

RETRACTED ARTICLE: Impact of postoperative dexmedetomidine infusion on incidence of delirium in elderly patients undergoing major elective noncardiac surgery: a randomized clinical trial

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Yuanyuan Sun*
Mingming Jiang*
Yunjing Ji
Yue Sun
Yao Liu
Wen Shen

Department of Anesthesiology, Affiliated
Hospital of Xuzhou Medical University,
Xuzhou, Jiangsu, People's Republic of
China

*These authors contributed equally to
this work

Purpose: Postoperative delirium is a serious and common complication, it occurs in 13–50% of elderly patients after major surgery, and brings adverse consequences. Emerging literature suggests that dexmedetomidine sedation in critical care units (intensive care unit) is associated with reduced incidence of delirium. However, few studies have investigated whether postoperative continuous infusion of dexmedetomidine could safely decrease the incidence of delirium in elderly patients admitted to general surgical wards after noncardiac surgery.

Patients and methods: This double-blind, randomized, placebo-controlled trial was conducted in patients aged 65 years and older undergoing major elective noncardiac surgery without a planned ICU stay. Fifty patients were randomly assigned to receive either dexmedetomidine (0.1 µg/kg/h) or placebo (0.9% normal saline) immediately after surgery through patient-controlled intravenous analgesia device. The primary outcome was the incidence of delirium during the first 5 postoperative days. Secondary outcomes included postoperative subjective pain scores and subjective sleep quality. The study dates were from January 2018 to January 2019.

Results: A total of 557 patients were randomly assigned to receive either dexmedetomidine (n=281) or placebo (n=276). The incidence of postoperative delirium had no difference between the dexmedetomidine and placebo groups (11.7% [33 of 281] vs 13.8% [38 of 276], $P=0.47$). Compared with placebo group, patients in dexmedetomidine group reported significant lower numerical rating score pain scores at 3, 12, 24, and 48 hrs after surgery (all $P<0.05$) and significant improved Richards Campbell Sleep Questionnaire results during the first 3 postoperative days (all $P<0.0001$). Dexmedetomidine-related adverse events were similar between the two groups.

Conclusion: Postoperative continuous infusion of dexmedetomidine did not decrease the incidence of postoperative delirium in elderly patients admitted to general surgical wards after elective noncardiac surgery.

Keywords: postoperative delirium, dexmedetomidine, elderly patients, pain, sleep

Introduction

Delirium can be defined as transient brain failure occurring in persons with diminished reserve capacity,¹ featured by an acute and fluctuating disturbance in attention and awareness, frequently develops within the first 5 postoperative days, and is classified into three motor subtypes: hyperactive, hypoactive, and mixed.^{2,3} Elderly patients aged 65 years and older are at the greatest risk of developing delirium,^{1,4} especially for hypoactive subtype, which often goes unrecognized and is associated with poorer prognosis.^{3,5,6} Previous studies revealed that the prevalence of postoperative delirium varies from 13% to 50% in elderly

Correspondence: Wen Shen
Department of Anesthesiology, Affiliated
Hospital of Xuzhou Medical University,
No. 99 Huaihai West Road, Xuzhou,
Jiangsu, People's Republic of China
Tel +86 05 160 850 2043
Email shenwen8694@163.com

patients after surgery.^{1,7,8} Postoperative delirium contributes independently to adverse outcomes including increased complications, prolonged hospital stay, and elevated post-discharge mortality.^{9,10} Once established, there is no robust evidence demonstrating the efficacy of any specific treatment for delirium. Antipsychotics and anxiolytics were frequently prescribed by clinicians to control associated agitation, which was clearly demonstrated to be lacking efficacy and having a risk of serious side effects.^{11,12} Emphasis is therefore placed on the importance of delirium prevention. Underlying pathophysiological mechanisms of delirium development remain poorly understood, but are certainly related to numerous modifiable risk factors such as exposure to general anesthetics and pain.^{1,13–15} Convincing, reproducible evidence that pharmacologic interventions may be effective for preventing delirium is still lacking.⁴

Dexmedetomidine is a highly selective and potent α_2 -adrenergic receptors agonist that provides dose-dependent sedation, anti-anxiety, and modest analgesia with minimal depression of respiratory function.¹⁶ Previous studies have shown that dexmedetomidine attenuated neurotoxicity induced by general anesthetics, improved postoperative analgesia, and inhibited inflammatory response after surgery.^{17–19} Dexmedetomidine is increasingly used in elderly patients admitted to the intensive care unit (ICU), where its use is associated with a lower incidence and severity of postoperative delirium when compared with other sedating agents infusion.^{20–22} A recent study by Su et al²³ providing a limited but promising evidence that low-dose dexmedetomidine infusion in elderly ICU patients after noncardiac surgery reduces the risk of delirium in the postoperative period. Although dexmedetomidine has demonstrated its effectiveness in preventing delirium, its use remains controversial.²⁴ Additionally, few previous studies have evaluated the efficacy of postoperative dexmedetomidine infusion to ameliorate delirium in patient population of general surgical wards. We hypothesized that postoperative administration of dexmedetomidine would lead to a reduced incidence of postoperative delirium compared to placebo.

