An Implementation-Effectiveness Study of a Perioperative Delirium Prevention Initiative for Older Adults

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BACKGROUND: Postoperative delirium is a common and serious problem for older adults. To better align local practices with delirium prevention consensus guidelines, we implemented a 5-component intervention followed by a quality improvement (QI) project at our institution.

METHODS: This hybrid implementation-effectiveness study took place at 2 adult hospitals within a tertiary care academic health care system. We implemented a 5-component intervention: preoperative delirium risk stratification, multidisciplinary education, written memory aids, delirium prevention postanesthesia care unit (PACU) orderset, and electronic health record enhancements between December 1, 2017 and June 30, 2018. This was followed by a department-wide QI project to increase uptake of the intervention from July 1, 2018 to June 30, 2019. We tracked process outcomes during the QI period, including frequency of preoperative delirium risk screening, percentage of "high-risk" screens, and frequency of appropriate PACU orderset use. We measured practice change after the interventions using interrupted time series analysis of perioperative medication prescribing practices during baseline (December 1, 2016 to November 30, 2017), intervention (December 1, 2017 to June 30, 2018), and QI (July 1, 2018 to June 30, 2019) periods. Participants were consecutive older patients (≥65 years of age) who underwent surgery during the above timeframes and received care in the PACU, compared to a concurrent control group <65 years of age. The a priori primary outcome was a composite of perioperative American Geriatrics Society Beers Criteria for Potentially Inappropriate Medication Use (Beers PIM) medications. The secondary outcome, delirium incidence, was measured in the subset of older patients who were admitted to the hospital for at least 1 night.

RESULTS: During the 12-month QI period, preoperative delirium risk stratification improved from 67% (714 of 1068 patients) in month 1 to 83% in month 12 (776 of 931 patients). Forty percent of patients were stratified as "high risk" during the 12-month period (4246 of 10,494 patients). Appropriate PACU orderset use in high-risk patients increased from 19% in month 1 to 85% in month 12. We analyzed medication use in 7212, 4416, and 8311 PACU care episodes during the baseline, intervention, and QI periods, respectively. Beers PIM administration decreased from 33% to 27% to 23% during the 3 time periods, with adjusted odds ratio (aOR) 0.97 (95% confidence interval [CI], 0.95–0.998; $P = .03$) per month during the QI period in comparison to baseline. Delirium incidence was 7.5%, 9.2%, and 8.5% during the 3 time periods with aOR of delirium of 0.98 (95% CI, 0.91–1.05, $P = .52$) per month during the QI period in comparison to baseline.

CONCLUSIONS: A perioperative delirium prevention intervention was associated with reduced administration of Beers PIMs to older adults. (Anesth Analg 2020;131:00–00)

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KEY POINTS

- **Question:** Can we better align perioperative delirium prevention practices with best practice patient care guidelines?
- **Findings:** A perioperative delirium prevention intervention led to reliable implementation of prevention processes and a month-over-month decrease in perioperative administration of Potentially Inappropriate Medications to older adults.
- **Meaning:** A multidisciplinary quality improvement intervention targeting postoperative delirium resulted in changes to care practices that may improve perioperative outcomes for older adults at risk of delirium.

GLOSSARY

AKI = acute kidney injury; **aOR** = adjusted odds ratio; **ASA** = American Society of Anesthesiologists; **AWOL** = Age > 80, failure to spell WORLD backward, disOrientation to place, and higher nurse-rated iLlness severity score; **AWOL-S** = Age > 80, failure to spell WORLD backward, disOrientation to place, higher iLlness severity score (ASA Classification), Surgery specific risk; **CAM** = Confusion Assessment Method; **CI** = confidence interval; **CKD** = chronic kidney disease; **EHR** = electronic health record; **ENT** = ear-nose-throat; **ESRD** = end-stage renal disease; **GEE** = generalized estimating equations; **GFR** = glomerular filtration rate; **GI** = gastrointestinal; ***ICD*** = *International Classification of Diseases*; **ICU** = intensive care unit; **intraop** = intraoperative; **IRB** = internal review board; **IV** = intravenous; **LOS** = length of stay; **NSAID** = nonsteroidal anti-inflammatory drug; **NSQIP** = National Surgical Quality Improvement Program; **OMFS** = oral and maxillofacial surgery; **OR** = operating room; **PACU** = postanesthesia care unit; **PIM** = Potentially Inappropriate Medication; **POD** = postoperative delirium; **PONV** = postoperative nausea and vomiting; **POQI-6** = Sixth Perioperative Quality Initiative; **q6h** = every 6 hours; **QI** = quality improvement; **SQUIRE** = Standards for QUality Improvement Reporting Excellence; **UCSF** = University of California, San Francisco

Older surgical patients are at elevated risk of perioperative morbidity,[1–4] including postoperative delirium (POD). Delirium is one of the most common postoperative complications described in older surgical patients, with a reported prevalence of up to 50%.[5] It has been associated with worsened traditional and patient-centered outcomes, including prolonged length of stay, increased institutional discharge,[6] impaired functional recovery,[7] and cognitive decline.[8] Notably, one-third to one-half of delirium cases are thought to be preventable using a multicomponent intervention,[9] making it an ideal target for quality improvement (QI) in the perioperative environment.

