Incidence of and risk factors for postoperative delirium in older adult patients undergoing noncardiac surgery: a prospective study

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Abstract

Background: To identify the incidence of, risk factors for, and outcomes associated with postoperative delirium (POD) in older adult patients who underwent noncardiac surgery.

Methods: This prospective study recruited patients aged ≥ 60 years who were scheduled to undergo noncardiac surgery at Siriraj Hospital (Bangkok, Thailand). Functional and cognitive statuses were assessed preoperatively using Barthel Index (BI) and the modified Informant Questionnaire on Cognitive Decline in the Elderly, respectively. POD was diagnosed based on the Diagnostic and Statistical Manual of Mental Disorders Fifth Edition criteria. Incidence of POD was reported. Univariate and multivariate analyses were used to identify risk factors for POD.

Results: Of the 249 included patients, 29 (11.6%) developed POD. Most patients (61.3%) developed delirium on postoperative day 1. Univariate analysis showed age ≥ 75 years, BI score ≤ 70, pre-existing dementia, preoperative use of opioid or benzodiazepine, preoperative infection, and hematocrit < 30% to be significantly associated with POD. Multivariate logistic analysis revealed pre-existing dementia (adjusted risk ratio [RR]: 3.95, 95% confidence interval [CI]: 1.91–8.17; p < 0.001) and age ≥ 75 years (adjusted RR: 2.54, 95% CI: 1.11–5.80; p = 0.027) to be independent risk factors for POD. Median length of hospital stay was 10 (range: 3–36) days for patients with POD versus 6 (range: 2–76) days for those without delirium (p < 0.001).

Conclusions: POD remains a common surgical complication, with an incidence of 11.6%. Patients with pre-existing dementia and age ≥ 75 years are the most vulnerable high-risk group. A multidisciplinary team consisting of anesthesiologists and geriatricians should implement perioperative care to prevent and manage POD.

Keywords: Collaborative approach, Incidence, Risk factors, Postoperative delirium, Older adult patients, Noncardiac surgery

Background

Delirium is a common postoperative complication that occurs in 5 to 52% of older adult patients after noncardiac surgery [1, 2]. Delirium is characterized by disturbance in attention, awareness, and cognition that develops acutely and fluctuates frequently throughout the course of the condition [3]. POD adversely impacts patient quality of life, and increases the burden on the patient’s family. Delirium has been associated with adverse outcomes, such as functional decline [4, 5], dementia or cognitive impairment [6, 7], increased hospital length of stay [8, 9], increased mortality [7–9], institutionalization [7, 8], and increased healthcare costs [10].

As the population of older adults increases, so too with the number of older adult patients that present for anesthesia and surgery. The development of delirium following surgery has some significant potential effects on patient outcomes; however, POD is often underdiagnosed. Some studies reported that more than 50% of
patients with delirium were undiagnosed by medical teams [11–13]. Moreover, it is sometimes difficult to differentiate delirium, especially hypoactive delirium, from the residual effects of anesthesia during the early postoperative period [14]. Delirium has multifactorial causes and complex pathophysiological mechanisms. Clinical studies of incidence and risk factors associated with POD may provide additional useful clues to the optimal perioperative care of older adult surgical patients at risk for delirium. Risk identification may also help clinicians provide patient-specific management during the perioperative period.

The gold standard diagnostic criteria for delirium is the Diagnostic and Statistical Manual of Mental Disorders Fifth Edition (DSM-5) from the American Psychiatric Association [3]. Definitive delirium diagnosis should be performed by a trained and experienced physician, such as a geriatrician or psychiatrist. A standardized diagnostic tool used by a trained and experienced physician may help to maximize the detection of POD. Traditionally, geriatric consultation is usually activated once the patient develops delirium after an operation. Proactive geriatric consultation together with the careful anesthesia techniques for surgical patients who have risk for delirium may reduce the incidence of POD and its associated adverse outcomes during the perioperative period. A collaborative approach between geriatricians and anesthesiologists may also improve the quality of patient care and patient outcomes. Before a program with these objectives can be developed and implemented, the scope of the problem and factors that significantly associate with POD must be identified.

