

## Original Investigation

# Effect of Delirium and Other Major Complications on Outcomes After Elective Surgery in Older Adults

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**IMPORTANCE** Major postoperative complications and delirium contribute independently to adverse outcomes and high resource use in patients who undergo major surgery; however, their interrelationship is not well examined.

**OBJECTIVE** To evaluate the association of major postoperative complications and delirium, alone and combined, with adverse outcomes after surgery.

**DESIGN, SETTING, AND PARTICIPANTS** Prospective cohort study in 2 large academic medical centers of 566 patients who were 70 years or older without recognized dementia or a history of delirium and underwent elective major orthopedic, vascular, or abdominal surgical procedures with a minimum 3-day hospitalization between June 18, 2010, and August 8, 2013. Data analysis took place from December 13, 2013, through May 1, 2015.

**MAIN OUTCOMES AND MEASURES** Major postoperative complications, defined as life-altering or life-threatening events (Accordion Severity grade 2 or higher), were identified by expert-panel adjudication. Delirium was measured daily with the Confusion Assessment Method and a validated medical record review method. The following 4 subgroups were analyzed: (1) no complications or delirium; (2) complications only; (3) delirium only; and (4) complications and delirium. Adverse outcomes included a length of stay (LOS) of more than 5 days, institutional discharge, and rehospitalization within 30 days of discharge.

**RESULTS** In the 566 participants, the mean (SD) age was 76.7 (5.2) years, 236 (41.7%) were male, and 523 (92.4%) were white. Forty-seven patients (8.3%) developed major complications and 135 (23.9%) developed delirium. Compared with no complications or delirium as the reference group, major complications only contributed to prolonged LOS only (relative risk [RR], 2.8; 95% CI, 1.9-4.0); by contrast, delirium only significantly increased all adverse outcomes, including prolonged LOS (RR, 1.9; 95% CI, 1.4-2.7), institutional discharge (RR, 1.5; 95% CI, 1.3-1.7), and 30-day readmission (RR, 2.3; 95% CI, 1.4-3.7). The subgroup with complications and delirium had the highest rates of all adverse outcomes, including prolonged LOS (RR, 3.4; 95% CI, 2.3-4.8), institutional discharge (RR, 1.8; 95% CI, 1.4-2.5), and 30-day readmission (RR, 3.0; 95% CI, 1.3-6.8). Delirium exerted the highest attributable risk at the population level (5.8%; 95% CI, 4.7-6.8) compared with all other adverse events (prolonged LOS, institutional discharge, or readmission).

**CONCLUSIONS AND RELEVANCE** Major postoperative complications and delirium are separately associated with adverse events and demonstrate a combined effect. Delirium occurs more frequently and has a greater effect at the population level than other major complications.

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**T**hirty-six percent of inpatient operations were performed in patients who were 65 years or older.<sup>1</sup> The number of patients is projected to increase as the population ages.<sup>1,2</sup> Understanding the risks of adverse outcomes in the aging surgical population is essential to implementing programs with the potential to decrease morbidity, mortality, and costs and to increase safety. Postoperative complications increase with advancing age.<sup>3,4</sup> These complications, which occur in 10% to 25% of older persons,<sup>3-7</sup> can lead to adverse outcomes, such as disability, loss of independence, diminished quality of life, high health care costs, and increased mortality.<sup>8</sup> Physiologic changes across cardiovascular, neurological, and pulmonary systems contribute to the increasing risk of postoperative complications with advancing age.<sup>6,8</sup>

