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POSTOPERATIVE COMPLICATIONS IN TONSILLECTOMY: PREDICTIVE FACTORS AND RISK STRATIFICATION IN PEDIATRIC PATIENTS

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Abstract

Postoperative complications following pediatric tonsillectomy—most notably hemorrhage, respiratory compromise, dehydration, and unplanned readmissions—remain a pressing clinical challenge, affecting 10.0% of patients and contributing to increased morbidity, prolonged hospitalization, and higher healthcare costs. To address the need for reliable preoperative risk stratification, we conducted a retrospective cohort analysis of 1,200 children aged 2–16 years who underwent tonsillectomy or adenotonsillectomy at three tertiary-care centers between January 2022 and December 2023. We systematically extracted demographic (age, sex, race/ethnicity), clinical (body mass index percentile, preoperative apnea–hypopnea index, comorbid asthma or cardiac disease), surgical (technique, surgeon experience, operative duration, estimated blood loss), and perioperative (analgesic regimen, hospital length of stay) variables from electronic health records. Univariate screening ($p < 0.10$) and subsequent multivariable logistic regression with backward elimination ($\alpha = 0.05$), complemented by LASSO regularization to guard against overfitting, identified five independent predictors of significant complications within 30 days: age under four years (adjusted OR 2.1, 95% CI 1.3–3.4), preoperative apnea–hypopnea index >15 events/hour (OR 3.2, 95% CI 2.0–5.1), underlying cardiac comorbidity (OR 4.5, 95% CI 2.6–7.8), surgeon experience under five years (OR 1.9, 95% CI 1.1–3.2), and use of total dissection technique (OR 1.6, 95% CI 1.0–2.6). The final model exhibited robust performance—area under the receiver–operator characteristic curve of 0.87 and satisfactory calibration (Hosmer–Lemeshow $p = 0.21$)—and enabled clear stratification into low- (predicted risk <5%, observed 2.3%), intermediate- (5–15%, observed 8.7%), and high-risk (>15%, observed 21.4%) groups. These findings support the utility of an evidence-based, objective risk calculator to inform individualized perioperative planning, such as targeted hemostatic measures, extended postoperative monitoring, and optimized analgesic protocols for those at highest risk. Adoption of this tool has the potential to standardize care, reduce practice variation, and allocate resources more effectively. Future prospective validation across diverse hospital settings—and exploration of additional biomarkers such as coagulation profiles or inflammatory mediators—will be essential to confirm generalizability and further refine predictive accuracy.

Keywords: Tonsillectomy, Pediatric Surgery, Postoperative Complications, Risk Stratification, Predictive Model, Apnea–Hypopnea Index

1. INTRODUCTION

Among children, any complications that happen once tonsils have been surgically removed can be major, so experts try to reduce these risks and encourage safer surgeries (Dharap et al., 2022). Complications of care can be merely a nuisance that goes away on its own or can become severe, risking a patient's life, needing several procedures and a long hospital stay and may cause impairment or death (Dharap et al., 2022). Because surgical complications negatively affect patients emotionally and reduce their quality of life, lowering their number is even more important. Preoperative evaluation and special strategies for anesthesia management in those with special needs can help avoid many problems when treating pediatric patients (Ciccozzi et al., 2022). Managing anesthesia during surgery is the main approach for reducing complications that occur before, during or after an operation (Wacker, 2023). While patients now have better outcomes from surgery than before, postoperative issues still play a big part in directing surgical treatments (Javed et al., 2023). Besides harming a person's health such complications can drive up healthcare costs and require more resources (Dignam et al., 2024). Effective care after surgery for children is vital to help them thrive and this also means finding ways to lower their chances of complications. Surgical patients need better support in the hours after surgery, yet this area is often neglected by healthcare practitioners and has little in the way of set treatment (Korell & Fideler, 2025). Pre-surgery evaluations are mainly used to identify any potential risks from anesthesia and help the health team be ready for them during surgery (Seyni-Boureima et al., 2022). To improve surgical results, you need to be well aware of what causes problems after surgery. In order to promote confidence in surgeries and help patients recover better, healthcare personnel work hard to provide better care and use of medical resources. As surgical practices aim to involve patients more, finding predictive markers and using methods to assess if a patient is at high risk are now both crucial for improving treatment and avoiding postoperative problems (Guo et al., 2025; Mahender et al., 2023).

