Functional and Cognitive Decline Among Older Adults After High-risk Surgery

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Objective: The aim of this study was to determine whether older adults are at higher risk of lasting functional and cognitive decline after surgery, and the impact of decline on survival and healthcare use.
Summary Background Data: Patient-centered outcomes after surgery are poorly characterized.
Methods: Using data from the Health and Retirement Study linked with Medicare, we matched older adults ($\geq$65 years) who underwent one of 163 high-risk elective operations (ie, inpatient mortality of $\geq$1%) with nonsurgical controls between 1992 and 2012. Functional decline was defined as an increase in the number of activities of daily living (ADLs) and/or instrumental activities of daily living (IADLs) requiring assistance from baseline. Cognitive decline was defined by worse response to a test of memory and mental processing from baseline. Using logistic regression, we examined whether surgery was associated with functional and cognitive decline, and whether declines were associated with poorer survival and increased healthcare use.
Results: The matched cohort of patients who did not undergo surgery consisted of 3591 (75%) participants compared to 1197 (25%) who underwent surgery. Patients who underwent surgery were at higher risk of functional and cognitive declines [adjusted odds ratio (aOR) 1.52, 95% confidence interval (CI): 1.23–1.87 and aOR 1.32, 95% CI: 1.03–1.71]. Declines were associated with poorer long-term survival [hazard ratio (HR) 1.67, 95% CI: 1.43–1.94 and HR 1.35, 95% CI: 1.15–1.58], and were significantly associated with nearly all measures of increased healthcare utilization ($P < 0.001$).
Conclusion: Older adults undergoing high-risk surgery are at increased risk of developing lasting functional and cognitive declines.

Keywords: cognition, complications, older adults, physical function, surgery

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By 2030, the proportion of adults older than 65 years is expected to exceed 20% in the United States.[1] With this aging population, an increasing number of older adults will undergo surgical procedures.[2] Although older adults represent 40% of all inpatient operations, they account for >60% of all postoperative deaths and a similarly disproportionate share of postoperative complications due to decreased functional reserve and therefore reduced capacity to recover from postoperative complications.[3,4] The unique challenges older adults face when considering surgery have led to the American College of Surgeons Geriatric Surgery Verification Program, which established standards aimed at improving surgical care and outcomes among this vulnerable population.[5]

However, this initiative is informed by few studies examining the extent to which undergoing surgery impacts lasting functional and cognitive outcomes.[6,7] Furthermore, no previous studies evaluate whether complications after surgery impact the trajectory of these outcomes. Although previous studies demonstrate that at least 10% of patients 65 years and older require discharge to skilled nursing facilities following major surgery, this measure is a crude characterization of functional and cognitive disability.[8–10] Rudimentary measures such as discharge destination do not optimally inform patients making complex decisions around surgery. Moreover, in patients who experience functional and cognitive declines after surgery, the impact on long-term abilities and survival has not been studied beyond 12 months.[7,11–13] Finally, even less is known about the impact on overall cost and healthcare utilization as a result of such limitations after surgery.

In this context, we sought to evaluate the longitudinal effects of high-risk surgery and serious complications on function, cognition, and survival among older adults. Furthermore, we aimed to evaluate the economic impact of functional and cognitive decline in such patients. We hypothesized that surgery and complications would significantly worsen function and cognition, and such disabilities would be associated with worse survival and increased health care utilization.

METHODS

Data Source

Health and Retirement Study Survey Data

The Health and Retirement Study (HRS) is an ongoing longitudinal study, which represents a cohort of community-dwelling US residents >50 years' old. Since 1992, >43,000 individuals have participated in biennial interviews with a follow-up rate >90%. The HRS uses multistage probability sample to identify participants, and is broadly representative of the older US population with regard to sociodemographics. Detailed information about sociodemographics, family, wealth and income, and health status are provided by the respondents.[14]

HRS-Linked Medicare Claims

Greater than 85% of Medicare-eligible HRS respondents (patients $\geq$65 years' old) consent to linkage of their administrative Medicare claims to their survey. We used data from the Centers for Medicare and Medicaid services Master Beneficiary Summary, Part B Carrier, Medicare Provider Analysis and Review (MedPAR), hospice cost report, inpatient, and outpatient files. Patient-level data

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include age, sex, race/ethnicity, comorbidities (principal and secondary diagnosis codes), procedural codes, 30-day morbidity and mortality, and information on length of stay.

