30 (1.11, 1.53)	1.11 (0.98, 1.24)
D vs. No D for pre-F	1.66 (1.60, 1.72)	1.37 (1.33, 1.41)
D vs. No D for non-F	1.66 (1.62, 1.70)	1.29 (1.27, 1.31)

Model	Odds ratio of non-routine discharges (95% CI)	Odds ratio of medical complication (95% CI)	Odds ratio of surgical complication (95% CI)
Model 1: ACG binary*			
D vs. No D for F	2.36 (1.95, 2.85)	1.85 (1.58, 2.17)	1.24 (1.06, 1.45)
D vs. No D for non-F	2.69 (2.49, 2.90)	1.98 (1.85, 2.12)	1.76 (1.57, 1.96)
Model 2: FRS index categories#			
D vs. No D for F	3.08 (1.20, 7.89)	2.48 (1.20, 5.13)	1.33 (0.67, 2.66)
D vs. No D for pre-F	3.06 (2.64, 3.55)	1.99 (1.76, 2.26)	1.33 (1.15, 1.55)
D vs. No D for non-F	2.61 (2.41, 2.82)	1.99 (1.86, 2.13)	1.86 (1.66, 2.09)

[a] The ACG binary is the Johns Hopkins Adjusted Clinical Groups (ACG) 10 frailty-defining diagnosis indicators and is a binary frail yes/no variable.

[b] A FRS index was created from the FRS measure by number of positive categories divided by 19. The non-frail, pre-frail, frail cut-points were ≤ 0.08, > 0.08 but < 0.25, and ≥ 0.25, respectively.

[c] N for LOS models = 2,979,475, after excluding outliers and observations with missing covariates. N for total hospital encounter cost models = 2,910,880, after excluding outliers and observations with missing covariates. N for discharge disposition models = 3,023,335, after excluding missing values for discharge disposition. N for medical complications models = 3,024,415, after excluding observations with missing covariates. Due to low prevalence, AIDS, Chronic blood loss anemia, Congestive heart failure, Drug abuse, Lymphoma, Paralysis, Pulmonary circulation disorders, Solid tumors without metastasis, Peptic ulcer disease excluding bleeding, and Psychoses were not considered as covariates in the models of medical complications. N for the surgical complications models = 1,332,180, after excluding observations with missing covariates. In the surgical complications subset, due to low prevalence, AIDS, Lymphoma, Peptic ulcer disease excluding bleeding, and Psychoses were not considered as covariates in these models. Otherwise, all models adjusted for: age, sex, race, primary payer, hospital bed-size, hospital geographic region, median household income, admission type, surgical procedure, and the Elixhauser Comorbidities.

