Outcomes of Early Delirium Diagnosis After General Anesthesia in the Elderly

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BACKGROUND: Postoperative delirium in the elderly, measured days after surgery, is associated with significant negative clinical outcomes. In this study, we evaluated the prevalence and in-hospital outcomes of delirium diagnosed immediately after general anesthesia and surgery in elderly patients.

METHODS: Consecutive English-speaking surgical candidates, aged 70 years or older, were prospectively enrolled during July to August 2010. After surgery, each participant was evaluated for a Diagnostic and Statistical Manual of Mental Disorders IV diagnosis of delirium in the postanesthesia care unit (PACU) and repeatedly thereafter while hospitalized. Delirium in the PACU was evaluated for an independent association with change in cognitive function from preoperative baseline testing and discharge disposition.

RESULTS: Ninety-one (58% female) patients, 78% of whom were living independently before surgery, were found to have a prevalence of delirium in the PACU of 45% (41/91); 74% (4/19) of all delirium episodes detected during subsequent hospitalization started in the PACU. Early delirium was independently associated with impaired cognition (i.e., decreased category word fluency) relative to presurgery baseline testing (adjusted difference [95% confidence interval] for change in T-score: −6.02 [−10.58 to −1.45]; P = 0.01). Patients whose delirium had resolved by postoperative day 1 showed negative outcomes that were intermediate in severity between those who were never delirious during hospitalization and those whose delirium in the PACU persisted after transfer to hospital wards (adjusted probability [95% confidence interval] of discharge to institution: 3% [0%–10%], 26% [1%–51%], 39% [0%–81%] for the 3 groups, respectively).

CONCLUSIONS: Delirium in the PACU is common, but not universal. It is associated with subsequent delirium on the ward, and potentially with a decline in cognitive function and increased institutionalization at hospital discharge. (Anesth Analg 2013;117:471–8)
The objectives of the current study were: (1) to evaluate the prevalence of delirium in the PACU and during subsequent inpatient hospital stay for elderly surgical patients undergoing general anesthesia for a wide variety of surgical procedures using direct neuropsychiatric examination and (2) to assess independent associations of delirium in the PACU with patient outcomes including change in cognition from preoperative baseline and health care resource utilization including discharge disposition.

**METHODS**

**Patients**

This study was approved by the Johns Hopkins IRB; the requirement for written informed consent was waived. Verbal informed consent was obtained from all participants.

All consecutive English-speaking patients, aged 70 years and older, scheduled to undergo elective or emergent surgery with general anesthesia at a teaching hospital on weekdays for 8 weeks from July to August 2010 were eligible for participation. Patients were excluded if they were cognitively incapable of providing informed consent before surgery using an IRB-approved structured evaluation of their decision-making capacity.13

**Baseline Physical and Cognitive Status Before Surgery**

The baseline physical and cognitive status of patients was obtained by a research assistant via either phone interview (if undergoing elective surgery) or in-person interview (if undergoing emergent surgery, or in the event that a phone interview could not be completed). The following instruments were used: (1) Activities of Daily Living,14 which assesses basic physical function (e.g., bathing, dressing); (2) Instrumental Activities of Daily Living,15 which assesses higher level physical function (e.g., ability to prepare meals and perform housekeeping); (3) Forward and Backward Digit Span tests, which evaluate immediate memory, frontal lobe, and executive function, respectively;1617 (4) Letter (“s” and “p”) and Category (animals) Word Fluency tests from the Calibrated Ideational Fluency Assessment were used to assess working memory, attention, and executive function;21 and (5) the Mini-Mental State Exam (MMSE),19 for in-person interviews or the 26-item version for telephone interviews20 converted to the standard 30-item MMSE score. For digit span and verbal fluency tests, raw scores were converted to T-scores (mean = 50, SD = 10), based on population norms controlling for age, sex, and education.21

**Other Covariates**

The following were obtained preoperatively from the patient interview: demographics; residence and living arrangements; alcohol, tobacco and sedative use; and self-reported memory problems. The following additional data were obtained from the medical record: Charlson comorbidity index,22 preoperative laboratory values (serum sodium, potassium, bicarbonate, total calcium, albumin, creatinine, blood urea nitrogen, hematocrit, white blood cell count), type and dose of IV anesthetics, total IV fluids received during surgery, and surgery duration (time between patient entry and exit from surgical suite). Hospital charges and length of stay data were also collected.