Materials and methods

Study design and participants

This was a randomized, placebo-controlled, double-blind clinical trial at a tertiary university teaching hospital in China, conducted from January 2018 to January 2019. The study protocol was approved by the clinical research ethics committee of Affiliated Hospital of XuZhou Medical University and the study number was XYFY2018-KL011-01. The trial was registered at Chinese Clinical Trial

Registry, with reference number ChiCTR1800016788. In conformation with the Declaration of Helsinki, every patient or patient's legally authorized representative provided written informed consent before entering the trial.

The inclusion criteria include (1) aged 65 years or older; (2) scheduled to undergo major elective noncardiac surgery (including spine, orthopedic, urologic, thoracic, or general surgery) under general anesthesia without a planned ICU stay; (3) American Society of Anaesthesiologist physical status classification I to III; (4) Mini Mental State Examination (MMSE) ≥ 20 points; (5) free to use of patient-controlled intravenous analgesia pump. Patients were excluded if they met any of the following criteria: (1) emergency surgery; (2) intracardiac or intracranial surgery; (3) inability to communicate because of severe vision or hearing impairment; (4) sick sinus syndrome, clinically significant sinus bradycardia or second-degree or higher heart block in the absence of a pacemaker; (5) serious liver dysfunction (Child-Pugh class C) or serious kidney failure (requiring dialysis); (6) previous history of schizophrenia, epilepsy, Parkinson's disease, or myasthenia gravis; (7) allergy to α_2 -adrenergic agonist or opioids; (8) prior recruitment in other clinical trial. MMSE was assessed to avoid enrolling patients suffering from frank dementia prior to surgery, which is scored as the number of correctly completed items, with lower scores indicative of poorer performance and greater cognitive impairment.²⁵ Major surgery was defined by a planned stay of at least 2 days.

Randomization, blinding, and allocation concealment

Computer-generated random numbers in a 1:1 ratio were provided by SPSS, version 16 (SPSS Inc., Chicago, IL, USA). The results of randomization were sealed in sequentially numbered opaque envelopes and stored at the site of the investigation until the end of the study. During the study period, each individual was randomly assigned to receive either dexmedetomidine or placebo (0.9% normal saline). Researchers who performed data collection and postoperative follow-up, statistical analyst, and trial patients remained blinded to the intervention assignment throughout the entire study period. In case of an emergency (occurrence of severe adverse events or any unexpected deterioration of the patient's clinical condition), study group allocation could be unmasked to ensure patients' safety.

Procedures

All potential participants aged 65 years or older scheduled for elective surgery will be consecutively screened for study eligibility the day before surgery and then recruited if consent is given. Detailed information, including baseline demographics, clinical characteristics, medical history, and preoperative comorbidities, were obtained after recruitment. We used the updated Charlson Comorbidity Index²⁶ to calculate comorbidity burden, which predicted hospital mortality by assigning points to each comorbid condition, with a higher score indicating greater mortality risk.

After each patient entered the operating room, an independent pharmacist dispensed study drugs according to the randomization results. This pharmacist prepared patient-controlled intravenous analgesia (PCIA) device with a blank label (dexmedetomidine group: 4.8 µg/kg dexmedetomidine, 2 µg/kg sufentanil and 6 mg tropisetron diluted with 0.9% normal saline to 96 mL; placebo group: 2 µg/kg sufentanil and 6 mg tropisetron diluted with 0.9% normal saline to 96 mL). In our study, dexmedetomidine was mixed with other drugs in PCIA device, which was prohibited single press to avoid leading to variations in the dosage of dexmedetomidine infusion according to the severity of a patient's pain level. The PCIA device was programmed a background infusion of 2 µg/kg per hour and was connected to patients immediately after surgery, and total continuous infusion time was 48 h (dexmedetomidine 0.1 µg/kg/h). A loading dose was not recommended due to the risk of hypotension. Vital signs including MAP, HR, and SpO₂ were monitored continuously throughout the study drug infusion period.

Anesthesiologists were instructed to avoid administering benzodiazepines, propofol, propofol hydrochloride as well as open-label dexmedetomidine during the whole study period. Any other induction agents were permissible. General anesthesia was maintained with propofol, sevoflurane, or both. opioids and muscle relaxants were administered according to the preference of the anesthesiologist, as were vasoactive medications. Atropine was used only for the purpose of reversing bradycardia (HR<40 beats/min). The heart rate and blood pressure were maintained within 20% of the baseline and BIS was maintained between 40 and 60. The target of nasopharyngeal temperature maintenance during surgery is from 36.0°C to 37°C. Patients were extubated at the end of surgery and were transferred to the postanesthesia care unit (PACU) for continuous routine

vital signs monitoring. They would be discharged from PACU to the general surgical wards after being assessed to have recovered from anesthesia.

