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Original Article

Predictive Value of Preoperative Vitamin D, Serum Calcium, and Hemoglobin Levels for Surgical Site Infection in Pediatric General Surgery

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ABSTRACT

Background: Surgical site infection (SSI) is an important cause of postoperative morbidity in pediatric surgical patients and may lead to prolonged hospitalization, additional antimicrobial treatment, and further surgical intervention. Preoperative nutritional and hematological parameters may influence immune function and wound healing. However, the predictive value of vitamin D, serum calcium, and hemoglobin levels for SSI in children undergoing general surgery remains uncertain.
Aim: To evaluate the predictive value of preoperative serum vitamin D, serum calcium, and hemoglobin levels for the development of SSI in children undergoing general surgical procedures.
Materials and Methods: A prospective observational cohort study was conducted among 200 children aged 0–17 years undergoing elective or emergency general surgical procedures at a tertiary-care hospital. Preoperative serum 25-hydroxyvitamin D, total serum calcium, and hemoglobin levels were recorded. Patients were followed for 30 days postoperatively for SSI. Statistical analysis included Student's t-test, odds ratios with 95% confidence intervals, and receiver operating characteristic (ROC) curve analysis. A p-value <0.05 was considered statistically significant.
Results: The mean age was 8.58 ± 4.28 years, and 60% of participants were male. SSI developed in 23 patients (11.5%). Vitamin D deficiency was observed in 65% of children, low serum calcium in 9%, and anemia in 60.5%. Mean operative duration was significantly longer in patients with SSI than in those without SSI (89.30 ± 22.03 versus 75.87 ± 25.31 minutes; p = 0.0075). Mean hemoglobin was significantly lower in the SSI group (10.25 ± 1.36 versus 11.16 ± 1.50 g/dL; p = 0.0032). Anemia was significantly associated with SSI (OR: 8.08; 95% CI: 1.84–35.54; p = 0.0057). Vitamin D deficiency and low serum calcium showed no significant associations with SSI. ROC analysis demonstrated limited discriminatory ability for hemoglobin (AUC: 0.61), vitamin D (AUC: 0.56), and calcium (AUC: 0.54).
Conclusion: Anemia and longer operative duration were significantly associated with SSI in pediatric surgical patients. Hemoglobin demonstrated the highest, although limited, predictive performance among the three biomarkers. Further studies with adjusted analyses are needed to establish their independent predictive value.

Keywords: Surgical site infection; pediatric general surgery; vitamin D deficiency; serum calcium; hemoglobin; anemia; wound infection; predictive value.

INTRODUCTION

Surgical site infection (SSI) is defined as an infection involving the skin and subcutaneous tissue of the incision, deeper soft tissues, organs or spaces manipulated during a surgical procedure. It is a significant cause of postoperative morbidity and may lead to wound dehiscence, abscess formation, need for reoperation, prolonged antimicrobial therapy and extended hospitalization. Prevention of SSI is therefore an essential component of perioperative patient safety. The World Health

Organization (WHO) and the Centers for Disease Control and Prevention (CDC) recommend evidence-based preventive measures across the preoperative, intraoperative and postoperative periods.[1,2]

Children undergoing general surgery constitute a heterogeneous population. Age, nutritional status, underlying disease, urgency of surgery, wound classification, type of procedure and operative duration may influence postoperative outcomes. Pediatric studies have identified operative duration and degree of wound contamination as important determinants of SSI. In a prospective multicenter study of pediatric surgical patients, wound contamination and operative duration were significantly associated with postoperative wound infection. In another cohort of 3,646 children, a predictive model incorporating operative and patient-related factors was developed. These findings highlight the need to evaluate laboratory markers in conjunction with established clinical and operative risk factors rather than in isolation.[3,4]