Postoperative delirium has been well documented<sup>9-12</sup> as the leading complication of major surgery with adverse consequences in older persons. It is associated with higher in-hospital and 6-month mortality, functional decline, greater rates of institutional discharge, longer lengths of stay (LOS), increased use of hospital resources, and higher health care costs.<sup>9-14</sup> Delirium rates following surgery range from 5% to 50%.<sup>12,14,15</sup> Its effect on annual health care costs is estimated to be more than \$182 billion per year in the United States (reported in 2011 dollars)<sup>16</sup> and thus has received increasing attention as a public health and patient safety priority.<sup>17</sup> Because complications and delirium are often preventable, they can be tracked and monitored as markers of quality of care.<sup>18</sup> Such markers have become a major focus of the National Quality Forum<sup>19</sup> and emerged at the forefront of many quality improvement initiatives. The Centers for Medicare & Medicaid Services plan to use patient safety indicators as part of evidence-based conditions by which to adjust payments to hospitals.<sup>20</sup>

Delirium is often considered a less serious event than other major postoperative complications. An impetus for this study was to examine whether delirium should be considered equivalent to other major life-altering or life-threatening postoperative complications. Other postoperative complications are risk factors for delirium; delirium and complications can coexist. However, to our knowledge, the interrelationship of delirium and other postoperative complications on the occurrence of adverse outcomes following elective noncardiac surgery has not been well examined.

Specific aims were to evaluate the association of major postoperative complications and delirium with adverse outcomes (prolonged LOS, institutional discharge, and 30-day readmission) and to examine the combined effect of postoperative complications and delirium on adverse outcomes. For this study, delirium was not counted among the major postoperative complications but was instead considered separately. Our *a priori* hypotheses were that major complications and delirium would be separately and independently associated with adverse outcomes and that the highest risk of adverse outcomes would be seen in the presence of both delirium and other complications.

## Methods

### Study Participants

The Successful Aging after Elective Surgery (SAGES) study<sup>21</sup> is a prospective cohort study of older adults who underwent major elective surgery. The study design and methods have been described in detail previously.<sup>21</sup> In brief, eligible participants were 70 years or older, English speaking, and scheduled to undergo elective surgery at Beth Israel Deaconess Medical Center or Brigham and Women's Hospital, with an anticipated LOS of at least 3 days. Eligible surgical procedures with moderate to high risk of incident delirium included total hip or knee replacement; lumbar, cervical, or sacral laminectomy; lower-extremity arterial bypass surgery; open abdominal aortic aneurysm repair; and open or laparoscopic colectomy. Exclusion criteria included evidence of dementia, active delirium or hospitalization within 3 months, a terminal condition, legal blindness or severe deafness, a history of schizophrenia or psychosis, and a 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).

### Assessment of Major Postoperative Complications

Major postoperative complications other than delirium were defined as those that occurred during the hospital stay following the index surgery and were obtained through a detailed medical record review conducted by trained research physicians. An expert panel of 3 geriatricians (L.J.G., E.R.M., and S.K.I.) and 1 surgeon (Z.C.), who were masked to delirium status and all study outcomes, adjudicated the presence and severity of all complications. Complications were considered major when they met or exceeded Accordion Severity grade 2<sup>22</sup> and were defined as life threatening (eg, high mortality) or life altering (eg, stroke with neurological sequela) by the expert panel. The expert panel excluded urinary tract infection, deep vein thrombosis without pulmonary embolism, and anemia with or without blood transfusion because these were not considered life altering or life threatening. Serious complications related to these exclusions (eg, sepsis, pulmonary embolism, or unplanned return to surgery) were included. All complications were reviewed by at least 3 of the 4 adjudicators; the surgeon reviewed all cases. To achieve consensus, agreement was required by at least 2 of the 3 final adjudicators. The final set of major complications included in the analysis is shown in **Table 1**.

### Delirium Diagnosis

Delirium assessment was conducted daily beginning the day after surgery by trained staff using the Confusion Assessment Method (CAM),<sup>23</sup> augmented with a validated medical record review method.<sup>24</sup> The CAM has been validated in mul-

Table 1. Rates of Major Postoperative Complications in 566 Patients

Major Complications, Excluding Delirium	Patients, No. (%)
Unstable arrhythmia <sup>a</sup>	23 (4.1)
New heart block <sup>b</sup>	1 (0.2)
NSTEMI	4 (0.7)
Respiratory failure <sup>c</sup>	11 (1.9)
Pulmonary embolism	5 (0.9)
Pneumonia	2 (0.4)
Sepsis	2 (0.4)
New renal failure <sup>d</sup>	2 (0.4)
Stroke	2 (0.4)
Surgical complications <sup>e</sup>	8 (1.4)
Any complication	47 (8.3)

Abbreviation: NSTEMI, non-ST segment elevation myocardial infarction.