**Delirium Assessment**

Reference raters for the delirium assessment included 2 physician experts who evaluated each patient for delirium using the Diagnostic and Statistical Manual of Mental Disorders (DSM) IV criteria: (1) a board-certified psychiatrist and director of the inpatient psychiatry consultation service with >20 years of clinical experience (KJN) and (2) a 4th year psychiatry resident. The resident psychiatrist performed >25 neuropsychiatric examinations under supervision of the board-certified psychiatrist before starting this study, and then performed DSM-IV–based delirium evaluations on 15 patients in the PACU throughout the study under the direct observation of the board-certified psychiatrist who made her own independent ratings of delirium with excellent inter-rater agreement (κ = 0.93).

The DSM-IV delirium assessment was based on a neuropsychiatric evaluation of the patient (including MMSE) and all available information gathered in the PACU, including interview of the nurses responsible for the patient. Timing of the PACU delirium assessment was standardized, occurring once the patient reached an Aldrete score23 ≥9 indicating an appropriate level of wakefulness, hemodynamic and respiratory stability for discharge to phase 2 recovery as an outpatient or transfer to an inpatient unit. This same neuropsychiatric assessment for delirium was repeated daily 5 days per week after surgery for those patients admitted to hospital. The psychiatrists performing all delirium evaluations were blind to preoperative cognitive testing results.

**Outcome Measures**

At hospital discharge, digit span and verbal fluency cognitive tests performed preoperatively were repeated by research assistants who were blind to the DSM-IV delirium assessment results. Outcome measures evaluated in this study were: (1) change in cognitive test scores at hospital discharge versus preoperative baseline and (2) disposition at hospital discharge. Since MMSE was used as part of the daily neuropsychiatric assessment,24 it was not included as an outcome measure. Assessment of Activities of Daily Living and Instrumental Activities of Daily Living were not repeated at hospital discharge due to the confounding effects of hospitalization, rather than delirium, on these measures.

**Statistical Analysis**

Fisher exact or Wilcoxon rank-sum tests were used to assess univariate (such as time to evaluation in the PACU) as well as bivariate associations of each of the baseline and demographic covariates in patients with versus without delirium in the PACU. The set of candidate covariates evaluated in this study was determined based on previous literature and knowledge of expected exposure–outcome associations. Not all covariates could be included in the multivariable regression model due to concern for overfitting.2526 Hence, a standard multivariable regression model building technique of choosing covariates based on strength of bivariable association with delirium was used. This was operationalized as the covariate having $P < 0.10$ in bivariantal analyses of the covariate and the outcome, with the goal of avoiding overfitting by aiming for a ratio of covariates to outcomes of approximately 1 to 10.2526 All $P$ values were 2-sided with $P < 0.05$ indicating...
statistical significance. Data analyses were performed using
STATA v.11(StataCorp, College Station, TX).27

To estimate the association of delirium in the PACU
(exposure), with the change in cognitive test scores from
preoperative baseline to hospital discharge (outcome), lin-
ear regression models with random intercepts28 were used,
adjusting for the following covariates: (1) baseline MMSE
and (2) surgery duration. There are 4 standard assump-
tions of any linear regression model: (1) linear relationship
between the independent and dependent variables, (2) con-
stant variance of residuals over time and as a function of
each covariate, (3) residuals are normally distributed, and
(4) residuals are independent. Our linear mixed effects
model is an extension to the standard linear regression
model, which allows for residuals to be correlated within
individuals over time. Appropriateness of assumptions and
model fit was assessed via graphical methods, including
plots of adjusted versus observed outcomes and adjusted
values versus residuals at each time point.

For evaluating the effect of PACU delirium (exposure) on
discharge location, logistic multivariable regression models
were used, adjusting for the following covariates: (1) base-
line MMSE, (2) surgery duration, and (3) preoperative resi-
dence (e.g., home, nursing home).

As a secondary analysis to evaluate for a dose–response
relationship of delirium duration,29 associations with each of
the above outcome measures were evaluated for the fol-
lowing discrete subgroups of admitted patients: (1) patients
who were never delirious during the hospitalization, (2)
patients with delirium only in the PACU (i.e., resolution
on postoperative day 1), and (3) patients with delirium that
started in the PACU and extended into the postoperative
hospitalization on the inpatient ward.