National Death Index

The National Death Index is one of the most frequently used source of data for mortality in the US Funded by the Centers for Disease Control.[15]

Patient Population

Our study sample included surgical patients who satisfied the following criteria: have claims-based data on 1 of 163 elective operations defined as high-risk (ie, inpatient mortality of at least 1%) for patients ≥65 years using the *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9*) codes[16]; have at least 1 survey conducted through HRS before the elective operation (baseline survey); and have at least 1 survey conducted through HRS after the elective operation (follow-up survey).

Our study sample also included patients who did not undergo surgery (ie, nonsurgical patients) selected as controls for the surgical patients. For each surgical patient included in our study sample, we selected 3 controls: HRS respondents who did not undergo major surgery and were matched on their propensity to receive surgery.

Major complications occurring within 30 days after the index operation are identified in the Medicare-linked data by *ICD-9* codes for the following categories: pulmonary failure, pneumonia, myocardial infarction, deep venous thrombosis/pulmonary embolism, renal failure, surgical site infection, gastrointestinal bleeding, and hemorrhage.[17]

Frailty was determined by a claims-based frailty index described by Kim et al[18] using the Medicare-linked data.

Measures

Functional status using HRS data was determined by the sum of Activities of Daily Living (ADLs: walking, dressing, bathing, eating, getting into and out of bed, and toileting) and Instrumental Activities of Daily Living (IADLs: preparing hot meals, grocery shopping, making telephone calls, taking medicines, and managing money) needing assistance. Functional classes were defined as 0 = no limitations; 1 to 3 = mild to moderate limitations; and ≥4 = severe limitations.[19]

Cognitive status using HRS data was determined by a 27-point scale administered at the time of the interview, a modified version of the Telephone Interview for Cognitive Status includes: immediate and delayed 10-word recall test; serial 7 subtractions; backward counting; and naming and orientation. Cognitive classes were defined as ≥11 = normal; 7 to 11 = mild cognitive impairment; and 0 to 6 = severe cognitive impairment. For patients who were unable to be interviewed, proxies were interviewed using a validated Informant Questionnaire on Cognitive Decline in the Elderly, which were defined as "excellent," "very good," or "good" = mild cognitive impairment and "fair" or "poor" = severe cognitive impairment.[19–21]

Functional and cognitive decline was defined as a worsened functional or cognitive state from baseline to follow-up survey. Patients whose status remained the same or improved were considered to have no decline.

Healthcare utilization was defined as daily healthcare spending, use of health services, and days spent as an inpatient, in the intensive care unit (ICU) or at a skilled nursing facility (SNF). To determine daily healthcare spending (excluding prescription medications) in the year following index operation, we used the date of operation as defined by procedure codes from Medicare claims. Utilization for nonsurgical patients was measured starting on the discharge day of their matched surgical patient for a period of 1 year. Using established methods that account for variation in Medicare reimbursement, we then price-standardized healthcare spending.[22] We identified health services use including the number of outpatient visits to primary care physicians, specialists, and emergency departments, identified in the Part B Carrier and outpatient files.[23] To identify the total number of days spent as an inpatient, in an ICU, at a SNF, or "days at home," we used data from MedPar files.

Time to death was measured as time from the follow-up survey to date of death for surgical patients and their controls. Surgical patients who died before their first follow-up surgery could not be evaluated for functional and cognitive decline, and were therefore excluded from this analysis.

Statistical Analysis

After identifying the surgical cohort, we selected 3 nonsurgical patients as controls for each surgical patient. These controls were selected based on how similar their propensities to undergo surgery to their surgical counterparts at the time of surgery. The propensity score was derived from a logistic regression modeling the likelihood of receiving surgery or not, as a function of sex, race, age, education, marital status, comorbidities, baseline functional and cognitive statuses, and year of survey. We then examined the balance of each covariate between matched surgical patients and their nonsurgical controls using chi-square tests for categorical variables and *t* tests for continuous variables. The matching was done using greedy matching techniques with more details available by Parsons.[24]

We first compared the covariate distributions between patients with complications and those without complications using either chi-square test or *t* tests among surgical patients. We then evaluated how surgery and complications were associated with patients' functional and cognitive declines using proportions and logistic regressions. We adjusted for the following covariates that have been shown previously to correlate with functional and cognitive declines in our models: sociodemographic factors (age, sex, race/ethnicity, educational attainment, household net worth); co-existing chronic conditions (high blood pressure, heart disease, diabetes, cancer, cognitive impairment, stroke, lung disease, arthritis); and health events (hospitalizations or falls within the last 2 years),[25] as well as baseline functional and cognitive status, frailty, time between surgery and surveys (both pre- and post-surgery), and date of operation. We then examined the proportion of patients with specific functional and cognitive limitations among individual ADLs and IADLs at baseline and follow-up among patients who experienced decline.