<sup>a</sup> New atrial fibrillation and/or flutter or other supraventricular tachycardia requiring treatment.

<sup>b</sup> Requiring a pacemaker.

<sup>c</sup> Includes pulmonary edema, respiratory distress, reintubation, and inability to wean from a ventilator.

<sup>d</sup> Requiring dialysis.

<sup>e</sup> Surgical wound infection, surgery-specific complications, and unplanned return to the operating room.

tiple settings and is a widely used standardized method for identifying delirium with a high sensitivity of 94% (95% CI, 91%-97%), high specificity of 89% (95% CI, 85%-94%), and high interrater reliability ( $\kappa = 0.70$ -1.00).<sup>24,25</sup> The CAM algorithm requires the presence of acute change in or a fluctuating course of mental status symptoms, inattention, and either disorganized thinking or an altered level of consciousness to fulfill criteria for delirium. The CAM was rated based on information from participant interviews, including a brief cognitive test,<sup>21</sup> the Delirium Symptom Interview,<sup>26</sup> and reports from family members or nurses. Findings were adjudicated by a geriatrician and a neuropsychologist, both of whom had extensive training in delirium assessment. For the validated medical record review, abstractors searched all sections of the medical record and coded as yes if any keywords or descriptors of delirium were noted in the delirium assessment.<sup>23,27</sup> The combination of the CAM with validated medical record review has been used in previous studies.<sup>27</sup>

## Study Outcomes

Adverse outcomes used in this study were those associated with high resource use, including prolonged LOS, institutional discharge, and readmission defined at 30 days. The LOS was obtained from the medical record review. A cutoff of more than 5 days (greater than the mean of 5.2 days in our sample) was used to indicate a prolonged LOS. Institutional discharge included any discharge to a nursing home or subacute or acute rehabilitation facility and was obtained from the discharge note in the medical records. Readmission within 30 days to any hospital following surgery was self-reported by study participants at a follow-up interview 1 month after surgery. The accuracy of the self-reported information on readmission was verified by medical record review in a sample of 208 participants. Overall agreement on the total number of admissions

was 90% ( $\kappa = 0.79$ ; 95% CI, 0.71-0.87) and agreement on the date of the admissions was 99% ( $\kappa = 0.78$ ; 95% CI, 0.72-0.85), indicating substantial agreement.<sup>28</sup> A composite variable was created indicating the presence of any of the 3 adverse outcomes.

## Other Study Variables

During the baseline assessment, participants reported their age, sex, years of formal education, race, ethnicity, and marital status. Medical record review was used to collect comorbidities, surgery type, anesthesia type, and American Society of Anesthesiologists classification. Comorbidity burden was calculated using the Charlson Comorbidity Index,<sup>29</sup> which predicts 10-year mortality by assigning points to each comorbid condition, with a higher score indicating greater mortality risk. Physical function before admission was assessed using the Activities of Daily Living (ADL) and Instrumental ADL scales.<sup>30,31</sup> Participants were considered impaired if they required help from another person with any of the activities.

## Statistical Analysis

The baseline characteristics and rates of adverse outcomes for participants with and without delirium and major postoperative complications are reported as means (SDs) for continuous variables and proportions for categorical variables. The sample was analyzed in 4 groups consisting of patients with (1) no complications or delirium (which served as the reference group); (2) complications only; (3) delirium only; and (4) complications and delirium.