Earlier this year, the American Society for Enhanced Recovery and the Sixth Perioperative Quality Initiative (POQI-6) published a joint consensus statement on prevention of POD.[10] This document complements earlier guidelines published by other professional societies.[5,11–13] Strong recommendations applying to the preoperative or intraoperative environment include implementing a multidisciplinary QI process to reduce POD, performing preoperative risk stratification and delirium assessment in high-risk patients, using multicomponent nonpharmacologic delirium prevention interventions, and minimizing use of deliriogenic medications. Medications commonly used in the perioperative period that are known to contribute to delirium in older patients include anticholinergic drugs (eg, diphenhydramine, scopolamine), benzodiazepines, and meperidine, among others (Table 1). These are termed Potentially Inappropriate Medications (PIMs) or Beers Criteria medications by the American Geriatrics Society.[14]

In 2016, the Delirium Reduction Campaign[15]—a health system-wide QI initiative to implement delirium screening, prevention, and treatment procedures in medical and surgical inpatients—was launched at University of California, San Francisco (UCSF) Health. In coordination with system-wide efforts, we developed a distinct multidisciplinary perioperative pathway to provide guidance on evidence-based perioperative delirium prevention (Supplemental Digital Content 1, Document, http://links.lww.com/AA/D208, which describes the UCSF Perioperative Delirium Prevention and Treatment Pathway in further detail). This was accompanied by a targeted 5-component implementation intervention and QI project with the goal of increasing departmental compliance with best practices recommended in the pathway. In this retrospective hybrid implementation-effectiveness study with an interrupted time series design, we report our experience with the implementation and outcomes of this perioperative initiative at UCSF Health.

METHODS

Clinical Setting

UCSF Health is an urban tertiary care health system. Work described here was performed at Moffitt-Long and Mission Bay Hospitals, the health system's 2 major adult inpatient hospitals with a combined 706 adult hospital

Table 1. Intervention Recommendations for Perioperative Use of Beers Criteria PIMs Commonly Used in Anesthesia

Medication Class	Examples	Precautions	Rationale
NSAIDs	Ketorolac Diclofenac Ibuprofen	Avoid when GFR <30 (stage IV–V CKD) or in AKI Use caution with repeated doses	Increased risk of GI bleeding, AKI, hypertension
Sedative hypnotics	Benzodiazepines	Avoid, except for specific indications such as seizure or alcohol withdrawal	Increased risk of delirium, cognitive impairment, falls, fractures
	Gabapentin	Reduce dose or avoid when GFR <60 Avoid in patients with ESRD	Increased risk of oversedation
	Meperidine	Avoid, especially in patients with CKD	Higher risk of neurotoxicity including delirium
Anticholinergics	Scopolamine Promethazine Prochlorperazine Diphenhydramine Hydroxyzine Tricyclic antidepressants	Avoid	Increased risk of central anticholinergic side effects including confusion, blurred vision, delirium, sedation
Other psychoactive medications	Steroids (eg, dexamethasone)	Avoid or use cautiously	Increased risk of delirium
	Antipsychotics	Avoid, except for use in psychiatric disease or as a short-term antiemetic Restrict use in delirium for failure of nonpharmacologic interventions AND patient presents harm to self or others	Increased risk of stroke, cognitive decline, mortality in patients with dementia

Abbreviations: AKI, acute kidney injury; CKD, chronic kidney disease; ESRD, end-stage renal disease; GFR, glomerular filtration rate; GI, gastrointestinal; NSAIDs, nonsteroidal anti-inflammatory drugs; PIM, Potentially Inappropriate Medication.
Data included from the 2019 American Geriatrics Society Beers Criteria Update Expert Panel.[14]

beds. Between 29,000 and 30,000 adult anesthesia cases are performed at these 2 hospitals yearly. The perioperative delirium prevention intervention was implemented for all patients ≥18 of age having surgery at 1 of these 2 hospitals. Patients receiving inpatient obstetric, electrophysiology, or cardiac catheterization procedures were not included, because they do not typically receive care in a postanesthesia care unit (PACU) targeted by this intervention; patients who underwent endoscopy or radiology procedures were included if they received care in the PACU. UCSF Health uses the Epic electronic health record (EHR) system (Verona, WI) including the Optime (periop) and Anesthesia modules. This article adheres to Standards for QUality Improvement Reporting Excellence (SQUIRE) guidelines.[16]

Internal Review Board (IRB) Approval

The Committee on Human Research at UCSF provided expedited review of the protocol for this retrospective study with minimal risk to human subjects (IRB No. 19-27578). The need to obtain written informed consent from study participants was waived by the committee.

Intervention Design and Implementation Strategy

The intervention was designed based on an assessment of existing organizational- and individual-level barriers to behavior change. Constructs from a framework published in the implementation science literature[17] were utilized to evaluate barriers and to develop implementation interventions that would be likely to address the needs of individuals at our institution and ultimately to result in the desired behavior change. During this process, we solicited feedback and obtained buy-in from champions from the perioperative nursing department and representatives from the anesthesia resident and nurse anesthetist groups. We also collaborated with stakeholders from the hospital-wide Delirium Reduction Campaign; members of surgical, geriatrics, and neurology departments; and executive-level hospital leadership.