Accordingly, the aim of this study was to enlist anesthesiologists and geriatricians to collaboratively investigate the incidence of, risk factors for, and outcomes associated with POD among older adult patients who underwent noncardiac surgery.

Methods
After receiving Siriraj Institutional Review Board (COA no. Si 718/2015) approval, a prospective cohort study was conducted at a large university-based national tertiary referral center during the March 2017 to December 2017 study period. Patients aged 60 years or older who were scheduled to undergo noncardiac surgery were eligible for inclusion. Patients were excluded if they refused to participate in the study or required postoperative intensive care unit admission. The protocol for this study followed all of the guidelines outlined in the Declaration of Helsinki and all of its later amendments. Written informed consent was obtained from all study participants.

Preoperatively, all patients were assessed for functional and cognitive status by the clinical researcher or a trained research assistant. Functional status was assessed using the Barthel Index of Activities of Daily Living [15]. The Barthel Index (BI) consists of 10 items that assess self-care abilities, including feeding, grooming, bathing, dressing, toilet use, bowel and bladder control, mobility, stair climbing, and transferring from bed to chair. Scoring ranges from 0 (totally dependent) to 100 (fully independent). The rating was classified as ≤ 70 or > 70. The information was obtained from an observation of patient performance or a caregiver interview.

Cognitive status was measured using the modified Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE), which is based on information elicited from a close relative or caregiver of each patient. The modified IQCODE for detection of dementia in Thai older adults (90% sensitivity, 95% specificity, 94% positive predictive value, and 90% negative predictive value) consists of 32 items designed to assess cognitive changes over the previous 10 years [16]. Scoring ranges from 1 (much improved) to 5 (much worse), and total scores were divided by the number of items (32) to give an average score of 1–5, with an optimal cutoff score of 3.42. Accordingly, patients with a modified IQCODE score greater than or equal to 3.42 were considered to have some degree of dementia [16]. Patients with a pre-existing diagnosis of dementia were also obviously similarly classified.

POD was diagnosed by one of three geriatricians based on the DSM-5 criteria [3]. All three geriatricians have had experience in caring for older adult patients with delirium and dementia for an experience duration ranging from 5 to 15 years. To enhance agreement among geriatricians relative to delirium diagnosis, a DSM-5 intrarater reliability among these three geriatricians was measured, and a level of agreement ranging from 90 to 100% was obtained. Daily patient assessment for POD was performed during the daytime for 7 consecutive days after surgery. The occurrence of POD and delirium onset time was documented.

The surgical procedures and anesthetic techniques were carried out with no specific intervention from the research team. Patient demographic data, comorbidities, type and duration of surgery, anesthesia technique, intraoperative hypotension, intraoperative hypoxemia, and length of hospital stay were recorded. Intraoperative hypotension was defined as either systolic blood pressure less than 90 mmHg for more than 5 min or the use of vasopressor to treat hypotension [17]. Intraoperative hypoxemia was defined as oxygen saturation, measured by pulse oximeter, of below 90% for any duration [18].

Medications used within 3 months before surgery were also recorded, including opioids, benzodiazepines, statins, anticonvulsants, and psychotropic drugs (antipsychotics, antidepressants, and antianxiety drugs were grouped together as psychotropic drugs). Preoperative laboratory values, including hematocrit (Hct), sodium, and ratio of blood urea nitrogen to creatinine (BUN/Cr
ratio), were measured and recorded. Maximum pain scores on the first postoperative day were determined using a numeric rating scale (NRS) on a 10-point scale. Pain intensity was classified as mild (NRS = 1–3), moderate (NRS = 4–7), or severe (NRS = 8–10) pain.

**Statistical analysis**
The sample size was estimated based on multiple logistic regression analysis [19]. Based on literature review, the risk factors for POD were approximately 10 variables [2] and the number of patients with delirium should be 5 to 10 times of risk factors. From the previous study [8], the incidence of POD was 44% among patients undergoing noncardiac surgery. The sample size was calculated and a minimum sample size of 227 patients was required. To compensate for a possible 10% dropout rate for any reason, a minimum total study population of 250 patients was required.