Vitamin D status is best assessed by serum 25-hydroxyvitamin D [25(OH)D]. Beyond its role in calcium and phosphate homeostasis, vitamin D participates in immune regulation and modulates innate and adaptive immune responses. Vitamin D deficiency has been investigated as a potential contributor to infection susceptibility and impaired wound healing. An observational study in adults undergoing surgery reported an association between preoperative 25(OH)D levels and postoperative SSI. Similarly, a prospective cohort study of adults undergoing right hemicolectomy reported an association between low preoperative vitamin D and SSI. However, findings from adult populations cannot be directly extrapolated to children, and observational associations do not establish a causal preventive role for supplementation.[5,6]

Serum calcium is another routinely measured biochemical parameter. Calcium is essential for neuromuscular function, intracellular signaling, coagulation and multiple cellular processes. Total serum calcium concentration is influenced by serum albumin and acid-base status. Thus, a low total calcium value does not necessarily indicate low biologically active calcium. Where clinically indicated, measurement of ionized calcium or albumin-corrected calcium may improve interpretation. Evidence that routine preoperative calcium levels independently predict SSI in children is less established than evidence for conventional operative risk factors.

Hemoglobin concentration reflects the oxygen-carrying capacity of blood. Adequate tissue oxygen delivery is essential for metabolism and wound repair, while anemia may reflect nutritional deficiency, chronic disease, blood loss or other comorbidities. However, the relationship between anemia and SSI is complex, as anemia is often associated with severity of illness, operative complexity, need for transfusion and prolonged operative time. In an observational surgical study, the crude association between anemia and SSI diminished after adjustment for confounders, underscoring the importance of adequate confounding control.[7]

Despite biological plausibility, the predictive value of preoperative vitamin D, serum calcium and hemoglobin levels has not been sufficiently established for routine SSI risk stratification in children undergoing general surgery. A prospective cohort study that measures these three parameters preoperatively and systematically follows children postoperatively using standardized SSI definitions could clarify their association with infection and determine whether they add meaningful discriminatory value beyond clinical and operative characteristics.

Aim of the study: To evaluate the predictive value of preoperative vitamin D, serum calcium and hemoglobin levels for surgical site infection in children undergoing general surgery.

METHODOLOGY

Study Design and Setting

A prospective observational cohort study was conducted in the Department of Pediatric Surgery at a tertiary-care hospital. The study period comprised participant recruitment, 30-day postoperative follow-up for each participants, and data analysis.

Study Population and Sample Size

The study included 200 children aged 0–17 years who underwent elective or emergency general surgical procedures. Sample size was calculated based on the expected incidence of surgical site infection (SSI) in pediatric general surgery. Assuming an SSI incidence of 12-15% from previous pediatric literature, with 95% confidence interval and 80% power to detect an odds ratio of 2.0 for low versus normal biomarker levels, and allowing for adjustment of 5-6 covariates in multivariate analysis, a minimum of 180 patients was required. Considering 10% loss to follow-up, the final target was 200 patients.

Inclusion criteria:

1. Children aged 0-17 years undergoing general surgical procedures (elective or emergency)
2. Availability of preoperative serum 25-hydroxyvitamin D [25(OH)D], total serum calcium and hemoglobin within 7 days prior to surgery
3. Written informed consent from parent/guardian and assent from child aged >7 years

Exclusion criteria:

1. Active preoperative infection at or near the surgical site precluding reliable diagnosis of new SSI
2. Missing essential preoperative laboratory data
3. Surgical procedures outside the defined scope of general surgery
4. Patients operated elsewhere and referred for management of complications

Chronic illnesses, malnutrition and other comorbidities were recorded as potential confounders rather than criteria for automatic exclusion to ensure generalizability.

Data Collection

Data were collected using a pre-designed, structured proforma.

Demographic and clinical variables: Age, sex, weight, weight-for-age Z-score, nutritional status (WHO growth charts), comorbidities, ASA physical status, primary diagnosis, indication for surgery and duration of preoperative hospitalization.

Preoperative laboratory parameters (within 7 days before surgery):

Serum 25(OH)D (ng/mL): Measured by chemiluminescence immunoassay (CLIA). Categorized as deficient <20 ng/mL, insufficient 20-29 ng/mL, sufficient ≥30 ng/mL as per Endocrine Society guidelines.