The final intervention ("the intervention") consisted of 5 components: introduction of preoperative delirium risk screening, provision of multidisciplinary education and training, distribution of written educational materials and memory aids, launch of a delirium risk PACU orderset, and development of EHR enhancements. The intervention was implemented between December 2017 and June 2018 and was followed by a department-wide QI project to improve uptake. The 5-component intervention and the QI project are described in further detail below. A timeline with important implementation milestones is depicted in Figure 1, and a more granular timeline can be found in Supplemental Digital Content 1, Table 1, http://links.lww.com/AA/D208.

The Intervention (December 2017 to June 2018).

1. Delirium risk stratification: To identify patients at highest risk of developing POD, we began risk-stratifying all adult surgical patients undergoing surgery with a planned overnight hospital

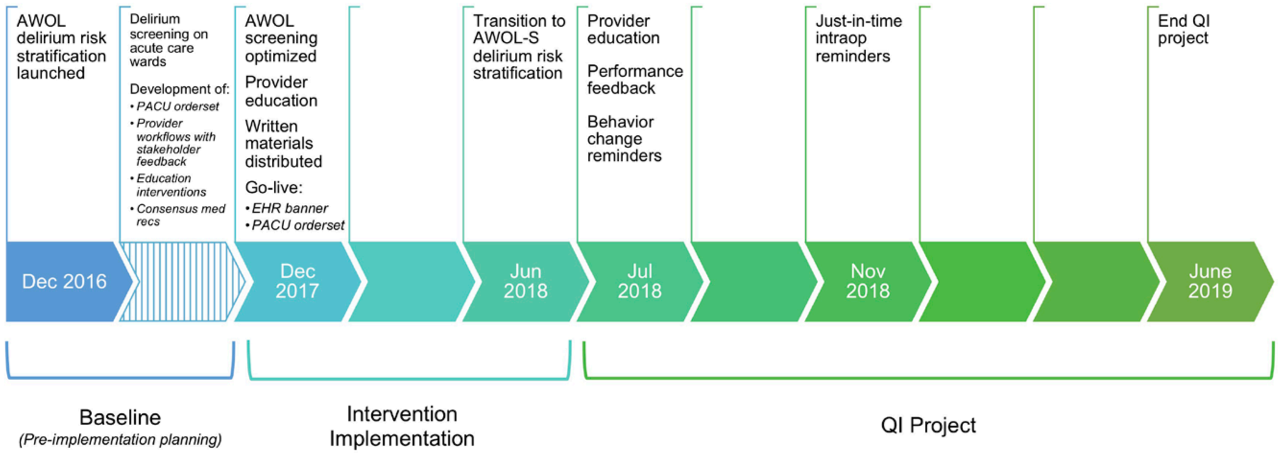

Figure 1. Timeline of intervention. A timeline of the intervention and quality improvement project is pictured with selected implementation milestones during the baseline (December 1, 2016 to November 30, 2017), intervention (December 1, 2017 to June 30, 2018), and QI project (July 1, 2018 to June 30, 2019) periods. AWOL indicates "Age, WORLD backward, orientation, iLlness severity" delirium risk stratification tool; AWOL-S, Age > 80, failure to spell WORLD backward, disOrientation to place, higher iLlness severity score (ASA Classification), Surgery specific risk; EHR, electronic health record; intraop, intraoperative; PACU, postanesthesia care unit; QI, quality improvement.

stay with the Age > 80, failure to spell WORLD backward, disOrientation to place, and higher nurse-rated iLlness severity score (AWOL) tool[18] in December 2017 and later the surgery-specific Age > 80, failure to spell WORLD backward, disOrientation to place, higher iLlness severity score (ASA Classification), Surgery specific risk (AWOL-S) tool[19] in June 2018. Briefly, AWOL-S is a surgery-specific delirium risk stratification tool that was modified from AWOL, a simple 4-point screening tool that was used hospital-wide to screen all inpatients at the time of admission to our institution for delirium risk. AWOL-S includes terms for surgery-specific risk (based on National Surgical Quality Improvement Program [NSQIP] and local data[6]) and American Society of Anesthesiologists (ASA) physical status, while retaining the original AWOL predictors of age, inability to spell WORLD backward, and disorientation to place. AWOL-S is an EHR-based tool that generates a predicted probability of delirium for an individual patient using odds ratios derived from logistic regression. AWOL-S predicted probability of delirium ≥5% was considered "high risk" for risk stratification purposes. More details on risk stratification procedures are given in Supplemental Digital Content 1, Document, http://links.lww.com/AA/D208.

2. Multidisciplinary education and training:

    a. Anesthesia department: An initial educational session on the impact of POD and recommendations for delirium prevention was conducted at a UCSF Department of Anesthesia and Perioperative Care Grand Rounds conference by project leadership (A.L.D.) and representatives from the Departments of Neurology (V.C.D.) and Geriatrics (S.R.). Concepts presented were reinforced with an educational email to all members of the department, and email reminders were sent to anesthesia providers periodically throughout the intervention period. An introduction to the new PACU orderset was provided to all members of the anesthesia department by EHR experts (D.L.R.) and the PACU medical director (M.R.B.).

