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ORIGINAL RESEARCH

Laryngoscope Investigative Otolaryngology

Completion of postoperative polysomnography for children with severe obstructive sleep apnea: A quality improvement project

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Abstract

Objective: Pediatric patients with severe obstructive sleep apnea (OSA) are at risk for residual OSA following tonsillectomy with/without adenoidectomy (T ± A). We initiated a quality improvement (QI) project to increase the percentage of postoperative (postop) polysomnography (PSG) completion to identify residual OSA.

Methods: This is a prospective QI project carried out at a tertiary pediatric academic hospital. Children ≤18 years of age who underwent T ± A for severe OSA were included. Our Specific, Measurable, Attainable, Relevant, and Time-based (SMART) aim was to increase the percentage of completed postop PSGs in this cohort from a baseline of 70% to95% by May 31, 2021. We focused on patient education and leveraged both clinical decision support and reporting functionalities of the electronic medical record for project implementation.

Results: During the pre-intervention period between January 1, 2019 to June 30, 2020, 472 patients met the inclusion criteria with an average age of 8.6 years (SD 4.6). The rate of postop PSG completion was 69.7% (SD 11.4%) with an average time of 99 days (SD 66) between surgery and the postop PSG. A shift was observed starting in September 2020, and the PSG completion rate improved to 94.9% by September 30, 2021. Post-intervention, there were 178 patients with an average age of 9.3 years (SD 4.9). The average time between surgery and the postop PSG was significantly reduced to 57 days (SD 16; $p < .001$).

Conclusions: Through a multidisciplinary approach, we successfully completed our SMART aim. With the establishment of QI infrastructure, our goal is to deliver better care in a sustainable fashion using QI methodology.

KEYWORDS
pediatric obstructive sleep apnea, polysomnography, quality improvement

1 | INTRODUCTION

Tonsillectomy remains one of the most frequently performed pediatric surgeries worldwide.[1] Surgical indications have evolved over time from recurrent tonsillitis to predominantly sleep disordered breathing and/or obstructive sleep apnea (OSA). The surgical indication of upper airway obstruction increased from 12% in 1970 to 77% in 2005.[2] Current clinical guidelines by the American Academy of Otolaryngology (AAO) and American Academy of Pediatrics recommend tonsillectomy with/without adenoidectomy (T ± A) as the first-line treatment for pediatric patients with adenotonsillar hypertrophy and OSA.[3,4] The AAO guideline recommends postop monitoring for high-risk patients with severe OSA. Because these patients are at increased risk for residual OSA following surgery, it is also recommended that patients should be re-evaluated postoperatively (postop) to determine whether further treatment is required.[4]

It is our institutional practice that all patients diagnosed with severe OSA on preoperative polysomnography (PSG), defined as obstructive apnea hypopnea index (oAHI) >10/h,[5] are admitted following surgery to monitor for potential respiratory complications, as well as obtain a repeat PSG 6–8 weeks postop. However, for various reasons, not all patients with severe OSA complete a postop PSG. We initiated a quality improvement (QI) project to increase the percentage of postop PSG completion, with an overarching global aim of improving the identification of persistent OSA after T ± A (Figure 1).

2 | METHODS

2.1 | Setting

Rady Children's hospital is a 511-bed free-standing academic pediatric tertiary care hospital located in San Diego, California. The division of otolaryngology consists of eight fellowship-trained pediatric otolaryngologists, four physician assistants (PAs), an otolaryngology fellow and residents. The electronic medical record (EMR) system used at our institution is EPIC (Epic Systems Corporation, Verona, WI, USA). The sleep laboratory has a 14-bed capacity, providing a full spectrum of diagnostic and therapeutic sleep services. This study met the exemption criteria by the University of California San Diego's Institutional Review Board and is not considered human subjects research, and no protected health information was used for analysis.

2.2 | Outcome measures

We included all patients from our practice who had a T ± A with documented severe OSA on the preop PSG during the study period. Given the QI nature of the study, we did not actively recruit or exclude any patients. The primary outcome measure was the percentage of patients who completed a postop PSG following T ± A.