Next, using Cox proportional hazards regression, we examined the association between surgery and surgical complications and time-to-death, while adjusting for potential confounders for both surgical patients and their nonsurgical controls. We evaluated the proportional hazards assumptions and incorporated time and age interaction and calculated the covariate-adjusted average survival probabilities for each group. Lastly, we compared the mean of healthcare utilizations and "days at home" between patients who experienced functional or cognitive declines and those who did not using ordinary least squares regression. All analyses were performed in SAS (SAS Institute Inc., Cary, NC, Version 9.4). The University of Michigan Institutional Review Board deemed this study as exempt (HUM00157651).

RESULTS

From 21,588 HRS participants ≥65 years with Medicare linkage between 1992 and 2012, we identified 1197 patients who underwent at least 1 elective high-risk surgery and had at least 1 follow-up survey. Of these, 696 patients did not experience a complication (ie, surgery without complication cohort) and 501 patients did (ie, surgery with complication cohort). Three-to-one propensity matching yielded a total of 3591 controls who did not have surgery (ie, nonsurgical cohort). Nonsurgical control patients were matched to surgical patients (Supplement 1, http://links.lww.com/SLA/C167). After matching, there were no significant differences in demographics, socioeconomic characteristics, and baseline functional and cognitive statuses between the surgical patients and their nonsurgical controls (Table 1). Mean interval between baseline survey and surgery was 12.5 [standard deviation (SD) 7.0] months, and between surgery and follow-up survey was 12.3 (SD 6.4) months. Mean follow-up for the entire (surgical and nonsurgical) cohort was 6.9 (SD 4.1) years.

In the surgery without complication cohort, mean age was 74.6 (SD 6.3) years, 333 (48%) were male, 614 (88%) White, 505 (74%) had no functional limitations, and 516 (74%) had no cognitive impairments at baseline. In the surgery with complication cohort, mean age was 75.0 (SD 6.4) years, 212 (42%) were male, 447 (89%) White, 320 (64%) had no functional limitations, and 351 (70%) had no cognitive impairments at baseline. Of the entire cohort, 18.4% of patients experienced functional decline and 17.0% experienced cognitive decline. As shown in Figure 1, both types of decline varied significantly by surgery and complication status ($P < 0.001$): the rate of functional decline was 16.5% in nonsurgical controls, 22.4% in the surgery without complication group, and 26.4% among the surgery with complication group. With regard to cognitive decline, the rate for nonsurgical controls was 15.8%, 20.2% in the surgery without complication group, and 21.0% in the surgery with complication group.

Surgery without and with complication were both significantly associated with functional decline [adjusted odds ratio (aOR) 1.52, 95% confidence interval (CI): 1.23–1.87 and aOR 1.90, 95% CI: 1.49–2.41, respectively]. In addition, increasing age (aOR 1.07, 95% CI: 1.06–1.09), increasing number of comorbid conditions (aOR 1.21, 95% CI: 1.11–1.31), and mild and moderate-severe baseline cognitive statuses (aOR 1.81, 95% CI: 1.45–2.26 and aOR 3.09, 95% CI: 2.07–4.60) were significantly associated with functional decline. Married status and educational attainment greater

TABLE 1. Baseline Characteristics for Matched Patients Undergoing Surgery With No Surgery (n = 4788)

