Original Article

Association between preoperative 25-hydroxyvitamin D3 levels and postoperative delirium in pediatric patients undergoing general anesthesia for laparoscopic surgery: a single-center retrospective study

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Background: Postoperative delirium (POD) is a common complication after pediatric general anesthesia, impairing recovery. While vitamin D deficiency (VDD) is linked to POD in adults, its role in children remains unclear. This study investigates the association between preoperative 25-hydroxyvitamin D3 [25(OH) D3] levels and POD in children undergoing laparoscopic surgery under general anesthesia.

Methods: This single-center retrospective study enrolled 320 pediatric patients. Demographic, surgical, anesthetic, and laboratory data were collected. Preoperative serum 25(OH)D3 was measured, and POD was assessed using the Cornell Assessment of Pediatric Delirium (CAPD) scale on postoperative days 1, 3, and 7. Meanwhile, patients were categorized into VDD (<30 ng/mL) and non-VDD (≥30 ng/mL) groups. Multivariable logistic regression identified independent risk factors for POD.

Results: The incidence of POD was 80.3% (257/320) based on the CAPD score ≥9. POD patients had significantly lower serum 25(OH)D3 levels (P<0.05). In multivariable analysis, preoperative VDD was independently associated with a significantly higher risk of POD [adjusted odds ratio (OR) =14.25; 95% confidence interval (CI): 3.33–61.0; P<0.001]. A sensitivity analysis incorporating postoperative sleep quality [Children's Sleep Habits Questionnaire (CSHQ) score] confirmed the robustness of this association (OR =8.15; 95% CI: 1.88–35.3; P=0.005). The area under the receiver operating characteristic (ROC) curve for 25(OH)D3 in identifying POD was 0.613.

Conclusions: Preoperative VDD is independently associated with a substantially increased risk of POD in pediatric patients undergoing general anesthesia for laparoscopic surgery. Preoperative screening for VDD may help identify at-risk children, and randomized controlled trials are warranted to evaluate whether preoperative vitamin D supplementation reduces POD incidence.

Keywords: Postoperative delirium (POD); general anesthesia; 25-hydroxyvitamin D3 [25(OH)D3]; pediatric populations

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Introduction

Delirium is a common but frequently overlooked form of acute non-traumatic brain injury that can occur after surgery (1). According to the Diagnostic and Statistical Manual of Mental Disorders Fifth Edition (2), delirium is characterized by acute onset, fluctuating symptoms, inattention, and cognitive impairment. Postoperative delirium (POD) typically occurs within the first week after surgery and is associated with prolonged hospital stays, increased healthcare costs, and poorer clinical outcomes. While particularly prevalent among elderly patients, POD also affects pediatric populations, with reported incidence rates of as high as 80% in children, and the risk of delirium during infancy and childhood may be higher than in adults, though estimates vary widely (3-5). Pediatric delirium can present with delayed responsiveness, persistent agitation, unusual crying, and diverse psychomotor changes. The wide variability in symptom presentation and severity poses a significant challenge to early recognition and effective management (6).

Vitamin D is a fat-soluble vitamin with multiple physiological functions, including promoting bone growth, regulating calcium and phosphorus metabolism, and modulating immune responses. In addition, vitamin D plays an important protective role in the nervous system, mitigating neuronal damage through anti-inflammatory, antioxidant, and anti-apoptotic mechanisms. According to data from the World Health Organization (WHO), over two billion people worldwide lack adequate levels of vitamin D. VDD is linked to cognitive impairment and is considered a plausible risk factor for delirium in adults.

However, research focusing on the relationship between vitamin D and POD in pediatric populations remains limited. Given the high prevalence of vitamin D deficiency (VDD) in pediatric populations (7,8), exploring the relationship between vitamin D levels and POD in children carries substantial clinical relevance. Therefore, this study aimed to analyze the association between preoperative serum 25-hydroxyvitamin D3 [25(OH)D3] levels and the incidence of POD in children undergoing general anesthesia for laparoscopic surgery, providing new evidence for the prevention of pediatric POD. We present this article in accordance with the STROBE reporting checklist (available at https://tp.amegroups.com/article/view/10.21037/tp-2026-0297/rc).