2.3 | QI methods

This QI project was initiated as part of a hospital-wide effort to systematically improve care delivery. The global aim of identifying persistent OSA following surgery is a clinical outcome that may be influenced by many factors. For the specific QI project, we formulated a narrower SMART (Specific, Measurable, Attainable, Relevant, and Time-based) aim, which in turn will help us achieve the global aim.[6] We formed a multidisciplinary QI team, performed root cause analysis, identified key drives and interventions and analyzed the results pre-intervention and post-intervention. Our SMART aim was to increase the percentage of completed postop PSGs in children with severe

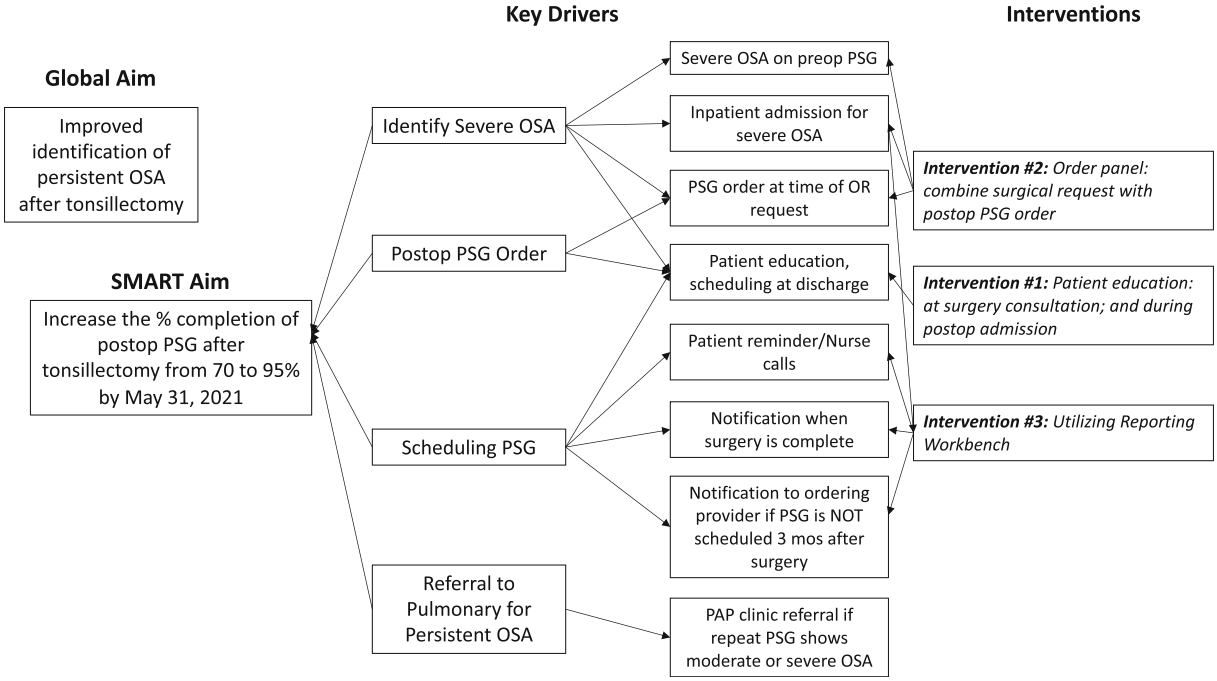

FIGURE 1 Key driver diagram for postop PSG completion

OSA who had undergone a T ± A from a baseline of 70% to 95% during an 11-months period ending on May 31, 2021.

The project began on July 1, 2020 and the active improvement phase concluded on May 31, 2021, followed by a sustained monitoring phase through September 30, 2021. A multidisciplinary QI team was formed with appropriate stakeholder division representatives and functioned as the overall steering team for the project. We met on a monthly basis to review data, plan interventions, and assess progress. The QI team included three otolaryngologists, one pulmonologist who is the director of pediatric sleep medicine, an administrative supervisor of the sleep lab, and a QI advisor who facilitated the group on QI methodology. In addition, each team member worked with their division to focus on specific interventions and changes necessary for the implementation of the project.