	No Surgery* N = 3,591	Surgery, N = 1,197	P†	Surgery Without Complication, N = 696	Surgery With Complication, N = 501	P‡
Age at index operation, mean (SD), y	74.8 (6.6)	74.8 (6.3)	0.7	74.6 (6.3)	75.0 (6.4)	0.26
Male, N (%)	1655 (46)	545 (46)	0.74	333 (48)	212 (42)	0.06
Race, N (%)			0.78			0.86
White	3205 (89)	1061 (89)		614 (88)	447 (89)	
Black	315 (9)	109 (9)		66 (9)	43 (9)	
Other	71 (2)	27 (2)		16 (2)	11 (2)	
Marital status			0.90			0.68
Married	2332 (65)	775 (65)		454 (65)	321 (64)	
Not Married	1259 (35)	422 (35)		242 (35)	180 (36)	
highest level of education			0.57			0.68
High school	877 (24)	309 (26)		173 (25)	136 (27)	
High school	1970 (55)	633 (53)		372 (53)	261 (52)	
Undergraduate	445 (12)	159 (13)		91 (13)	68 (14)	
Graduate	299 (8)	96 (8)		60 (9)	36 (7)	
Elixhauser comorbidity score, mean (SD)	0.45 (1.06)	0.48 (1.14)	0.46	0.45 (1.09)	0.52 (1.21)	0.36
Baseline Functional class, N (%)§			0.27			0.006
No impairment	556 (71)	825 (69)		505 (74)	320 (64)	
Mild to moderate	771 (21)	271 (23)		142 (21)	132 (26)	
Severe	264 (7)	101 (8)		38 (6)	49 (10)	
Baseline cognitive class, N (%)‖			0.33			0.26
No impairment	2650 (74)	867 (72)		516 (74)	351 (70)	
Mild	703 (20)	257 (21)		142 (20)	115 (23)	
Moderate to severe	238 (7)	73 (6)		38 (5)	35 (7)	
Surgery type						< 0.001
Cardiothoracic		543 (45)		269 (37)	274 (55)	
Intraabdominal (incl. gastrointestinal, hernia repair, gynecologic)		421 (35)		280 (38)	141 (28)	
Peripheral vascular		168 (14)		105 (15)	63 (13)	
Other (incl. neurological and otolaryngological)		65 (5)		42 (6)	23 (5)	
Length of stay, days, mean (SD)		9.5 (7.7)		6.7 (6)	12.0 (9)	< 0.001
Required mechanical ventilation, N (%)		14 (1)		3 (0)	11 (2)	0.005
Intensive care unit stay, N (%)		725 (61)		358 (51)	367 (73)	< 0.001
Required dialysis, N (%)		16 (1)		8 (1)	8 (2)	0.51

*No surgery patients were matched with their surgical counterparts by their propensities to undergo surgery. Propensity scores are derived from logistic regression of receiving surgery based on patient demographics, comorbidities, baseline functional class and baseline cognitive class, and year of survey. No statistically significant differences between matched surgical and nonsurgical groups were found.

†P value comparing surgical patients to their nonsurgical controls.

‡P value comparing surgery without complication to surgery with complication.

§Functional Class determined by sum of ADLs (walking, dressing, bathing, eating, getting out of bed, and toileting) and IADLs (preparing a hot meal, shopping for groceries, making telephone calls, taking medicines, and managing money); 0 = no limitations; 1–3 = mild to moderate; ≥4 = severe.

‖Cognitive Class determined by a 27-point self-administered test; ≥11 = normal; 7–11 = mild cognitive impairment; 0–6 = severe.

