Predicting delirium in post-anaesthesia recovery: a retrospective analysis and validation of a nomogram model for patients undergoing benign biliary surgery

Li-jun Wu, Teng Song, Li Li

Abstract

This study aimed to develop a nomogram for predicting post-anaesthetic delirium in patients who underwent benign biliary surgery under general anaesthesia. We retrospectively analysed 460 patients from March 2019 to March 2023 using IBM SPSS Statistics 26.0 and R 4.2.3, identifying predictors of delirium through logistic regression. Notable predictors included anaesthetic dosage, extubation time, post-anaesthesia care unit（PACU） duration, and American Society of Anaesthesiologists (ASA) classification > 2. The developed nomogram demonstrated high predictive accuracy, with an area under the curve (AUC) of 0.881 in the training set and 0.828 in validation. This tool provides clinicians with reliable pre-operative risk assessment capabilities.

Keywords: General anaesthesia, Biliary surgery, Post-operative delirium, Nomogram model.

DOI: https://doi.org/10.47391/JPMA.11515

Introduction

The incidence of benign biliary diseases as cholecystitis and cholelithiasis is rising due to improved living standards. Treatment modalities practiced are laparoscopic or open cholecystectomy as common procedures.[1] General anaesthesia, crucial for surgical success, often leads to post-operative delirium, especially in the elderly and those with conditions like coronary artery disease, due to factors such as neuroinflammation and oxidative stress.[2,3]

Case Series

This retrospective cohort study at Tongling Municipal Hospital, Anhui, China, involved 460 patients who underwent benign biliary surgery under general anaesthesia from March 2019 to March 2023. Participants aged 18-85 years with benign biliary diseases and complete medical records were included, while those with anaesthesia contraindications, prior surgeries, or incomplete examinations were excluded. Data of all patients was obtained from the hospital's unified electronic medical record system, ensuring a consistent and comprehensive data collection process. The study was conducted in adherence to the Declaration of Helsinki, received ethical approval, and obtained informed consent from all participants for the publication of their data.

Prior to data collection, no formal power calculation was performed due to the retrospective design. However, a post-hoc power analysis was conducted using G*Power (version 3.1)[4] to verify sample adequacy. Assuming an estimated delirium prevalence of 25-30% in patients who underwent benign biliary surgery under general anaesthesia, a sample size of at least 400 participants was required to achieve 80% power with α=0.05. Our final sample of 460 individuals exceeded this threshold, ensuring robust statistical validity.

A standardised anaesthesia protocol was applied to all patients undergoing benign biliary surgery at our institution. This protocol specifies recommended induction and maintenance dosages, sedation regimens, and ventilation parameters, ensuring methodological consistency across cases. Minor dose adjustments were allowed solely at the discretion of a senior anaesthesiologist, in accordance with institutional guidelines. The anaesthesia team, comprising at least two senior anaesthesiologists, managed anaesthesia induction with 2mg Midazolam, 12mg Etomidate, 25μg Sufentanil, and 50mg Rocuronium bromide, followed by tracheal intubation. Maintenance of anaesthesia involved Sevoflurane inhalation and a continuous Remifentanil infusion at 0.03μg/kg/min, with oxygen flow maintained at 3L/min.

Patients' data was gathered through outpatient services, electronic records, and follow-ups via phone or WeChat, forming a database that included demographics, disease type, American Society of Anaesthesiologists (ASA) classification,[5] comorbidities, surgical details, anaesthesia dosages, and post-operative outcomes including PACU stay and VAS scores.

This hospital employs a standardised protocol for delirium screening in the PACU, whereby trained PACU nurses and attending anaesthesiologists administer the Confusion Assessment Method (CAM)[6] at regular intervals or whenever a patient exhibits any change in mental status. This policy ensures early and consistent detection

Table-1: Balance test of training set and validation set.