Highlight box

Key findings

- Preoperative vitamin D deficiency (VDD; <30 ng/mL) was independently associated with a 14.25-fold increased risk of postoperative delirium (POD) in children undergoing laparoscopic surgery (adjusted odds ratio =14.25; 95% confidence interval: 3.33–61.0; P<0.001).

What is known and what is new?

- While VDD is linked to POD in elderly and critically ill adults, its role in children remains unclear.
- Preoperative low serum 25-hydroxyvitamin D3 [25(OH)D3] levels are associated with the occurrence of POD in pediatric patients undergoing general anesthesia for laparoscopic surgery, and 25(OH)D3 serves as a protective factor against POD in pediatric populations.

What is the implication, and what should change now?

- This study suggests that serum 25(OH)D3 may have a potential predictive effect on POD, and emphasizes the need for further prospective studies to verify its efficacy and evaluate the preventive effect of vitamin D supplementation.

Methods

Study population

This single-center study enrolled 320 pediatric participants aged 3–6 years with American Society of Anesthesiologists (ASA) physical status I–II who underwent elective laparoscopic surgery at Tianjin Children's Hospital between July 2024 and July 2025. This study was conducted in accordance with the Declaration of Helsinki and its subsequent amendments. The study protocol received approval from the Clinical Research Ethics Committee of Tianjin Children's Hospital (No. 2025-TYXWKY-001), with written informed consent provided by the parents or guardians of all participants.

Inclusion and exclusion criteria

Inclusion criteria for the study were: (I) age 3–6 years; (II) ASA grade I–II; (III) undergoing laparoscopic surgery; (IV) general anesthesia with sevoflurane; and (V) complete clinical data.

Patients were excluded based on the following criteria: (I) preoperative diagnosis of cognitive impairment or developmental delay; (II) history of psychiatric-neurological disorders; (III) central nervous system diseases; (IV) immune system or chronic inflammatory diseases; (V) hearing impairment; (VI) intake of vitamin D supplements or other medications affecting vitamin D metabolism within the preceding 6 months; (VII) severe hepatic or renal dysfunction; (VIII) known or suspected coagulopathy; and (IX) incomplete clinical data.

Data collection and anesthesia

Patient data were extracted from the electronic medical record (EMR) system and included demographic characteristics (age, sex, weight, height, body mass index), laboratory indicators, and surgical details (disease type, surgical procedure, duration of surgery, and length of hospital stay).

Anesthesia was administered by an attending anesthesiologist with over 3 years of pediatric experience. Participants fasted and abstained from water after 10:00 PM to 6:00 AM on the day preceding the procedure. No sedative premedication was administered to avoid confounding effects on delirium assessment. Induction was achieved via inhalation of 8% sevoflurane in 80% oxygen (balance air) using a face mask. Following induction, anesthesia was maintained with sevoflurane (titrated between 2% and 3%) in a 1:1 mixture of oxygen and medical air. End-tidal sevoflurane concentration (EtAC) was measured after pneumoperitoneum establishment, once mean arterial pressure (MAP) and heart rate had stabilized; this concentration remained stable from the point of stabilization until the end of surgery. All patients underwent tracheal intubation for airway management. Extubation was performed when spontaneous breathing had resumed, and oxygen saturation remained >95% without supplemental oxygen, with the child not fully awake. Anesthesia-related characteristics comprised three categories: (I) hemodynamic parameters (heart rate and MAP), recorded at predefined time points; (II) anesthetic depth EtAC; and (III) time metrics [duration of anesthesia and length of post-anesthesia care unit (PACU) stay]. MAP is defined as the sum of the diastolic blood pressure and one-third of the pulse pressure.