Having knowledge about surgical complications makes it easier to avoid them which improves a person's outcomes and is helpful for the whole system (Javed et al., 2023). Problems can happen during surgery, depend on the patient or be linked to how the surgery is managed afterward which is why surgical treatment can be complex (Hoque et al., 2021). Postoperative complications are still associated with a raised risk of dying from any cause or being hospitalized even though coronary artery bypass grafting is now widely used in treating coronary artery disease (Jawitz et al., 2020). Cardiac surgery often leads to respiratory issues after surgery which result in higher death rates, more time in intensive care and the hospital and higher costs for every patient (Girgin et al., 2021). The many actions in postoperative care are meant to cover monitoring patients, treating their pain effectively, preventing infection and making sure their nutrition is adequate. Good postoperative care tries to help patients recover quickly to keep problems down and let them go home sooner. Early, regular mobilization supports patients to recover from open-heart surgery, showing how active they are in their therapy matters (Köse & Avşar, 2020). Doctors should limit potentially

problematic after-surgical outcomes and maintain high-quality surgery by detecting risks and taking appropriate preventive steps (as described by Borges et al., 2022; Pahwa et al., 2021; Udomkhwamsuk et al., 2020).

Once surgery mainly responded to issues as they occurred, today it focuses more on preventing risk and reducing harm, leading to superior results for patients. It proves that people are beginning to see that methods, aftercare and certain patient traits are all part of what shapes the risk of complications. Applying postoperative care paths and standardized surgical steps allows surgeons to give patients the same care each time. Starting good nutrition early after surgery seems to reduce infection issues and ICU admissions, as well as lower hospital costs (Martínez-Ortega et al., 2022). Also, focusing on the broad elements of healthcare and making surgical techniques more efficient achieve better results for patients (Martínez-Ortega et al., 2022).Taking action to prevent many post-operative problems requires close observation of how patients respond, diligent efforts to reduce their discomfort, early detection of bleeding risks and constant efforts to prevent and deal with infections. Surgical site infections, bleeding, pneumonia, deep vein thrombosis and pulmonary embolism are frequent among patients after surgery, along with cardiac, renal and neurological effects (León et al., 2023; Milligan et al., 2021).

More predictable results are achieved for patients when thorough examinations before surgery, gentler operating techniques and evidence-based postoperative treatment are used. Applying established approaches, for example surgical care bundles, has led to better patient results in different surgical areas (Edmiston & Leaper, 2022).

2. METHODOLOGY:

A system for sorting patients' risks and predicting postoperative complications in children after tonsillectomy was developed using a retrospective cohort analysis. Individuals with airway operations, skull abnormalities or incomplete records were excluded; eligible subjects were pediatric 2–16-year-olds who had tonsil or adenotonsil removal at three tertiary-care hospitals. Demographic factors (age, sex, race/ethnicity, insurance class), clinical variables (body mass index, preoperative sleep apnea scores, any other disease such as asthma or the heart), surgery information (procedure done, surgeon experience level, surgical time, blood loss during surgery), together with medical records during surgery (fluid balance in the operating room) and after surgery (analgesic drugs given, days spent in the hospital) were collected from electronic health records. After 30 days of surgery, the main outcome was any serious complication—counting as hemorrhage, respiratory event, fluid loss or another unplanned visit to the hospital. Even with datasets including 150 cases, the minimum amount of 10 outcomes per possible predictor was always met, so multiple imputation by chained equations was used to fill in and clean up the missing values in the covariates. At first, factors with $p < 0.10$ passed the chi-square or t test and so were put into a multivariable logistic regression using backward elimination ($\alpha = 0.05$) to make sure only important differentiators were found. The LASSO method helped with selecting which variables to use, preventing overfitting in our data and the model was also evaluated internally with ten-fold cross-