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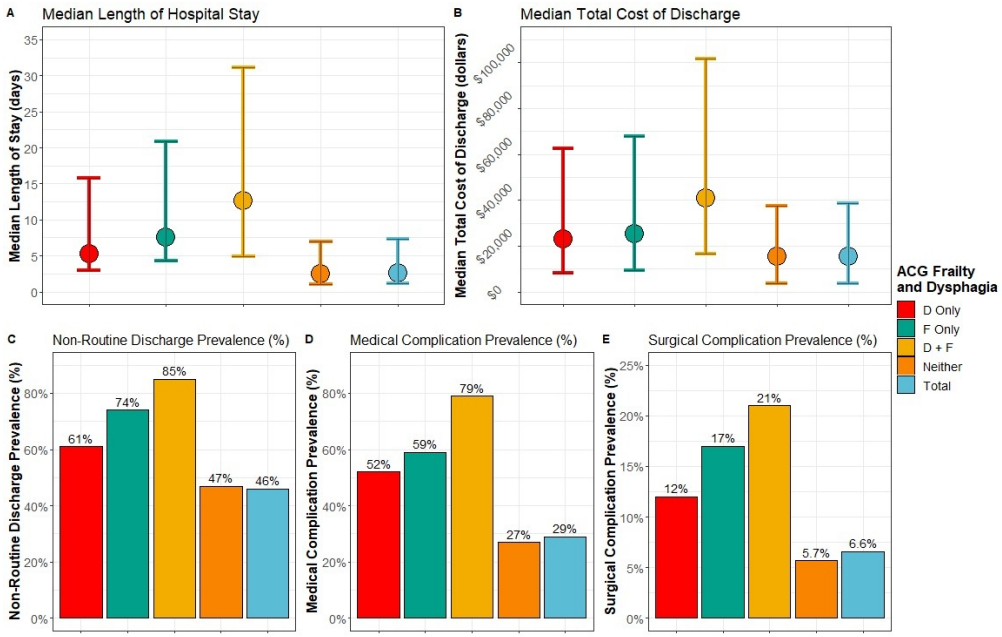
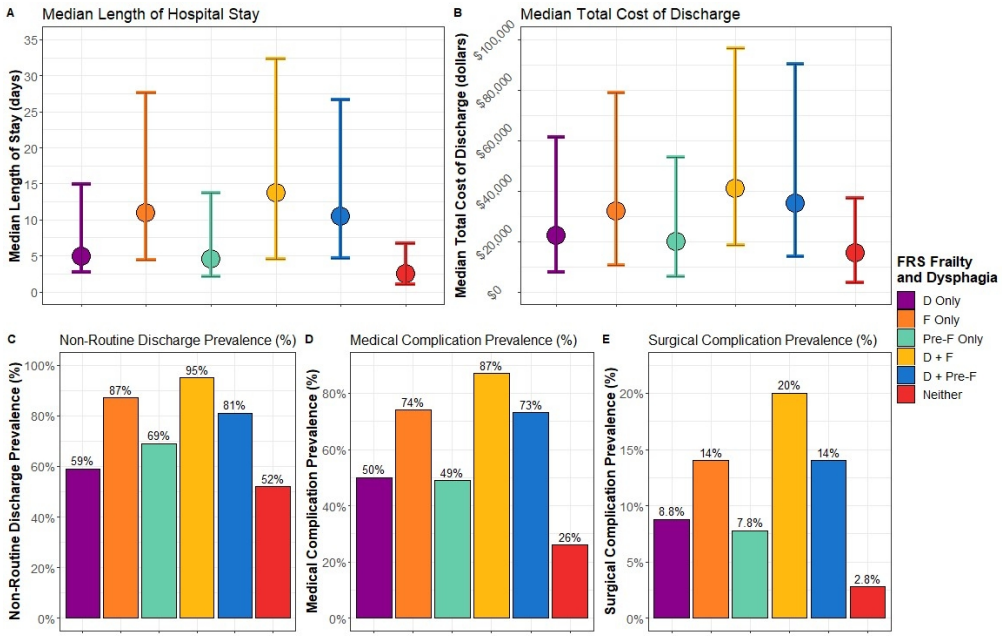


Distribution of outcomes by dysphagia and binary 10-item Johns Hopkins Adjusted Clinical Groups (ACG) frailty-defining diagnosis indicators frailty measure. D = dysphagia. F = frailty. For length of stay and total cost of discharge, the point represents the median and the bars represent the Q1 and Q3, respectively.

304x198mm (96 x 96 DPI)



Distribution of outcomes by dysphagia and 19-item Frailty Risk Score indexed and categorized by non-frail, pre-frail, frail. The non-frail, pre-frail, frail cut-points were ≤ 0.08, > 0.08 but < 0.25, and ≥ 0.25, respectively. D = dysphagia. F = frailty. Pre-F = pre-frail. For length of stay and total cost of discharge, the point represents the median and the bars represent the Q1 and Q3, respectively.

304x198mm (96 x 96 DPI)

Supplemental Tables

Supplemental Table 1. ICD-9-CM Volume 3 codes for surgical procedures.