Total serum calcium (mg/dL): Measured by automated biochemistry analyzer. Albumin-corrected calcium calculated where serum albumin was available: Corrected Ca = Measured Ca + 0.8 × (4.0 - Albumin [g/dL]).

Hemoglobin (g/dL): Measured by automated hematology analyzer. Anemia defined as per WHO age-specific cut-offs.

Operative variables: Type of procedure, elective and emergency surgery, wound classification as per CDC (clean, clean-contaminated, contaminated, dirty), duration of surgery (minutes), type and timing of antimicrobial prophylaxis, intraoperative contamination, blood loss and intraoperative complications.

Outcome Assessment and Follow-up

Primary outcome was occurrence of SSI within 30 days after surgery, defined and classified as superficial incisional, deep incisional and organ/space SSI as per Centers for Disease Control and Prevention / National Healthcare Safety Network [CDC/NHSN] criteria, 2023.

Participants were monitored daily during hospitalization. After discharge, follow-up was performed through outpatient visits on postoperative days 7, 15 and 30, supplemented by telephonic interview using a validated questionnaire when in-person visit was not feasible.

For patients developing SSI, the following were documented: day of onset, type of SSI, clinical features, microbiological culture and sensitivity, antibiotic therapy, need for wound drainage, reoperation, duration of hospital stay and readmission.

Statistical Analysis

Data were entered in Microsoft Excel and analyzed using SPSS v26.0. Normality was assessed by Shapiro-Wilk test. Continuous variables were expressed as mean ± SD or median [IQR]. Categorical variables were expressed as frequency. Association was tested using Student t-test and Chi-square/Fisher exact test. Univariate and multivariate logistic regression was performed to identify independent predictors of SSI. Predictive value was assessed by Receiver Operating Characteristic [ROC] curve and area under curve [AUC]. $P<0.05$ was considered statistically significant.

RESULTS

Table 1: Demographic and baseline characteristics of all patients

Variable		**n = 200**	**In %**
Age (Mean ± SD)		8.58 ± 4.28	
Gender	**Male**	120	60.0%
	Female	80	40.0%
SSI	**Present**	23	11.5%
	Absent	177	88.5%
Surgery Procedure	**Appendectomy**	76	38.0%
	Hernia repair	64	32.0%
	Intestinal surgery	30	15.0%
	Other abdominal surgery	30	15.0%
Vitamin	**Deficiency (< 20 ng/mL)**	130	65.0%
	Sufficiency (≥ 20 ng/mL)	70	35.0%
Calcium	**Low (< 8.5 mg/dL)**	18	9.0%
	Normal (≥ 8.5 mg/dL)	182	91.0%
Anemia	**Present**	121	60.5%

	Absent	79	39.5%

A total of 200 children were included with mean age 8.58 ± 4.28 years. Male predominance was observed with 120 males [60.0%] and 80 females [40.0%]. The overall incidence of surgical site infection [SSI] was 23 cases [11.5%]. Most common procedure was appendectomy 76 [38.0%] followed by hernia repair 64 [32.0%], intestinal surgery 30 [15.0%] and other abdominal surgeries 30 [15.0%]. Regarding biochemical parameters, vitamin D deficiency [<20 ng/mL] was present in 130 children [65.0%] while 70 [35.0%] had sufficiency. Low calcium [<8.5 mg/dL] was observed in only 18 [9.0%] children. Anemia was highly prevalent with 121 [60.5%] children being anemic.