    Actionable recommendations for anesthesia providers were primarily focused on perioperative medication management, although other important concepts contained in best practice patient care guidelines[5,12,13] were also emphasized (Supplemental Digital Content 1, Document, http://links.lww.com/AA/D208, for further detail). We recommended medication management according to the Beers Criteria[14,20]; specifically, we recommended avoiding administration of deliriogenic medications whenever possible (Table 1). We developed a preferred approach for management of

Table 2. UCSF Multidisciplinary Consensus Recommendations for the Prevention and Management of Postoperative Nausea and Vomiting in Older Adults

Preferred Order of Antiemetics	Avoid When Possible
Preventative measures	Dexamethasone
Intraoperative propofol infusion	(especially doses >4 mg)
Aprepitant (if very high risk)	Diphenhydramine
Rescue antiemetics	Hydroxyzine
Ondansetron (4 mg IV q6h)	Lorazepam
Haloperidol (0.5–1 mg q6h)	Prochlorperazine
Metoclopramide (5 mg IV once)	Scopolamine

Abbreviations: IV, intravenous; q6h, every 6 hours; UCSF, University of California, San Francisco.

postoperative nausea and vomiting (PONV), which incorporated guidance from institutional experts from geriatrics, neurology, and pharmacy where uncertainty existed in the literature (Table 2). Further description of the rationale for specific medication recommendations can be found in Supplemental Digital Content 1, Document, http://links.lww.com/AA/D208.

b. Preoperative and PACU nurses: Nurses received education on the prevalence and impact of POD, effectiveness of preventative measures, and logistics of the new PACU orderset by project and PACU leadership (A.L.D. and M.R.B.) at staff meetings, by peer-to-peer training, and via an online educational module. They also received training by project and nursing leadership before launch of AWOL and AWOL-S screening through formal presentations at staff meetings, one-on-one or group peer training, email messages, and posted visual aids. More details are given in Supplemental Digital Content 1, Document, http://links.lww.com/AA/D208.

c. Surgical departments: Education on POD prevention and management was provided to surgical teams by the Delirium Reduction Campaign (S.R. and V.C.D.).

3. Distribution of written educational materials and memory aids: Written materials, visual reminders, and memory aids were created for anesthesia providers, surgeons, and nursing staff (Supplemental Digital Content 2, Document, Part 1, http://links.lww.com/AA/D209, depicting visual aids and educational materials used for the intervention). Printed materials were placed in strategic locations around the operating rooms (ORs), including the preoperative holding area, PACU workstations, OR anesthesia carts, workspaces for surgeons, and common spaces for nursing and anesthesia providers. Certain materials were also made available online for reference in any location and were sent to providers via email.
4. Launch of a delirium risk PACU orderset: Our institution's standard adult PACU orderset contains opt-in orders for 3 PIMs: meperidine, prochlorperazine, and metoclopramide. To minimize inadvertent exposure to PIMs, we created a novel PACU orderset for high-risk patients, termed the delirium risk PACU orderset. Modifications included removal of the 3 opt-in PIMs, addition of haloperidol as an alternative agent for PONV (Supplemental Digital Content 2, Document, Part 2, http://links.lww.com/AA/D209, which shows the "Other Medications" panel of the PACU orderset), and addition of a multicomponent nursing care bundle (Supplemental Digital Content 2, Document, Part 2, http://links.lww.com/AA/D209, which shows the "Delirium Prevention Interventions" panel of the PACU orderset). The new PACU orderset was launched in December 2017. The rationale for specific medication changes is described further in Supplemental Digital Content 1, Document, http://links.lww.com/AA/D208.
5. Implementation of EHR enhancements: New EHR builds were required to facilitate recommended practice changes. To aid identification of patients stratified as at high risk for delirium, a visual flag was added to the patient's EHR banner so that providers could target the intervention to appropriate patients (Supplemental Digital Content 2, Document, Part 2, http://links.lww.com/AA/D209, which shows the anesthesia caution banner). Modifications to the PACU orderset, as described above, were launched in December 2017. As a response to initially poor compliance with appropriate orderset use, just-in-time intraoperative reminders for anesthesia providers were introduced in November 2018 (Supplemental Digital Content 2, Document, Part 2, http://links.lww.com/AA/D209, which shows intraoperative reminders for anesthesia providers). These enhancements were introduced during the QI period (described below) as an iterative part of continuous process improvement; however, we describe them here for simplicity.

QI Project (July 2018 to June 2019). Following implementation of the intervention, a targeted QI project was conducted between July 1, 2018 and June 30, 2019. The goal of the QI project was to increase uptake of delirium prevention recommendations. The QI project most specifically targeted appropriate PACU orderset use in high-risk patients based on AWOL-S results. This process metric was selected because it was simple, measurable, and a surrogate for individual behavior change. QI activities were conducted by residents and faculty advisors on the Anesthesia Resident Quality Improvement Committee. Representatives provided additional intensive departmental education on perioperative delirium best practices at departmental conferences and via email. Committee members tracked monthly departmental compliance with appropriate PACU orderset use, provided monthly feedback on compliance to the entire anesthesia department via email and during conferences, and sent reminders to use the orderset via email and pages.