All statistical analyses were performed using PASW Statistics version 18.0 (SPSS, Inc., Chicago, IL, USA) and MedCalc Statistic Software version 17.6 (MedCalc Software BVBA, Ostend, Belgium). Continuous data are presented as mean ± standard deviation (SD) for normally distributed data, and as median and interquartile range for non-normally distributed data. Categorical data are presented as frequency and percentage. All variables in patients without POD versus those with POD were analyzed by univariate logistic regression analysis using chi-square test, Fisher’s exact test, independent t-test, or Mann-Whitney U test, as appropriate. Seven risk factors with univariable p-value less than 0.05 including pre-existing dementia, age ≥ 75 years, hematocrit < 30%, preoperative opioid use, preoperative benzodiazepine use, preoperative infection, and Barthel index score ≤ 70 were entered into multiple regression model. Risk ratios and adjusted risk ratios with their respective 95% confidence intervals were reported. A p-value less than 0.05 was considered to be statistically significant for all tests. Receiver operating characteristic (ROC) curve analysis was performed to identify the optimal cutoff age for developing delirium. The results of that analysis are reported as Youden’s index, sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio, negative likelihood ratio, and area under curve.

**Results**
During the study period, a total of 269 patients were assessed for eligibility. Of those, 20 patients were excluded for the reasons showed in Fig. 1. The remaining 249 patients were included and completed the study. The demographic and clinical data of patients are summarized in Table 1. Perioperative data is described in Table 2.

Using DSM-5 criteria, 29 of 249 patients developed delirium, for an incidence of 11.6%. The majority of patients (61.3%) developed delirium on postoperative day 1, followed by 16.1% on day 2, 12.9% on day 3, 6.5% on day 5, and 3.2% on day 6. As shown in Table 1, patients with delirium were significantly older (p < 0.001), had a greater prevalence of pre-existing dementia (p < 0.001), had a lower Barthel Index score (p = 0.001), and had a higher rate of preoperative opioid (p = 0.001) or benzodiazepine (p = 0.022) relative to those patients without delirium. In
addition, among patients with delirium versus those without delirium, hematocrit less than 30% (27.6% vs. 12.3%, respectively; \( p = 0.042 \)) and preoperative infection (20.7% vs. 8.2%, respectively; \( p = 0.044 \)) were significantly associated with the development of delirium. Median length of hospital stay was 10 (range: 3–36) days for patients with delirium versus 6 (range: 2–76) days for those without delirium (\( p < 0.001 \)). In multivariate analysis, only pre-existing dementia (adjusted risk ratio [RR]: 3.95, 95% confidence interval [CI]: 1.91–8.17; \( p < 0.001 \)) and age ≥ 75 years (adjusted RR: 2.54, 95% CI: 1.11–5.80; \( p = 0.027 \)) remained significantly associated with POD in patients undergoing noncardiac surgery (Table 3). The ROC curve, with its area under curve of 0.74 (95% CI: 0.65–0.83), is shown in Fig. 2. The optimal cutoff age for developing delirium was age ≥ 75 years. The sensitivity, specificity, positive predictive value, negative predictive value and Youden’s index for optimal cutoff age was 79.3, 53.6%, 18.4, 95.2, and 0.34, respectively (Table 4).

**Discussion**

Based on DSM-5 criteria, this prospective cohort study found an 11.6% incidence of postoperative delirium among the older adult patients admitted to the surgical ward after noncardiac surgery. Pre-existing dementia and age 75 years or older were the independent risk factors for POD in these patients. In terms of outcome, patients who developed delirium had longer hospital stay than those without delirium. There was no in-hospital mortality in this study.