Outcomes

Our primary outcome was the incidence of delirium during the 5 postoperative days, assessed by research members who were trained prior to the study and were masked to treatment. The first assessment of postoperative delirium was done before PACU discharge by the Confusion Assessment Method for the ICU (CAM-ICU),²⁷ which has established feasibility in the recovery room. Twice daily (8–10 am and 6–8 pm) during the first 5 days postoperatively, we assessed delirium with the Confusion Assessment Method (CAM),²⁸ which was published in 1990 with high sensitivity (94–100%) and specificity (90–95%) and is reported as the most widely used standardized method for the identification of delirium in clinical practice and research.²⁹ Both CAM and CAM-ICU make the diagnosis according to four features of delirium: (1) acute onset and fluctuating course, (2) inattention, (3) disorganized thinking, and (4) altered level of consciousness. The diagnosis of delirium was determined by the presence of features 1 and 2 plus either feature 3 or 4.^{27,28}

Before delirium assessment, the level of consciousness was assessed with the Richmond Agitation Sedation Scale (RASS).³⁰ If the patient was deeply sedated or unarousable (RASS score -4 to -5), delirium assessment was stopped and the patient was noted as comatose, if the RASS score was -3 or higher, delirium assessment was performed. Intravenously administered of haloperidol was a first-line treatment in delirious patients with severe agitation, in the increments of 2.5–5 mg, repeated every 30–60 mins when necessary.³¹ For patients who were discharged or died within the scheduled 5 follow-up days after surgery, the results of the last delirium assessment were considered as the missing data.

Secondary outcomes included postoperative subjective pain scores, the percentage of patients requiring flurbiprofen axetil for pain rescue, cumulative consumption of nonsteroid anti-inflammatory drugs, and subjective sleep quality. Subjective pain scores at rest and with movement were assessed using the Numeric Rating Scale (NRS, an 11-point scale where 0 indicated no pain and 10 indicated the worst possible pain)³² at 1, 3, 12, 24, and 48 hrs after surgery, respectively. If the patient reported a NRS of 4 or higher at resting state, nonsteroid anti-inflammatory drugs (flurbiprofen axetil, 50 mg injected intravenously for up to

two times per day) were used for pain rescue. Subjective sleep quality was measured using the Richards Campbell Sleep Questionnaire (RCSQ),³³ a five-item visual analog scale, which is one of the few validated assessments measuring overnight sleep and has been used by another delirium-related study.³⁴ The RCSQ was offered to patients at 8:00 am on the first, second, and third days after surgery during the study period. Each item is scored from 0 to 100 mm (higher numbers indicate better sleep responses) on a visual scale, summed, and then divided by 5 to obtain a total score.³³

Additional outcomes included time to extubation, postoperative length of stay (from the day of surgery to hospital discharge), the incidence of non-delirium postoperative complications, adverse events, as well as all-cause mortality within 30 days after surgery. Non-delirium postoperative complications within 30 days after surgery include acute myocardial infarction, unstable angina, new-onset arrhythmia, heart failure, respiratory failure, pneumonia, stroke, pulmonary embolism, deep venous thrombosis, and infection. All patients were followed up weekly after the first week by telephone interview with patients and/or their family members until 30 days after surgery. Adverse events include bradycardia (heart rate <40 beats/min), tachycardia (heart rate >100 beats/min), hypotension (systolic blood pressure <90 mm Hg or a decrease of more than 30% from baseline), hypertension (systolic blood pressure >180 mm Hg or an increase of more than 20% from baseline), hypoxemia (pulse oxygen saturation less than 90%), and nausea or vomiting. Intervention for bradycardia, tachycardia, hypertension, and nausea or vomiting included administration of medication or stopping infusion temporarily. Intervention for hypotension included intravenous fluid bolus or administration of medication or stopping infusion temporarily. Intervention for hypoxemia included administration of oxygen or physical therapy. Patients were excluded from the analysis if study drug infusion was interrupted permanently before the scheduled end due to severe adverse events.

Statistical analysis

The sample size calculation is based on the incidence of delirium. Previous studies showed that the incidence of postoperative delirium was 14.8% in elderly patients after noncardiac surgery.⁸ Assuming that the placebo group in the present study would have a similar delirium incidence as in previous studies, we adopted an estimation based on a 15% incidence of delirium among the placebo group and

a reduction of 50% in delirium incidence in the dexmedetomidine group. With the power set at 80% and significant level at 0.05, the sample size required to obtain reliable results for the reduction of delirium incidence was 556 patients, calculated with PASS 11.0 software (NCSS, LLC, Kaysville, USA). Considering a dropout rate of about 10%, we planned to enroll 618 patients.

For continuous variables, Kolmogorov–Smirnov test was used to assess the normality. Normally distributed continuous variables were presented as the means (SD), and abnormal variables were presented as medians (interquartile range). Categorical variables were presented as number (percentage). Normally distributed continuous variables were analyzed using an independent two-sample *t*-test. Continuous variables with abnormal distribution and ranked data were analyzed using Mann–Whitney U test. Categorical variables were analyzed using χ^2 test or Fisher exact tests. Time-to-event variables were calculated with the Kaplan–Meier estimator, with differences between groups assessed by the log-rank test. Statistical analyses were conducted using SPSS, version 16 (SPSS Inc., Chicago, IL, USA). All statistical tests were two-tailed, and *P* values of <0.05 were considered to indicate statistical significance.