2.4 | Root cause analysis

During early sessions, QI team members met and performed a root cause analysis to identify factors that may contribute to delayed or missed postop PSG. The factors were organized into categories and visually represented in an Ishikawa or fishbone diagram (Figure 2). These factors were selected based on patient feedback, provider feedback, consensus, and expert opinions of the QI team. We contacted patients who did not complete their postop PSGs prior to July 2020 by phone to identify causes of the missed PSG. We grouped these causes under "communication" and "education." We met with all otolaryngology providers to elicit feedback on causes and grouped these under "policy and procedures" and "documentation." Additionally, members of the QI team identified system causes under "environment" and "monitoring" (Figure 2).

2.5 | Key drivers and interventions

Key drivers focused on three main areas where specific interventions were created and tested sequentially through several plan-do-study-act cycles (Figure 1). After the implementation of each intervention, monthly data was analyzed and reviewed as a group. The specifics of each intervention and how they were carried out during the different phases of the surgical process are summarized in Table 1.

2.5.1 | Intervention 1: Patient education

From the root cause analysis, we identified that patient education was a key component to the successful completion of the postop PSG. Some parents reported that they were not aware of the need for a postop PSG. Many had the common misconception that the surgery was uniformly curative. Parents also reported that the snoring and respiratory symptoms had improved significantly following surgery that they did not feel a repeat PSG was necessary. We then designed strategies to provide patient education at two key time points. The first one was during the initial consultation session for surgery. Providers were encouraged to discuss with parents and patients the anticipated success rate of the surgery with regards to OSA based on current medical evidence, the recommendation of completing a postop PSG to identify residual OSA and the importance of treating unresolved OSA for the patients' long-term health. Families were then given sleep lab pamphlets with scheduling information at the conclusion of the visits together with surgery scheduling information. They were instructed to contact the sleep lab to schedule the postop PSG as soon as the surgery date was confirmed. Surgery schedulers also were given standard telephone script to remind patients to schedule a postop PSG at the time of surgery scheduling. The second key point was during the postop admission. It was built into the rounding workflow that our inpatient PA, resident and fellow verified that a postop PSG had been scheduled. If not, the inpatient providers helped the family with scheduling prior to discharge by contacting the sleep lab directly during the hospital stay and to verify correct family contact information. We also provided assistance for those non-English speaking families by contacting the sleep lab with a certified telephone medical translator.

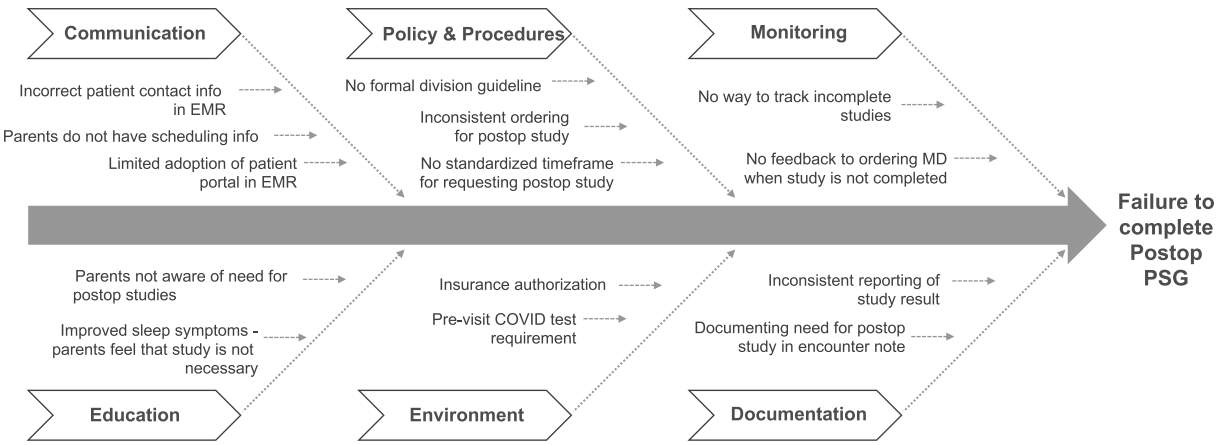

FIGURE 2 Fishbone Diagram: factors that may contribute to a delayed or missed postop PSG, identified based on a root cause analysis by the QI team