RESULTS

Figure 1 outlines the consort flow diagram. The participants
had a mean age of 79 years, 58% were females, 89% were
Caucasian, and 45% reported at least some college educa-
tion (Table 1). Most (82%) were retired, 78% were living in
their own homes, and 23% were living alone before surgery.
Anesthetic technique was comparable among subjects and
for >90% of the sample, consisted of propofol induction fol-
lowed by maintenance with isoflurane, narcotic, and muscle
relaxation as needed. Forty-six percent (n = 42) of patients
received midazolam.

On reaching an Aldrete score ≥9, the prevalence of
delirium in the PACU was 45%. The median interquartile
range (IQR) time from operating room exit to start of neu-
ropsychiatric examination in the PACU for those patients
determined to be delirious versus not delirious was 48
(33–62) vs 42 (28–53) minutes (P = 0.70). Table 1 includes
the bi-variate analyses of preoperative factors associated with
delirium in the PACU. Other covariates collected in this study
but not reported in Table 1 were not associated with delirium,
including the doses of narcotic (administered both intraopera-
tively and in the recovery room), propofol, and midazolam.

After PACU delirium assessment, 24 patients (of whom
38% were delirious) were discharged home the same day
(Fig. 1). Of the 67 admitted patients, 58 had at least 1 delir-
ium assessment on subsequent hospital days, for a total of
224 days of observation, with delirium identified on 32% of
those days. Of admitted patients who did not have delirium
in the PACU, 23 of 28 (82%) had no delirium on any assess-
ment during their hospitalization, whereas the remaining
5 (18%) developed new onset delirium in subsequent days
at a median (IQR) of 1 (1–3) days of observation after sur-
gery. Of the 30 admitted patients who had delirium in the
PACU, 16 (53%) resolved on our next day of observation on
the hospital ward, whereas the remaining 14 (47%) patients
continued to have subsequent days of delirium. The median
(IQR) number of consecutive positive delirium assessments
was 3 (2–6). Six patients (10% of all admitted patients) were
delirious on the day of hospital discharge (3 discharged to
an institution and 3 discharged to home).

Of the 67 inpatients, 35 (82%) completed repeat cogni-
tive testing at hospital discharge. Twelve were not tested
due to being discharged over the weekend (9), unavailabil-
ity of patient to complete cognitive testing on day of dis-
charge (2), and patient declining to complete (1). Another
5 patients who were delirious in the PACU lacked cogni-
tive testing at baseline due to lack of time before surgery
or patient declining testing. Table 2 presents the unadjusted
outcomes for these patients. In adjusted analyses, includ-
ing baseline MMSE and surgery duration, PACU delirium
was significantly associated with decline in the verbal flu-
cy cognitive test (for categories) from baseline testing
(Table 3—adjusted difference [95% CI] for change in T-score:
6.02 [−10.58 to −1.45]; P = 0.01). This association remained
statistically significant after excluding patients found to be
delirious at hospital discharge. After adjusting for MMSE,
surgery duration and residence before admission, the effect
of delirium in the PACU remained large in magnitude but
no longer reached statistical significance in association with
discharge to an institution (versus home) (Table 3—adjusted
odds ratio [95% confidence interval]: 4.2 [0.9–19.7]; P = 0.07).

In secondary analyses of only those patients admitted
after surgery, a multivariable regression model compared
the outcomes of patients (1) who had no delirium at any
time during their hospital stay (n = 23; Fig. 1) with (2) those
patients who had delirium only in the PACU and did not
have delirium on the hospital ward, (n = 16) versus (3) those
with delirium both in the PACU and on subsequent hospi-
tal days (n = 14). This analysis (Table 4) demonstrated that
delirium only in the PACU was associated with worse ver-
bal fluency (category) (P = 0.07) and with a greater prob-
ability of discharge to an institution (26% vs 3%; P = 0.05)
when compared with patients who had no delirium diag-
nosis at any time. Pairwise comparison among the 3 patient
groups with different durations of delirium (“never” versus
“PACU only” versus “both PACU and hospital ward” delir-
ium) revealed outcomes for the “PACU only” group were
intermediate between the other 2 groups for the following
outcomes (Table 4): (1) verbal category fluency change from
baseline (adjusted T-score: 2.74 vs −2.00 vs −8.40), (2) digit
span backward change from baseline (adjusted T-score:
−1.17 vs −2.60 vs −7.90), and (3) probability of discharge to
institution (3% vs 26% vs 39%).