Surgical procedure	**ICD-9-CM codes**
Peripheral arterial bypass	39.21, 39.22, 39.23, 39.24, 39.25, 39.26, 39.29
Cardiac surgery	35.1 35.10, 35.11, 35.12, 35.13, 35.14, 35.2, 35.20, 35.21, 35.22, 35.23,35.24, 35.25, 35.26, 35.27,35.28, 36.1, 36.10, 36.11, 36.12, 36.13, 36.14, 36.15, 36.16, 36.17, 36.19
CEA	38.12
AAA	38.44
Total/partial/revision hip	81.51, 81.52, 81.53
Total/revision knee	81.54, 81.55
Cervical fusion	81.32, 81.02, 84.61, 84.62, 84.66
Large bowel surgery	45.7, 45.71, 45.72, 45.73, 45.74, 45.75, 45.76, 45.79, 45.8, 45.81, 45.82, 45.83, 45.93, 45.94
Liver resection	50.3, 50.4, 50.22
Pancreas resection	52.5, 52.51, 52.52, 52.53, 52.59, 52.6, 52.7
Nephrectomy	55.4, 55.5, 55.51, 55.52, 55.53, 55.54
Cystectomy	57.6, 57.7, 57.71, 57.79
Pneumonectomy	32.5, 32.50, 32.59
Lobectomy/segmental resection	32.3, 32.30, 32.39, 32.4, 32.41, 32.49
General surgery	51.2, 51.21, 51.22, 51.23, 51.24, 53.0, 53.00, 53.01, 53.02, 53.03, 53.04, 53.05, 53.1, 53.10, 53.11, 53.12, 53.13, 53.14, 53.15, 53.16, 53.17, 53.5, 53.51, 53.59, 53.6, 53.61, 53.62, 53.63, 53.69

Supplemental Table 2. Frailty measures with associated conditions and related ICD-9-CM codes.

	10-Item ACG[a]		**19-Item FRS[b]**	
Variable	**Diagnoses**	**Codes**	**Diagnosis**	**Codes**
Malnutrition	Nutritional marasmus Other severe protein-calorie malnutrition	261, 262, 263.8, 263.9, V77.2	Malnutrition	261, 262, 263.0, 263.1, 263.2, 263.8, 263.9, V77.2
Dementia	Senile dementia with delusional or depressive features Senile dementia with delirium	290.20, 290.21, 290.3	Cognition problems/Dementia	290.0, 290.20, 290.2, 290.21, 290.3, 294.2, 294.20, 294.21,
Severe vision impairment	Profound impairment, both eyes Moderate or severe impairment, better eye/lesser eye profound	369.0, 369.00, 369.01, 369.03, 369.04, 369.06, 369.07, 369.08, 369.1, 369.10, 369.16, 396.18, 396.12, 369.14	Severe vision impairment	369.0, 369.00, 369.01, 369.03, 369.04, 369.05, 369.06, 369.07, 369.08, 369.1, 369.10, 369.11, 369.13, 369.16, 369.15, 369.17, 396.18, 396.12, 369.14, 369.20, 369.21, 369.22,369.23, 369.24, 369.25, 369.4, 366.9, 366.8, 366.1, 366.10, 366.11, 366.13, 366.14, 366.15, 366.16, 366.17, 366.18, 366.19, 366.12, 366.18, 366.4, 366.46, 366.45, 366.41, 366.43, 366.42, 366.2,366.20, 366.21, 366.22, 366.23, 366.3, 366.30, 366.31, 366.32, 366.33, 366.34, 366.53, 365.10, 365.11, 365.12, 365.13, 365.15, 365.20, 365.21, 365.20, 365.23, 365.24, 365.31, 365.32, 365.51, 365.52, 365.9, 365.1, 365.13, 365.11, 365.10, 365.8, 365.89, 365.81, 365.82, 365.9, 365.7, 365.70, 365.71, 365.72, 365.73, 365.74, 365.73, 365.60, 365.61, 365.62, 365.63, 365.64, 365.65, 362.5,