TABLE 1 Summary of key interventions implemented during the QI project

Interventions	Preop	Admission	Postop
1. Patient Education	• Discussion about postop PSG by surgeon • Sleep lab handout	• Inpatient team verify postop PSG scheduling • Active assistance in scheduling • Translation services	
2. Order Panel	• Postop PSG ordering at the time of surgery request	• Admission auto-populated to set based on severe OSA	• Sleep lab generates work queue for "postop PSG" based on order panel
3. RWB		• Admission is a criterion for reporting postop PSG to identify those with severe OSA preop	• Monthly reporting on postop PSG completion • Notification to ordering physician when PSG was not completed • Telephone contact for no shows

2.5.2 | Intervention 2: Order panel

The second key driver was the workflow of the postop PSG ordering process. Although there were published guidelines, we did not have a formalized division guideline regarding when to obtain a postop PSG. During the root cause analysis, we found that the timing of the postop PSG ordering was highly variable among providers with occasional missing orders. The intervention that we proposed was to standardize the workflow by combining the surgical case request of the T ± A and the postop PSG into one order set for any patient with severe OSA, with many auto-populated ordering fields. For example, because all patients with severe OSA required postop admission, the ordering field for surgical postop disposition were prechecked as "admission." The PSG order also indicated automatically that the diagnosis was "severe OSA" and the study was "postop," and the completion time was recommended as 6–8 weeks according to guideline.[4] The order panel also allowed the sleep lab the ability of generate a work queue for "postop" PSGs and contact families if they fail to call to schedule.

2.5.3 | Intervention 3: Reporting workbench (RWB)

Both pre-intervention baseline data and post-intervention progress were collected using the RWB tool embedded within EPIC. RWB reports are "real-time" operational reports of data contained within EPIC. The report was designed to include all patients who underwent T ± A within a specified time frame (monthly). The patient class was limited to "surgery admit" to capture all patients who were admitted following surgery. The RWB also allowed reporting of the encounter date of the "last sleep lab." The records were then individually verified to ensure that the patients indeed had severe OSA on the preoperative PSG. This was necessary because not all admitted patients required a postop PSG. Many patients without preoperative PSGs or with mild or moderate OSA were admitted for other medical reasons such as existing syndromes, age younger than three, combined procedures or other comorbidities. Also using EMR, notification was sent to the sleep lab when surgery was completed. Utilizing the reporting feature, the sleep lab also generated notifications to the ordering physician when they have not been able to contact the family to schedule a study after three telephone attempts and/or a PSG had not been completed after 3 months from the original surgery, prompting the provider to contact the family (Figure 1).

Progress was presented formally on a monthly basis to the QI team as well as at a structured hospital-wide QI leadership meeting where physician QI leaders from other divisions were able to provide feedbacks and suggestions.

2.6 | Data collection

After development of the EPIC report, the baseline data was collected retrospectively. We included all patients who underwent a T ± A over the 18 months period prior to the initiation of the QI project, from January 1, 2019 to June 30, 2020 with severe OSA preoperatively. Then we reported on the date of the completed postop PSG and the length of time between surgeries and PSGs.

After the initiation of the project, the same report was generated on a monthly basis. Since there was a 1–2 months recovery period between surgery and the postop PSG, these reports were also carried out in the subsequent monthly analysis.

2.7 | Analysis

Analysis of the outcome measures were conducted using a statistical process control (SPC) chart (or Shewhart chart),[7] a graphical display of the data points plotted over time with centerline (CL), upper control limit (UCL) and lower control limit (LCL). The use of SPC chart takes into account the variabilities of the data over time, and CL representing the mean, and UCL and LCL represents 99.7% confidence intervals or 3 SD.[8] The analysis was performed using QI Macros, a SPC software for Excel (KnowWare International, Denver, CO, USA). For the primary outcome, measures were plotted as a p-chart, a type of control chart used to represent the proportion of nonconforming units in subgroups of varying sizes.[9] Specifically, p-chart was used to display the proportion of completed PSGs each month where the number of actual patients varied from month to month. A shift in CL according to QI methodology is defined as six or more consecutive points occurring

either all above or below the previous mean.[10] Age differences between pre-intervention and pos-tintervention, intervals between surgery and the PSG, as well as comparison of the case volumes pre-pandemic and post-pandemic were analyzed using two-sample *t*-tests, with statistical significance set at $p < .05$.