Results

A total of 1232 patients who were scheduled to undertake elective major noncardiac surgery had been screened for eligibility from January 2018 to January 2019. Five hundred and sixteen patients were excluded according to inclusion and exclusion criteria. Ninety-eight patients declined to participate. Six hundred and eighteen patients gave consents and were randomly allocated to the dexmedetomidine and placebo groups. During the study period, 61 patients (28 patients in the dexmedetomidine group and 33 patients in the placebo group) were excluded from the analysis due to surgical cancellation, study drug infusion interrupted permanently, or experiencing an unplanned ICU stay after surgery. No assessment was aborted because of deep sedation. Finally, 281 patients received dexmedetomidine and 276 patients received 0.9% normal saline. The specific flow diagram of patient selection is presented in Figure 1.

Baseline characteristics

There were no significant differences in other demographics and perioperative variables between two groups, except that the updated Charlson Comorbidity Index was

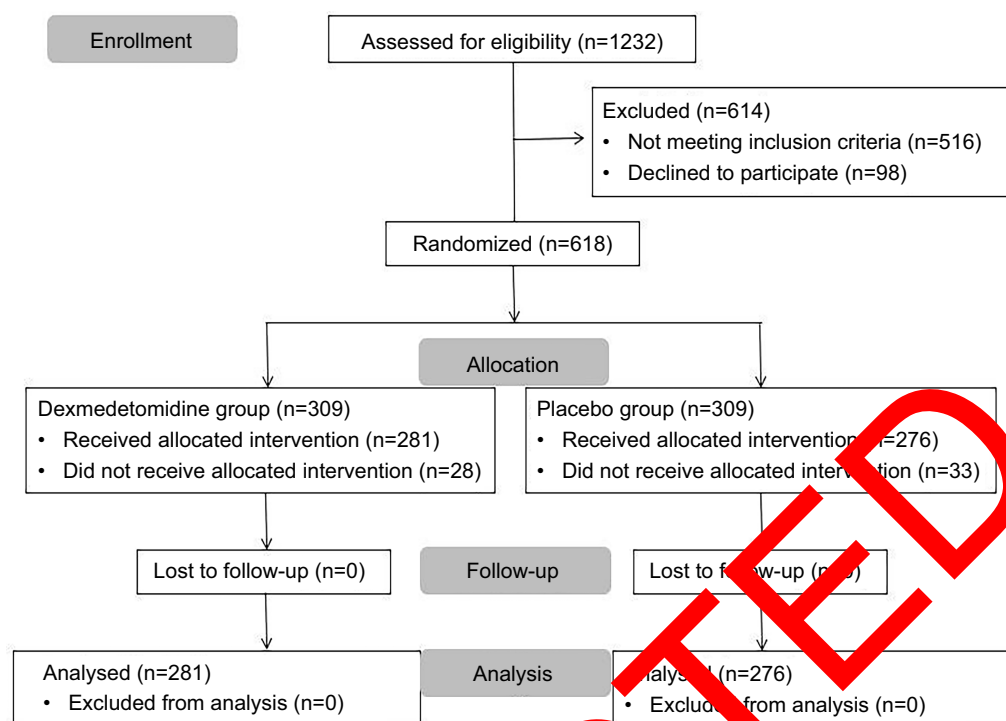


Figure 1 Flow diagram based on Consolidated Standards of Reporting Trials (CONSORT) statement.

lower in the placebo group than in the dexmedetomidine group ($P=0.010$) and the percentage of patients with lower RCSQ results of subjective sleep quality than in the placebo group was lower in the dexmedetomidine group ($P=0.019$) (Tables 1 and 2).

Primary outcome

Postoperative delirium occurred in 12.7% ($n=557$) of all patients. There was no significant difference between the two groups regarding the incidence of delirium during the first 5 days after surgery (11.7% [33/281] in the dexmedetomidine group vs 13.8% [58/276] in the placebo group, $P=0.47$) (Table 3).

Secondary outcomes

Dexmedetomidine group had lower NRS pain scores at rest than in the placebo group at 3, 12, 24, and 48 hrs after surgery (all $P<0.05$), except for 1 hr after surgery ($P=0.063$). The NRS pain scores with movement were lower in the dexmedetomidine group than in the placebo group at 1, 3, 12, 24, and 48 hrs after surgery (all $P<0.05$). The percentage of patients requiring flurbiprofen axetil for pain rescue was significantly lower in the dexmedetomidine group than in the placebo group (23.5% [66 of 281] vs 33.7% [93 of 276], $P=0.008$), but the total consumption of flurbiprofen axetil was similar between the two groups

($P=0.76$). Dexmedetomidine was significantly associated with higher RCSQ results of subjective sleep quality than in the placebo group on the first, second, and third postoperative mornings (all $P<0.0001$) (Table 3).