Measurement of Results

Participants analyzed retrospectively were consecutive patients ≥65 years of age who underwent surgery or a procedure requiring anesthesia care and received care in the PACU, excluding those who underwent electroconvulsive therapy treatments only, during 3 time periods: baseline (December 1, 2016 to November 30, 2017), intervention (December 1, 2017 to June 30, 2018), and QI (July 1, 2018 to June 30, 2019). A 1-year baseline time period was selected to allow for adjustment of results for trends preceding the intervention. Patients <65 years of age served as a contemporaneous control group during all time periods. The primary outcome, use of 1 or more of 7 commonly used deliriogenic Beers Criteria PIMs (diphenhydramine, lorazepam, meperidine, midazolam, prochlorperazine, promethazine, and scopolamine) between anesthesia start and PACU end, was chosen a priori to measure practice change associated with implementation of the intervention. The secondary outcome measure was delirium incidence for those patients staying at least 1 night in the hospital. We also performed exploratory hypothesis-generating analyses on prescriber behavior for Beers Criteria antiemetics (prochlorperazine, promethazine, and scopolamine), preferred antiemetics (dexamethasone, haloperidol, and metoclopramide), and midazolam. Process measures during the QI period included frequency of preoperative delirium risk screening, frequency of high-risk delirium screen, and frequency of appropriate PACU orderset use.

Delirium rates in the first 7 postoperative days were measured in the subpopulation of adults ≥65 years of age who received care in PACU (except electroconvulsive therapy) and were hospitalized for at least 1 night after surgery. This population was chosen because patients would have been eligible to receive POD screening during their hospital stay. Delirium was identified on acute care wards using the NuDesc screen.[21] Screening was performed by nurses once per shift (morning and evening), and a score of ≥2 was defined as a positive result. Patients who were later transferred to the intensive care unit (ICU) received delirium screening with Confusion Assessment Method (CAM) for the ICU.[22] Compliance with delirium screens was tracked by hospital leadership and remained >90% after hospital units were on-boarded with delirium screening education, which evolved during the study period as additional hospital floors were trained over time.

Statistical Analysis

Sample size was based on the number of older patients having surgery at our institution within the specified timeframes. No statistical power calculation was conducted before the study because of the consecutive sample used. A 2-tailed P value <.05 was considered the threshold for statistical significance, and no adjustment for multiple testing was performed.

Univariate retrospective comparisons of patient characteristics and primary (composite Beers PIM), secondary (delirium incidence), and hypothesis-generating (composite Beers PIM antiemetics, composite preferred antiemetics, midazolam) outcomes among the 3 time periods were performed with χ^2 test, after checking that cell frequency assumptions were met. Statistically significant χ^2 test results were followed by a post hoc examination of the Pearson residuals divided by the standard error; if the absolute value of the adjusted residual was >3, it was considered potentially contributing to the overall statistically significant test and flagged with a "*" in the table to assist in interpretation. Age and hospital length of stay, which were not normally distributed, were compared with the Kruskal–Wallis test; median and interquartile range are reported.

For the primary analysis, multiple records were retained for patients with >1 encounter. Segmented regression[23] was conducted using generalized estimating equations (GEE) logistic model for 39,741 patients with 54,450 observations to account for confounding and within-subject correlation (exchangeable correlation assumed). We also assessed the unstructured variance covariance matrix, but this could not be fit due to the limited number of response pairs, and the simpler exchangeable structure was adequate. The outcomes were binary, so the logit link function was used in SAS proc genmod (SAS Institute, Cary, NC). We simultaneously estimated intercept and slopes for cases (≥65 years of age) and controls (<65 years of age) for each period measured in months: baseline (December 1, 2016 to November 30, 2017), intervention (December 1, 2017 to June 30, 2018), and QI (July 1, 2018 to June 30, 2019). We assessed the form of the covariate time, including quadratic, using the Z statistic (P < .05), and we found that time as a linear effect provided the best fit.

Models were adjusted by age, gender, ASA physical status, emergency case status, type of surgery, and the Elixhauser comorbidities of obesity, hypertension, diabetes, congestive heart failure, renal failure, liver failure, obstructive sleep apnea, and dementia, which were calculated from *ICD*-9 and *ICD*-10 codes available in the electronic medical record.[24,25] There were no missing values for age, emergency case status, type of surgery, or Elixhauser comorbidities; for care episodes of patients at any age, 621 of the 54,450 (1.1%) were missing ASA physical status and 11 of 54,450 (0.02%) were missing gender, with an additional 6 (0.01%) listed as nonbinary. For those missing ASA, "ASA missing" was