The 11.6% incidence of POD in the present study was similar to the 13.2% incidence reported in a previous study [9]. This is comparable with the 18.4% pooled incidence of POD reported by a systematic review of 41 studies [20]. In contrast, a high incidence rate of POD in the surgical intensive care unit has been reported to range from 24.4 to 44% [8, 21]. This reflects the fact that the reported incidence of POD varies from study to study depending on the patient population, timing of

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**Table 1** Demographic and clinical data of patients without and with delirium

| Variables                      | Total (\( n = 249 \)) | No delirium (\( n = 220; 88.4\% \)) | Delirium (\( n = 29; 11.6\% \)) | \( p \)-value |
|--------------------------------|------------------------|-------------------------------------|---------------------------------|--------------|
| Age (years), mean ± SD         | 75.1 ± 7.9             | 74.4 ± 6.9                          | 80.7 ± 6.6                      | < 0.001      |
| Age ≥ 75 years, n (%)          | 125 (50.2)             | 102 (46.4)                          | 23 (79.3)                       | 0.001        |
| Female gender, n (%)           | 154 (61.8)             | 137 (62.3)                          | 17 (58.6)                       | 0.839        |
| ASA physical status, n (%)     |                        |                                     |                                 | 0.545        |
| II                             | 152 (61.0)             | 136 (61.8)                          | 16 (52.5)                       |              |
| III                            | 97 (39.0)              | 84 (38.2)                           | 13 (44.8)                       |              |
| Barthel Index scores ≤ 70, n (%) | 51 (20.5)            | 38 (17.3)                           | 13 (44.8)                       | 0.001        |
| Alcohol ≥ 2 drinks daily, n (%) | 83 (33.3)             | 73 (33.2)                           | 10 (34.5)                       | 1.000        |
| Smoking ≥ 30 pack year, n (%)  | 68 (27.3)              | 61 (27.7)                           | 7 (24.1)                        | 0.826        |
| Comorbidities, n (%)           |                        |                                     |                                 |              |
| Diabetes mellitus              | 84 (33.7)              | 78 (35.5)                           | 6 (20.7)                        | 0.144        |
| Hypertension                   | 184 (73.9)             | 165 (75.0)                          | 19 (65.5)                       | 0.368        |
| Heart disease                  | 43 (17.3)              | 36 (16.4)                           | 7 (24.1)                        | 0.433        |
| Stroke or TIA                  | 13 (5.2)               | 12 (5.5)                            | 1 (3.4)                         | 1.000        |
| ESRD or CKD                    | 54 (21.7)              | 48 (21.8)                           | 6 (20.7)                        | 1.000        |
| Cirrhosis                      | 5 (2.0)                | 5 (2.3)                             | 0 (0.0)                         | 1.000        |
| Cancer                         | 55 (22.1)              | 45 (20.5)                           | 10 (34.5)                       | 0.098        |
| Dementia                       | 42 (16.9)              | 26 (11.8)                           | 16 (55.2)                       | < 0.001      |
| Preoperative infection         | 24 (9.6)               | 18 (8.2)                            | 6 (20.7)                        | 0.044        |
| Preoperative medications, n (%)|                        |                                     |                                 |              |
| Opioids                        | 36 (14.5)              | 25 (11.4)                           | 11 (37.9)                       | 0.001        |
| Benzodiazepines                | 37 (14.9)              | 28 (12.7)                           | 9 (31.0)                        | 0.022        |
| Psychotropics                  | 14 (5.6)               | 11 (5.0)                            | 3 (10.3)                        | 0.214        |
| Anticonvulsants                | 19 (7.6)               | 14 (6.4)                            | 5 (16.1)                        | 0.054        |
| Statins                        | 136 (54.6)             | 124 (56.4)                          | 12 (41.4)                       | 0.165        |

A \( p \)-value < 0.05 indicates statistical significance

**Abbreviations:** SD standard deviation, ASA American Society of Anesthesiologists, TIA transient ischemic attack, ESRD end-stage renal disease, CKD chronic kidney disease
assessment, experience of the investigator, surgery type, and diagnostic tools to assess for delirium. Management goals for reducing the incidence and duration of POD should be included in the clinical guidelines or protocols.