Additional outcomes

There were no significant differences in postoperative length of stay, time to extubation, and all-cause 30-day mortality between the two groups (Figures 2 and 3, Table 3). There was no significant difference between the two groups regarding the overall incidence of non-delirium complications within 30 days after surgery (5.3% [15 of 281] vs 5.1% [14 of 276], $P=0.89$), despite that the incidence of pneumonia tended to be lower in the dexmedetomidine group than in the placebo group (0.4% [1 of 281] vs 2.5% [7 of 276], $P=0.036$) (Table 4).

Main adverse events were reported in Table 5. RASS scores were similar between the two groups, as well as the incidences of tachycardia, hypotension, hypertension, hypoxemia, and nausea or vomiting (all $P>0.05$). Patients who received dexmedetomidine showed an increasing trend in experiencing bradycardia, but the difference was not significantly different compared to patients received placebo ($P=0.06$). The percentages of patients requiring intervention for adverse events were similar between the two groups (all $P>0.05$).

Table 1 Baseline variables

Variable	Dexmedetomidine (n=281)	Placebo (n=276)	P-value
Age, median (IQR), years	68.0 (66.0–73.0)	69.0 (65.0–74.0)	0.13
Male, no. (%)	161 (57.3)	154 (55.8)	0.72
BMI, mean (SD)	24.6 (3.4)	24.3 (3.6)	0.27
Educational level, median (IQR), years	6.0 (4.0–9.0)	6.0 (3.8–9.0)	0.49
MMSE, median (IQR), score	25.0 (22.0–27.0)	24.0 (22.0–26.3)	0.16
CCI, median (IQR), score	2.0 (0.0–2.0)	1.0 (0.0–2.0)	0.010
ASA classification, no. (%)			
Class I-II	222 (79.0)	221 (80.1)	0.76
Class III	59 (21.0)	55 (19.9)	
Chronic smoking, no. (%)	103 (36.7)	110 (39.9)	0.44
Alcoholism, no. (%)	58 (20.6)	69 (25.0)	0.22
Hypertension, no. (%)	99 (35.2)	106 (38.4)	0.24
Diabetes, no. (%)	41 (14.6)	43 (15.6)	0.74
Coronary artery disease, no. (%)	24 (8.5)	20 (7.3)	0.81
Arrhythmia, no. (%)	22 (7.8)	16 (5.8)	0.34
Previous stroke, no. (%)	38 (13.5)	33 (12.0)	0.58
Anemia, no. (%)	64 (22.8)	71 (25.7)	0.42
Hypoalbuminemia, no. (%)	33 (11.7)	33 (12.0)	0.94
Electrolyte imbalance, no. (%)	44 (15.7)	50 (18.1)	0.38
History of surgery, no. (%)	77 (27.4)	93 (33.7)	0.09

Notes: Data are presented as number (%), mean (SD), or median (IQR). Significant differences are at $P < 0.05$.

Abbreviations: IQR, interquartile range; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); MMSE, Mini-Mental State Examination; CCI, the updated Charlson Comorbidity Index; ASA, American Society of Anesthesiologists.

Table 2 Perioperative variables

Variable	Dexmedetomidine (n=281)	Placebo (n=276)	P-value
Surgical procedure, no. (%)			
Spine	27 (9.6)	38 (13.8)	0.09
Orthopedic	57 (20.3)	72 (26.1)	
Urologic	47 (16.3)	50 (18.1)	
Thoracic	24 (8.5)	19 (6.9)	
General	126 (44.8)	97 (35.1)	
Anesthesia time, median (IQR), mins	199.0 (159.0–252.0)	193.0 (160.0–246.3)	0.56
Intraoperative medication			
Sevoflurane, no. (%)	256 (91.1)	251 (90.9)	0.95
Sufentanil citrate, median (IQR), µg	40.0 (30.0–50.0)	40.0 (30.0–50.0)	0.53
Propofol, median (IQR), mg	550.0 (420.0–770.0)	560.0 (450.0–710.0)	0.92
Atropine, no. (%)	18 (6.4)	21 (7.6)	0.58
Glucocorticoids, no. (%)	44 (15.7)	47 (17.0)	0.66
Surgical time, median (IQR), mins	169.0 (132.0–219.0)	164.5 (135.0–218.0)	0.83
Total intraoperative infusion, median (IQR), mL	2000 (1500–2500)	2000 (1500–2500)	0.24
Estimated intraoperative blood loss, median (IQR), mL	200 (100–400)	200 (100–400)	0.91
Intraoperative blood transfusion, no. (%)	26 (9.3)	37 (13.4)	0.12
Cancer, no. (%)	143 (50.9)	113 (40.9)	0.019

Notes: Data are presented as number (%), or median (IQR). Significant differences are at $P < 0.05$.

Abbreviation: IQR, interquartile range.