Table 3. Cohort Characteristics

	Baseline	Intervention	Quality Improvement	*P* Value
All encounters resulting in care in PACU[a]	20,274	12,161	22,015	
Encounters in patients 65+ years old who received care in PACU	7212	4416	8311	
Age	72 [68–77]	72 [68–77]	72 [68–77]	.14[b]
Female gender	2991 (41%)	1946 (44%)	3566 (43%)	.053[c]
ASA physical status				
I	107 (1.5%)	45 (1.0%)	90 (1.1%)	**.037[d]**
II	3158 (44%)	1836 (42%)	3489 (42%)	
III	3629 (51%)	2306 (53%)	4331 (53%)	
IV	248 (3.5%)	167 (3.8%)	310 (3.8%)	
V	2 (0.03%)	0	2 (0.02%)	
Emergency case status	681 (9.4%)	468 (11%)	808 (9.7%)	.12[c]
Type of procedure				
General	1053 (15%)[d]	595 (13%)	1055 (13%)	**<.001[e]**
Orthopedic	1252 (17%)	804 (18%)	1453 (17%)	
Plastic	157 (2.2%)	75 (1.7%)	143 (1.7%)	
Neurosurgery/neurointerventional radiology	662 (9.2%)[d]	469 (10.6%)	914 (11%)	
Cardiac/vascular/thoracic	1005 (14%)	664 (15%)	1257 (15%)	
ENT/ophthalmic/OMFS	546 (7.6%)	321 (7.3%)	555 (6.7%)	
Urology/gynecology	1306 (18%)	745 (17%)	1392 (17%)	
Endoscopy/radiology	1231 (17%)	743 (17%)	1542 (19%)	
Elixhauser comorbidities:				
Obesity	450 (6.2%)	280 (6.3%)	580 (7.0%)	.14[c]
Hypertension				
Uncomplicated	3148 (44%)	1840 (42%)	3580 (43%)	**<.001[e]**
Complicated	1016 (14%)[d]	700 (16%)	1401 (17%)[d]	
Diabetes				
Uncomplicated	897 (12%)	479 (11%)	963 (12%)	.086[c]
Complicated	726 (10%)	434 (9.8%)	860 (10%)	
Congestive heart failure	594 (8.2%)	386 (8.7%)	809 (9.7%)[d]	**.004[e]**
Renal failure	944 (13%)	600 (14%)	1166 (14%)	.23[c]
Liver failure	388 (5.3%)	240 (5.4%)	419 (5.0%)	.53[c]
Obstructive sleep apnea	728 (10%)[d]	449 (10%)	1063 (13%)[d]	**<.001[e]**
Dementia	169 (2.3%)	105 (2.4%)	207 (2.5%)	.83[c]
Depression	566 (7.9%)	340 (7.7%)	722 (8.7%)	.072[e]
Encounters in patients 65+ years old who received care in PACU and were admitted at least 1 night	4884	3051	5606	
Hospital LOS in those admitted overnight	2 [1–5]	3 [1–5]	2 [1–5]	.34[b]

Abbreviations: ASA, American Society of Anesthesiologists; ENT, ear-nose-throat (otorhinolaryngology); LOS, length of stay; OMFS, oral and maxillofacial surgery; PACU, postanesthetic care unit.
[a]Excluding electroconvulsive therapy encounters.
[b]Kruskal–Wallis test.
[c]χ^2 test.
[d]Cells marked are considered potentially contributing to the overall statistically significant test.
[e]χ^2, with post hoc examination of the residuals.

assigned its own categorical variable for model adjustment purposes. For those missing gender or listed as nonbinary, due to the small number, the values were imputed to all men and all women to assess sensitivity of conclusions to that missingness; we concluded that there was no impact on the findings.

Using post hoc estimate statements in SAS, we estimated the "difference-in-difference" by first estimating the difference in the slopes of the cases and controls for each time period. We then compared the difference of those slopes between QI and baseline periods; that is, the adjusted rates of medication administration between postintervention and preintervention. Adjusted odds ratios (aOR) and associated 95% confidence intervals (CIs) were reported. Statistical analysis was performed with Stata 14.2 software (StataCorp LLC, College Station, TX) and SAS v9.4.

RESULTS

Patients

We analyzed medication use in 7212 PACU care episodes for older adults during the baseline period, 4416 during the intervention period, and 8311 during the QI period; cohort characteristics are in Table 3. Of those care episodes, 4884, 3051, and 5606, respectively, resulted in a hospitalization for at least 1 night after surgery and therefore contributed to the delirium screening rates.

Process Measures

Preoperative Delirium Risk Stratification During QI Period. During the QI period, frequency of preoperative delirium risk stratification with AWOL-S improved from 714 of 1068 (67%) in July 2018 to 776 of 931 (84%) of eligible patients in June 2019. Average risk stratification compliance in eligible patients was 79% (10,494 of