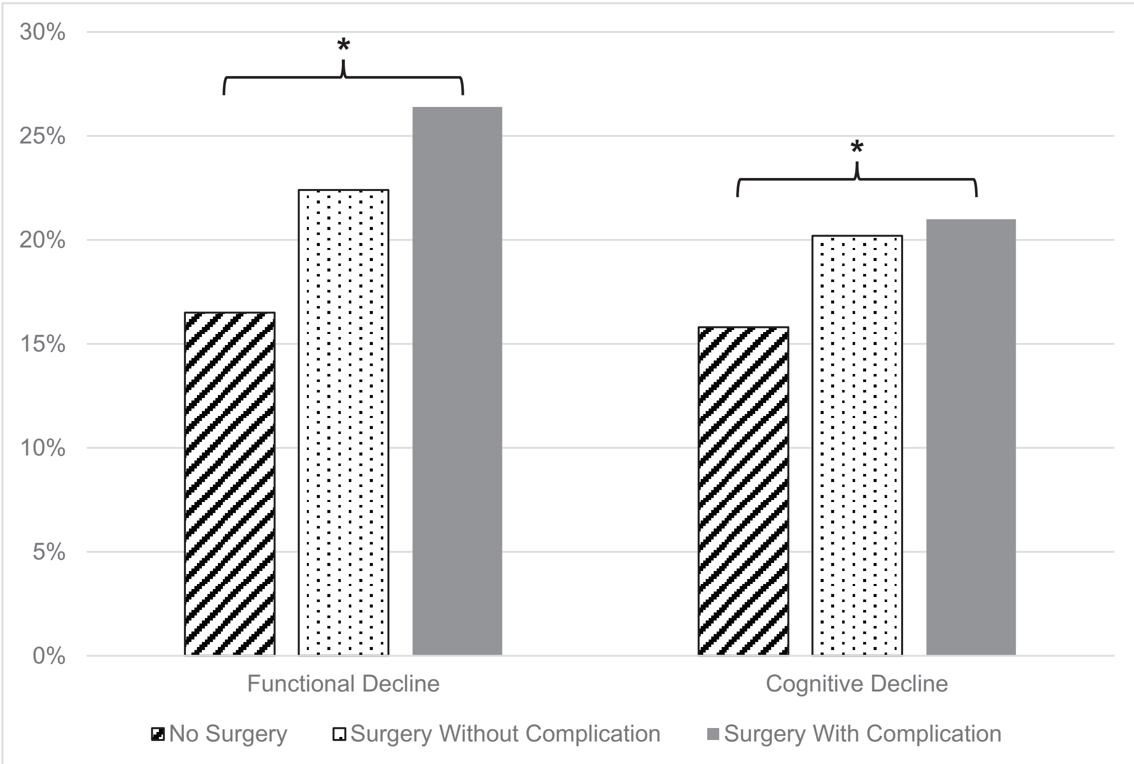

FIGURE 1. Unadjusted rates of functional and cognitive decline by surgery and complications. *Indicates statistical significance ($P < 0.001$).

than high school were significantly less likely to experience functional decline than their counterparts (Table 2).

Predictors of cognitive decline included both surgery without and with complication (aOR 1.32, 95% CI: 1.03–1.71 and aOR 1.42, 95% CI: 1.15–1.76, respectively), Black or other race (aOR 2.0, 95% CI: 1.45–2.77 and aOR 1.99, 95% CI: 1.13–3.53, respectively), increasing age (aOR 1.07, 95% CI: 1.05–1.09), and increasing number of comorbid conditions (aOR 1.08, 95% CI: 1.0–1.17). Mild to moderate and severe baseline functional status were also predictive of worsening cognitive status (aOR 1.59, 95% CI: 1.29–1.98 and aOR 2.48, 95% CI: 1.69–3.65 respectively). In contrast, educational attainment greater than high school was protective of cognitive decline. Of note, adjusted ORs for decline were not calculated for severe functional status and moderate to severe cognitive class due to a ceiling effect (ie, no further decline is possible after patients reach the most severe functional and/or cognitive classes) (Table 2).

Due to incomplete diagnosis and procedure code data, frailty was available only for a subset of the cohort (n = 2025). As such, a sensitivity analysis was performed of this subset. Greater frailty was significantly associated with functional and cognitive decline in both bivariate and multivariate analyses ($P < 0.01$ for all comparisons). However, inclusion of frailty in our multivariable models did not affect the significance of the other covariates. Supplement 2, http://links.lww.com/SLA/C168 details how specific complications contribute to both functional and cognitive decline. Although renal failure was a significant predictor of functional decline and pulmonary failure was a significant predictor of cognitive decline, individual complications did not change the significance of other covariates.

Figure 2 demonstrates the rates of patient-reported assistance required for specific ADLs and IADLs among patients who experienced functional decline. All measures of ADLs and IADLs were reported to need more assistance at follow-up than baseline. The increase was larger among the surgery with complications cohort than the surgery without complications cohort and nonsurgical controls, particularly for ADLs of walking, bathing, getting in and out of bed, and the IADLs of grocery shopping, preparing hot meals, and managing money. Figure 3 demonstrates memory and mental status scores at baseline and follow-up. With higher numbers indicating better scores, all cohorts demonstrated worsened cognition from baseline survey to follow-up survey.

In a survival model adjusting for covariates, poorer survival was associated with both functional [hazard ratio (HR) 1.67, 95% CI: 1.43–1.94] and cognitive (HR 1.35, 95% CI: 1.15–1.58) decline. Adjusted 5-year survival was 73.7% for patients with functional decline versus 83.1% for those without. For patients with cognitive decline, adjusted 5-year survival was 77.2% versus 82.7% for those without.

Finally, healthcare utilization was significantly greater in those that demonstrated functional decline (\$15,650 vs \$26,099, $P < 0.001$) and cognitive decline (\$16,497 vs \$23,473, $P < 0.001$). In addition, ''days at home'' were fewer in those that demonstrated function decline (330.9 vs 342.2 days, $P < 0.001$) and cognitive decline (331.1 vs 339.9 days, $P < 0.001$) (Supplement 3, http://links.lww.com/SLA/C169). Subsequent covariate adjustments were made, and these findings remained consistent.