Table 3 Clinical outcomes

Variable	Dexmedetomidine (n=281)	Placebo (n=276)	P-value
Primary outcome			
Incidence of delirium, no. (%)	33 (11.7)	38 (13.8)	0.47
Secondary outcomes			
NRS for pain at rest, median (IQR), score			
1 hr after surgery	2 (1–3)	2 (1–3)	0.06
3 hrs after surgery	2 (1–3)	2 (1–4)	0.011
12 hrs after surgery	2 (1–2)	2 (1–3)	<0.0001
24 hrs after surgery	1 (1–2)	2 (1–3)	0.003
48 hrs after surgery	1 (1–2)	1 (1–2)	0.002
NRS for pain at movement, median (IQR), score			
1 hr after surgery	3 (2–4)	3 (2–4)	0.001
3 hrs after surgery	3 (2–4)	3 (2–4)	0.004
12 hrs after surgery	2 (1–3)	2 (2–4)	0.004
24 hrs after surgery	2 (1–3)	2 (1–3)	0.001
48 hrs after surgery	1 (1–2)	2 (1–3)	<0.0001
Supplemental analgesics during the first 48 hrs after surgery			
Flurbiprofen axetil, no. (%)	66 (23.5)	93 (33.7)	0.008
Flurbiprofen axetil, median (IQR), mg [#]	50 (50–100)	100 (50–100)	0.76
RCSQ for subjective sleep quality, mean (SD), score			
First morning after surgery	64.6 (15.5)	53.5 (17.0)	<0.0001
Second morning after surgery	62.7 (19.0)	54.8 (18.2)	<0.0001
Third morning after surgery	58.4 (16.3)	58.5 (17.9)	<0.0001
Length of stay in hospital after surgery, median (IQR), days	11.0 (8.0–14.0)	11.0 (8.0–14.0)	0.88
Patients discharged within 5 days, no. (%)	24 (8.5)	24 (8.7)	0.95
All-cause mortality within 30 days, no. (%)	1 (0.4)	0 (0)	>0.99

Notes: Data are presented as number (%), mean (SD), or median (IQR). Significant differences are at $P < 0.05$. [#]Dosage among patients who had received the drugs.

Abbreviations: IQR, interquartile range; NRS, numeric rating scale; RCSQ, Richards Campbell Sleep Questionnaire.

Discussion

Our results showed that continuous infusion of dexmedetomidine did not decrease the incidence of delirium compared to placebo in elderly patients admitted to general surgical wards after noncardiac surgery. Delirium was diagnosed in 33 of 281 patients (11.7%) in the dexmedetomidine group and in 38 of 276 patients (13.8%) in the placebo group, which is not a clinically or statistically significant difference. However, dexmedetomidine significantly improved analgesia for postoperative pain treatment and improved sleep quality, but does not increase adverse events. The overall incidence of non-delirium complications within 30 days after surgery and the all-cause 30-day mortality were similar between the two groups.

In our study, the incidence of postoperative delirium among all patients was 12.7%, lower than previous studies.^{8,23} The reasons that led to the low delirium incidence in the current patient population might include a more severe underlying condition in ICU patients, which was associated with an increased risk of postoperative delirium.⁴ Moreover, anticholinergics were much less used than previously, which might have led to a higher incidence of postoperative delirium.³⁵ In our study, penehyclidine hydrochloride was prohibited and atropine was used only for the treatment of bradycardia. Furthermore, the supplemental analgesics in our protocol were nonsteroid anti-inflammatory drugs instead of opioids, which might lead to drug and metabolite accumulation and increase the risk of postoperative delirium.³⁶ In addition,

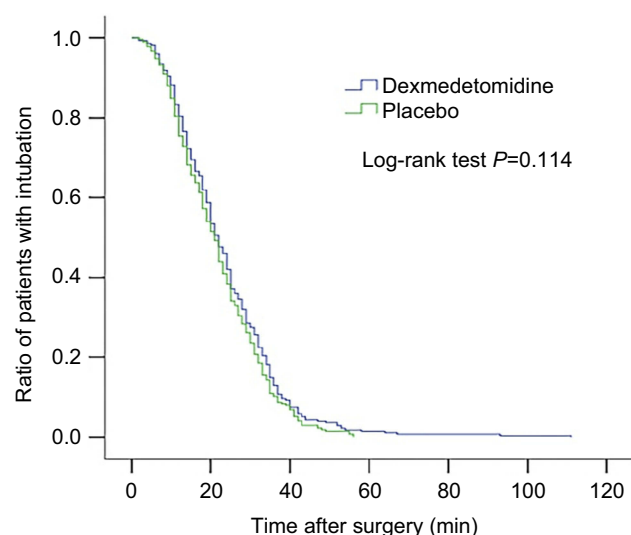


Figure 2 Kaplan-Meier curves for ratio of patients with intubation after surgery between the two groups.