3 | RESULTS

During the baseline (pre-intervention) 18-months period from January 1, 2019 to June 30, 2020, a total of 472 patients were included in the analysis. The number of patients per months ranged from 14 to 39, with a median of 27. The average time between surgery and the postop PSG was 99 days (SD 66), with a range of 12–367 days. The percentage of completed PSGs following surgery averaged at 69.7% (SD 11.4%; Figure 3). The average age of this population was 8.6 years (SD 4.6), with 60.8% males and 39.2% females. The average age of those who completed a PSG was 9.2 (SD 4.6), and those who did not was 7.1 (SD 4.4), which was significantly younger ($p < .001$). The male/female distribution for the cohort who did not complete a postop PSG were not significantly different when compared to those who completed a postop PSG.

A shift occurred when the data from six consecutive months were observed to be above the previous mean of 69.7%, which started in September 2020. During the intervention and monitoring period (July 1, 2020–September 30, 2021), due to the COVID pandemic, there was a significant decrease in clinical volume and elective procedures. The number of patients meeting inclusion criteria ranged from 9 to 24 per months, with a median of 18. This paralleled the overall decrease in T ± A case volume for the institution from a monthly average of 100.5 (SD 17.1) pre-pandemic to 70.9 (SD 30.2) post-pandemic ($p = .002$; Figure 4). An additional change in the overall workflow impacted by the COVID pandemic was the requirement of a negative COVID reverse transcription–polymerase chain reaction test within 48 h of the PSG appointment.

The active intervention phase of the project concluded on May 31, 2021, the project end date prospectively set by the hospital initiative and our SMART aim. Between September 1, 2020 and May 31, 2021, the percent of completed postop PSGs in children with severe OSA increased from baseline of 69.7% to 93.7%, just below the targeted goal. Following the active intervention phase of the QI project, we continued to monitor the monthly data by reporting the completion of PSGs using the RWB tool. Although this process is ongoing, we reported this sustained monitoring phase here through the end of September 2021. The completion rate continued to improve with the percentage of PSG completion reaching 94.9% by September 30, 2021 (Figure 3). During this period, there was a total of 178 patients, with 127 patients during the intervention period and 51 patients during the monitoring period. The average age of the patients was 9.3 years (SD 4.9), with 62.9% males and 37.1% females. The average age of the patients during the QI project was not significantly different when compared to the age of the pre-intervention cohort ($p = .08$). The average age of those who completed a PSG was 9.4 (SD 4.9), and those who did not had an average age of 7.4 (SD 5.1), which was not significantly different ($p = .40$). The average time between surgery and the postop PSG was significantly reduced from 99 days pre-intervention to 57 days (SD 16), with a range of 20 to 158 days ($p < .001$). The average time between surgery and the postop PSG was 57.3 days (SD 16.6) during the intervention period, and 56.4 days (SD 15.8) during the monitoring period.