				362.50, 362.53, 362.51, 362.52, 362.54, 362.56, 362.7, 362.76, 362.75, 362.77, 362.70, 362.73, 362.1, 362.11, 362.12, 362.10, 362.0, 362.02, 362.03, 362.04, 362.05, 362.06, 362.01, 362.4, 362.41, 363.31
Decubitus ulcer	Decubitus ulcer	707.0, 707.00, 707.01, 707.02, 707.03, 707.04, 707.05, 707.06, 707.07, 707.09, 707.20, 707.21, 707.22, 707.23, 707.24, 707.25	Decubitus ulcer	707.0, 707.00, 707.01, 707.02, 707.03, 707.04, 707.05, 707.06, 707.07, 707.09, 707.20, 707.21, 707.22, 707.23, 707.24, 707.25
Incontinence of urine	Incontinence without sensory awareness Continuous leakage	788.34, 788.37	Incontinence of urine	788.34, 788.37, 788.39, 788.30, 788.38, 788.31, 788.32, 788.33, 788.91, 625.6
Loss of weight	Abnormal loss of weight and underweight Feeding difficulties and mismanage-ment	783.2, 783.21, 783.22, 783.3, CM_WGHTLOSS	Loss of weight	783.2, 783.21, 783.22, 783.3, CM_WGHTLOSS
Fecal incontinence	Incontinence of feces	787.6, 787.60	Fecal incontinence	787.6, 787.60
Social support needs	Lack of housing Inadequate housing	V60.0, V60.1, V60.2	Social support needs	V60.0, V60.1, V60.2, V60.3, V60.4, V62.0, V62.3, V62.4

	Inadequate material resources			
Difficulty in walking	Difficulty in walking Abnormality of gait	719.7, 781.2	Difficulty in walking	719.7, 781.2
Fall	Fall on stairs or steps Fall from wheelchair	E880, E880.0, E880.1, E880.9, E884.3	Fall	E880, E880.0, E880.1, E880.9, E884.3, E884.2, E884.4, E884.5, E884.6
			Weakness	728.87
			Fatigue	780.79, 780.71, 780.7
			Dyspnea	786.00, 786.01, 786.02, 786.03, 786.04, 786.05, 786.06, 786.07, 786.09
			Chronic pain	338.21, 338.22, 338.28, 338.29
			Anemia	280.0, 280.1, 280.8, 280.9, 285.2, 285.21, 285.22, 285.29, 285.9, 281.0, 281.1, 281.2, 281.3, 281.4, 281.8, 281.9
			Depression	311, 296.2, 296.20, 296.21, 296.22, 296.23, 296.24, 296.25, 296.3, 296.30, 296.31, 296.32, 296.33, 296.34, 296.35
			High WBC	288.6, 288.60
			Low WBC	288.5, 288.59, 288.50
			Delirium	293.0, 293.1, 780.97

[a] The 10-item ACG is the Johns Hopkins Adjusted Clinical Groups (ACG) frailty-defining diagnosis indicators and is a binary frail yes/no variable.
[b] The 19-item FRS is the Frailty Risk Score and can have a score of 0 to 19.

Supplemental Table 3. Elixhauser Comorbidities by ACG Frailty[a] and Dysphagia Groups.