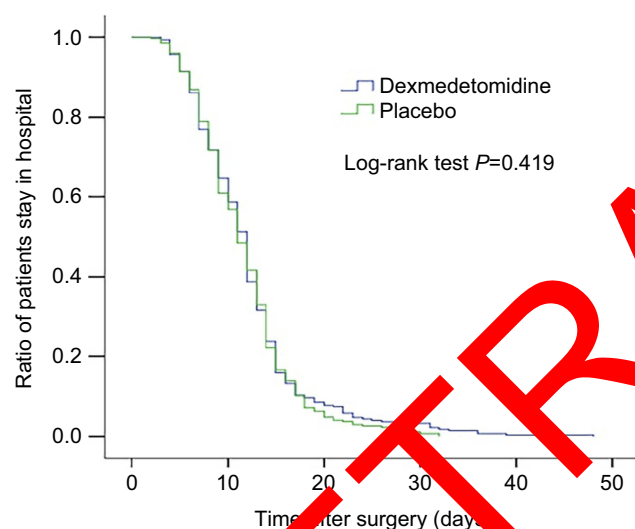


Figure 3 Kaplan-Meier curves for ratio of patients' stay in hospital after surgery between the two groups.

nonpharmacologic multicomponent delirium-preventing approaches were used commonly in daily nursing practice, including reorientation, cognitive stimulation, sleep promotion, and hearing/vision aids.³⁷ A recent Cochrane review³⁸ found that among hospitalized non-ICU patients multicomponent nonpharmacological interventions reduced the rates of delirium by approximately 30%.

In contrast to previous reports in patients admitted to the ICU after noncardiac surgery, Su X and colleagues²³ randomized elderly patients to receive either low-dose dexmedetomidine infusion or placebo through postoperative day 1 and observed a reduction in the prevalence of

postoperative delirium. In our study, we restricted dexmedetomidine administration in patient population of general surgical wards rather than patients requiring sedation in the intensive care unit, where dexmedetomidine had been shown to reduce the incidence of postoperative delirium compared with other sedating agents.^{20,21} The pathogenesis of postoperative delirium is not fully understood whilst previous studies demonstrated that use of high-dose sedatives after surgery is an important predisposing factor.³⁹ Therefore, our study suggested that the mechanism of dexmedetomidine's ability to lower the risk of delirium might be not an intrinsic neuroprotective property on delirium, but rather deriving from reducing exposure to potentially deliriogenic sedatives. This conclusion would be in accordance with a recent study²⁴ of an elderly non-cardiac surgery population in that randomly assigned patients to dexmedetomidine or saline placebo infused during surgery and for 48 hrs in the recovery room and did not observe a reduction in delirium.

Our results also showed that postoperative continuous infusion of dexmedetomidine decreased postoperative NRS pain score at all time points except for 1 hr at rest after surgery. However, the mean differences in NRS scores are small, and thus unlikely to have clinical significance. The percentage of patients requiring flurbiprofen axetil for pain rescue was significantly lower in the dexmedetomidine group than in the placebo group, we believe that patients who received dexmedetomidine experienced better analgesia. Consistent with a previous meta-analysis⁴⁰ that examined randomized controlled trials, dexmedetomidine administration decreased postoperative opioid consumption and pain intensity. Analgesic effects of dexmedetomidine are thought to be mediated by activating α_2 -receptor located in the central nervous system and spinal cord and modulating nociceptive input and transmission.¹⁸ Therefore, dexmedetomidine might be an interesting option for multimodal postoperative pain therapy.

In the study of Frances et al,⁴¹ higher age is associated with lower sleep efficiency after surgery. Therefore, elderly patients are more prone to develop postoperative sleep disturbances, and its occurrence is harmful for postoperative recovery.⁴² Our current results show that dexmedetomidine infusion significantly ameliorated the subjective sleep quality of postoperative patients admitted to general surgical wards, which were consistent with other studies⁴³ that dexmedetomidine infusion improved sleep quality in ICU patients. Previous literature reported that dexmedetomidine improves sleep quality through activating the

Table 4 Non-delirium postoperative complications within 30 days

Variable	Dexmedetomidine (n=281)	Placebo (n=276)	P-value ^a
Non-delirium complications, no. (%)			
Overall	15 (5.3)	14 (5.1)	0.89
Acute myocardial infarction	0	0	>0.99
Unstable angina	1 (0.4)	1 (0.4)	>0.99
New-onset arrhythmia	4 (1.4)	2 (0.7)	0.69
Heart failure	0	0	>0.99
Respiratory failure	0	0	>0.99
Pneumonia	1 (0.4)	7 (2.5)	0.036
Stroke	0	0	>0.99
Pulmonary embolism	1 (0.4)	0	>0.99
Deep venous thrombosis	2 (0.7)	1 (0.4)	>0.99
Infection	6 (2.1)	3 (1.1)	0.50

Notes: Data are presented as number (%). Significant differences are at $P<0.05$. ^aBy Fisher exact test.