Postoperative information comprised adverse events (e.g., hypoxemia, nausea and vomiting, laryngospasm, and bleeding) as well as standardized assessments for POD and sleep quality. All data collection procedures were supervised by the principal investigator to ensure consistency and accuracy.

Serum collection and 25(OH)D3 measurement

On the morning of surgery, a 3-mL whole blood sample was collected from the antecubital vein. The sample was placed in a non-anticoagulant tube and allowed to clot at room temperature for 30 minutes. After clotting, it was centrifuged at 2,000 rpm for 10 minutes at 4 ℃ to separate the serum. Finally, the obtained serum was aliquoted and stored at −80 ℃ until subsequent analysis.

Enzyme-linked immunosorbent assay (ELISA)

Serum levels of 25(OH)D3 were measured by ELISA with a commercial kit (product code: CB10022-Hu; COIBO BIO; Shanghai, China), according to the manufacturer's instructions. According to the specifications, the intra-assay coefficient of variation (CV) was <10%, and the inter-assay CV was <15%. All samples were analyzed in a single batch to eliminate inter-assay variation, and each sample was measured in duplicate to ensure accuracy. Human monoclonal anti-25(OH)D3 antibody was immobilized onto 96-well microtiter plates to form the solid phase. Standards or pretreated serum samples were added to the wells, followed by a biotin-conjugated detection antibody. After washing to remove unbound components, horseradish peroxidase (HRP)-labeled streptavidin was added. Following another wash step, 3,3',5,5'-tetramethylbenzidine (TMB) substrate was added for color development. The TMB is catalytically converted by HRP to a blue product, which turns yellow upon acidification to stop the reaction. The resulting color intensity at this stage is directly proportional to the concentration of 25(OH)D3 in the sample. Finally, the absorbance at 450 nm was measured using a microplate reader, and 25(OH)D3 concentrations were calculated against the standard curve.

POD assessment

POD was assessed using the Cornell Assessment of Pediatric Delirium (CAPD) scale on postoperative days 1, 3, and 7. The CAPD, derived from the PAED scale, is validated for repeated delirium assessments outside the PACU and is applicable to children of all ages and developmental stages. A CAPD score of ≥9 was used as the diagnostic threshold for POD. All assessments were conducted by trained nurses and subsequently verified by attending physicians, who were blinded to preoperative vitamin D levels.

Sleep quality assessment

All guardians of patients completed the Children's Sleep Habits Questionnaire (CSHQ) on postoperative day 7.

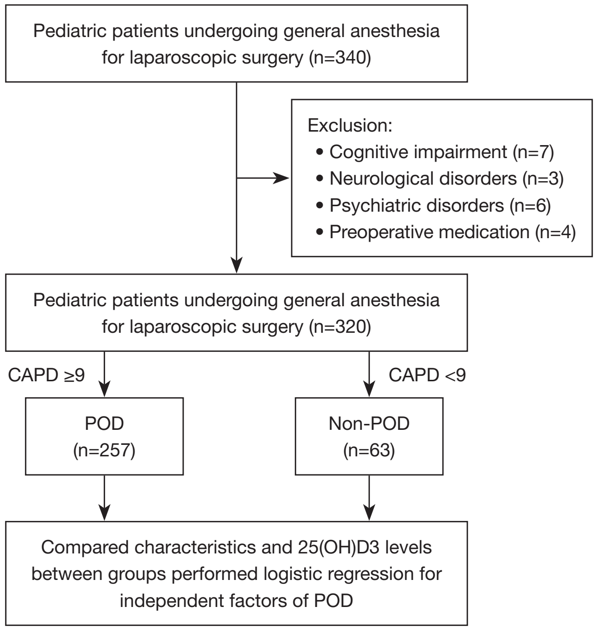

Figure 1 Flowchart of participant recruitment, grouping, and study procedures. 25(OH)D3, 25-hydroxyvitamin D3; CAPD, Cornell Assessment for Pediatric Delirium; POD, postoperative delirium.