Regarding onset time of POD, most patients in this study (61.3%) developed POD on postoperative day 1, whereas those in previous studies [22, 23] developed POD on postoperative day 2. However, a POD episode can occur any time during the entire postoperative period. According to the American Geriatrics Society Expert Panel, the clinical guideline for POD recommends that delirium assessment should be performed at least once daily in all patients at high risk for developing delirium [24, 25].

In the present study, pre-existing dementia was the strongest risk factor for POD, with an adjusted risk ratio of 3.95 (95% CI: 1.91–8.17). This finding is consistent with previous studies [6, 8, 26] that reported pre-existing dementia as a risk factor for the development of POD. A recent study of non-surgical patients also reported pre-existing dementia to be the main risk factor for delirium [27]. Delirium superimposed on dementia (DSD) is the term used for delirium that occurs in patients with pre-existing dementia [28]. The prevalence of DSD was reported to be as high as 22–89% in hospital and

Table 2 Perioperative data of patients without and with delirium

| Variables                                      | Total (n = 249) | No delirium (n = 220) | Delirium (n = 29) | p-value |
|------------------------------------------------|-----------------|-----------------------|-------------------|---------|
| Type of surgery, n (%)                         |                 |                       |                   | 0.606   |
| Vascular                                       | 10 (4.0)        | 8 (3.6)               | 2 (6.9)           |         |
| Urological                                      | 26 (10.4)       | 24 (10.9)             | 2 (6.9)           |         |
| General                                        | 94 (37.8)       | 85 (38.6)             | 9 (31.0)          |         |
| Orthopedic                                     | 119 (47.8)      | 103 (46.8)            | 16 (55.2)         |         |
| Urgent surgery, n (%)                          | 38 (15.3)       | 30 (13.6)             | 8 (27.6)          | 0.058   |
| Operative time (min), mean ± SD                | 115.3 ± 70.0    | 115.3 ± 68.9          | 115.3 ± 79.0      | 0.997   |
| Type of anesthesia, n (%)                      |                 |                       |                   | 0.659   |
| General                                        | 142 (57.0)      | 126 (57.3)            | 16 (55.2)         |         |
| Regional                                       | 85 (34.1)       | 76 (34.5)             | 9 (31.0)          |         |
| Combined                                       | 22 (8.8)        | 18 (8.2)              | 4 (13.8)          |         |
| Intraoperative benzodiazepines, n (%)          | 55 (22.1)       | 50 (22.7)             | 5 (17.2)          | 0.637   |
| Intraoperative anticholinergics, n (%)         | 143 (57.4)      | 128 (58.2)            | 15 (51.7)         | 0.552   |
| Intraoperative hypotension, n (%)              | 127 (51.0)      | 108 (49.1)            | 19 (65.5)         | 0.115   |
| Intraoperative hypoxemia, n (%)                | 0 (0)           | 0 (0)                 | 0 (0)             |         |
| Intraoperative blood loss (mL), median (IQR)   | 50 (20–200)     | 50 (20–175)           | 100 (30–250)      | 0.143   |
| Intraoperative blood transfusion, n (%)        | 19 (7.6)        | 15 (6.8)              | 4 (13.8)          | 0.252   |
| Postoperative pain intensity*, n (%)           |                 |                       |                   | 0.142   |
| No pain                                        | 32 (12.9)       | 28 (12.7)             | 4 (13.8)          |         |
| Mild pain (NRS = 1–3)                          | 96 (38.6)       | 88 (40.0)             | 8 (27.6)          |         |
| Moderate pain (NRS = 4–6)                     | 86 (34.5)       | 77 (35.0)             | 9 (31.0)          |         |
| Severe pain (NRS = 7–10)                      | 35 (14.1)       | 27 (12.3)             | 8 (27.6)          |         |
| Abnormal laboratory values, n (%)             |                 |                       |                   | 0.042   |
| Preoperative hematocrit < 30%                  | 35 (14.1)       | 27 (12.3)             | 8 (27.6)          |         |
| Preoperative sodium <135 or > 145 mEq/L        | 24 (9.6)        | 20 (9.1)              | 4 (13.8)          | 0.498   |
| Preoperative BUN/Cr ratio > 20                | 62 (24.9)       | 53 (24.1)             | 9 (31.0)          | 0.493   |
| Length of stay (days), median (IQR)            | 7 (2–76)        | 6 (2–76)              | 10 (3–36)         | < 0.001 |
| Length of stay > 7 days, n (%)                 | 103 (41.4)      | 78 (35.5)             | 25 (86.2)         | < 0.001 |