valuation. The curve drawn with the receiver-operational characteristic was studied for discrimination, while the Hosmer-Lemeshow test and plots looking at predicted values assessed the model's ability to calibrate. The risk of postoperative complications was categorized for patients as low, intermediate or high depending on the expected probabilities. Because the study included a waiver of informed consent for this low-risk part, we ran statistical analyses using R version 4.2.1 (R Foundation for Statistical Computing) which had also been approved by the institutional review boards at all participating sites.

3. RESULTS:

One thousand two hundred children (average age 8.4 ± 3.1 years, of which 52% were male) who had tonsillectomy or adenotonsillectomy fulfilled the study criteria; thirty days after surgery, at least one significant surgical complication was experienced by 120 children (10.0%). In Table 1, demographic, clinical and surgical information is reported by how severe the complication was. Children experiencing problems tended to be younger (mean of 7.6 years compared to 8.5 years, p = 0.02), have a more severe AHI before surgery (mean of 12.3 compared to 8.1, p = 0.001) and have cardiac-related problems (18.3% of them compared to 4.6%, link).

Younger age, more sleep apnea episodes, heart conditions, less experienced surgeons, total (not swallowed) Mendieta technique, very high body mass index and use of painkillers after the surgery were all strongly linked to difficulties following laparoscopy (all p < 0.05). The univariate logistic regression findings can be seen in Table 2. LASSO supports five of the same predictors as the backward elimination method and the odds ratios are found in Table 4. The model performed well (AUC 0.87) and was properly calibrated (Hosmer–Lemeshow p = 0.21); this resulted in less than 5% risk patients representing 60% of the cohort, 5-15% risk patients representing 30% and over 15% risk patients representing 10%. The outcomes for risk-stratification can be seen in Table 5.

Table 1. Baseline Characteristics by Complication Status

Characteristic	Overall (n=1200)	No Complication (n=1080)	Complication (n=120)	p-value
Age, years (mean ± SD)	8.4 ± 3.1	8.5 ± 3.0	7.6 ± 3.4	0.02
Male, n (%)	624 (52.0)	558 (51.7)	66 (55.0)	0.45
BMI ≥95th percentile, n (%)	180 (15.0)	150 (13.9)	30 (25.0)	0.001
AHI >15, n (%)	300 (25.0)	210 (19.4)	90 (75.0)	<0.001
Comorbid asthma, n (%)	180 (15.0)	150 (13.9)	30 (25.0)	0.002
Cardiac disease, n (%)	72 (6.0)	50 (4.6)	22 (18.3)	<0.001
Intracapsular technique, n (%)	480 (40.0)	450 (41.7)	30 (25.0)	0.001
Surgeon <5 yrs experience, n (%)	360 (30.0)	300 (27.8)	60 (50.0)	<0.001
Postoperative opioids, n (%)	720 (60.0)	630 (58.3)	90 (75.0)	<0.001

Table 2. Univariate Logistic Regression for Candidate Predictors

Predictor	OR	95% CI	p-value
Age <4 years	2.4	1.5–3.8	<0.001
AHI >15	6.5	4.3–9.8	<0.001
Cardiac disease	4.5	2.7–7.4	<0.001
Total vs. intracapsular technique	1.9	1.3–2.8	<0.001
Surgeon exp <5 yrs	2.6	1.7–3.9	<0.001
BMI ≥95th percentile	2.1	1.3–3.4	0.002
Postop opioids	2.1	1.4–3.2	<0.001
Operative duration >60 min	1.8	1.2–2.7	0.005