CSHQ assesses eight domains of sleep behavior: bedtime resistance, sleep onset delay, sleep duration, sleep anxiety, night wakings, parasomnias, sleep-disordered breathing, and daytime sleepiness (9). Each item is rated by parents using a three-point Likert scale: "usually" (5–7 times/week, scored 3), "sometimes" (2–4 times/week, scored 2), or "rarely" (0–1 times/week, scored 1). The total score is the sum of all items, with higher scores indicating more severe sleep disturbances. A total score exceeding 41 is considered clinically significant, suggesting a possible sleep disorder.

Statistical analysis

All statistical analyses were performed using SPSS version 25.0 (IBM) and GraphPad Prism version 7.0 (GraphPad Software). Data normality was assessed using the Kolmogorov-Smirnov test. Continuous variables are presented as mean ± standard deviation (SD), and categorical variables as numbers (percentages). Intergroup comparisons were conducted using the Student's t-test for continuous variables and the Chi-squared test or Fisher's exact test for categorical variables. The correlation between preoperative serum 25(OH)D3 levels and clinical variables in patients with POD was assessed using Pearson or Spearman correlation analysis. To identify independent risk factors for POD, multivariable logistic regression analysis was performed, and odds ratios (ORs) with corresponding 95% confidence intervals (CIs) were calculated. The diagnostic value of 25(OH)D3 for POD was assessed via receiver operating characteristic (ROC) curve analysis. A sensitivity analysis was additionally conducted by including postoperative CSHQ score to assess the robustness of the association between VDD and POD. A two-sided P value <0.05 was considered statistically significant for all analyses.

Results

Characteristics of study subjects

Clinical data were collected from 320 patients. The study process is shown in *Figure 1*. The average age of the cohort was 4.40±1.10 years, with a notable male predominance (70.63%). Other demographic characteristics of patients were presented in *Table 1*. Among the patients, the most common diagnoses and corresponding surgical procedures were bilateral inguinal hernia treated with high ligation of the hernial sac (28.44%) and bilateral spermatic cord or testicular hydrocele treated with bilateral high ligation of the processus vaginalis (26.56%). The average durations for surgery and anesthesia were 62.86±21.08 and 83.08±22.05 min, respectively. The mean hospital stay was

Table 1 Demographic, surgical, and anesthetic characteristics of pediatric patients undergoing general anesthesia for laparoscopic surgery

Characteristics	Data (n=320)
Age (years)	4.40±1.10
Sex (male/female)	226/94
Height (cm)	109.80±10.19
Weight (kg)	18.79±4.55
BMI (kg/m^2)	15.39±1.74
Diseases	
Bilateral inguinal hernia	91 (28.44)
Bilateral spermatic cord or testicular hydrocele	85(26.56)
Bilateral cryptorchidism	5 (1.56)
Inguinal hernia + hydrocele	24 (7.50)
Inguinal hernia + cryptorchidism	22 (6.88)
Lumps in different locations	24 (7.50)
Appendicitis	21 (6.56)
Hydronephrosis or renal cyst	11 (3.44)
Intestinal malformation or mesenteric lymphangioma	9 (2.81)
Other diseases	28 (8.75)
Surgical procedures	
High ligation of the hernial sac	91 (28.44)
Bilateral high ligation of the processus vaginalis	85 (26.56)
Bilateral testicular fixation surgery	5 (1.56)
High ligation of the hernial sac + high ligation of the processus vaginalis	24 (7.50)
High ligation of the hernial sac + orchidopexy	22 (6.88)
Lumps excision	24 (7.50)
Appendectomy	21 (6.56)
Pyeloplasty or nephrectomy for renal cyst decortication	11 (3.44)
Intestinal resection and anastomosis or mesenteric lymphangioma resection	9 (2.81)
Other surgical approaches	28 (8.75)
Surgery duration (min)	62.86±21.08
Anesthesia duration (min)	83.08±22.05
PACU duration (min)	33.69±4.66
Length of hospital stay (days)	6.48±2.35

Data are presented as mean ± SD, number, or number (%). BMI, body mass index; PACU, post-anesthesia care unit; SD, standard deviation.