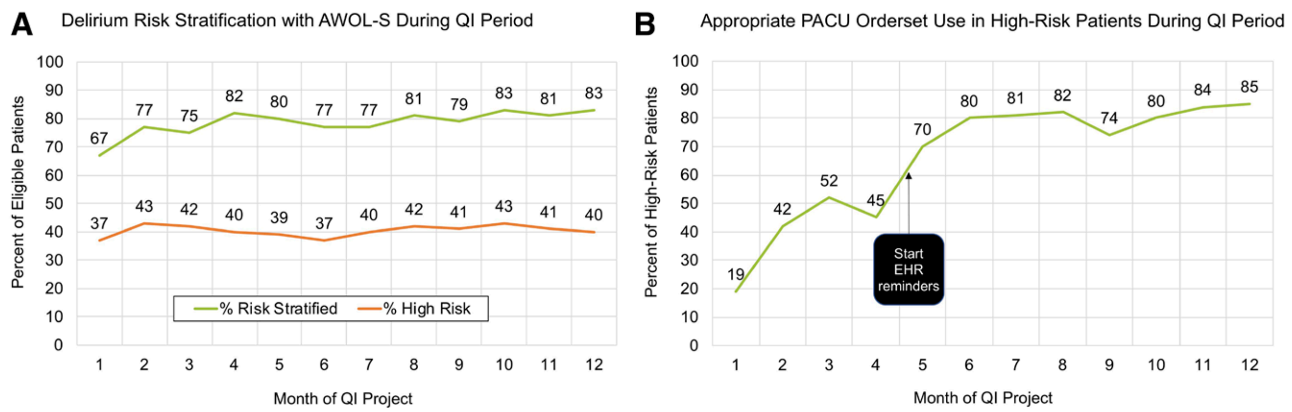

Figure 2. Process measures. A, Monthly rates of preoperative delirium risk stratification with the AWOL-S tool (green line) and percentage of risk-stratified patients classified as high-risk (orange line) during the 12 mo of the QI period starting in July 2018. B, The frequency of appropriate PACU orderset use in high-risk individuals during the same timeframe. Note that the introduction of intraoperative electronic health record reminders to guide orderset usage was a critical implementation milestone that allowed orderset compliance to increase to approximately 80% for the remainder of the project period. AWOL-S indicates Age > 80, failure to spell WORLD backward, disOrientation to place, higher iLlness severity score (ASA Classification), Surgery specific risk; EHR, electronic health record; PACU, postanesthesia care unit; QI, quality improvement.

Table 4. Outcome Measures

Outcome	Baseline (n = 7212)	Intervention (n = 4416)	QI (n = 8311)	$\chi 2$ *P* Value[a]	aOR per mo[b]	*P* Value
Beers list medication[c] (primary outcome)	2397 (33%)[a]	1200 (27%)	1937 (23%)[a]	**<.001**	0.97 [0.95–0.998]	**.033**
Delirium[d] (secondary outcome)	365/4884 (7.5%)	280/3051 (9.2%)	477/5606 (8.5%)	**.020**	0.98 [0.91–1.05]	.52
Preferred antiemetic[e] (exploratory analysis)	2634 (36%)	1673 (38%)	3214 (39%)	**.022**	1.01 [0.99–1.04]	.38
Beers list antiemetic[f] (exploratory analysis)	268 (3.7%)[a]	127 (2.9%)	165 (2.0%)[a]	**<.001**	0.96 [0.91–1.02]	.21
Midazolam (exploratory analysis)	2073 (29%)	1042 (24%)	1677 (20%)	**<.001**	0.97 [0.94–0.997]	**.031**

Abbreviations: aOR, adjusted odds ratio; QI, quality improvement.

[a]Potentially contributing to the overall statistically significant χ^2 test based on post hoc examination of the residuals.

[b]Adjusted odds ratio comparing the change in slopes between baseline and the QI period calculated via segmented regression adjusting for patient demographics and comorbidities.

[c]Composite of any use of diphenhydramine, lorazepam, meperidine, midazolam, prochlorperazine, promethazine, or scopolamine.

[d]Delirium incidence was calculated only in patients who were hospitalized at least 1 night; the denominator is reported in the table.

[e]Composite of any use of dexamethasone, haloperidol, or metoclopramide.

[f]Composite of any use of prochlorperazine, promethazine, or scopolamine.

13,353) during the 12-month QI period and 81% (5438 of 6736) in the last 6 months of the QI period. Throughout the 12-month period, 4246 of 10,494 (40%) of risk-stratified patients had a "high-risk" result (Figure 2A).

PACU Orderset Compliance During QI Period. Monthly compliance with appropriate PACU orderset use (ie, ordering the "Delirium Prevention Interventions" in the delirium reduction PACU orderset in patients stratified as high risk for delirium by AWOL-S) was tracked throughout the QI period. Compliance started at 19% (59 of 308 eligible patients) in July 2018 and increased steadily to 85% (263 of 309 eligible patients) in June 2019. By the end of the QI period, monthly compliance had increased to consistently above 80% in an average of 275 eligible patients per month (Figure 2B). Compliance with orderset use increased sharply and remained high once intraoperative EHR reminders were introduced in November 2018 (Figure 2B).

Outcome Measures

Perioperative Medication Administration for Patients Admitted to the PACU. During the baseline period, 33% of care episodes where an older adult received anesthesia care and then went to PACU resulted in the administration of at least 1 Beers Criteria PIM. This decreased to 27% during the intervention period and 23% during the QI period. Segmented regression analysis demonstrated an aOR of 0.97 (95% CI, 0.95–0.998; $P = .033$) per month of the QI period compared to baseline for administration of the Beers Criteria composite medications (ie, 3% month-on-month decrease in administration), after adjustment for patient characteristics (Table 4). Exploratory analyses of preferred antiemetics, Beers Criteria antiemetics, and midazolam suggested that this may be driven by reduced midazolam prescribing (OR = 0.97; 0.94–0.997; $P = .031$), although the point estimates for use of Beers Criteria and preferred antiemetics during the QI period also suggested statistically nonsignificant improvements in prescribing behavior (Table 4).

Delirium Incidence for Admitted Patients. Delirium incidence in older patients varied during the 3 periods, from 7.5% during the baseline period (during which delirium screening was occurring inconsistently on postoperative floors) to 9.2% during the intervention and 8.5% during the QI period. There was no statistically significant difference in adjusted delirium incidence month-by-month during the QI period compared to baseline using segmented regression (aOR = 0.98; 0.91–1.05; P = .52; Table 4).