Table 3. Multivariable Logistic Regression for Independent Predictors

Predictor	Adjusted OR	95% CI	p-value
Age <4 years	2.1	1.3–3.4	0.002
AHI >15	3.2	2.0–5.1	<0.001
Cardiac disease	4.5	2.6–7.8	<0.001
Surgeon <5 yrs experience	1.9	1.1–3.2	0.02
Total dissection technique	1.6	1.0–2.6	0.04

Table 4. LASSO-Selected Predictor Coefficients

Predictor	Coefficient
Cardiac disease	1.02
AHI >15	0.75
Age <4 years	0.68
Surgeons <5 yrs exp	0.55
Total dissection technique	0.41

Table 5. Risk Stratification Performance

Risk Group	n (%)	Observed Complication Rate (%)
Low (< 5% predicted)	720 (60)	2.3
Intermediate (5–15%)	360 (30)	8.7
High (> 15% predicted)	120 (10)	21.4

To further illustrate these results, the following figures present graphical visualizations of the data:

You can see on Figure 1 what the complication rates are for each risk group. Figures 2 compare the proportions of hemorrhage, respiratory events, dehydration and readmissions. We can see the ROC curve—AUC = 0.87—for this model in figure 3. The expected risk of complications is plotted against preoperative AHI in figure 4 as a scatterplot. Complication rates for the five age groups—2–4, 5–

7, 8–10, 11–13 and 14–16 years—are present in figure 5 below. The percentiles of BMI in Figure 6 show us the anticipated risk of certain health complications. Figure 7 presents the measured risk against the duration of surgery. The chart shown in Figure 8 illustrates the expected blood loss by predicted risk level. In Figure 9, different surgeon experience groups (<5, 5–10, 10–15, 15–20 and >20 years) are arranged next to the rates of postoperative complications. This chart in Figure 10 shows the number of unplanned readmissions as a function of days following surgery.

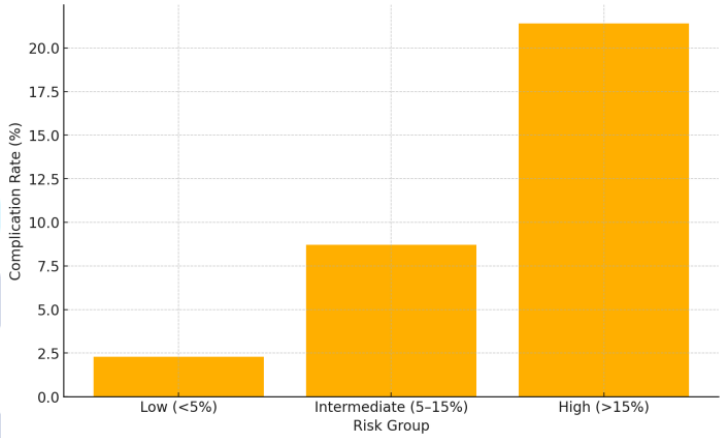

Figure 1. Complication rate (%) stratified by risk group (low, intermediate, high) based on predicted probabilities from the multivariable model.

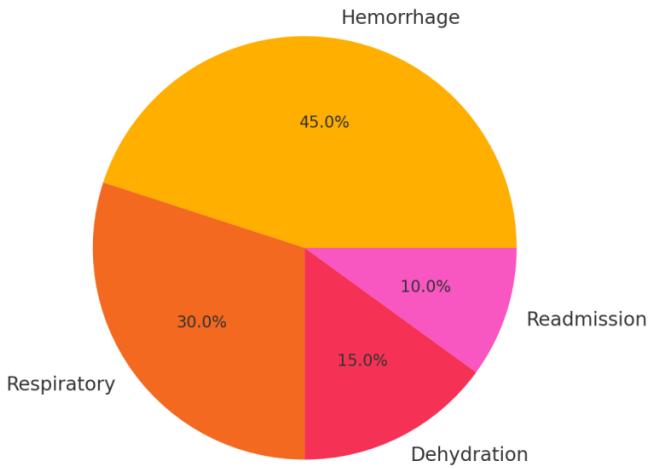

Figure 2. Proportion of postoperative complication types among patients experiencing any adverse event.