Table 2 Comparison of characteristics between pediatric patients with and without POD

Characteristics	POD (n=257)	Non-POD (n=63)	P value
Age (years)	4.35±1.10	4.60±1.09	0.10
Sex (male/female)	180/77	46/17	0.64
Height (cm)	109.44±10.08	111.40±10.56	0.21
Weight (kg)	18.68±4.48	19.25±4.84	0.46
BMI (kg/m^2)	15.40±1.71	15.32±1.83	0.48
Preoperative heart rate (bpm)	96.78±10.17	94.79±10.08	0.19
Preoperative MAP (mmHg)	69.39±5.27	70.40±5.41	0.16
Preoperative 25(OH)D3 (ng/mL)	45.03±25.80	54.44±31.93	<0.001*
VDD (<30 ng/mL)	78 (30.4)	2 (3.2)	<0.001*
Surgery duration (min)	63.23±22.20	61.33±15.73	0.44
EtAC (%)			
Length of hospital stay (days)	6.34±2.29	6.57±2.39	0.40
CSHQ score	45.33±9.80	38.05±4.63	<0.001*

Data are presented as mean ± SD, number, or number (%). *, P<0.05. 25(OH)D3, 25-hydroxyvitamin D3; BMI, body mass index; CSHQ, Children's Sleep Habits Questionnaire; EtAC, end-tidal sevoflurane concentration; MAP, mean arterial pressure; POD, postoperative delirium; SD, standard deviation; VDD, vitamin D deficiency.

6.48±2.35 days. The overall incidence of POD (CAPD-defined) was 80.3% (257/320).

Comparison between POD and non-POD groups

Table 2 compares the characteristics of patients with and without POD. Patients with POD had lower age, height, and weight, as well as higher preoperative heart rate and lower preoperative MAP compared to non-POD patients (all P>0.05). Notably, serum 25(OH)D3 levels were significantly lower in the POD group (45.03±25.80 *vs.* 54.44±31.93 ng/mL, P<0.001) (*Figure 2*). CSHQ score on postoperative day 7 was also significantly higher in the POD group (45.33±9.80 *vs.* 38.05±4.63, P<0.001).

Correlation of serum 25(OH)D3 levels with the characteristics in the POD patients

To evaluate the association between serum 25(OH)D3 levels and the characteristics in the POD patients, Spearman's rank correlation was performed. As shown in *Table 3*, preoperative serum 25(OH)D3 levels were significantly correlated with several parameters. Serum 25(OH)D3 levels were negatively correlated with preoperative MAP (r=−0.152, P=0.02) and CSHQ score on postoperative day 7 (r=−0.215, P=0.001), indicating that children with lower vitamin D levels had higher preoperative MAP and worse postoperative sleep quality.

No significant correlations were found between serum 25(OH)D3 levels and age, BMI, preoperative heart rate, surgery duration, EtAC, or length of hospital stay (P>0.05, *Table 3*).

Multivariable analysis

As shown in *Table 4*, preoperative VDD emerged as a strong independent risk factor for POD, with deficient children having a 14.25-fold higher risk of POD compared to non-deficient children (adjusted OR =14.25; 95% CI: 3.33–61.0; P<0.001). None of the other included variables reached statistical significance (all P>0.05).