	Total (n = 460)	train_set (n = 322)	valid_set (n = 138)	t/χ2 value	P value
Mea Age, (years)	53.98 ± 11.79	53.80 ± 11.68	54.42 ± 12.06	-0.521	0.603
Mean Height, (cm)	1.66 ± 0.08	1.65 ± 0.08	1.66 ± 0.09	-1.164	0.245
Mean Weight,(kg)	63.51 ± 9.49	63.30 ± 9.30	63.98 ± 9.92	-0.699	0.485
Mean BMI,(kg/m^2)	23.31 ± 4.01	23.28 ± 4.08	23.39 ± 3.84	-0.253	0.800
Gender, n (%)				1.600	0.206
Female	290 (63.0)	209 (64.9)	81 (58.7)		
Male	170 (37.0)	113 (35.1)	57 (41.3)		
ASA, n (%)				3.543	0.060
1-2	368 (80.0)	265 (82.3)	103 (74.6)		
>2	92 (20.0)	57 (17.7)	35 (25.4)		
Disease, n (%)				0.588	0.443
gallstone or cholecystitis	384 (83.5)	266 (82.6)	118 (85.5)		
biliary calculus with cholecystitis	76 (16.5)	56 (17.4)	20 (14.5)		
Coronary Heart Disease, n(%)	104 (22.6)	71 (22.1)	33 (23.9)	0.192	0.662
Diabetes, n (%)	122 (26.5)	87 (27.0)	35 (25.4)	0.136	0.712
Hypertension, n (%)	208 (45.2)	142 (44.1)	66 (47.8)	0.542	0.462
Mean Dosage of anaesthetic drugs, (mg)	370.95 ± 21.79	369.12 ± 23.65	371.25 ± 10.66	0.918	0.359
Mean Extubation Time, min	1.56±0.25	1.55±0.19	1.56±0.21	0.501	0.617
Mean PACU Stay Time, hours	30.85±2.54	30.18±3.36	29.52±3.98	1.705	0.090
Mean Preoperative Haemoglobin g/L	128.84±5.28	128.32±5.94	129.12±5.69	1.340	0.181

of post-operative delirium. The CAM was used to evaluate post-anaesthetic emergence, diagnosing delirium based on: acute onset, inattention, altered consciousness, and disorganised thinking. Delirium is identified by the presence of the first two criteria and either of the latter two.

Table-2: Single factor analysis of delirium post-general anaesthesia in benign biliary surgery

Variable	Delirium group （n=101）	normal group (n=221)	t/χ^2 value	P value
Gender, n (%)			0.020	0.889
Male	36 （35.6）	77 （34.8）		
Female	65 （64.4）	144 （65.2）		
Mean Age, (years)	53.88 ± 7.38	53.76 ± 13.20	0.109	0.913
Mean Height,m	1.65 ± 0.09	1.65 ± 0.08	0.124	0.902
Mean Weight, kg	61.96 ± 7.68	63.92 ± 9.91	1.929	0.055
Mean BMI, kg/m^2	22.83 ± 3.47	23.49 ± 4.33	1.347	0.179
Disease, n (%)			0.610	0.436
gallstone or cholecystitis	55 (33.3)	110 (66.7)		
biliary calculus with cholecystitis	46 (29.3)	111 (70.7)		
ASA, n (%)			136.451	＜0.001
1-2	46 (45.5)	219 (99.1)		
>2	55 (54.5)	2 (0.9)		
Hypertension, n (%)	42 (32.1)	100 (67.9)	0.43	0.513
Diabetes, n (%)	27 (27.8)	60 (62.2)	0.01	0.938
Coronary Artery Disease, n (%)	21 (69.3)	50 (0.5)	1.02	0.3118
Mean Doses of anaesthetic drugs ,mg	399.95 ±27.79	330.62 ± 30.65	19.379	＜0.001
Mean Extubation Time, min	1.78±0.25	1.40±0.19	13.857	＜0.001
Mean PACU Stay Time, hours	36.35±3.69	29.18±4.53	15.027	＜0.001
Mean Preoperative Haemoglobin,	129.17±4.52	129.62±5.55	0.770	0.442