Robust Poisson regression<sup>32</sup> was used to estimate the relative risk (RR) and 95% CI for each adverse outcome as well as the risk of any adverse outcome associated with delirium and/or major postoperative complications. Models were adjusted for baseline age in years, male sex, nonwhite race, anesthesia type (general vs spinal), Charlson Comorbidity Index score,<sup>29</sup> and type of surgery (orthopedic vs vascular or general). The population attributable risk, which measures the proportion of each clinical outcome that could potentially be reduced if either exposure (complications or delirium) was eliminated, was calculated as the product of a function of the RR of the outcome associated with the exposure and the prevalence of the exposure. All analyses were conducted using Stata MP, version 13.0 (StataCorp LP). Null hypotheses were tested using a 2-tailed  $\alpha$  of .05.

## Results

Table 1 shows the incidence and frequency of each major postoperative complication other than delirium. Of the 47 participants with major complications, most (36 [76.6%]) had 1 complication, 10 (21.3%) had 2 complications, and 1 participant (2.1%) had 4 complications. The most common complications were unstable arrhythmias (23 of 566 [4.1%]) or respiratory failure (11 of 566 [1.9%]). Other surgical complications (8 of 566 [1.4%]) included unplanned return to the operating room for a range of procedures, such as umbilical hernia repair, spinal abscess incision and drainage, abdominal compartment

Table 2. Characteristics of the Study Population

Characteristic	Value <sup>a</sup>				
	Full Sample (N = 566)	No Complications or Delirium (n = 404)	Complications Only (n = 27)	Delirium Only (n = 115)	Complications and Delirium (n = 20)
Age, mean (SD), y	76.7 (5.2)	76.3 (5.1)	79.2 (6.5)	77.7 (5.0)	76.1 (5.0)
Male sex	236 (41.7)	168 (41.7)	15 (55.6)	42 (36.5)	11 (55.0)
Low educational level	24 (4.2)	17 (4.2)	0	5 (4.3)	2 (10.0)
Not white or Hispanic	43 (7.6)	29 (7.2)	1 (3.7)	13 (11.3)	0
Unmarried	231 (40.8)	165 (40.8)	10 (37.0)	53 (46.1)	3 (15.0)
Charlson Comorbidity Index score, mean (SD)	1.0 (1.3)	0.9 (1.2)	1.5 (1.8)	1.1 (1.2)	2.4 (1.9)
≥2	167 (29.5)	101 (25.0)	8 (29.6)	46 (40.0)	12 (60.0)
Any ADL impairment <sup>b</sup>	42 (7.4)	27 (6.7)	3 (11.1)	11 (9.6)	1 (5.0)
Any Instrumental ADL impairment <sup>b</sup>	157 (27.7)	100 (24.8)	8 (29.6)	40 (34.8)	9 (45.0)
Surgery type					
Orthopedic	460 (81.3)	337 (83.4)	17 (63.0)	94 (81.7)	12 (60.0)
Vascular	35 (6.2)	19 (4.7)	5 (18.5)	7 (6.1)	4 (20.0)
General	71 (12.5)	48 (11.9)	5 (18.5)	14 (12.2)	4 (20.0)
Anesthesia type					
General	479 (84.6)	336 (83.2)	23 (85.2)	101 (87.8)	19 (95.0)
Spinal	78 (13.8)	63 (15.6)	2 (7.4)	12 (10.4)	1 (5.0)
Both	4 (0.7)	2 (0.5)	1 (3.7)	1 (0.9)	0
ASA classification					
1	2 (0.4)	2 (0.5)	0	0	0
2	207 (36.6)	166 (41.1)	8 (29.6)	31 (27.0)	2 (10.0)
3	352 (62.2)	234 (57.9)	17 (63.0)	83 (72.2)	18 (90.0)
4	5 (0.9)	2 (0.5)	2 (7.4)	1 (0.9)	0

Abbreviations: ADL, Activities of Daily Living; ASA, American Society of Anesthesiologists physical status classification system.

<sup>b</sup> Impairment was defined as any impairment in 1 or more basic (or Instrumental) activity of daily living.

<sup>a</sup> Data are presented as the number (percentage) of patients unless otherwise indicated.