Table 2: Comparison of preoperative operative time & laboratory values between children with and without SSI

Variables	SSI (n=23)	No SSI (n=177)	Mean difference Δ	t-test	p-value
Operative duration (min.)	89.30 ± 22.03	75.87 ± 25.31	13.42	2.7	0.0075
Vitamin D (ng/mL)	15.87 ± 7.68	17.38 ± 7.52	-1.51	-0.85	0.3942
Serum calcium (mg/dL)	9.20 ± 0.56	9.21 ± 0.53	-0.01	-0.081	0.9355
Hemoglobin (g/dL)	10.25 ± 1.36	11.16 ± 1.50	-0.91	-2.98	0.0032

Mean operative duration was significantly longer in SSI group [89.30 ± 22.03 min] compared to non-SSI group [75.87 ± 25.31 min] with mean difference of 13.42 minutes [t=2.7, p=0.0075]. Mean Vitamin D level was lower in SSI group [15.87 ± 7.68 ng/mL] vs non-SSI group [17.38 ± 7.52 ng/mL] but difference was not statistically significant [Δ -1.51 ng/mL, p=0.3942]. Serum calcium showed almost identical values in both groups [9.20 ± 0.56 vs 9.21 ± 0.53 mg/dL, p=0.9355], indicating no association with SSI. Mean hemoglobin was significantly lower in SSI group [10.25 ± 1.36 g/dL] compared to non-SSI group [11.16 ± 1.50 g/dL] with mean difference of -0.91 g/dL [t=-2.98, p=0.0032], suggesting association of lower Hb with SSI.

Table 3: Association of laboratory findings and wound contamination with SSI by using odds ratio

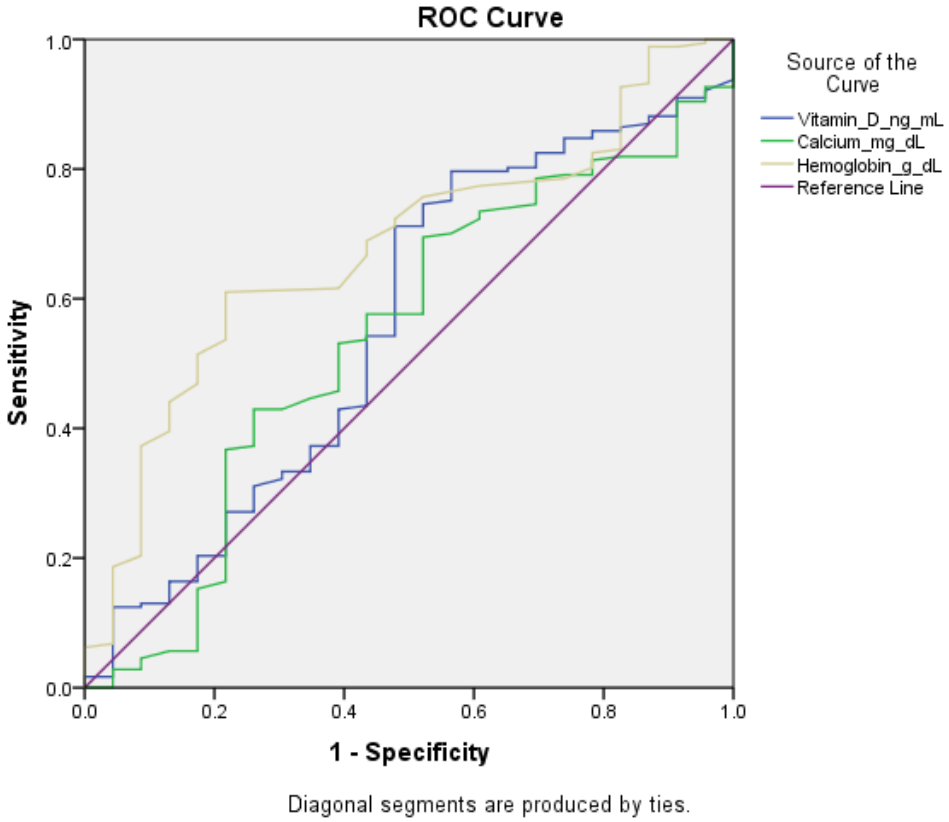
Variables		SSI Exposed	SSI non-exposed	Odds Ratio	95% CI	Z-test	P - Value
Vitamin D	**< 20 ng/mL**	15	115	1.01	0.41 – 2.52	0.023	0.9815
	≥ 20 ng/mL	8	62	-	-	-	-
Calcium	**< 8.5 mg/dL**	1	17	0.43	0.054 - 3.38	0.81	0.4204
	≥ 8.5 mg/dL	22	160	-	-	-	-
Anemia	**Anemic**	21	100	8.08	1.84 - 35.54	2.77	0.0057
	Non-Anemic	2	77	-	-	-	-
Wound	**Contaminated/ dirty wound**	7	47	1.21	0.47 - 3.13	0.39	0.6936
	Other wound classes	16	130	-	-	-	-