Data analysis utilised IBM SPSS Statistics 26.0 and R. The Kolmogorov-Smirnov test confirmed data normality (P≥0.05). Quantitative data was analysed as mean ± standard deviation and compared using the Student's t-test, while qualitative data was examined as proportions and assessed with the Chi-square test. Binary logistic regression was performed to identify predictors of post-operative delirium. The stepwise forward method was used to optimise the model, entering variables showing P<0.05 in univariate analysis. Adjusted odds ratios (OR) and 95% confidence intervals (CI) were derived to quantify effect sizes. Model performance was evaluated using the Hosmer-Lemeshow test, receiver operating characteristic (ROC) curves, and decision curve analysis. The nomogram, developed in R 4.2.3, divided data into training and validation sets to evaluate model specificity, sensitivity, and accuracy using Decision Curve Analysis and the Hosmer-Lemeshow test, with significance set at P<0.05.

During the study, 460 patients with ages between 18 to 85 years (mean age 53.98 ±11.79) met the inclusion criteria. They were first evaluated within three days of the onset of symptoms. The cohort comprised 170 (37.0%) males and 290 (63.0%) females. Patients' height ranged from 1.50 to 1.85 metres (average 1.66 ±0.84 metres), weight from 43 to 95 kilograms (average 63.51 ±9.49 kilograms), and BMI from 14.4 to 32 kg/m^2 (average 23.31 ± 4.00 kg/m^2).

Before surgery, no patient showed symptoms of delirium or neurological disorders. Post-operatively, using CAM criteria, 150 (32.6%) patients experienced delirium, while 310(67.39%) did not.

The sample was split into training (70.0%) and validation (30.0%) sets. A balance test confirmed statistical consistency between the sets (P > 0.05). See Table 1 for details.

In the training set, patients were categorised into delirium group (n=101) and normal group (n=221) based on post-operative delirium occurrence. Comparative analysis revealed significant differences (P<0.05), with the delirium

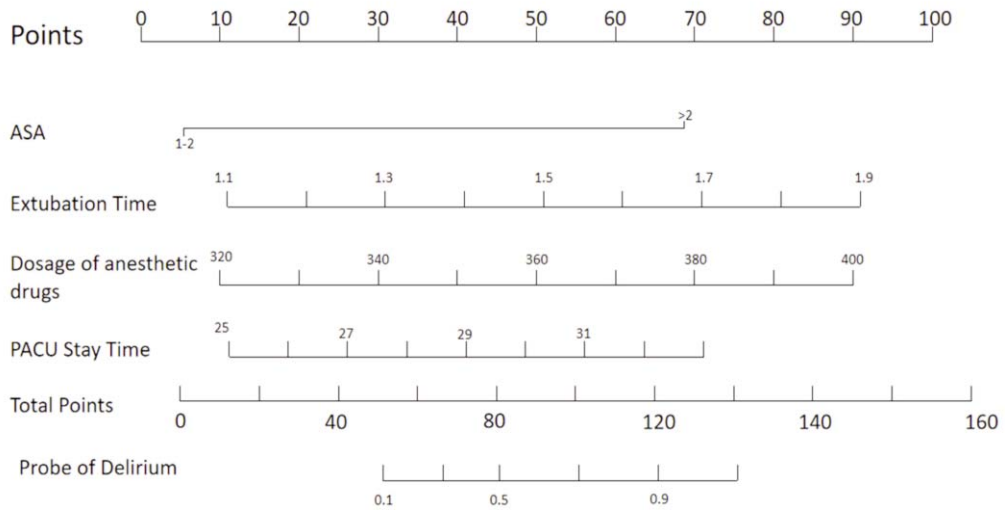

Figure-1: Nomogram Prediction Model for Delirium in Patients Undergoing Benign Biliary Surgery Under General anaesthesia.

group exhibiting higher anaesthetic usage, prolonged extubation times, extended PACU durations, and more frequent ASA scores above 2. No other significant difference was noted between the two groups (P>0.05). (Table 2.)