DISCUSSION

In this nationally representative study using a robust longitudinal data source, we found that older adults undergoing high-risk surgery are at higher risk of functional and cognitive decline, and that a serious postoperative complication exacerbates this risk. In

TABLE 2. Predictors of Functional and Cognitive Decline (n = 4788)

	Functional Decline			Cognitive Decline		
Surgery	aOR	95% CI	*	aOR	95% CI	*
No surgery	Ref			Ref		
Surgery w/o complication	1.52	(1.23–1.87)		1.32	(1.03–1.71)	
Surgery w/complications	1.90	(1.49–2.41)		1.42	(1.15–1.76)	
Female Sex	1.21	(0.98–1.49)		1.11	(0.91–1.36)	
Race			*			*
White	ref			Ref		
Black	0.99	(0.72–1.39)		2.00	(1.45–2.77)	
Other	0.31	(0.15–0.65)		1.99	(1.13–3.53)	
Age, y	1.07	(1.06–1.09)	*	1.07	(1.05–1.09)	*
Comorbidities (Elixhauser CI)	1.21	(1.11–1.31)	*	1.08	(1.00–1.17)	*
Married status	0.68	(0.55–0.84)	*	1.03	(0.82–1.27)	
Education			*			*
Less than high school	ref			Ref		
High school	0.73	(0.59–0.91)		0.63	(0.51–0.78)	
Undergraduate	0.71	(0.52–0.98)		0.32	(0.22–0.46)	
Graduate	0.52	(0.35–0.79)		0.23	(0.14–0.38)	
Year of survey	1.01	(0.99–1.03)		0.99	(0.97–1.01)	
Baseline functional class†			*			*
None	ref			Ref		
Mild to moderate	0.65	(0.52–0.82)		1.59	(1.29–1.98)	
Severe	—	—		2.48	(1.69–3.65)	
Baseline cognitive class‡			*			*
None	Ref			Ref		
Mild	1.81	(1.45–2.26)		0.57	(0.44–0.72)	
Moderate to severe	3.09	(2.07–4.60)		—	—	

*Indicates statistical significance ($P < 0.05$).

†Functional Class determined by sum of ADLs (walking, dressing, bathing, eating, getting out of bed, and toileting) and IADLs (preparing a hot meal, shopping for groceries, making telephone calls, taking medicines, and managing money); 0 = no limitations; 1–3 = mild to moderate; ≥4 = severe.

‡Cognitive Class determined by a 27-point self-administered test; ≥11 = normal; 7–11 = mild cognitive impairment; 0–6 = severe.

addition, increasing age, frailty, number of comorbid conditions, and worse baseline functional and cognitive statuses predicted a significantly higher risk of functional and cognitive decline, which translated to poorer long-term survival and increased healthcare utilization. With the aging population and an increasing number of older adults undergoing surgical procedures, these data have important implications.

Although substantial efforts have been made to reduce postoperative complications and mortality, particularly in older adults who have decreased physiologic reserve to recover from both the

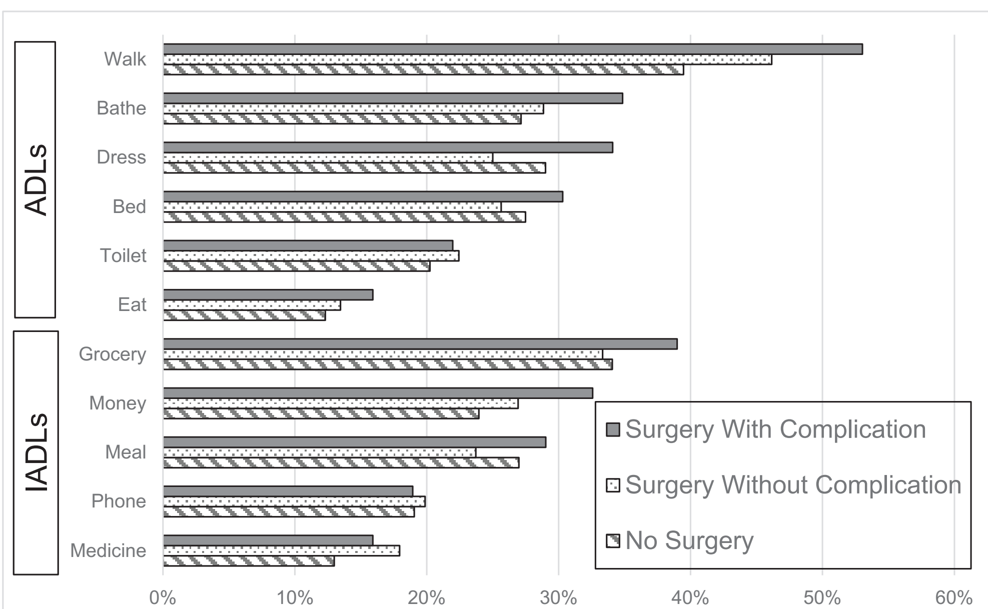

FIGURE 2. Specific functional limitations among those who experience decline. Proportion of patients requiring assistance among each of the functional measures.