Vitamin D deficiency [<20 ng/mL] showed odds of SSI [OR 1.01, 95% CI 0.41-2.52] but association was not statistically significant [p=0.9815], indicating no association. Low calcium [<8.5 mg/dL] did not show increased risk of SSI [OR 0.43, 95% CI 0.054-3.38, p=0.4204]. Anemia was significantly associated with SSI. Anemic children had 8.08 times higher odds of developing SSI compared to non-anemic children [OR 8.08, 95% CI 1.84-35.54, p=0.0057]. Wound contamination [contaminated/dirty vs clean/clean-contaminated] was not significantly associated with SSI in this cohort [OR 1.21, 95% CI 0.47-3.13, p=0.6936].

Table 4: diagnostic performance of preoperative vitamin D, Calcium and hemoglobin for prediction of surgical site infection (SSI) by using Receiver Operating Characteristic curve

Marker	AUC	95% CI	Cut off Value	Sensitivity	Specificity
Vitamin D	0.56	0.432–0.697	13.45	71.2%	52.2%
Calcium	0.54	0.397–0.668	8.97	69.5%	47.8%
Hemoglobin	0.61	0.578–0.776	10.75	67.7%	43.3%

On ROC analysis, hemoglobin showed the highest performance among three markers with AUC 0.61 [95% CI 0.528-0.776], indicating fair predictive value. At cut-off 10.75 g/dL, sensitivity was 67.7% and specificity 43.3%. Vitamin D showed poor discriminatory ability with AUC 0.56 [95% CI 0.432-0.697] at cut-off 13.45 ng/mL with sensitivity 71.2% and specificity 52.2%. Serum calcium showed poorest performance with AUC 0.54 [95% CI 0.397-0.668] at cut-off 8.97 mg/dL with sensitivity 69.5% and specificity 47.8%, indicating no useful predictive value. Overall, none of the three biomarkers showed good diagnostic performance [AUC >0.80], with hemoglobin showing only modest predictive value.



Receiver Operating Characteristic (ROC) Curves of preoperative vitamin D, Calcium and hemoglobin for prediction of SSI

DISCUSSION:

The present study evaluated the predictive value of preoperative vitamin D, serum calcium, and hemoglobin levels for surgical site infection (SSI) among 200 pediatric patients undergoing general surgical procedures. The overall SSI incidence was 11.5% (23/200). The mean age was 8.58 ± 4.28 years, and males constituted 60% of participants. Appendectomy was the most common procedure (38%), followed by hernia repair (32%). Vitamin D deficiency was observed in 65% of children, low serum calcium in 9%, and anemia in 60.5%. The principal finding was that anemia and longer operative duration were significantly associated with SSI, whereas vitamin D and serum calcium were not statistically significant predictors.

The SSI incidence observed in this study emphasizes the importance of infection prevention in pediatric surgical practice. SSI is multifactorial and may be influenced by patient characteristics, surgical complexity, wound contamination, operative duration, and perioperative care. The Centers for Disease Control and Prevention (CDC) and World Health Organization (WHO) recommend comprehensive prevention strategies, including appropriate antimicrobial prophylaxis, aseptic technique, and standardized postoperative wound surveillance [1,8]. The observed incidence should be interpreted in relation to the types of procedures performed and the duration of follow-up.