Multivariate logistic regression analysis revealed that anaesthetic dosage, extubation time, PACU stay duration, and an ASA classification >2 were independent predictors of post-operative delirium (all P<0.05). The adjusted ORs

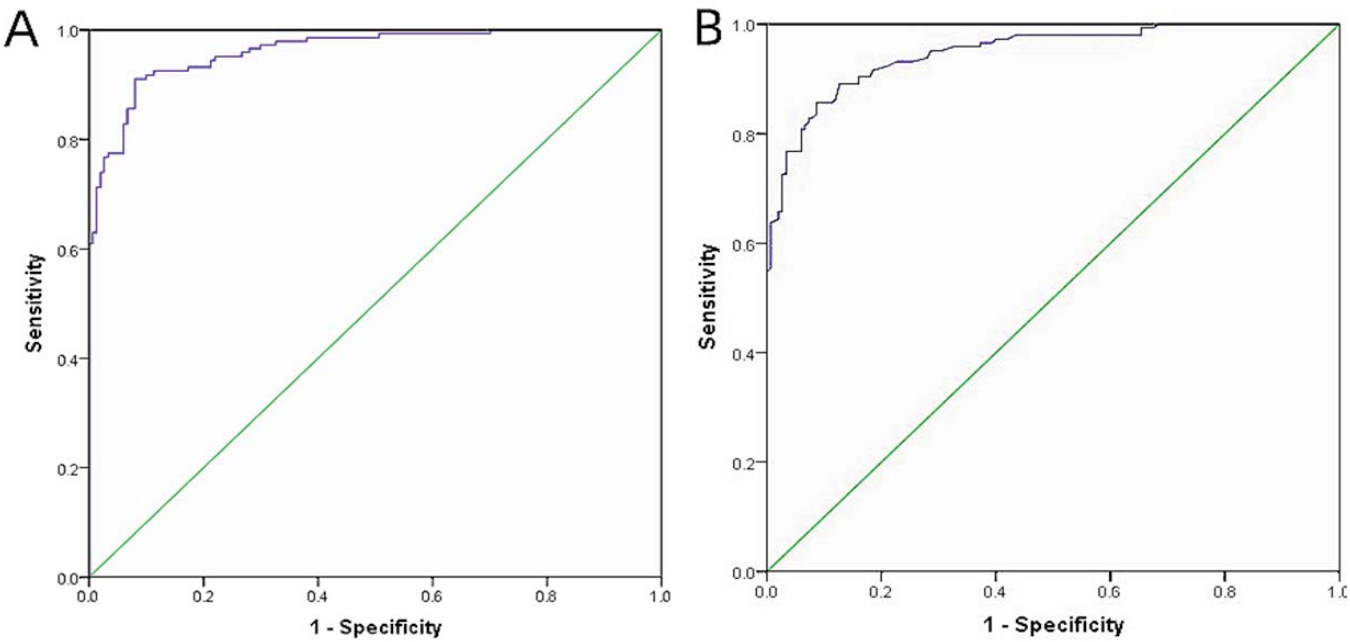

Figure-2: Diagnostic efficacy of predictive model. (A) The training set. (B) The validation set.

Table-3: Multifactorial analysis of delirium post-benign biliary surgery under general anaesthesia.

Variable	B value	SE	Wald χ^2	P value	aOR value	95%CI
X_1 ASA	3.656	1.1780	14.745	＜0.001	8.92	6.83～25.05
X_2 PACU Stay Time	5.811	1.3346	28.651	＜0.001	10.77	2.39～31.43
X_3 Dosage of anaesthetic drugs	3.204	1.3021	19.302	＜0.001	8.29	6.28～28.22
X_4 Extubation Time	3.196	0.9551	26.652	＜0.001	4.10	3.30～19.21

(aOR) and 95% CIs for these factors are summarised in Table 3.