DISCUSSION

We implemented a multidisciplinary perioperative QI initiative designed to better align our institution's perioperative delirium prevention practices with expert consensus recommendations. After implementation of the intervention followed by a targeted QI project to increase uptake, preoperative delirium risk stratification and use of multicomponent delirium prevention interventions in the PACU occurred reliably, and perioperative administration of Beers Criteria PIMs, particularly midazolam, was reduced when controlling for patient characteristics and secular trends using an interrupted time series study design.

The practice change we demonstrated brought our institutional practice better in line with strong recommendations made in the Joint Consensus Statement from the American Society for Enhanced Recovery and POQI-6 Workgroup, including preoperative delirium risk stratification procedures, use of multicomponent interventions in the PACU, and decreased PIM administration.[10] Though most PIMs were administered to only a small percentage of older patients undergoing surgery, small differences in administration rates may still be clinically significant because each case of POD can result in individual patient harm. Unfortunately, few specific intraoperative interventions effectively prevent POD, with recent trials failing to show a preventative effect for intraoperative use of dexmedetomidine,[26] ketamine,[27] and processed electroencephalography monitoring,[28,29] for example. Therefore, the guidance provided by consensus statements such as that published by POQI-6,[10] with which our intervention is consistent, is the current standard.

No statistical difference was observed in POD incidence after the intervention. There are several likely explanations for this finding. First, delirium screening with NuDesc was rolled out on hospital wards at varying times during the 1-year baseline period, so delirium rates were likely undercounted during that time. Data on the sensitivity of NuDesc for detecting delirium vary; it has been recommended for use in the postoperative setting,[30] although it, and the CAM-ICU, have also elsewhere been criticized for low sensitivity.[31] Furthermore, there were many concurrent delirium reduction efforts occurring at a health system-wide level throughout our analysis, which further confounds the delirium data. Any changes observed would not be clearly attributed to our specific perioperative intervention. Therefore, making conclusions about the effectiveness of the intervention in this case is limited by variability in delirium detection across time periods. Because no intraoperative interventions reliably decrease delirium incidence across a broad population of surgical patients, our goal at the outset of the intervention was to bring our department's perioperative management into better alignment with best practice care guidelines rather than to directly change delirium rates.

Creating and sustaining individual- and organizational-level practice change is difficult.[32,33] Factors crucial to our success include capitalizing on momentum from hospital-wide initiatives with high-level institutional support; early engagement of stakeholders from multiple departments (especially nursing); considering feedback about feasibility, workflow impact, and individual- and organizational-level barriers in design of the intervention; providing robust repetitive education to all stakeholder groups; and providing feedback on performance to providers. We also leveraged the EHR to improve provider practice habits through utilization of a variety of custom EHR builds, including just-in-time intraoperative reminders to increase compliance with appropriate orderset use. In fact, introduction of intraoperative reminders was the crucial step that allowed for improvement and maintenance of compliance with orderset use above our departmental goal. Various other EHR capabilities, including best practice advisories and automated order selection based on delirium risk stratification results, were not used for a variety of institutional reasons including compliance with the resident QI program guidelines, but these may be good options for others to consider. We intend to continue to analyze the effectiveness of the EHR enhancements in this setting in an attempt to balance the risks of alert fatigue[34–36] with the observed—and expected—effectiveness of just-in-time alerts,[37] and we plan to continue support of the low-risk passive clinical decision support interventions described in Supplemental Digital Content 2, Document, http://links.lww.com/AA/D209. These passive clinical decision support interventions have been noncontroversial—they may not have the full effectiveness of a highly visible alert, but they also carry minimal cognitive burden and risk of distraction.

Based on our experience, we offer several recommendations to others interested in implementing similar POD prevention initiatives at their institutions. First, interprofessional collaboration is of utmost importance to the success of any large-scale initiative. Our efforts would not have been possible without collaboration from our extraordinary preoperative and PACU nursing colleagues and multiple practitioners throughout the hospital. Furthermore, delirium prevention efforts focused solely on anesthesia management are unlikely to be successful without continuation of delirium detection, prevention, and treatment throughout the patient's entire hospital stay. Support from health system leadership for a hospital-wide delirium reduction program and coordination with providers outside of the immediate perioperative environment (which may include surgeons, geriatricians, consulting physicians, nurses, pharmacists, rehabilitation specialists, and others) are keys to success. Provision of constant feedback on compliance and process metrics may be helpful. To optimize effectiveness of interventions, involvement of experts in implementation science may also be beneficial.

Our study has several limitations in addition to those already described. The intervention was designed to be used at a single center, incorporating analysis of our institution's organizational barriers. Our risk stratification tool and EHR builds are also institution specific. These features limit the generalizability of the intervention; it would require adaptation to be used elsewhere. Furthermore, our intervention occurred in the context of a health system-wide delirium QI intervention. In order for a more limited perioperative intervention to be successful, delirium screening and prevention practices would need to occur on a broader scale outside of the perioperative environment. Finally, sustainability of this intervention is improved by EHR enhancements but inhibited by labor-intensiveness of providing education to new groups of practitioners and ongoing performance feedback.

In conclusion, we report our experience with implementing a perioperative delirium QI intervention that was associated with a statistically significant reduction in the perioperative administration of Beers Criteria PIMs to adults ≥65 years of age. This interprofessional clinical intervention may serve as a foundation for others to build on in their own institutions.

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