Sensitivity analysis: including postoperative sleep quality

To assess the robustness of our findings and explore the relationship between postoperative sleep quality and POD, we conducted a sensitivity analysis by adding the postoperative day 7 CSHQ score to the primary model. As shown in Table S1, VDD remained significantly associated with POD (adjusted OR =8.15; 95% CI: 1.88–35.3; P=0.005), although the effect size was attenuated compared

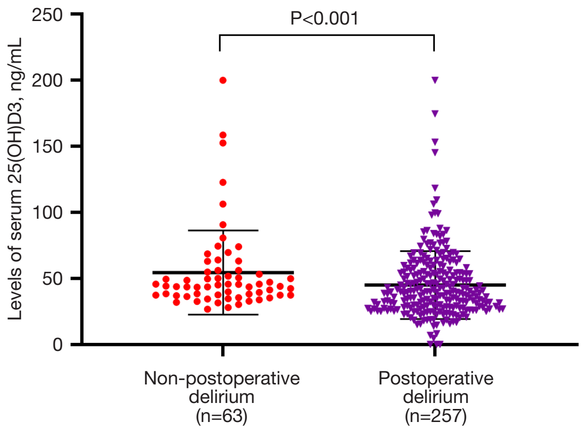

Figure 2 Preoperative serum expression levels of 25(OH)D3 in pediatric patients undergoing laparoscopic surgery. Comparison of serum 25(OH)D3 levels, assessed by ELISA, between patients with and without POD. Data are presented as mean ± SD, and intergroup difference was assessed using the Student's t-test. 25(OH)D3, 25-hydroxyvitamin D3; ELISA, enzyme-linked immunosorbent assay; POD, postoperative delirium; SD, standard deviation.

Table 3 Correlation of serum 25(OH)D3 levels with characteristics in pediatric patients with POD

Characteristics	Correlation coefficient (r)	P value
Age (years)	0.037	0.55
BMI (kg/m^2)	0.035	0.58
Preoperative heart rate (bpm)	0.027	0.66
Preoperative MAP (mmHg)	−0.152	0.02
Surgery duration (min)	−0.061	0.37
EtAC (%)	0.022	0.74
Length of hospital stay (days)	0.034	0.59
CAPD score		
Postoperative day 1	−0.334	<0.001*
Postoperative day 3	−0.379	<0.001*
Postoperative day 7	−0.298	<0.001*
CSHQ score	−0.215	0.001*

*, P<0.05. Spearman's rank correlation coefficient was used. 25(OH)D3, 25-hydroxyvitamin D3; BMI, body mass index; CAPD, Cornell Assessment of Pediatric Delirium; CSHQ, Children's Sleep Habits Questionnaire; EtAC, end-tidal sevoflurane concentration; MAP, mean arterial pressure; POD, postoperative delirium.

to the primary analysis. CSHQ score itself emerged as an independent correlate of POD (adjusted OR =1.13; 95% CI: 1.07–1.19; P<0.001), indicating that each one-point increase in CSHQ score was associated with an approximately 13% increase in POD risk.

No significant interaction was detected between vitamin D status and CSHQ score (P for interaction =0.659; Table S2), suggesting that the effects of VDD and poor sleep quality on POD are independent of each other.

Sensitivity analysis: association between vitamin D status and POD

To fully explore the association between preoperative

Table 4 Multivariate logistic regression analysis of risk factors influencing the occurrence of POD

Characteristics	β	SE	Wald χ^2	P value	OR	95% CI
Age (years)	−0.131	0.239	0.302	0.58	0.88	0.55–1.40
BMI (kg/m^2)	0.045	0.092	0.234	0.63	1.05	0.87–1.25
Preoperative heart rate (bpm)	0.006	0.017	0.117	0.73	1.01	0.97–1.04
Preoperative MAP (mmHg)	−0.044	0.033	1.768	0.18	0.96	0.90–1.02
EtAC (%)	0.287	1.378	0.043	0.84	1.33	0.09–19.9
VDD group	2.656	0.742	12.828	<0.001*	14.25	3.33–61.0

*, P<0.05. BMI, body mass index; CI, confidence interval; EtAC, end-tidal sevoflurane concentration; MAP, mean arterial pressure; OR, odds ratio; POD, postoperative delirium; SE, standard error; VDD, vitamin D deficiency.