ACG Frailty and Dysphagia Group	Dysphagia Only	Frailty Only	Frailty + Dysphagia	Neither	Total
Weighted N	N=31,440	N=130,920	N=7,465	N=3,129,010	N=3,298,835
AHRQ comorbidity measure: Acquired immune deficiency syndrome					
Not present	31,425 (100.0%)	130,720 (99.8%)	7,440 (99.7%)	3,126,995 (99.9%)	3,296,580 (99.9%)
Present	15 (0.0%)	200 (0.2%)	25 (0.3%)	2,015 (0.1%)	2,255 (0.1%)
AHRQ comorbidity measure: Alcohol abuse					
Not present	30,395 (96.7%)	124,755 (95.3%)	7,040 (94.3%)	3,070,895 (98.1%)	3,233,085 (98.0%)
Present	1,045 (3.3%)	6,165 (4.7%)	425 (5.7%)	58,115 (1.9%)	65,750 (2.0%)
AHRQ comorbidity measure: Rheumatoid arthritis/collagen vascular diseases					
Not present	30,050 (95.6%)	125,980 (96.2%)	7,265 (97.3%)	3,020,430 (96.5%)	3,183,725 (96.5%)
Present	1,390 (4.4%)	4,940 (3.8%)	200 (2.7%)	108,580 (3.5%)	115,110 (3.5%)
AHRQ comorbidity measure: Congestive heart failure					
Not present	28,835 (91.7%)	115,855 (88.5%)	6,225 (83.4%)	3,016,615 (96.4%)	3,167,530 (96.0%)
Present	2,605 (8.3%)	15,065 (11.5%)	1,240 (16.6%)	112,395 (3.6%)	131,305 (4.0%)
AHRQ comorbidity measure: Chronic pulmonary disease					
Not present	23,430 (74.5%)	99,205 (75.8%)	5,290 (70.9%)	2,565,695 (82.0%)	2,693,620 (81.7%)
Present	8,010 (25.5%)	31,715 (24.2%)	2,175 (29.1%)	563,315 (18.0%)	605,215 (18.3%)
AHRQ comorbidity measure: Coagulopathy					
Not present	27,610 (87.8%)	113,290 (86.5%)	5,860 (78.5%)	2,971,950 (95.0%)	3,118,710 (94.5%)
Present	3,830 (12.2%)	17,630 (13.5%)	1,605 (21.5%)	157,060 (5.0%)	180,125 (5.5%)
AHRQ comorbidity measure: Diabetes, uncomplicated					
Not present	23,610 (75.1%)	102,820 (78.5%)	5,765 (77.2%)	2,451,280 (78.3%)	2,583,475 (78.3%)
Present	7,830 (24.9%)	28,100 (21.5%)	1,700 (22.8%)	677,730 (21.7%)	715,360 (21.7%)
AHRQ comorbidity measure: Diabetes with chronic complications					
Not present	29,485 (93.8%)	121,845 (93.1%)	6,835 (91.6%)	3,026,025 (96.7%)	3,184,190 (96.5%)
Present	1,955 (6.2%)	9,075 (6.9%)	630 (8.4%)	102,985 (3.3%)	114,645 (3.5%)
AHRQ comorbidity measure: Drug abuse					
Not present	30,805 (98.0%)	127,925 (97.7%)	7,325 (98.1%)	3,098,065 (99.0%)	3,264,120 (98.9%)
Present	635 (2.0%)	2,995 (2.3%)	140 (1.9%)	30,945 (1.0%)	34,715 (1.1%)
AHRQ comorbidity measure: Hypothyroidism					
Not present	26,300 (83.7%)	112,375 (85.8%)	6,255 (83.8%)	2,674,925 (85.5%)	2,819,855 (85.5%)
Present	5,140 (16.3%)	18,545 (14.2%)	1,210 (16.2%)	454,085 (14.5%)	478,980 (14.5%)
AHRQ comorbidity measure: Hypertension (combine uncomplicated and complicated)					
Not present	8,815 (28.0%)	45,085 (34.4%)	2,280 (30.5%)	1,010,430 (32.3%)	1,066,610 (32.3%)
Present	22,625 (72.0%)	85,835 (65.6%)	5,185 (69.5%)	2,118,580 (67.7%)	2,232,225 (67.7%)