DISCUSSION

This study demonstrates that elderly postoperative patients
can be successfully evaluated for delirium in the PACU set-
ting after reaching an Aldrete score ≥9. The prevalence of
Outcomes of Early Delirium After General Anesthesia

delirium in this sample was 45%. This phenomenon was not universal: more than half of elderly patients were not delirious despite general anesthesia, and 82% of these patients remained delirium free throughout their hospitalization. Delirium in the PACU was independently associated with decreased cognitive performance, from preoperative baseline, in verbal category fluency (a measure of working memory and frontal lobe and executive function), and possibly with institutionalization at hospital discharge. Half of patients (53%) with PACU delirium experienced resolution within 1 day of inpatient follow-up after surgery, while the remainder continued to have delirium during subsequent assessments with a median duration of 3 days. Delirium occurring only in the PACU (and not on the hospital ward) appeared to have negative consequences, demonstrating a potential dose–response relationship between delirium duration in the postoperative setting and negative outcomes.

Early diagnosis of delirium in the PACU is associated with delirium on hospital units. Of 19 episodes of delirium identified during the subsequent hospitalization, 74% were preceded by delirium in the PACU. In contrast to prior research,11 our findings suggest that the majority of

Figure 1. Consort flow diagram. PACU = postanesthesia care unit.
### Table 1. Patient Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>All patients (n = 91)</th>
<th>Delirium in recovery room (n = 41)</th>
<th>No delirium in recovery room (n = 50)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sociodemographics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, mean (SD), y</td>
<td>79 (6)</td>
<td>79 (6)</td>
<td>77 (5)</td>
</tr>
<tr>
<td>Female</td>
<td>53 (58%)</td>
<td>26 (63%)</td>
<td>27 (54%)</td>
</tr>
<tr>
<td>Caucasian</td>
<td>81 (89%)</td>
<td>35 (85%)</td>
<td>46 (92%)</td>
</tr>
<tr>
<td><strong>Education level</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than high school</td>
<td>25 (28%)</td>
<td>14 (34%)</td>
<td>11 (22%)*</td>
</tr>
<tr>
<td>High school</td>
<td>25 (28%)</td>
<td>15 (37%)</td>
<td>10 (20%)</td>
</tr>
<tr>
<td>Some college or college graduate</td>
<td>30 (33%)</td>
<td>10 (24%)</td>
<td>20 (40%)</td>
</tr>
<tr>
<td>Post-graduate training</td>
<td>11 (12%)</td>
<td>2 (5%)</td>
<td>9 (18%)</td>
</tr>
<tr>
<td><strong>Employment status, retired</strong></td>
<td>75 (82%)</td>
<td>36 (88%)</td>
<td>39 (78%)*</td>
</tr>
<tr>
<td>Residence, living in own home</td>
<td>71 (78%)</td>
<td>28 (68%)</td>
<td>43 (86%)*</td>
</tr>
<tr>
<td><strong>Living arrangement, before surgery</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alone</td>
<td>21 (23%)</td>
<td>11 (27%)</td>
<td>10 (20%)</td>
</tr>
<tr>
<td>Spouse</td>
<td>36 (40%)</td>
<td>16 (39%)</td>
<td>20 (40%)</td>
</tr>
<tr>
<td>Other</td>
<td>34 (37%)</td>
<td>14 (34%)</td>
<td>20 (40%)</td>
</tr>
<tr>
<td><strong>Status before surgery</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charlson comorbidity index, mean(SD)</td>
<td>2.2 (2.2)</td>
<td>2.6 (2.6)</td>
<td>1.9 (1.8)</td>
</tr>
<tr>
<td>ASA physical status classification score, &gt;3</td>
<td>58 (64%)</td>
<td>31 (76%)</td>
<td>27 (54%)*</td>
</tr>
<tr>
<td>Activities of daily living, mean (SD)*</td>
<td>5.5 (1.0)</td>
<td>5.3 (1.3)</td>
<td>5.6 (0.6)</td>
</tr>
<tr>
<td><strong>Instrumental activities of daily living, mean(SD)</strong></td>
<td>7.2 (1.4)</td>
<td>6.9 (1.8)</td>
<td>7.5 (1.0)</td>
</tr>
<tr>
<td><strong>Self-reported memory problems</strong></td>
<td>37 (41%)</td>
<td>21 (51%)</td>
<td>16 (32%)*</td>
</tr>
<tr>
<td><strong>Presurgery cognitive testing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbal fluency (standardized T-score)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S word list, mean (SD)</td>
<td>44 (11)</td>
<td>44 (10)</td>
<td>45 (12)</td>
</tr>
<tr>
<td>P word list, mean (SD)</td>
<td>44 (12)</td>
<td>44 (12)</td>
<td>45 (12)</td>
</tr>
<tr>
<td>Animal word list category, mean (SD)</td>
<td>47 (11)</td>
<td>47 (11)</td>
<td>46 (11)</td>
</tr>
<tr>
<td><strong>Digit span (standardized T-score)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward, mean (SD)</td>
<td>48 (10)</td>
<td>47 (9)</td>
<td>49 (11)</td>
</tr>
<tr>
<td>Backward, mean (SD)*</td>
<td>49 (12)</td>
<td>47 (11)</td>
<td>50 (12)</td>
</tr>
<tr>
<td><strong>Mini-mental state exam score</strong></td>
<td>25 (3)</td>
<td>24 (4)</td>
<td>26 (2)*</td>
</tr>
<tr>
<td><strong>Surgery characteristics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of surgery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orthopedics</td>
<td>31 (34%)</td>
<td>15 (37%)</td>
<td>16 (32%)</td>
</tr>
<tr>
<td>Urinary and gynecologic</td>
<td>25 (28%)</td>
<td>8 (20%)</td>
<td>17 (34%)</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>10 (11%)</td>
<td>6 (15%)</td>
<td>4 (8%)</td>
</tr>
<tr>
<td>Other</td>
<td>25 (28%)</td>
<td>12 (29%)</td>
<td>13 (26%)</td>
</tr>
<tr>
<td>Surgery duration, mean (SD), h</td>
<td>3.1 (1.7)</td>
<td>3.7 (1.8)</td>
<td>2.6 (1.5)*</td>
</tr>
</tbody>
</table>