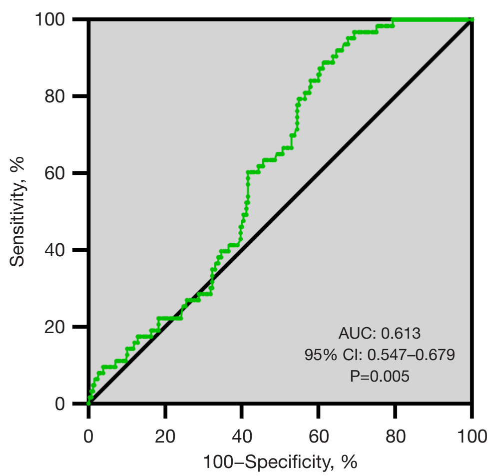

Figure 3 Diagnostic performance of serum 25(OH)D3 for POD. ROC curve analysis was performed to evaluate the ability of serum 25(OH)D3 levels to differentiate between patients with and without POD. The AUC value was 0.613 (95% CI: 0.547–0.679), with a sensitivity of 38.9%, and a specificity of 88.9%. 25(OH)D3, 25-hydroxyvitamin D3; AUC, area under the curve; CI, confidence interval; POD, postoperative delirium; ROC, receiver operating characteristic.

vitamin D status and POD, we conducted dichotomous and three-category analyses.

In the dichotomous comparison, baseline data were similar between VDD and non-VDD groups. The VDD group had a significantly higher POD rate (97.5% *vs.* 74.6%, P<0.001). Children with VDD also presented higher postoperative CSHQ scores (P<0.001; Table S3), suggesting poorer sleep quality.

Diagnostic performance of serum 25(OH)D3 for POD

The potential diagnostic value of serum 25(OH)D3 for distinguishing patients with POD from those without was assessed using ROC curve analysis. As shown in *Figure 3*, serum 25(OH)D3 demonstrated moderate diagnostic accuracy, with an area under the curve (AUC) value of 0.613 (95% CI: 0.547–0.679) (P<0.05), a cutoff value of 33.79 ng/mL, a sensitivity of 38.9%, and a specificity of 88.9%.

Notably, the ROC-derived optimal cutoff value (28.86 ng/mL) closely approximates the 30 ng/mL threshold used to define VDD in the primary and subgroup analyses above. This concordance supports the clinical validity of our grouping strategy and suggests that the 30 ng/mL cutoff is appropriate for identifying children at elevated risk of POD in this population. Consistent with the markedly higher POD incidence observed in the VDD group (<30 ng/mL) compared to the non-VDD group (97.5% *vs.*

74.6%, P<0.001), the ROC analysis further confirms the discriminative ability of preoperative 25(OH)D3 levels, albeit with modest overall accuracy (AUC =0.613).

Discussion

To reduce the risk of POD in pediatric patients, it is crucial to recognize and monitor for known risk factors. Studies have identified several risk factors, including developmental delay, need for mechanical ventilation, use of physical restraints, and receipt of either benzodiazepines, opiates, steroids, or vasoactive medication (10). Although numerous studies have investigated the relationship between 25(OH)D3 and POD in adults (11), its association with pediatric POD remains unclear. This study of pediatric patients undergoing general anesthesia for laparoscopic surgery found that serum 25(OH)D3 levels were significantly reduced in those who developed POD. Furthermore, a higher 25(OH)D3 level was identified as an independent protective factor against POD. These preliminary findings suggest that 25(OH)D3 deficiency should be considered among the risk factors for pediatric POD.

Research reports indicated that the incidence of pediatric POD ranges from 2% to 80% (5,6), consistent with the 80.3% incidence of POD observed in our study. Notably, in our cohort, the hospital stay was comparable between patients with and without POD, a finding potentially explained by the generally brief duration of hospitalization.