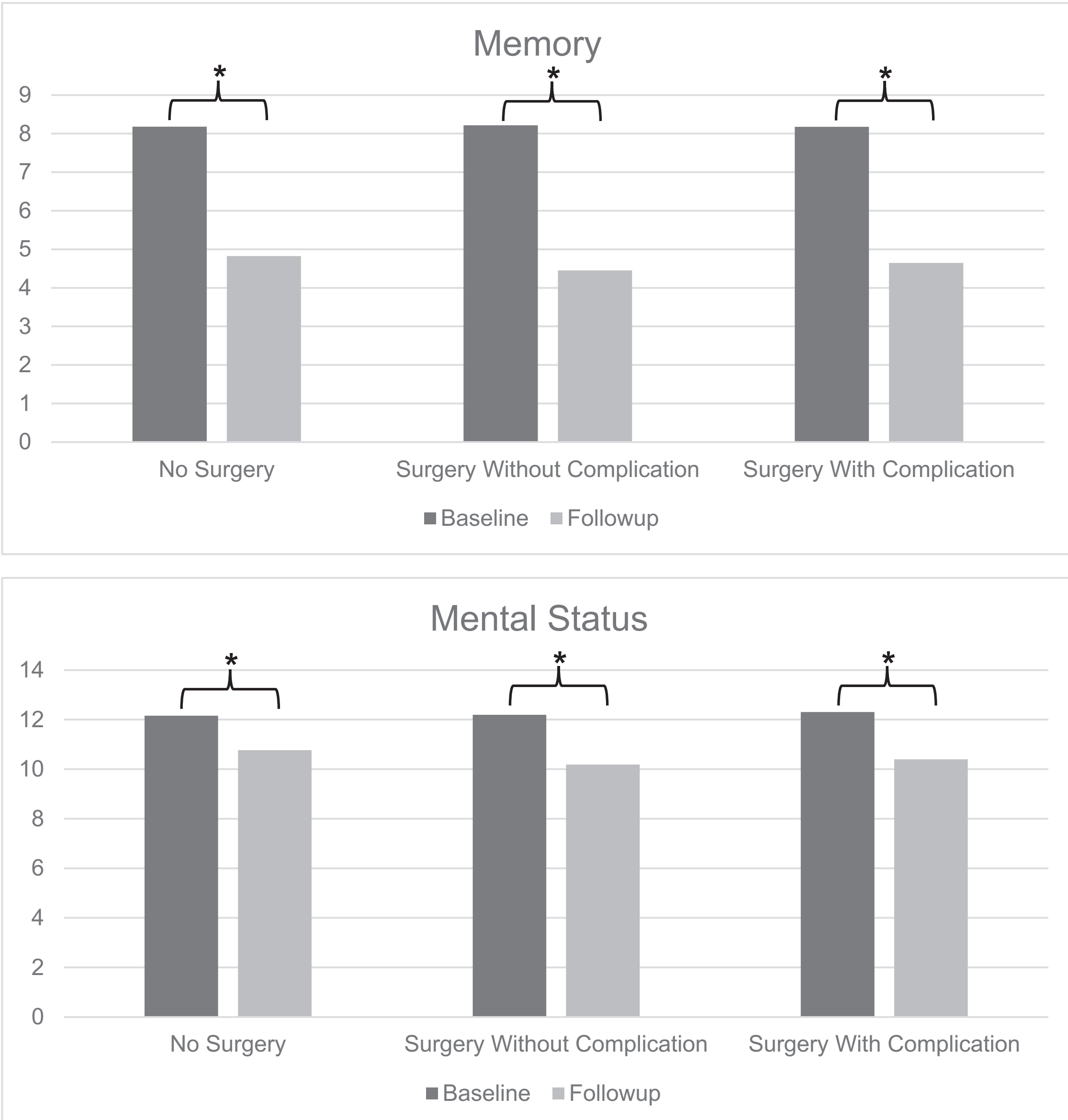

FIGURE 3. Specific cognitive impairments among those who experienced decline. Memory and mental status scores at baseline and follow-up (higher scores are better). ∗Indicates statistical significance ($P < 0.01$)