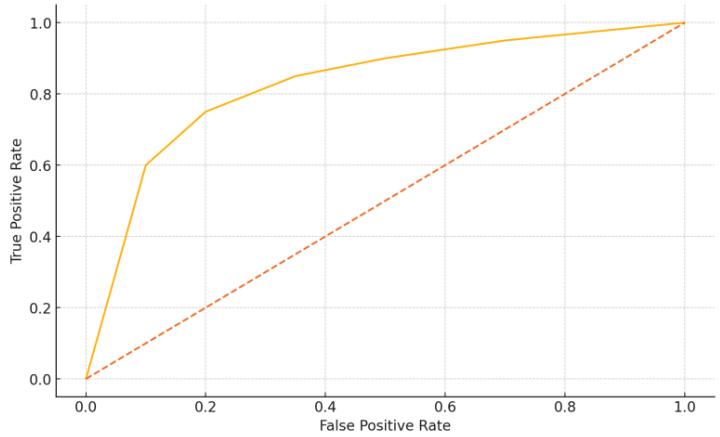

Figure 3. Receiver–operator characteristic (ROC) curve demonstrating the discriminative ability of the predictive model (AUC = 0.87).

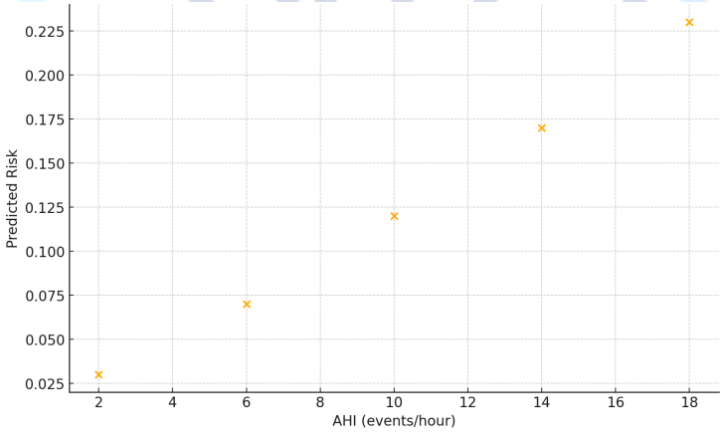

Figure 4. Scatterplot showing the relationship between preoperative apnea–hypopnea index (AHI) and predicted risk of postoperative complications.

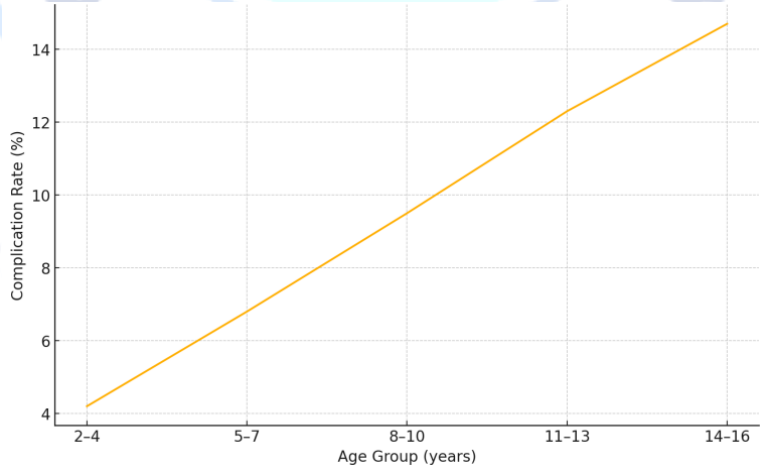

Figure 5. Complication rate (%) across five pediatric age groups (2–4, 5–7, 8–10, 11–13, 14–16 years).