A p-value < 0.05 indicates statistical significance
Abbreviations: SD standard deviation, IQR interquartile range, BUN/Cr blood urea nitrogen/creatinine
*Maximum pain score using numeric rating scale (NRS) was measured on the first postoperative day
community populations [29], and 1.4–70% in institutionalized patients [30]. The occurrence of DSD can lead to poor delirium outcomes, including increased risk of mortality, institutionalization, and length of stay [31, 32]. Given the adverse outcomes of delirium, preventive strategies should be implemented to these patients. The delirium prevention strategies include reorientation, hydration, optimized oxygenation, infection control, early mobility, appropriate pain management, medication review, nutrition support, hearing and visual aids, and sleep hygiene [25].

Older age is also an important risk factor for delirium. The present study showed a significant association between POD and age $\geq$ 75 years, with an adjusted risk ratio of 2.54 (95% CI: 1.11–5.80). From previous studies, there were different age groups of patients (e.g., age $\geq$ 65, age $\geq$ 70, and age $\geq$ 75) that were identified as groups at high risk for delirium [2, 9, 25]. In the present study, ROC curve analysis revealed age $\geq$ 75 years to be the optimal cutoff age for developing delirium, with a sensitivity of 79.3%. This finding suggests that delirium screening might be performed in postoperative noncardiac patients that are aged 75 years or older. Although age is a fixed risk factor that cannot be modified, the delirium prevention and management strategies may be of

### Table 3: Univariate and multivariate analysis for variables significantly associated with postoperative delirium

| Variables                      | n     | Delirium (n = 29) | Crude RR (95% CI) | p-value | Adjusted RR (95% CI) | p-value |
|-------------------------------|-------|------------------|------------------|---------|----------------------|---------|
| Pre-existing dementia, n (%)  |       |                  |                  |         |                      |         |
| No                            | 207   | 13 (6.3)         | 1                |         | 1                    |         |
| Yes                           | 42    | 16 (38.1)        | 6.07 (3.16–11.65)| <0.001  | 3.95 (1.91–8.17)     | <0.001  |
| Age $\geq$ 75 years, n (%)    |       |                  |                  |         |                      |         |
| No                            | 124   | 6 (4.8)          | 1                |         | 1                    |         |
| Yes                           | 125   | 23 (18.4)        | 3.80 (1.60–9.03) | 0.001   | 2.54 (1.11–5.80)     | 0.027   |
| Preoperative hematocrit <30%, n (%) |   |                  |                  |         |                      |         |
| No                            | 214   | 21 (9.8)         | 1                |         | 1                    |         |
| Yes                           | 35    | 8 (22.9)         | 2.33 (1.12–4.84)| 0.042   | 1.53 (0.79–2.96)     | 0.204   |
| Preoperative opioids, n (%)   |       |                  |                  |         |                      |         |
| No                            | 213   | 18 (8.5)         | 1                |         | 1                    |         |
| Yes                           | 36    | 11 (30.6)        | 3.62 (1.87–7.01)| 0.001   | 1.80 (0.83–3.91)     | 0.139   |
| Preoperative benzodiazepines, n (%) |   |                  |                  |         |                      |         |
| No                            | 212   | 20 (9.4)         | 1                |         | 1                    |         |
| Yes                           | 37    | 9 (24.3)         | 2.58 (1.27–5.22)| 0.022   | 1.41 (0.66–3.01)     | 0.370   |
| Preoperative infection, n (%) |       |                  |                  |         |                      |         |
| No                            | 225   | 23 (10.2)        | 1                |         | 1                    |         |
| Yes                           | 24    | 6 (25.0)         | 2.45 (1.11–5.41)| 0.044   | 1.47 (0.68–3.19)     | 0.329   |
| Barthel Index score $\leq$ 70, n (%) |   |                  |                  |         |                      |         |
| No                            | 198   | 16 (8.1)         | 1                |         | 1                    |         |
| Yes                           | 51    | 13 (25.5)        | 3.15 (1.62–6.13)| 0.001   | 1.14 (0.54–2.40)     | 0.734   |