A predictive model was developed using identified factors: anaesthetic dosage,

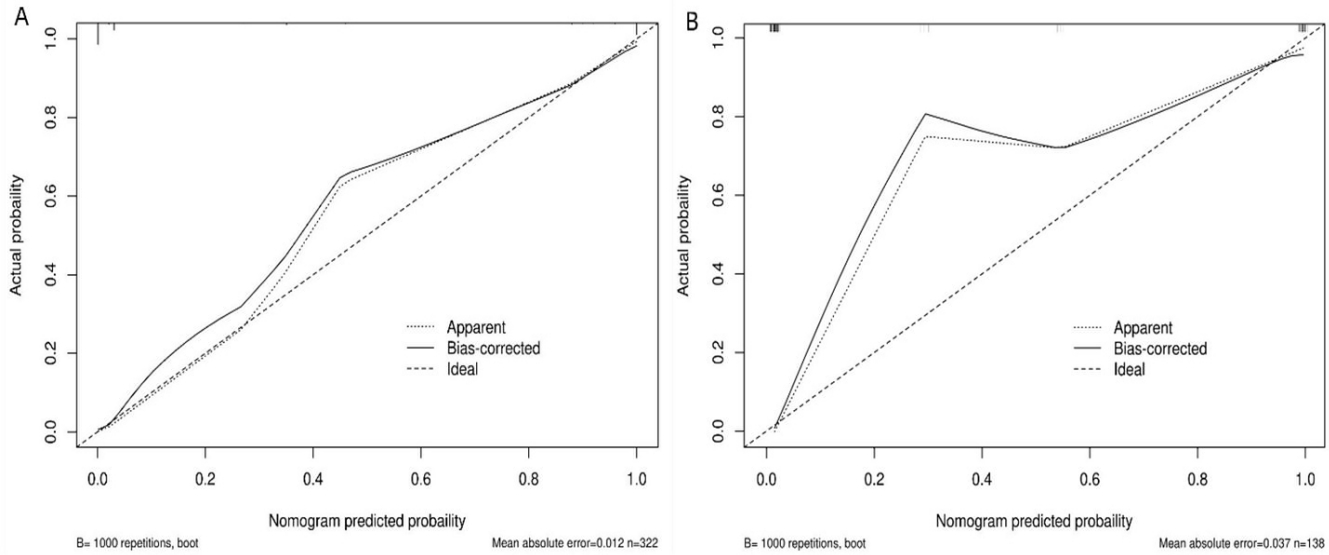

Figure-3: Calibration curve of the predictive model. (A) The training set. (B) The validation set.

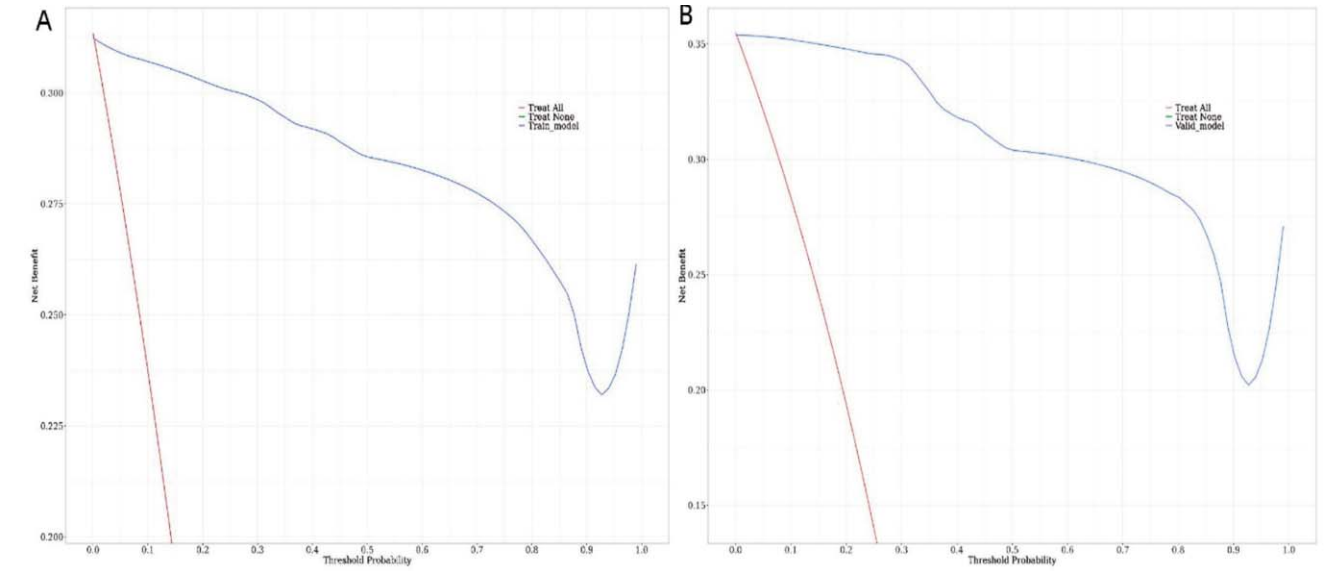

Figure-4: Clinical decision curve of the predictive model. (A) The training set. (B) The validation set.