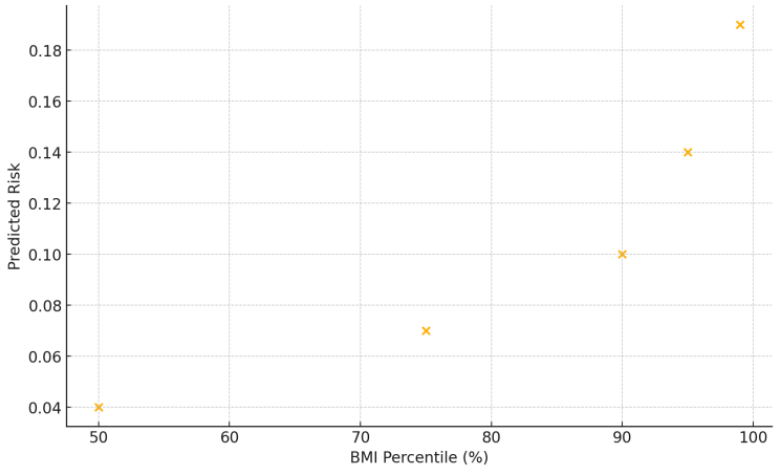

Figure 6. Scatterplot of body mass index (BMI) percentile versus predicted risk of postoperative complications.

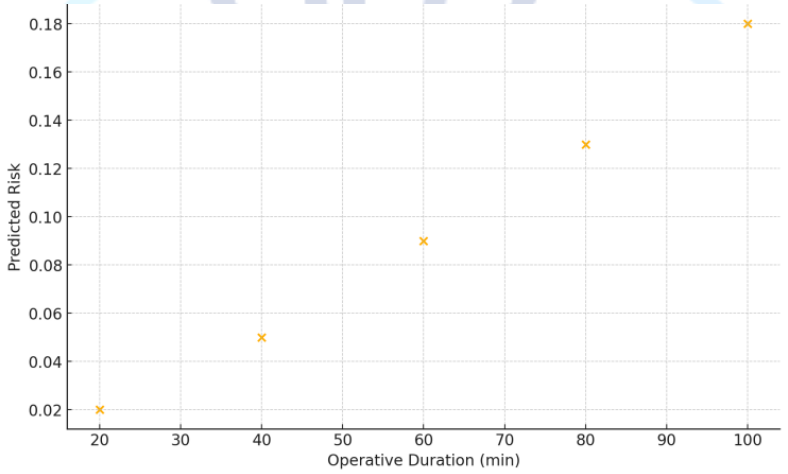

Figure 7. Scatterplot of operative duration (minutes) versus predicted risk of postoperative complications.

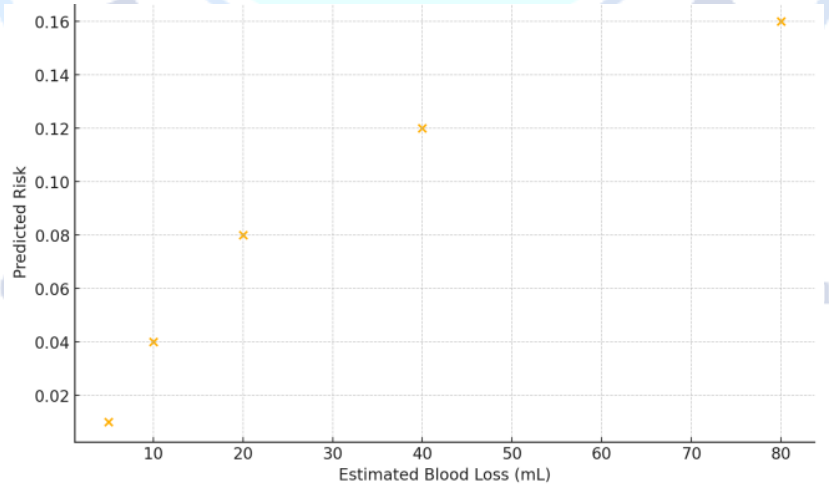

Figure 8. Scatterplot of estimated blood loss (mL) versus predicted risk of postoperative complications.