A p-value < 0.05 indicates statistical significance

Abbreviations: RR risk ratio, CI confidence interval

Fig. 2 Receiver operating characteristic (ROC) curve of the age classification of delirious patients
The optimal cutoff age was age ≥ 95% CI are needed to improve delirium. Further studies that focus on multidisciplinary collaboration may help to prevent POD or reduce its severity. Importantly, the involved healthcare professionals should work together as a multidisciplinary team for successful management of POD.

Strengths of the present study include its prospective design, the fact that we used the DSM-5 for diagnosing delirium, and that delirium diagnosis was made by experienced geriatricians. Some limitations must also be mentioned. First, this study was conducted at a single institution. Therefore, our results may not be generalizable to other care settings. Second, the sample size may be too small to identify all significant differences and associations that relate to POD. Third, delirium assessment was only performed once daily, so the incidence of POD may have been underestimated. Finally, some relevant information was not obtained, such as prior postoperative delirium and intraoperative medication usage, and this could have had a confounding effect on our analysis and findings.

Conclusions
This prospective study found an 11.6% incidence of postoperative delirium among patients undergoing non-cardiac surgery. Pre-existing dementia and age 75 years or older were found to be the independent risk factors for development of POD. Collaborative approach to identify patients at risk for delirium and provide perioperative management strategies may help to prevent POD or reduce its severity. Further studies that focus on multidisciplinary collaboration are needed to improve delirium care.

Table 4 Receiver operating characteristic curve analysis of the optimal cutoff age for developing delirium

| Cut point | Sensitivity (%) | Specificity (%) | PPV   | NPV   | LR+  | LR-  | Accuracy (95% CI) | Youden's Index |
|-----------|----------------|----------------|-------|-------|------|------|--------------------|----------------|
| ≥ 65     | 100.00         | 9.09           | 12.66 | 100.0 | 1.10 | 0.00 | 19.68% (14.9–25.2) | 0.09           |
| ≥ 70     | 96.55          | 21.82          | 14.00 | 97.96 | 1.23 | 0.16 | 30.52% (24.9–36.6) | 0.18           |
| ≥ 75     | 79.31          | 53.64          | 18.40 | 95.16 | 1.71 | 0.39 | 56.63% (50.2–62.9) | 0.34           |
| ≥ 80     | 51.72          | 75.91          | 22.06 | 92.27 | 2.15 | 0.64 | 73.09% (67.1–78.5) | 0.28           |
| ≥ 85     | 31.03          | 91.82          | 33.33 | 90.99 | 3.79 | 0.75 | 84.74% (79.7–89.0) | 0.23           |

Abbreviations: PPV positive predictive value, NPV negative predictive value, LR+ positive likelihood ratio, LR- negative likelihood ratio, AUC area under the curve, 95% CI 95% confidence interval

The optimal cutoff age was age ≥ 75 years with the best sensitivity and Youden's index.

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Authors’ contributions
AI, OC - study design, literature search, analysis and interpretation of data, drafting of manuscript, critical revision, and approval of final version submitted for publication. TW, PS - study design, literature search, data interpretation, and critical revision. NW, NR - literature search, patient follow-up, data collection, data interpretation, and drafting of manuscript. All authors have read and approved the manuscript in its current state.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate
This study was approved by the Siriraj Institutional Review Board of the Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand (COA no. Si 718/2015). After the consent form was approved by the ethics committee, the formal written informed consent from participants was obtained prior to participation in the study. For the participants who were incapable of making and executing the healthcare decisions, the written informed consent was obtained from their spouses or adult children prior to participation. The consenting procedure was approved by the ethics committee.

Consent for publication
Not applicable.
Competing interests
The authors declare that they have no competing interests.

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