AHRQ comorbidity measure: Lymphoma					
Not present	31,280 (99.5%)	129,770 (99.1%)	7,380 (98.9%)	3,116,375 (99.6%)	3,284,805 (99.6%)
Present	160 (0.5%)	1,150 (0.9%)	85 (1.1%)	12,635 (0.4%)	14,030 (0.4%)
AHRQ comorbidity measure: Liver disease					
Not present	30,655 (97.5%)	125,070 (95.5%)	7,155 (95.8%)	3,061,400 (97.8%)	3,224,280 (97.7%)
Present	785 (2.5%)	5,850 (4.5%)	310 (4.2%)	67,610 (2.2%)	74,555 (2.3%)
AHRQ comorbidity measure: Fluid and electrolyte disorders					
Not present	21,320 (67.8%)	68,310 (52.2%)	2,745 (36.8%)	2,664,830 (85.2%)	2,757,205 (83.6%)
Present	10,120 (32.2%)	62,610 (47.8%)	4,720 (63.2%)	464,180 (14.8%)	541,630 (16.4%)
AHRQ comorbidity measure: Other neurological disorders					
Not present	28,205 (89.7%)	120,600 (92.1%)	6,200 (83.1%)	3,000,670 (95.9%)	3,155,675 (95.7%)
Present	3,235 (10.3%)	10,320 (7.9%)	1,265 (16.9%)	128,340 (4.1%)	143,160 (4.3%)
AHRQ comorbidity measure: Metastatic cancer					
Not present	30,890 (98.3%)	120,675 (92.2%)	7,055 (94.5%)	3,082,350 (98.5%)	3,240,970 (98.2%)
Present	550 (1.7%)	10,245 (7.8%)	410 (5.5%)	46,660 (1.5%)	57,865 (1.8%)
AHRQ comorbidity measure: Obesity					
Not present	26,260 (83.5%)	106,115 (81.1%)	6,330 (84.8%)	2,467,390 (78.9%)	2,606,095 (79.0%)
Present	5,180 (16.5%)	24,805 (18.9%)	1,135 (15.2%)	661,620 (21.1%)	692,740 (21.0%)
AHRQ comorbidity measure: Paralysis					
Not present	29,495 (93.8%)	126,785 (96.8%)	6,655 (89.1%)	3,110,540 (99.4%)	3,273,475 (99.2%)
Present	1,945 (6.2%)	4,135 (3.2%)	810 (10.9%)	18,470 (0.6%)	25,360 (0.8%)
AHRQ comorbidity measure: Peripheral vascular disorders					
Not present	27,495 (87.5%)	112,490 (85.9%)	6,195 (83.0%)	2,908,535 (93.0%)	3,054,715 (92.6%)
Present	3,945 (12.5%)	18,430 (14.1%)	1,270 (17.0%)	220,475 (7.0%)	244,120 (7.4%)
AHRQ comorbidity measure: Pulmonary circulation disorders					
Not present	30,565 (97.2%)	125,760 (96.1%)	7,050 (94.4%)	3,093,760 (98.9%)	3,257,135 (98.7%)
Present	875 (2.8%)	5,160 (3.9%)	415 (5.6%)	35,250 (1.1%)	41,700 (1.3%)
AHRQ comorbidity measure: Renal failure					
Not present	26,645 (84.7%)	107,980 (82.5%)	5,710 (76.5%)	2,876,090 (91.9%)	3,016,425 (91.4%)
Present	4,795 (15.3%)	22,940 (17.5%)	1,755 (23.5%)	252,920 (8.1%)	282,410 (8.6%)
AHRQ comorbidity measure: Solid tumor without metastasis					
Not present	30,875 (98.2%)	126,640 (96.7%)	7,200 (96.5%)	3,095,165 (98.9%)	3,259,880 (98.8%)
Present	565 (1.8%)	4,280 (3.3%)	265 (3.5%)	33,845 (1.1%)	38,955 (1.2%)
AHRQ comorbidity measure: Peptic ulcer disease excluding bleeding					
Not present	31,430 (100.0%)	130,805 (99.9%)	7,460 (99.9%)	3,128,450 (100.0%)	3,298,145 (100.0%)
Present	10 (0.0%)	115 (0.1%)	5 (0.1%)	560 (0.0%)	690 (0.0%)
AHRQ comorbidity measure: Valvular disease					