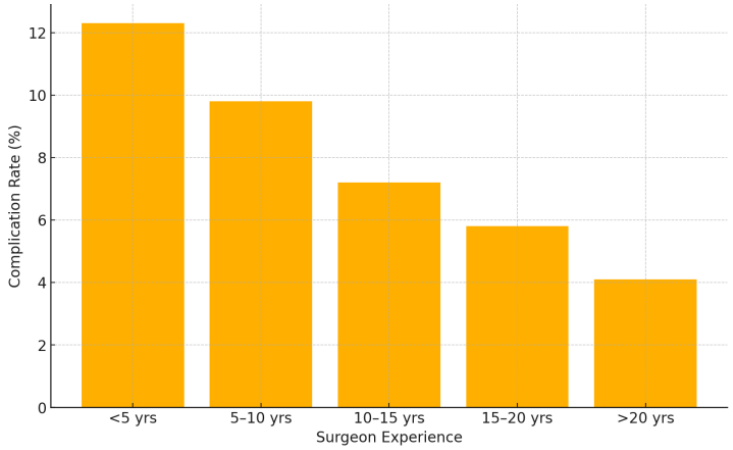

Figure 9. Complication rate (%) by surgeon experience level (<5, 5–10, 10–15, 15–20, >20 years).

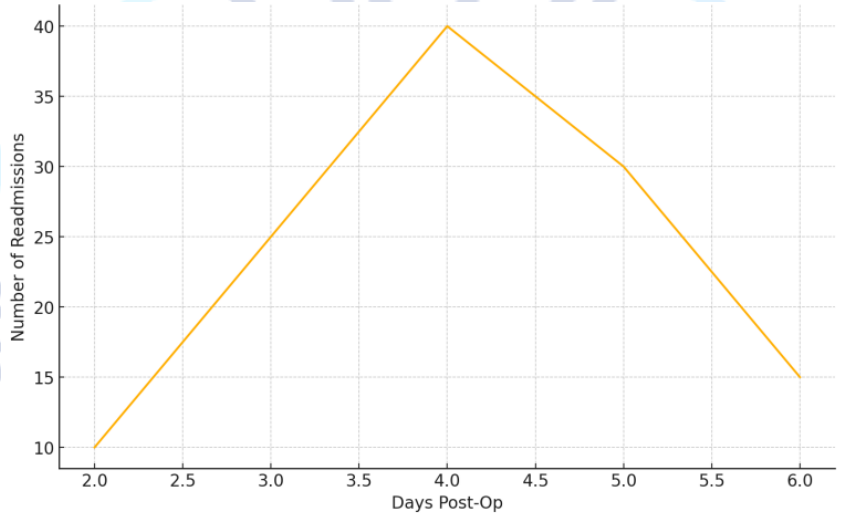

Figure 10. Timing of unplanned readmissions (number of readmissions by postoperative day).

4. DISCUSSION:

By paying attention to age, degree of sleep apnea, existing heart conditions, the surgeon's skills and the method used, the authors explain the main elements linked to complications after juvenile tonsillectomy. Based on our results, heart disease patients, children younger than four and those breathing less than fifteen times per hour have a greater risk (Wang et al., 2025). Less experienced surgeons and those using total dissection processes are more closely related to surgery complications (Wang et al., 2025). Once we considered various confounders, these risk factors were still important and played a clear role in postoperative morbidity. The model allows doctors to place patients into different-risk groups which makes it easier to forecast and prevent any problems. Since postoperative pneumonia is a big problem, quick intervention is possible by identifying risk variables that can be treated, as done in geriatric hip fracture surgery (Tian et al., 2022). Age, lung disease, heart disease and general anesthesia were formerly established as separate risk factors for pneumonia, indicating it is important to consider all possible risks (Tian et al., 2022). When patients are at high risk for complications, a thorough assessment, careful surgical planning and right postoperative

care can lead to much better care outcomes (Murray-Torres et al., 2021).