*Activities of daily living is scored from a minimum of 0 to a maximum of 6 which indicates full independence.

†Robust test scores for verbal fluency and digit span were transformed to T-scores based on population norms standardized for age, sex, education, and race with mean = 50 and SD = 10.

‡n = 74 with 41 without delirium and 33 with delirium: 17 patients did not complete verbal fluency tasks and digit span forwards preoperatively due to a lack of time before surgery or patient declining.

§n = 73 with 41 without delirium and 32 with delirium: 18 patients did not complete digit span backwards preoperatively due to a lack of time before surgery or patient declining.

*Mini-mental state examination (MMSE) scores range from 0 to 30 with 30 indicating good cognitive function; MMSE was missing in 3 patients, all found to be delirious in the postanesthesia care unit.

P values are calculated from Fisher exact test or a Wilcoxon rank-sum test: *P < 0.05; †P = 0.05; ‡P < 0.01.

### Table 2. Cognitive and Health Care Resource Utilization Outcomes for Inpatients

<table>
<thead>
<tr>
<th>Cognitive testing at discharge</th>
<th>All patients</th>
<th>Delirium in recovery room</th>
<th>No delirium in recovery room</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal fluency (standardized T-score)*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S word list, mean (SD)</td>
<td>42 (12)</td>
<td>41 (12)</td>
<td>44 (11)</td>
</tr>
<tr>
<td>P word list, mean (SD)</td>
<td>43 (11)</td>
<td>40 (10)*</td>
<td>46 (10)*</td>
</tr>
<tr>
<td>Animal word list mean (SD)</td>
<td>46 (10)</td>
<td>42 (10)†</td>
<td>49 (8)†</td>
</tr>
<tr>
<td>Digit Span (standardized T-score)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward, mean (SD)*</td>
<td>46 (12)</td>
<td>45 (12)</td>
<td>47 (13)</td>
</tr>
<tr>
<td>Backward, mean (SD)</td>
<td>44 (9)</td>
<td>40 (9)†</td>
<td>47 (9)†</td>
</tr>
<tr>
<td>Health care resource utilization</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge to institution versus home</td>
<td>18 (20%)</td>
<td>15 (37%)†</td>
<td>3 (6%)†</td>
</tr>
</tbody>
</table>

*Raw test scores for verbal fluency and digit span were transformed to T-scores based on population norms standardized for age, sex, education, and race with mean = 50 and SD = 10.

**n = 55 with 28 no delirium and 27 with delirium: 12 patients did not complete verbal fluency tasks postoperatively before discharge.