Not present	29,835 (94.9%)	123,360 (94.2%)	6,840 (91.6%)	3,021,795 (96.6%)	3,181,830 (96.5%)
Present	1,605 (5.1%)	7,560 (5.8%)	625 (8.4%)	107,215 (3.4%)	117,005 (3.5%)
Psychoses					
Not present	30,990 (98.6%)	128,865 (98.4%)	7,270 (97.4%)	3,108,975 (99.4%)	3,276,100 (99.3%)
Present	450 (1.4%)	2055 (1.6%)	195 (2.6%)	20,035 (0.6%)	22,735 (0.7%)

[a] The 10-item ACG is the Johns Hopkins Adjusted Clinical Groups (ACG) frailty-defining diagnosis indicators and is a binary frail yes/no variable.

Supplemental Table 4. Diagnoses and related ICD-9-CM constituting medical and surgical complications.

Acute cardiac event	410.0, 410.01, 410.00, 410.02, 410.1, 410.2, 410.21, 410.20, 410.22, 410.3, 410.31, 410.4, 410.5, 410.6, 410.61, 410.60, 410.62, 410.7, 410.71, 410.70, 410.72, 410.8, 410.9, 411.1, 411.8, 415.0, 420.0, 420.9, 421.0, 421.1, 421.9, 422.0, 422.9, 427, 427.1, 427.2, 427.3, 427.31, 427.32, 427.4, 427.41, 427.42, 427.5, 427.8, 427.89, 427.9, 428, 428.0, 428.1, 428.2, 428.20, 428.21, 428.22, 428.23, 428.3, 428.30, 428.31, 428.32, 428.33, 428.4, 428.40, 428.41, 428.42, 428.43, 428.9
Acute pulmonary edema/failure	514, 518.4, 518.8, 518.81, 518.82, 518.84
Acute cerebrovascular event	997.00, 997.01, 997.02, 997.09
Acute renal failure	584, 584.5, 584.6, 584.7, 584.8, 584.9
Acute hepatic failure	570
Sepsis	995.9, 038, 038.0, 038.1, 038.10, 038.11, 038.12, 038.19, 038.2, 038.3, 038.4, 038.40, 038.41, 038.42, 038.43, 038.44, 038.49, 999.3
Urinary tract infection	599.0, 996.64, 996.31, V13.02
Pneumonia	480, 480.0, 480.1, 480.2, 480.3, 480.8, 480.9, 481, 482, 482.0, 482.1, 482.3, 482.30, 482.31, 482.32, 482.39, 482.40, 482.41, 482.42, 482.49, 482.8, 482.81, 482,82, 482.83, 482.84, 482.89, 482.9, 483, 483.1, 483.8, 484, 484.1, 484.3, 484.5, 484.6, 484.7, 484.8, 485, 487.0, 997.31, 507.0, 518.4, 518.5, 516, 516.8, V12.61
Venous thromboembolism	415.1, 451.11, 451.19, 451.2, 451.81, 453.8
GI bleed	530.82, 531.0, 531.1, 531.2, 531.4, 531.6, 531.60, 531.61, 532.0, 532.1, 532.2, 532.4, 532.6, 533.0, 533.1, 533.2, 533.4, 533.6, 534.0, 534.1, 534.2, 534.4, 534.6, 535.01, 535.11, 535.21, 535.31, 535.41, 535.51, 535.61, 578.9
Shock	998.00, 998.01, 998.02, 998.09
Hemorrhage, hematoma, or seroma	998.1, 998.11, 998.12, 998.13
Accidental perforation or laceration of blood vessel, nerve, or organ	998.2
Wound dehiscence	998.3, 998.30, 998.31, 998.32, 998.33
Foreign body	998.4
Postoperative infection	958.3, 998.5, 998.51, 998.59
Postoperative fistula	998.6
Nonhealing surgical wound	998.83
Other unspecified procedural complications	998.8, 998.81, 998.89, 998.9