extubation time, PACU duration, and ASA classification >2. The regression formula is: Logit(P)=3.656X1+5.811X2+3.204X3+3.196X4-7.048, and a corresponding Nomogram was constructed (Figure 1). The model exhibited high discriminative power in the training set with an AUC of 0.881 (95% CI: 0.790-0.905), sensitivity of 0.823, and specificity of 0.896, and maintained performance in the validation set with an AUC of 0.828 (95% CI: 0.798-0.889), sensitivity of 0.807, and specificity of 0.856 (Figure 2).

The model's consistency was validated using the Hosmer-Lemeshow test, showing no significant discrepancy between predicted and actual delirium prevalence in the training set ($\chi2$=0.948, P=0.918). Calibration curves for both the sets confirmed the model's accuracy and reliability (Figure 3).

The DCA for the training and validation sets showed the model's strong predictive performance and clinical utility, highlighting its value in clinical decision-making (Figure 4). In both the training set (Figure 4A) and the validation set (Figure 4B), from threshold probabilities of approximately 10% to 80%, the model's net benefit curve (blue line) remains above the "treat-all" (red line) and "treat-none" strategies. This range highlights the model's strong predictive performance in guiding clinical decisions to prevent post-operative delirium. However,

slight fluctuations in net benefit were observed in the 70%-80% threshold range, particularly in the validation set, which suggests the need for careful consideration of high-threshold predictions in clinical applications.

Discussion

Research indicates that delirium can signal severe illnesses, extended hospital stays, and causes long-term brain issues.[7,8] Nearly a third of the patients experienced delirium after benign biliary surgery under general anaesthesia. Their medical data, identifying anaesthetic dosage, extubation time, PACU stay, and health status were analysed as key risk factors. Using these insights, a Nomogram was crafted to predict post-surgery delirium, improving risk management for doctors.

Risk factors for post-operative delirium include high anaesthetic dosage, advanced age, and elevated ASA scores, which impair systemic circulation and cerebral perfusion. Jin[9] highlights the importance of thorough pre-operative assessment to mitigate risks, while Pereira[10] reports that 21.5% of the patients experience delirium post-anaesthesia, correlated with anaesthetic dosage and PACU duration. Additionally, a Canadian study and Whitlock confirm that high ASA scores and prolonged extubation times increase the prevalence of delirium, underscoring the need for careful pre-operative planning and stable intraoperative management.[11,12]

Current clinical research on predictive models for post-operative delirium is limited. Lindroth[13] conducted cognitive tests and calculated risk scores for severe complications, using logistic regression to predict the severity of post-operative delirium. Their model achieved a AUC of 0.81 (95% CI, 0.72-0.90). In contrast, our study developed a model incorporating variables such as the dosage of anaesthetic agents, extubation time, PACU stay duration, and ASA classification greater than 2. The ROCs for the training and validation sets were 0.881 and 0.828, respectively, indicating good accuracy and high clinical value of the model.

The present study has its quirks—being retrospective, there is some selection bias, but it was mixed with a diverse patient group to keep things even. The entire cohort was from one hospital, so take it with a grain of salt for wider use. Also, we could do with more data and a broader setting to beef up the findings. Next steps? More detailed research to pump up our predictive model's value.

Conclusion

The study pinpointed anaesthetic dosage, extubation time, PACU duration, and ASA classification >2 as key risk factors for post-operative delirium after benign biliary surgery under general anaesthesia. We developed a nomogram that effectively aids anaesthesiologists in pre-operative risk assessment and care optimisation.