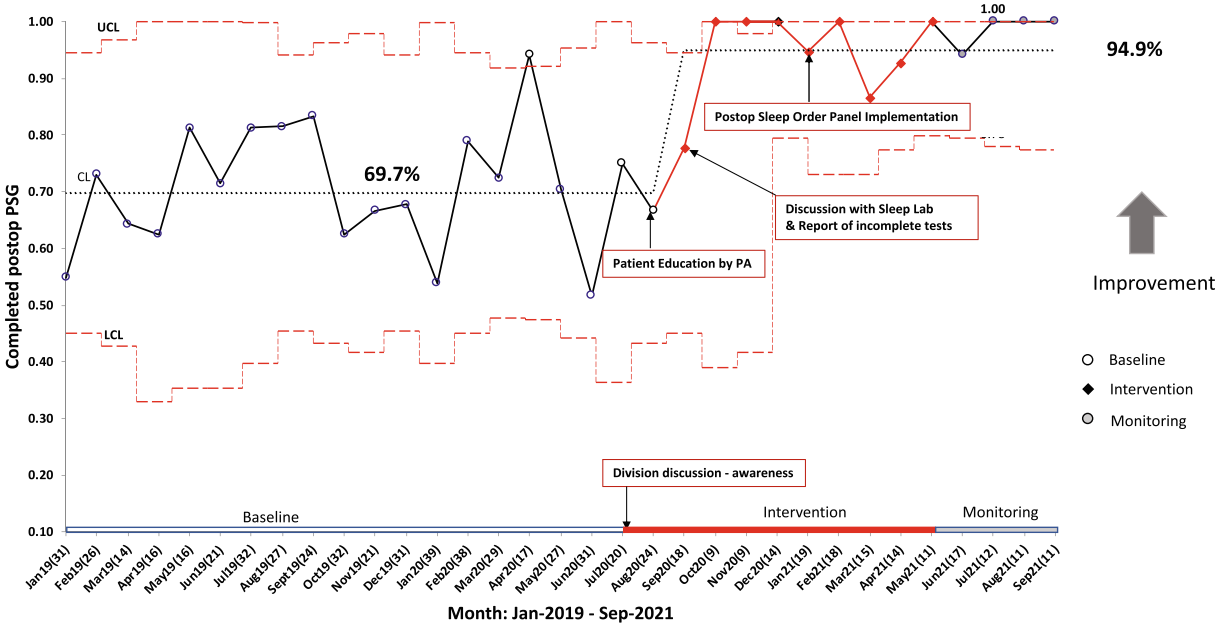

FIGURE 3 SPC chart on the completion rate of postop PSGs from January 1, 2019 to September 31, 2021. The percent completion is plotted monthly on a p-chart, in which the number of total eligible tonsillectomies is displayed in parenthesis next to the month on the x-axis. The dotted line denotes the CL, and the dashed lines denotes UCL and LCL. The initiation of each intervention is indicated on the timeline

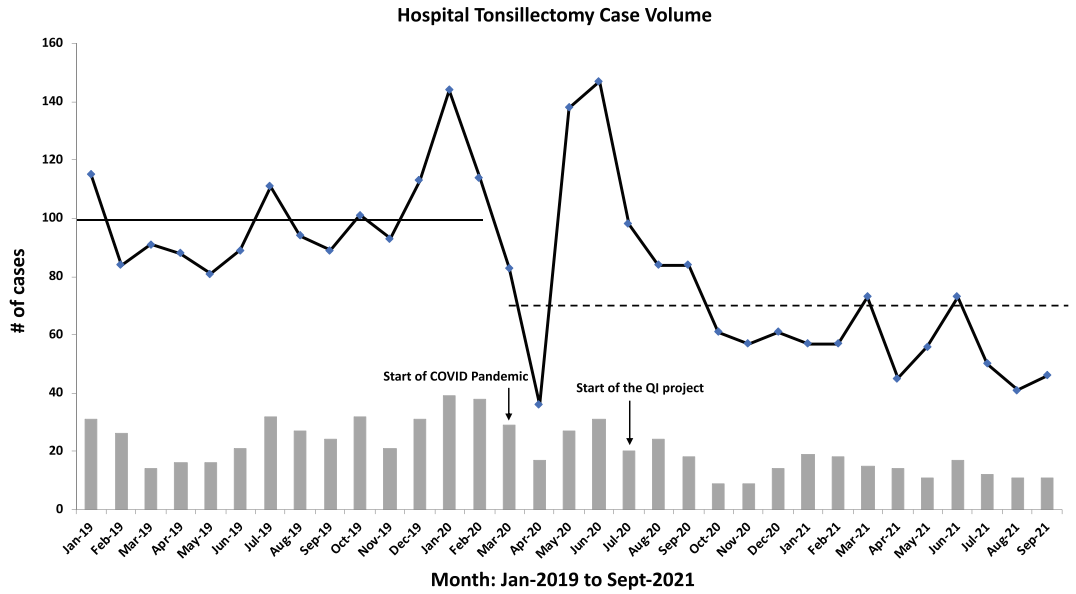

FIGURE 4 Due to the COVID pandemic, there was a significantly decreased surgical volume from a monthly average of 100.5 (SD 17.1) prepandemic to 70.9 (SD 30.2) postpandemic ($p = .002$). The graphed line shows the monthly total T ± A hospital case volume, and the columns below indicated the number of tonsillectomies performed on patients with severe OSA, which was included in the QI analysis

After the implementation of the QI project, the patients who did not complete a postop PSG (1–2 per months) were almost always due to no show for the scheduled PSG and subsequent inability to contact family for further follow-up. For patients who were unable to be contacted by phone after three attempts, a formal letter was sent to the address on file urging families to contact our department to reschedule of the PSG. Throughout the entire study period, including pre-intervention, intervention, and monitoring periods, the availability of the sleep lab did not change, with a typical wait time of 2–3 weeks. The improvement of the postop PSG completion did not appear to impact the overall patient access to the sleep lab.