Table 5 Adverse events

Variable	Dexmedetomidine (n=281)	Placebo (n=276)	P-value
RASS score at the end of study drug infusion, median (IQR), scale	0 (0–0)	0 (0–0)	0.62
Postoperative adverse events, no. (%)			
Bradycardia	2 (0.7)	14 (5.1)	0.06
Bradycardia with intervention	3 (1.1)	2 (0.7)	>0.99
Tachycardia	5 (1.8)	7 (2.5)	0.54
Tachycardia with intervention	2 (0.7)	1 (0.4)	0.50
Hypotension	4 (1.4)	2 (0.7)	0.70
Hypotension with intervention	1 (0.4)	0	>0.99
Hypertension	12 (4.3)	18 (6.5)	0.24
Hypertension with intervention	9 (3.2)	13 (4.7)	0.36
Hypoxemia	13 (4.6)	16 (5.8)	0.53
Hypoxemia with intervention	7 (2.5)	10 (3.6)	0.44
Nausea or vomiting	37 (13.2)	30 (10.9)	0.41
Nausea or vomiting with intervention	28 (10.0)	20 (7.2)	0.25

Notes: Data are presented as number (%). Significant differences are at $P<0.05$.

endogenous sleep-promoting pathways and produces a state resembling physiologic stage 42 sleep.^{43,44} Additionally, patients who received dexmedetomidine experienced better analgesia, which might contribute to better sleep perception. Several studies^{34,45} have documented that poor sleep is associated with a higher prevalence of postoperative delirium. We hypothesized that whether delirium could be mitigated due to improvement of sleep quality under dexmedetomidine. However, in our study, dexmedetomidine group had significantly higher scores on RCSQ results when compared with the placebo group, but with no improvement in the prevalence of postoperative delirium. Another trial conducted by Hong et al⁴⁶ found that dexmedetomidine cyclical infusion might prevent delirium by

restoration of the circadian rhythm and correction of sleep disorders. Therefore, this difference might be due to dexmedetomidine continuous infusion in our trial rather than nighttime infusion or dexmedetomidine cycling, which might only increase total sleep duration and improve perceived sleep quality, but without preserving circadian rhythm of sleep and translating into better sleep outcomes. Consequently, it is possible that the duration of use and timing relative to the endogenous circadian rhythm is likely important.

In the present study, administration of dexmedetomidine did not decrease the overall incidence of non-delirium postoperative complications within 30 days after surgery, but it tended to decrease the incidence of pneumonia after

surgery. Preclinical studies demonstrated that dexmedetomidine reduced oxidative stress and inflammatory response and provided a protective effect on lung ischemia/reperfusion injury caused by one-lung ventilation.⁴⁷ However, biomarkers of inflammation were not measured in our study and it is not possible to assess whether low-dose dexmedetomidine infusion could suppress the inflammation.

The dose of dexmedetomidine we chose was similar to previous research, which did not increase drug-related adverse events (such as severe bradycardia and hypotension). The RASS score at the end of study drug infusion was similar between the two groups. It is possible that the small dose of dexmedetomidine does not produce a very strong sedative effect, which may be related to the awakening sedation of dexmedetomidine. The incidence of adverse events did not differ significantly between dexmedetomidine and placebo, except that more bradycardia was observed in dexmedetomidine, an expected consequence of α_2 -adrenergic receptors agonist. However, considering that the occurrence of bradycardia was transient and the percentage of patients requiring intervention was very low, postoperative administration of low-dose dexmedetomidine in clinical practice may be an acceptable and safe strategy for the patients in general surgical wards, but a larger-scale study is required to rule out possible safety concerns.

Our study has many strengths. Firstly, our study was a randomized, double-blinded and placebo-controlled design with the enrolment of a relatively large sample size (618 patients), the results of which would provide high-quality evidence. Secondly, the RASS level is monitored in all enrolled patients, which will help us to avoid unnecessary and potentially harmful deep anesthesia. Thirdly, we chose to exclude patients with ASA classification of >III or planned postoperative admission to ICU, which provided a homogeneous group for us to make conclusive statements. Several limitations of the study warrant consideration. Delirium was assessed twice daily in our study. Considering the transient and fluctuating characteristics of delirium, we might have missed delirium occurring between assessments or during nights. Moreover, we did not collect data regarding the motor subtypes of delirium, the number of delirium episodes, or the duration of delirium. Additionally, we chose low-dose dexmedetomidine to avoid possible adverse effects. We cannot exclude a potential benefit from higher doses. Furthermore, the incidence of postoperative delirium was lower than in previous studies.

Therefore, our pre-calculated sample size may be insufficient to detect the difference between the two groups. A large sample size randomized trial is needed to further clarify the effects of postoperative dexmedetomidine.

Conclusion

Our study showed that postoperative continuous infusion of dexmedetomidine did not decrease the incidence of postoperative delirium in elderly patients admitted to general surgical wards after elective noncardiac surgery. Timing of dexmedetomidine and particular patient populations who would gain the most benefit from dexmedetomidine administration warrant further studies to elucidate.

Data sharing statement

The individual participant's data underlying published results reported in this study can be accessed with approval from the corresponding author after 6 months of publication of the main results. The study protocol, statistical analysis plan, and clinical study report will also be available.

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Disclosure

The authors report no conflicts of interest in this work.

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