Disclaimer: None to declare.

Conflict of Interest: None to declare.

Funding Sources None to declare.

References

1. Argiriov Y, Dani M, Tsironis C, Koizia LJ. Cholecystectomy for Complicated Gallbladder and Common Biliary Duct Stones: Current Surgical Management. Front Surg 2020;7:42. doi: 10.3389/fsurg.2020.00042.
2. Eschweiler GW, Czornik M, Herrmann ML, Knauer YP, Forkavets O, von Arnim CAF, et al. Pre-surgical Screening Improves Risk Prediction for Delirium in Elective Surgery of Older Patients: The PAWEL RISK Study. Front ageing Neurosci 2021;13:679933. doi: 10.3389/fnagi.2021.679933.
3. Maldonado JR. Neuropathogenesis of delirium: review of current etiologic theories and common pathways. Am J Geriatr Psychiatry 2013;21:1190-222. doi: 10.1016/j.jagp.2013.09.005.
4. UCLA: Statistical Consulting Group. G*Power: Statistical power analyses, Version 3.1.9.7. [Online] 2021 [Cited 2025 March 19]. Available from URL: https://stats.oarc.ucla.edu/other/gpower/
5. Augustinus S, Sijberden JP, Bieze M, Agarwal V, Aldrighetti LA, Alseidi A, et al. Inter-rater variability for the American Society of Anesthesiologists classification in patients undergoing hepato-pancreato-biliary surgery (MILESTONE-2): international survey among surgeons and anaesthesiologists. BJS Open 2024;9:zrae162. doi: 10.1093/bjsopen/zrae162.
6. Ristescu AI, Pintilie G, Moscalu M, Rusu D, Grigoras I. Pre-operative Cognitive Impairment and the Prevalence of Postoperative Delirium in Elderly Cancer Patients-A Prospective Observational Study. Diagnostics (Basel) 2021;11:275. doi: 10.3390/diagnostics11020275.
7. Nair A, Arfan S, Holder SS, Bacchus KI, Stear TJ. Persistent Post-operative Delirium Following Laparoscopic Cholecystectomy. Cureus 2023;15:e40523. doi: 10.7759/cureus.40523.
8. Sampson EL, West E, Fischer T. Pain and delirium: mechanisms, assessment, and management. Eur Geriatr Med 2020;11:45-52. doi: 10.1007/s41999-019-00281-2.
9. Jin Z, Hu J, Ma D. Postoperative delirium: perioperative assessment, risk reduction and management. Br J Anaesth 2020;125:492-504. doi: 10.1016/j.bja.2020.06.063.
10. Pereira H, Antunes MV, Teles D, Pereira LG, Abelha F. Association between intraoperative ketamine and the incidence of emergence delirium in laparoscopic surgeries: an observational study. Braz J Anesthesiol 2024;74:744414. doi: 10.1016/j.bjane.2022.10.002.
11. Khaled M, Youssef N, Choi S, Uppal V, Chui J, Marcucci M, et al. Preoperative assessment of postoperative delirium: a cross-sectional study of patients and anaesthesiologists in Canada. Can J Anaesth 2023;70:1600-10. doi: 10.1007/s12630-023-02537-9.
12. Whitlock EL, Braehler MR, Kaplan JA, Finlayson E, Rogers SE,

Douglas V, et al. Derivation, Validation, Sustained Performance, and Clinical Impact of an Electronic Medical Record-Based Perioperative Delirium Risk Stratification Tool. Anaesth Analg 2020;131:1901-10. doi: 10.1213/ANE.0000000000005085.

13. Lindroth H, Bratzke L, Twadell S, Rowley P, Kildow J, Danner M, et al. Predicting postoperative delirium severity in older adults: The role of surgical risk and executive function. Int J Geriatr Psychiatry 2019;34:1018-28. doi: 10.1002/gps.5104.

AUTHOR'S CONTRIBUTION:
LJW: Research design, statistical analysis and writing.
TS: Disease diagnosis, treatment of disease and follow-up.
LL: Research design, personnel coordination and writing.