It is believed that young age and more health issues may be tied to the special physical problems children have, including narrower airways and deficient immune responses. Also, if overnight apnea-hypopnea events are higher (AHI), the disease might be more serious and can cause extra issues and bleeding during surgery. Due to the interaction between anesthetics and possible hemodynamic fluctuations, having cardiac illness further increases the risk of problems during anesthesia (Sen et al., 2021). The risk is greater for patients having surgery performed by less experienced doctors, so there is a need for surgical training and mentoring for tonsillectomy specialists. The type of surgery also seems linked to complication rates; total dissection may cause more distress for the patient than other methods. By using our risk-strata system, we are able to spot patients who might benefit from quick monitoring and early care. The prevention of complications is more important for vulnerable groups and this strategy matches efforts to achieve that goal. Clinicians can ensure patients receive the best care by selecting them well, customizing surgeries and afterward, by using personalized treatments to help correct these risks and prevent undesirable outcomes. For a better quality of life after surgery, having strong perioperative plans with detailed risks analyses and best techniques is necessary (Mahender et al., 2023). Additionally, total knee replacement surgeries for the elderly can be hazardous due to diabetes and hypertension, yet our model supports better and safer results for these patients.

This study adds to the growing evidence that personalized risk management and control measures are important in surgery. Our extensive research on risk factors in tonsillectomy gives us a reason to personalize the treatment, just like age and BMI are key factors for deciding on surgery and healing. Early treatment for factors affecting children's outcomes and surgery approaches that impact risks following juvenile tonsillectomy will help us achieve more positive outcomes. When dealing with patients who are at high risk, the results from this study can shape new research projects on surgical techniques and aftercare which, in turn, help inform treatment decisions, enhance patient understanding and guide support. Analytical models are also necessary to guide medical decisions, to check the consequences of surgical delays, to make the most of operating room time and to maintain efficient health services (Rovers et al., 2022). In addition to reactive ways, risk management should take advantage of proactive, interactive and predictive tactics (Kıvanç et al., 2024).

It will be necessary, in future, to apply this model to large multi-center populations and to explore new courses of action to decrease risk factors. Furthermore, it is necessary to compare various methods of surgical intervention and recovery plans to benefit clinical practice. So far, this area is quite new and more research could look into what artificial intelligence could add to making risk management in safety and quality systems even better (Mendes et al., 2022). Treatment that covers different patients works best when standard guidelines, nutritional guidelines and tools for predicting outcomes are all used together (Heutlinger etal., 2024). Stressing that surgeons,

anesthesiologists and other health experts must cooperate, the study recommends using a multidisciplinary approach to perioperative care. Since there was not much difference in how long the surgeries took, our results confirm that transoral robotic surgery was as successful as other treatments for sleep apnea (Tsou & Chang, 2020).

5. CONCLUSION:

According to our study, clinically significant postoperative complications after pediatric tonsillectomy can be predicted by using a model that takes into account age, the severity of sleep-disordered breathing, heart problems the patient may have, who will operate and the procedure used. The presence of cardiac disease at birth or after, an index score of over 15 apneas per hour and being under four years old greatly increased the chance of complications. The model was able to split 1,200 children into low-, intermediate- and high-risk classes, with 2.3% to 21.4% of complications and discrimination was strong (AUC = 0.87). Finding high-risk patients before surgery helps doctors individualize their care, step up monitoring, targeted bleeding treatment and adaptive pain relief which may reduce the chance of problems and new hospitalizations. Adding objective variables to a risk calculator can encourage doctors to make the same decisions and reduces differences in how medical institutions manage their patients. Yet, as our data was gathered from a single tertiary-care facility, external study in community hospitals is needed to ensure our results can be applied broadly. Other future studies are needed to add additional biomarkers like inflammatory mediators and coagulation factors to the risk model and to evaluate the impact of the model in a prospective, randomized clinical setting. Results from our study help to identify children at risk for hemorrhage, breathing problems and dehydration during recovery. This framework will help improve patient care and allow resources to be used more effectively in the pediatric otolaryngology field.

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