4 | DISCUSSION

With respect to our stated SMART aim, we were able to successfully increase the percentage of completed postop PSGs in children with severe OSA who had undergone a T ± A from a baseline of 69.7% to 93.7% during an 11-months period ending on May 31, 2021. This metric continued to improve during a sustained monitoring phase, with the percentage of PSG completion reaching 94.9% by September 30, 2021.

Although conceptually, the combined order set was felt to be the most important piece during the initial phase of the project from the providers' standpoint, the biggest impact turned out to be patient education. The completion of the order set took longer than expected due to a shortage of information technology (IT) support during the COVID-19 pandemic whereas a significant portion of the IT staffing throughout the hospital was utilized for COVID related projects.

Patient education was essential in the success of this QI project. We were able to initiate the educational process early in the workflow by having the surgeons discuss the importance of postop PSGs for those with severe OSA, and by providing additional scheduling information regarding the postop PSG at the time of the surgical consultation for T ± A. Subsequently, the importance of the postop PSG was reinforced at multiple time points, at the time of surgery scheduling by surgical schedulers, and during admission by our inpatient providers. Also, during the hospitalization, resources from both nurses and PAs were utilized to help with those parents who needed additional assistance for scheduling such as translation services. With combined order sets and reporting, the PSG order rate may have improved, but the completion rate would not have reached the QI goal without the family engagement and cooperation.

Utilization of combined order sets is an example of real-time, evidence-based, and context-based tool within the EMR that provides clinicians with clinical decision support capability.[11] When ordering a T ± A surgery, the combined order set named "tonsillectomy with postop sleep study" appeared automatically as a top choice reminding the ordering physician to order the postop PSG when appropriate. The auto-populated fields in the order set helped to maximize standardization and increase provider efficiency with fewer clicks. After the implementation of the order set, for those patients who did not complete a postop study, a lack of PSG order was never the cause.

Monthly reporting combined with timely feedbacks from the sleep lab helped us identify those patients who did not complete a postop PSG. Then internal messages were sent to providers or nursing support staff to contact family and remind them to complete the PSG. This ongoing feedback and reporting mechanism allowed the continued improvement where our targeted aim can be sustainable even after the completion of the active project intervention.

Although the age of the entire cohort of T ± A patients remained stable during the pre-intervention and post-intervention period, it is

interesting to note that during the baseline pre-intervention period, the average age of the children who failed to complete a postop PSG was significantly younger (7.1 years vs. 9.2 years) than those who successfully completed the PSG. This may be due to the intrinsic challenges of performing a PSG in the younger pediatric population.[12] Another reason may be due to the better surgical responses reported in younger patients.[13] Therefore, they may be less symptomatic following surgery when compared to older children and are less likely to complete a repeat PSG. This has provided us with a future direction for improvement, with a focus on younger patients with OSA. We would need to focus on increased parental education on the importance of postop PSGs in younger patients; and address the technical challenges in the completion of a PSG with increased sleep technician support.

Despite recommendations by the AAO guideline for the postop monitoring of high-risk patients with severe OSA, Friedman et al. documented only 37% adherence to this recommendation based on survey results from the members of the American Society of Pediatric Otolaryngology.[14] It is also recommended that these patients should be re-evaluated postop to determine whether further treatment is required.[4] To our knowledge, there is no study in the existing literature addressing the specific issues of postop PSG compliance. Therefore, the success of the current QI project and the reporting of our results help to fill a gap in the published literature.

With the QI nature of the study, rather than the specific results obtained at our institution, the QI methodology described here is the focus of the initiative. By setting a SMART aim, conducting a root cause analysis, identifying key drivers and interventions, the methods for improvement may be implemented at other institutions with organization-specific goals for improvement.