**n = 54 with 28 no delirium and 26 with delirium: 13 patients did not complete digit span tasks postoperatively before discharge.

P values are calculated from Fisher exact test or a Wilcoxon rank-sum test: *P = 0.01; †P = 0.05; ‡P < 0.001.
episodes of postoperative delirium are temporally associated with recovery from anesthesia and begin in the PACU without a period of lucidity.

The 45% prevalence of PACU delirium in this study is the same as observed by Sharma et al. who evaluated 50 elderly patients exclusively undergoing hip surgery. Our data demonstrate that delirium prevalence is high in elderly patients undergoing hip surgery. Radtke et al. documented a delirium incidence early after general anesthesia may be important.

The finding that patients with delirium in the PACU declined in cognitive performance on verbal category fluency between admission and hospital discharge, even after controlling for baseline MMSE and surgery duration, suggests that the impact of even brief episodes of delirium on cognition may be important; this has been demonstrated in studies that followed cognitive function of older patients after cardiac surgery. Initiating monitoring for delirium on the first postoperative day, instead of in the PACU, in this sample would have missed 53% of the patients who experienced delirium, suggesting that beginning surveillance early after general anesthesia may be important.

The decline in cognitive performance on verbal category fluency testing, but not verbal letter fluency testing, is likely due to the more cognitively taxing nature of the category test. Recent neuroimaging investigations suggest that category and letter fluency are dependent on partially distinct neural networks with category fluency involving temporal lobe activation and letter fluency involving frontal lobe activation. Studies have shown that decreased verbal fluency in general, and category word fluency in particular, are associated with greater functional impairment among older adults.

<p>| Table 3. Association of Recovery Room Delirium with Change in Cognitive and Health Care Resource Utilization Outcomes |</p>
<table>
<thead>
<tr>
<th>Change (SE) in cognitive T-scores (hospital discharge minus presurgery baseline)</th>
<th>Unadjusted</th>
<th>Adjusted&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Recovery room delirium (n = 22)</td>
<td>No recovery room delirium (n = 28)</td>
</tr>
<tr>
<td>Verbal fluency (letters “s” and “p”)</td>
<td>−1.55 (1.47)</td>
<td>−0.02 (1.31)</td>
</tr>
<tr>
<td>Verbal fluency (animal category)</td>
<td>−4.91 (1.74)</td>
<td>1.11 (1.54)</td>
</tr>
<tr>
<td>Digit span forward</td>
<td>−2.33 (2.09)</td>
<td>−0.50 (1.81)</td>
</tr>
<tr>
<td>Digit span backward</td>
<td>−5.25 (2.04)</td>
<td>−2.07 (1.72)</td>
</tr>
</tbody>
</table>

PACU = postanesthesia care unit.
<sup>a</sup>Adjusted change in cognitive scores based on linear regression model with random intercept; the equation is $Y_{ij} = \beta_0 + \alpha_0 + \beta_1 \times \text{time} + \beta_2 \times \text{PACU}_{\text{anytime}} + \beta_3 \times \text{time} \times \text{PACU}_{\text{anytime}} + \epsilon_{ij}$, where $Y_{ij}$ represents the measurement for the $i$th patient at the $j$th timepoint.
<sup>b</sup>A total of 22 delirious patients had both preoperative and discharge testing with 10 patients missing 1 set of testing for verbal fluency; digit span forward included 21 delirious patients with 11 patients missing 1 set of testing and 20 delirious patients for digit span backward with 12 patients missing 1 set of testing.
<sup>c</sup>Adjusted for baseline Mini-Mental State Exam (MMSE) and surgery duration with no changes demonstrated from the unadjusted results.

| Table 4. Change in Cognitive and Health Care Resource Utilization Outcomes by Delirium Subgroup |
|-------------------------------------------------|-------------|--------------|
| | Never delirious (n = 23) | Recovery room only delirium (n = 16) | Recovery room and hospital delirium (n = 14) | P-value for recovery room only versus never delirium | P-value for recovery room and hospital delirium |
| Change (SE) in cognitive T-Scores (hospital discharge minus presurgery baseline)<sup>a</sup> | | | | | |
| Verbal fluency (letters “s” and “p”) | 0.46 (1.54) | 1.79 (1.86) | −5.55 (2.03) | 0.56 | 0.008 |
| Verbal fluency (animal category) | 2.74 (1.55) | −2.00 (2.15) | −8.40 (2.36) | 0.07 | 0.05 |
| Digit span forward | −0.96 (1.98) | −0.73 (2.86) | −4.10 (3.00) | 0.95 | 0.42 |
| Digit span backward | −1.17 (1.84) | −2.60 (2.79) | −7.90 (2.36) | 0.67 | 0.18 |
| Difference in health care resource utilization<sup>b</sup> | | | | | |
| Discharge to institution as a probability (95% confidence interval) | 3% (0%–10%) | 26% (1%–51%) | 39% (0%–81%) | 0.05 | 0.48 |