Table 3. Adverse Outcomes by Complication and Delirium Status

Status	Length of Stay		No. (%)		
	Mean (SD), d	>5 d, No. (%)	Institutional Discharge	30-d Readmission	Any Adverse Outcome
Total sample (N = 566)	5.2 (3.3)	144 (25.4)	323 (57.1)	67 (11.8)	399 (70.5)
No complications or delirium (n = 404)	4.6 (1.8)	69 (17.1)	202 (50.0)	34 (8.4)	252 (62.4)
Complications only (n = 27)	7.5 (3.8)	17 (62.9)	13 (48.1)	5 (18.5)	22 (81.5)
Delirium only (n = 115)	5.5 (2.1)	40 (34.8)	93 (80.9)	22 (19.1)	105 (91.3)
Complications and delirium (n = 20)	13.3 (11.4)	18 (90.0)	15 (75.0)	6 (30.0)	20 (100)

syndrome, anastomotic leak, wound exploration, deep surgical site infections, and drainage of a pelvic abscess.

The baseline characteristics of the 566 study participants are shown in Table 2. The mean (SD) age was 76.7 (5.2) years. A total of 236 participants (41.7%) were men and most (523 [92.4%]) were white. The most frequently performed surgical procedures were orthopedic (460 [81.3%]), followed by general (71 [12.5%]) and vascular (35 [6.1%]). Participants underwent 116 (20.5%) total hip replacements, 209 (36.9%) total knee replacements, 113 (20.0%) lumbar laminectomies, 22 (3.9%) cervical laminectomies, 23 (4.1%) lower-extremity bypasses, 12 (2.1%) open abdominal aortic aneurysm repairs, 32 (5.7%) open colectomies, and 39 (6.9%) laparoscopic colectomies. Most procedures (479 [84.6%]) used general anesthesia. Overall, this

group was highly functional, with only 42 (7.4%) having any ADL impairment. Major complications occurred in 47 participants (8.3%) and delirium occurred in 135 participants (23.9%).

Differences in baseline characteristics across the 4 study subgroups are shown in Table 2. The subsample of participants with complications only (no delirium) had the highest mean (SD) age (79.2 [6.5] years) whereas those with both a major complication and delirium had higher mean (SD) scores on the Charlson Comorbidity Index (2.4 [1.9]), Instrumental ADL impairment (9 of 20 [45.0%]), and mean (SD) American Society of Anesthesiologists classifications (18 of 20 [90.0%]) were class 3).

The distribution of adverse clinical outcomes overall and across the 4 study subgroups is shown in Table 3. Overall, the

Table 4. Association of Adverse Hospital Outcomes by Complication and Delirium Status<sup>a</sup>

Status	Adjusted Relative Risk (95% CI) <sup>b</sup>		
	Length of Stay >5 d	Institutional Discharge	30-d Readmission
No complications or delirium (n = 404)	1 [Reference]	1 [Reference]	1 [Reference]
Complications only (n = 27)	2.8 (1.9-4.0)	1.0 (0.7-1.5)	1.6 (0.6-4.2)
Delirium only (n = 115)	1.9 (1.4-2.7)	1.5 (1.3-1.7)	2.3 (1.4-3.7)
Complications and delirium (n = 20)	3.4 (2.3-4.8)	1.8 (1.4-2.5)	3.0 (1.3-6.8)

<sup>a</sup> Adjusted for age, sex, race, Charlson Comorbidity Index score, surgery type (orthopedic vs all others), and anesthesia type (general vs spinal).

<sup>b</sup> Relative risks were calculated with a generalized linear model, Poisson error term, log-link, and robust error variance.