Vitamin D plays a crucial role in preventing neurodegenerative diseases by regulating glial cell-derived neurotrophic factor, choline acetyltransferase, nitric oxide, and β-amyloid clearance, while also modulating the immune system via antioxidant mechanisms. These multifaceted actions underscore how VDD can increase the risk of POD and related complications. Supporting the link between VDD and delirium, previous studies in adult and elderly populations have reported significant associations (11,12). Our findings in children align with the growing body of evidence from studies in adults and elderly populations, confirming that patients with POD had significantly lower serum 25(OH)D3 levels.

Multivariable logistic regression analysis identified a higher 25(OH)D3 level as an independent protective factor against POD, and children with VDD had a 14.25-fold higher risk of POD compared to those with adequate levels. This association remained robust in sensitivity analyses adjusting for postoperative sleep quality. These findings identify preoperative VDD as a strong, independent risk factor for POD in pediatric patients. Subsequent ROC analysis revealed that serum 25(OH)D3 holds modest diagnostic utility for POD identification, though sensitivity was limited to 38.9 %. Together, these findings point to a potential predictive role for serum 25(OH)D3 and highlight the need for further prospective studies to validate its utility and assess the preventive efficacy of vitamin D supplementation.

In our sensitivity analysis, the CSHQ score was strongly associated with POD. However, due to the temporal overlap between the CSHQ assessment (capturing the past week) and CAPD assessments (postoperative days 0–7), this association should be interpreted as a cross-sectional correlation rather than a predictive relationship. Accordingly, we found no significant interaction between vitamin D status and sleep quality, indicating that these two factors independently contribute to POD risk. These findings appear to differ from previous reports showing positive associations between vitamin D and sleep quality, which are mediated by vitamin D receptors in brain regions, neurotransmitter modulation, neuroplasticity, and cross-regulation with melatonin (13-15). Several factors may explain this discrepancy. The acute postoperative period involves strong confounders—surgical stress, pain, opioids, and environmental disruptions—that may overshadow vitamin D's subtle long-term regulatory effects on sleep. Additionally, our 7-day acute window differs fundamentally from the chronic timescales of nutritional epidemiology studies, and the bidirectional delirium-sleep disturbance cycle during the acute phase may dominate over any direct vitamin D effect. Thus, rather than contradicting existing literature, our findings suggest that vitamin D's impact on sleep may only manifest under steady-state conditions and longer follow-up, while perioperative factors play a more immediate and potent role in determining sleep quality and delirium risk.

This study has several limitations. First, the sample size was relatively small, and the single-center recruitment may limit the generalizability of the findings. Second, the absence of nighttime screening could have led to an underestimation of POD incidence. Moreover, the heterogeneity of postoperative analgesia regimens may have confounded the results related to POD. Therefore, while suggesting an association between preoperative serum 25(OH)D3 levels and pediatric POD, the modest discriminative ability of 25(OH)D3 alone (AUC =0.613) indicates that it should not be used as a standalone screening tool but rather in combination with other clinical risk factors. Nevertheless, this link requires validation in larger, multicenter prospective cohorts.

Conclusions

In conclusion, our study demonstrates that preoperative VDD (<30 ng/mL) is independently associated with a substantially increased risk of POD in children aged 3–6 years undergoing laparoscopic surgery under general anesthesia. These findings suggest that preoperative VDD may help identify at-risk children, and preoperative decreased serum 25(OH)D3 could serve as a potential biomarker for increased POD risk.

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None.

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://tp.amegroups.com/article/view/10.21037/tp-2026-0297/rc

Data Sharing Statement: Available at https://tp.amegroups.com/article/view/10.21037/tp-2026-0297/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tp.amegroups.com/article/view/10.21037/tp-2026-0297/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the Declaration of Helsinki and its subsequent amendments. The study protocol received approval from the Clinical Research Ethics Committee of Tianjin Children's Hospital (No. 2025-TYXWKY-001). The written informed consent was provided by the parents or guardians of all participants.

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