Operative duration was significantly longer among children who developed SSI than among those without infection (89.30 ± 22.03 versus 75.87 ± 25.31 minutes; p = 0.0075). This finding agrees with Cheng et al., whose systematic review demonstrated an association between prolonged operative duration and SSI across different surgical specialties [9]. Longer operations may increase tissue exposure and manipulation and may also indicate greater surgical complexity. However, because the present study did not provide an adjusted analysis, operative duration cannot be considered an independent predictor without accounting for procedure type, disease severity, and other potential confounders.[10]

Vitamin D deficiency was common, affecting 130 children (65%). Mean vitamin D levels were lower in the SSI group than in the non-SSI group (15.87 ± 7.68 versus 17.38 ± 7.52 ng/mL), but the difference was not statistically significant (p = 0.3942). Similarly, vitamin D deficiency was not significantly associated with SSI (OR 1.01, 95% CI 0.41–2.52; p = 0.9815). Vitamin D contributes to immune regulation and antimicrobial defense, providing a biological rationale for investigating its role in postoperative infections. Lakhera et al. examined preoperative vitamin D deficiency in relation to SSI following oral cavity oncology surgery in India [11]. However, differences in age, underlying disease, and surgical complexity limit direct comparisons with the present pediatric population. Overall, the present results do not support vitamin D deficiency as a useful standalone predictor of SSI.

Serum calcium levels were nearly identical in the SSI and non-SSI groups (9.20 ± 0.56 versus 9.21 ± 0.53 mg/dL; p = 0.9355). Low calcium was not significantly associated with SSI (OR 0.43, 95% CI 0.054–3.38; p = 0.4204). Only 18 children had low calcium, limiting the precision of this estimate. The ROC AUC was 0.54, indicating poor discrimination. Therefore, the study did not establish serum calcium as a useful standalone SSI predictor.

Anemia was significantly associated with SSI. Mean hemoglobin was lower in the SSI group than in the non-SSI group (10.25 ± 1.36 versus 11.16 ± 1.50 g/dL; p = 0.0032). Of 23 children with SSI, 21 were anemic. The estimated odds ratio was 8.08 (95% CI 1.84–35.54; p = 0.0057). Anemia may impair tissue oxygen delivery, potentially affecting wound healing and immune function.[12,13] A systematic review and meta-analysis of patients undergoing lower-extremity joint replacement also reported an association between preoperative anemia and postoperative infections [14]. However, differences between adult orthopedic and pediatric general surgery populations limit direct comparison. The wide confidence interval and absence of adjusted analysis mean that the magnitude of risk remains uncertain.

ROC analysis showed that hemoglobin had the highest AUC (0.61), followed by vitamin D (0.56) and calcium (0.54). At the reported hemoglobin cutoff of 10.75 g/dL, sensitivity was 67.7% and specificity was 43.3%. These values indicate limited standalone predictive performance. CDC and WHO recommendations emphasize comprehensive infection-prevention measures rather than reliance on isolated laboratory markers [1,8,15]. Combining clinical, surgical, and laboratory variables may improve prediction, but any proposed model would require validation.

The study's strengths include prospective assessment and evaluation of three preoperative biomarkers in 200 children. Limitations include the small number of SSI events, possible confounding by operative complexity and wound characteristics, and the lack of adjusted analyses. Further multicenter studies with larger samples and standardized follow-up are needed.

CONCLUSION

The present study found an SSI incidence of 11.5% among 200 children undergoing general surgical procedures. Anemia was significantly associated with SSI, with an estimated eightfold increase in the odds of infection, while lower mean hemoglobin levels were also observed among children who developed SSI. Longer operative duration was significantly associated with SSI. In contrast, vitamin D deficiency and low serum calcium were not significantly associated with infection.

Hemoglobin demonstrated the highest performance among the three biomarkers, its AUC of 0.61 remained inadequate for reliable standalone prediction. Vitamin D and calcium showed similarly limited diagnostic utility. These findings support the consideration of preoperative anemia assessment within broader pediatric surgical risk evaluation, while emphasizing that effective SSI prevention requires a comprehensive approach incorporating patient characteristics, surgical factors, and established infection-control practices.

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