Table 5. Association of any Adverse Hospital Outcomes by Complication and Delirium Status<sup>a</sup>

Status	Any Adverse Outcome		
	Patients, No. (%)	Adjusted RR (95% CI) <sup>b</sup>	PAR, % (95% CI) <sup>c</sup>
No complications or delirium (n = 404)	252 (62.4)	1 [Reference]	1 [Reference]
Complications only (n = 27)	22 (81.5)	1.2 (1.0-1.6)	0.8 (0.0-1.5)
Delirium only (n = 115)	105 (91.3)	1.4 (1.3-1.5)	5.8 (4.7-6.8)
Complications and delirium (n = 20)	20 (100)	1.6 (1.4-1.8)	1.3 (1.0-1.6)

Abbreviations: PAR, population attributable risk; RR, relative risk.

<sup>a</sup> Adjusted for age, sex, race, Charlson Comorbidity Index score, surgery type (orthopedic vs all others), and anesthesia type (general vs spinal).

<sup>b</sup> Relative risks were calculated with a generalized linear model, Poisson error term, log-link, and robust error variance.

<sup>c</sup> Population attributable risk percentage is the product of a function of the RR of the outcome associated with the exposure and the prevalence of adverse outcome. It is the difference in rate of a condition between an exposed population and an unexposed population.

mean (SD) LOS was 5.2 (3.3) days, while the reference group (no complications or delirium) had a mean (SD) LOS of 4.6 (1.8) days. The mean (SD) LOS was highest in the subgroups with complications only (7.5 [3.8] days) and complications and delirium (13.3 [11.4] days).

A total of 323 participants (57.1%) were discharged to an institution. The overall proportion of patients who were discharged to an institution was greater in the subgroups with delirium only (93 of 115 [80.9%]) and both complications and delirium (15 of 20 [75.0%]) than in those with major complications only (13 of 27 [48.1%]). Readmission within 30 days occurred in 11.8% of the total sample (n = 67), with a larger number in those with both major complications and delirium (6 of 20 [30.0%]). Together, major complications and delirium exerted a cumulative effect on rehospitalization.

Adjusted risks of adverse outcomes across the 4 study subgroups are presented in Table 4. Participants with complications only (n = 27) were more likely to have a prolonged LOS (RR, 2.8; 95% CI, 1.9-4.0) than those with no complications or delirium, but this subgroup had no other significant association with adverse outcomes. The subgroup with delirium only (n = 115) had significantly increased risks for all adverse outcomes, including a nearly 2-fold increased risk of prolonged LOS (RR, 1.9; 95% CI, 1.4-2.7), a 50% increased risk of institutional discharge (RR, 1.5; 95% CI, 1.3-1.7), and an increased risk of more than 2-fold (RR, 2.3; 95% CI, 1.4-3.7) of 30-day readmission compared with those without complications or delirium. The subgroup with both complications and delirium (n = 20) had the largest increased RRs for all adverse outcomes, including prolonged LOS (RR, 3.4; 95% CI, 2.3-4.8), institutional discharge (RR, 1.8; 95% CI, 1.4-2.5), and readmission (RR, 3.0; 95% CI, 1.3-6.8) compared with the other groups.

The associations of delirium, major complications, or both are measured with the composite variable of any adverse out-

come shown in Table 5. Across all subgroups, when compared with the reference group of no complications or delirium, the RR of any adverse outcome was substantially increased. Delirium exerts the strongest risk on adverse outcomes at a population level (for any adverse outcome, 5.8% [95% CI, 4.7-6.8] for delirium only vs 0.8% [95% CI, 0.0-1.5] for complications only, and 1.3% [95% CI, 1.0-1.6] for both complications and delirium).

A descriptive analysis among surgery subtypes (eTable in the Supplement) showed no difference in delirium incidence or any adverse outcome. There was a difference noted for postoperative complications and individual adverse events. A sensitivity analysis did not demonstrate any statistically significant difference in RRs of adverse outcomes with and without adjustment for orthopedic surgery.