Despite the success of the QI project, there are several limitations to the study. The current QI project is conducted at a pediatric tertiary care center where a sleep lab is readily available, and we utilized the rounding team including residents, fellows and PAs in the effort of postop PSG scheduling. We also relied heavily on the use of EMR for order panel creation, RWB and data analysis. We acknowledge that both human and IT resources may be different at other centers; therefore, similar QI projects will need to be tailored to resource availability and utilization at each individual organization. We have a robust sleep laboratory where the availability was not an issue that affected the successful completion of the QI study, even with the increased number of postop PSGs completed. Because the postop PSG order was placed at the time of the surgery order, there was a significant lead time for the completion of the postop PSG scheduling. At our institution, otolaryngologists account for the majority of the PSG order placements in the system; therefore, changes made within our division were most likely to impact the sleep lab workflow. The result achieved here may not be easily adopted by another institution if sleep lab availability is a limiting resource, or that providers outside of otolaryngology order the majority of the PSGs, limiting the availability of the sleep lab to otolaryngology patients. On the other hand, our findings suggest that improving access to sleep lab is critical to providing better quality care in children with OSA in a broader context. In institutions where infrastructures of the sleep laboratory are underdeveloped, increasing availability may be a focus of QI in and of itself. Although current data does not support the widespread application of home sleep testing especially in younger children, future development of home studies may alleviate issues of access to care.[15,16]

During the project period, the surgical volume was significant less when compared to our baseline volume. The decreased surgical volume each month (smaller sample size) has made it more challenging to complete the overall QI goal as each missed PSG impacts the percentage more significantly. On the other hand, the decreased volume made reporting and scheduling workload relatively easy and only one or two patients who missed the postop PSG had to be contacted every month. With the ongoing COVID-19 pandemic, our surgical volume remains significantly below our baseline. As future surgical volume increases, it may be more challenging to sustain the QI effort with ongoing reporting and scheduling of postop PSGs. It remains to be seen if we can continue the decision support process and maintain our goal once surgical volume returns to pre-pandemic levels.

Overall, we feel that the project performed better than expected because one of the obstacles was the COVID test requirement prior to the PSG appointment. We anticipated at the beginning of the project that this may significantly lower the completion rate of the postop PSG because a caretaker may be averse to coming to the hospital for a separate COVID test appointment. Most caretakers however complied with the requirement without complaint once they realized the importance of detecting residual OSA.

It is outside of the scope of the current study to assess the ramifications of identifying more residual OSA following surgery. Although patients are not required to be seen in the pulmonary clinic prior to completing the postop PSG, if persistent OSA with (oAHI) >5/h were identified, patients were referred to pulmonary clinic for the assessment of nonsurgical management including possible positive airway pressure treatment. This would be considered a resultant balancing measure of the QI project, which increases the utilization of the sleep lab and the pulmonary clinic. Although we have not formally studied this impact, the limited number of postop PSGs per months has not so far adversely affected patient access to the pulmonary ambulatory clinics. In fact, the average wait time for pulmonary clinic visits was significantly shorter in 2021 (5–15 days) when compared to 2020 (30–40 days), although many other factors including the COVID pandemic may have affected this metric. Again, with anticipated increase in surgical volume, the balancing measure may need to be addressed formally in the future. Lastly, with increased number of postop PSGs and the identification of those patients who may need additional treatment such as positive airway pressure treatment, there will be additional cost and resource utilization associated with the overall care of this population.

5 | CONCLUSION

Through a multidisciplinary approach, we successfully completed our SMART aim during the study period by improving the completion rate

of postop PSGs from baseline of 70% to 95%. We identified important key drivers with emphasis on patient education and leveraged both clinical decision support and reporting functionalities of the EMR for the implementation and monitoring of this project. The use of QI methodologies with a formulated SMART aim may be generalized to other areas of otolaryngology to systematically improve our care delivery. With the establishment of the QI infrastructure in our division, our goal is to establish a culture for QI by systematically identifying areas of improvement needs, design interventions and deliver better care in a sustainable fashion through ongoing monitoring and care assessment.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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