operation and any inadvertent sequelae, far less attention has been aimed at the long-term implications of surgery and complications among this vulnerable patient population.[26,27] Even in older adult patients who are "rescued" from death following a serious complication, the risk of prolonged recovery and potential disability is high.[28] Furthermore, ongoing care designed to prolong life among seriously ill patients may have only short-term impact—>40% of older adults admitted to intensive care units die within the year.[19,29] Indeed, a recent systematic review and meta-analysis by Watt et al identified 44 studies characterizing factors associated with postoperative complications among older adults undergoing elective surgery, and found only 6 studies examining functional decline and 13 measuring discharge destination.[30] Fewer studies specifically examine both functional and cognitive outcomes after surgery and complications beyond the immediate postoperative period, and the majority represent patients from single institutions with no regard for the effect on survival or economic impacts.[13] Here, we characterize the impact of surgery and complications on functional limitation and cognitive impairment among a broad range of individuals across the United States, with all levels of presurgical functional and cognitive abilities, using a unique dataset that allows for detailed examination of disability. Furthermore, we found that acquired deficiencies following surgery are associated with poorer long-term survival and increased healthcare utilization.

Avoidance or minimizing complications after major surgery is critical as subsequent disability affects well-being and social involvement as well as hospital and nursing home admissions. Moreover, older adults favor quality of life (eg, maintaining independence, living at home, not being a burden to family) over prolongation of life.[31,32] However, current measures for patient-reported postoperative recovery are poor, with function and cognition rarely assessed even in primary care settings.[33–35] Furthermore, beyond cardiac and orthopedic surgery, cognitive outcomes have received almost no attention.[36–38] Our study evaluated self-reported functional and cognitive outcomes after surgery in addition to specific disabilities that may be acquired. These detailed outcomes, lacking in other large datasets, are meaningful and interpretable to older adults.

Older adults may consent to procedures with unrealistic expectations due to an underappreciation for prolonged recovery and continued disability following surgery.[13] As a result, patients who undergo surgery and suffer a postoperative complication or a series of complications frequently receive unwanted invasive procedures.[39,40] These patients are subjected to further burdensome surgery, protracted recovery and disability, and poor quality of life or even prolonged dying.[41] With this knowledge and our findings of functional and cognitive prognoses, surgeons may be better equipped to have meaningful conversations about surgery and setting realistic expectations, particularly in those most vulnerable to postoperative complications and subsequent declines. Furthermore, such knowledge enables surgeons to better anticipate the needs of patients and their families such that specific individuals may be identified who may benefit from targeted interventions, particularly among the frail, such as prehabilitation, multicomponent interventions to reduce postoperative delirium, and/or strategies to restore independence in the postoperative setting such as intensive therapy in rehabilitation hospitals, all of which have been associated with better long-term outcomes.[42,43] This may also be an important opportunity to introduce nonsurgical options and/or initiate discussions with palliative care.[44] Finally, knowledge of these outcomes allows for better resource utilization and planning.[10]

We acknowledge the limitations to our study including the lack of granularity inherent to large data sets including details about decision-making and unmeasured factors including different measures of frailty and socioeconomic disadvantage, which are well known to negatively impact surgical and health outcomes.[45,46] However, we were able to examine an important patient-centered outcomes, ‘‘days at home,’’ between those who experience and those who do not experience decline, which is of great consequence to older adults.[47] In addition, the HRS linked with Medicare data permits data on functional and cognitive ability while ensuring accuracy in receipt of surgery and healthcare use. Using a nationally representative sample strengthens the generalizability of our results. Second, self-reported measures may be subject to bias but multiple landmark studies utilize self-reported ADLs and IADLs, which are acceptable in the geriatric literature.[7,48,49] Furthermore, the frequency of surveys may not capture immediate postoperative disability and recovery, which may influence long-term outcomes, and those who were lost to follow-up or died may underestimate our results.[50] However, the frequency of these surveys allows us to capture lasting, rather than self-limited, disability. Finally, we identified only those having undergone high-risk elective surgery and may have excluded patients who underwent lower risk surgery and still experienced a postoperative complication and subsequent decline, further underestimating the effect of surgery. Despite these limitations, however, the goal of this study was to evaluate meaningful and person-centered effects of surgery over time.

We identified those most vulnerable to worsening disability and ultimate death following high-risk surgery. Although we may not be able to avoid surgery, we may be able to improve patient selection and mitigate perioperative risk. Furthermore, knowledge of these longitudinal outcomes after surgery allows for more informed surgical decision-making and provides critical insight into how to better anticipate and manage the needs of older adults undergoing surgery. Finally, understanding the magnitude of healthcare utilization allows for resource planning. Together, this will allow for tailoring to specific needs and better inform surgeons and patients during the perioperative period when the risk of complications is high and the opportunity for meaningful recovery becomes less likely.

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