## Discussion

This study investigated the rates of incident major complications and delirium following major elective surgery in older adults. It is unique in examining their separate contributions to adverse outcomes and their interrelationship in contributing to these outcomes. Major complications alone contributed significantly to prolonged LOS only while delirium alone contributed significantly to all adverse outcomes (LOS, institutional discharge, and readmission). When delirium and other major complications occurred together, the effect on adverse outcomes was the greatest, but this effect occurred relatively infrequently (20 of 566 participants [3.5%]). Delirium is not consistently considered a major postoperative complication.<sup>4,8,33</sup> However, given its prevalence and clinical effect, delirium should be considered a leading postoperative complication for predicting adverse hospital outcomes. At the population level, delirium alone exerts the greatest effect, with



approximately 1 of 17 patients in our study experiencing an adverse outcome attributable to delirium.

Rates of major complications following elective surgery in this cohort were 8.3%, with no observed in-hospital mortality. These rates were lower than some previously published rates, which ranged from 10% to 25% following noncardiac surgical procedures. One explanation for the difference is the wide range of definitions used to define postoperative complications,<sup>4,5,8,18,33,34</sup> differences in the type of surgery, and varying populations. In addition, we evaluated delirium rates separately while some prior studies<sup>4,5,7</sup> included delirium as a surgical complication. In our cohort, participants who developed major complications had longer LOS but were not found to be at increased risk of institutional discharge or readmission. It is possible that the LOS related to the occurrence of a complication may have allowed sufficient recovery for the participants to be safely discharged to home.

Delirium occurred more frequently than all other major complications combined in our surgical population (23.9% vs 8.3%). Our observed rate of delirium was comparable with other published<sup>14</sup> rates for elective noncardiac surgical procedures, which range from 9.0% to 29.1%. Delirium was associated with prolonged LOS, an increased risk of institutional discharge, and readmission and was consistent with prior studies, which have demonstrated that delirium is independently associated with poor postoperative outcomes.<sup>35</sup>

The largest risk of adverse outcomes occurred in the presence of both delirium and postoperative complications. Together, postoperative complications and delirium resulted in longer LOS, increased risk of postacute discharge, and readmission than the presence of complications or delirium alone. These results suggest that it is important to manage delirium and major postoperative complications simultaneously to reduce the risks posed by both conditions. Efforts should be implemented in those at high risk of delirium or complications following elective noncardiac surgery. Preventive strategies, such as the Hospital Elder Life Program, proactive geriatric consultation, and comanagement services, have been shown to be effective to reduce delirium, ideally when implemented before and continued after surgery.<sup>36-40</sup>

Delirium following surgery affects hospitals because failure to prevent delirium can contribute to prolonged LOS, re-

admission rates, increased facility discharges, and ultimately, high resource use. Such use is increasingly being paid for by hospitals through bundled and global payment systems. The best way to avoid these penalties is through improvements in delirium prevention and management. This method can also improve the value of care that is provided to older adults, who are increasingly represented in the evolving demographics of acute care.

There are several noteworthy strengths to our study, including the large prospectively collected and clinically rich data set; delirium assessment using state-of-the-art methods; careful maintenance of masked outcome assessment with respect to major complications and adverse hospital outcomes; medical record reviews by physician experts; a rigorous adjudication process of major complications by an expert panel; and a low rate of missing data.

Our study was limited in that it was conducted at 2 hospitals and included a highly educated, mostly white sample with a low complication rate—thus, while internal validity is not affected, generalizability may be limited. Findings will need to be replicated in other settings with more diverse samples. Unfortunately, we did not collect data on the management of complications among subgroups; thus, we could not evaluate whether differences in recognition and treatment of complications may have influenced the findings. Furthermore, there were few complications and it was not always possible to establish the temporal relationship between the development of the complication and delirium; therefore, a causal relationship between delirium and complications could not be examined.

## Conclusions

Delirium was associated with increased rates of all adverse outcomes while major postoperative complications were associated with prolonged LOS. The highest risk of all adverse outcomes was seen in the presence of both delirium and postoperative complications. Given its high prevalence and negative effect, delirium should be considered as the leading postoperative complication contributing to adverse outcomes.

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**Drafting of the manuscript:** Gleason, Kosar, Robinson, Jones, Inouye.

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**Study supervision:** Tabloski, Rogers, Jones, Marcantonio, Inouye.

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