PACU = postanesthesia care unit.
<sup>a</sup>Adjusted change in cognitive scores based on linear regression model with random intercept and adjusted for baseline Mini-Mental State Exam (MMSE) and surgery duration; The model equation is $Y_{ij} = \beta_0 + \alpha_0 + \beta_1 \times \text{time} + \beta_2 \times \text{PACU}_{\text{anytime}} + \beta_3 \times \text{time} \times \text{PACU}_{\text{anytime}} + \epsilon_{ij}$, where $Y_{ij}$ represents the measurement for the $i$th patient at the $j$th timepoint.
<sup>b</sup>Adjusted for baseline MMSE, residence before admission, and surgery duration.
Our result is similar to a prior multicenter study that measured postoperative changes in cognitive function and demonstrated an association between delirium in the postoperative course and cognitive dysfunction 7 days later and another recent study that documented cognitive decline after postoperative delirium up to 6 months later. Other investigators studying the impact of delirium after cardiac surgery used cognitive testing similar to our study, including digit span (forward and backward) and verbal letter fluency and also found that category fluency was particularly affected. They compared the unadjusted change in scores in delirious versus nondelirious patients, demonstrating a significant change in a composite digit span and a trend toward a difference in verbal letter fluency. An adjusted analysis was not provided to control for baseline factors, such as surgery duration and baseline MMSE, which were found to be important confounders in our current study.

An important strength of this current study is the use of expert reference raters who prospectively and rigorously assessed delirium according to DSM-IV criteria using a neuropsychiatric examination, concurrent with independent and blinded prospective screening evaluations of baseline and discharge cognitive function. To our knowledge, this is the first report using this kind of rigorous PACU examination in the delirium literature. Prior studies have used screening tools not yet validated in this patient population that were based on nursing observation or rating of the CAM algorithm in the PACU; and not on direct and prospective neuropsychiatric examination of the patient in this setting.

The current study has limitations. First, our sample size reduces the power to detect clinically important differences in some of the outcomes including some of the cognitive measures. However, our sample size is comparable with several prior studies of postoperative delirium. We caution readers to interpret the associations of PACU delirium and patient outcomes as hypothesis-generating for future studies. However, we have successfully demonstrated the feasibility of delirium evaluation once an Aldrete score of 29 is obtained after general anesthesia. Second, cognitive assessments were not always possible in a relatively small number of the pre- and postsurgery assessments. However, comprehensive efforts were made to minimize missed assessments, with our rates being similar to prior studies. Ongoing delirium might account for poorer performance on cognitive testing at hospital discharge; however, our results persisted even after excluding those patients in a sensitivity analysis. Finally, our evaluation of only in-hospital outcome measures does not permit insights into any long-term associations of PACU delirium on cognition and subsequent health care utilization. Future studies should include prospective long-term follow-up of individuals with delirium found in the PACU setting as well as the hospital ward.

In conclusion, this prospective study of 91 elderly patients undergoing general anesthesia and surgery identified a 45% prevalence of delirium in the PACU. The majority of patients with postoperative delirium had delirium starting in the PACU. Hence, recognizing delirium in the PACU may be important for identifying patients at higher risk of in-hospital harms (e.g., falls), as well as cognitive impairment and institutionalization at hospital discharge. Early identification and intervention for delirium in the PACU setting requires evaluation of its potential to improve patient outcomes.

DISCLOSURES

Name: Karin J. Neufeld, MD, MPH.
Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript.
Attestation: Karin J. Neufeld has seen the original study data, reviewed the analysis of the data, approved the final manuscript, and is the author responsible for archiving the study files.
Conflicts of Interest: The author has no conflicts of interest to declare.
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Conflicts of Interest: The author has no conflicts of interest to declare.
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Outcomes of Early Delirium After General Anesthesia

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Attestation: Dale M. Needham has seen the original study data, reviewed the analysis of the data, and approved the final manuscript.

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REFERENCES


