International Journal of Otorhinolaryngology and Head and Neck Surgery
Zaballa K et al. Int J Otorhinolaryngol Head Neck Surg. 2023 Oct;9(10):777-783
http://www.ijorl.com
pISSN 2454-5929 | eISSN 2454-5937

DOI: https://dx.doi.org/10.18203/issn.2454-5929.ijohns20232895

Original Research Article

Preoperative continuous positive airway pressure use improves the hospital experience of children undergoing adenotonsillectomy for obstructive sleep apnea

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Received: 06 June 2023
Accepted: 16 August 2023

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ABSTRACT

Background: Objective of the study was to determine how the preoperative use of continuous positive airway pressure (CPAP) in children diagnosed with obstructive sleep apnea (OSA), and their compliance with the therapy, impact perioperative outcomes of adenotonsillectomy.
Methods: A retrospective chart review was conducted on patients diagnosed with OSA on polysomnography, who underwent adenotonsillectomy between 2011-2017. Comparisons were made between patients who were not prescribed CPAP (N-CPAP), prescribed CPAP but non-compliant (NC-CPAP), and those compliant with their CPAP prescription (C-CPAP) therapy. OSA severity was categorized by total apnea-hypopnea index into mild <5, moderate 5-10, and severe >10.
Results: A total of 55 of the 162 patients (34%) were recommended CPAP. For those recommended CPAP, 25 were NC-CPAP and 30 C-CPAP. Compared to N-CPAP, NC-CPAP had a 47% reduction in wait time to surgery (p=0.0008) but 59% increase in LOS (p=0.001), while C-CPAP had 24% reduction in wait time (p=0.12) but 34% increase in LOS (p=0.026). Risk for post-operative admission to pediatric intensive care unit (PICU) was highest in NC-CPAP (OR=12 CI 3-44) and increased in C-CPAP (OR=9 CI 2-33). Children with severe OSA had higher frequency of postoperative CPAP use, NC-CPAP 29% and C-CPAP 64% (p≤0.0001). However, use of CPAP did not prevent a requirement for post-operative oxygen.
Conclusions: Amongst children prescribed pre-operative CPAP, compliance with therapy had a positive impact on the patient hospital experience following adenotonsillectomy.

Keywords: CPAP ventilation, Obstructive sleep apnea, Adenoidectomy, Tonsillectomy, Children

INTRODUCTION

In children the most common cause of obstructive sleep apnea (OSA) in children is adenotonsillar hypertrophy, and as such the primary treatment recommendation is adenotonsillectomy.[1-6] However, children having adenotonsillectomy for OSA are up to five times more likely to have respiratory complications post operatively compared to children without OSA.[7] Major post-operative respiratory complications in children with OSA undergoing adenotonsillectomy include laryngospasm, bronchospasm, pulmonary edema, pneumonia and requirement for re-intubation.[8] The risk for these perioperative complications increases with increasing severity of OSA.[8]

De et al demonstrated significant residual sleep disordered breathing and altered sleep architecture on the first night

following adenotonsillectomy, with similar values for AHI, oxygen nadir, arousal index and sleep efficiency to the preoperative PSG.

Other modalities for treatment of OSA include intranasal steroids and/or oral montelukast for mild OSA. More severe disease may require therapy with continuous positive airway pressure (CPAP) or additional surgery such as lingual tonsillectomy.[6]

To date, the primary recommendations for use of CPAP in children are for persistent disease following adenotonsillectomy, with some reports of the post-operative use of CPAP or BiLevel to manage medically complex children with post-operative respiratory complications.[1,10]

We found no previous studies evaluating the use of CPAP prior to adenotonsillectomy in children. This retrospective study evaluated how a recommendation for pre-operative use of CPAP impacted the peri-operative course of children undergoing adenotonsillectomy for OSA, including length of wait for surgery, post-operative use of respiratory support, admission to PICU, postoperative oxygen saturation, length of stay in hospital, and readmission to hospital.

METHODS

A retrospective chart review was undertaken at an Australian tertiary pediatric hospital. Inclusion criteria were children diagnosed with OSA on PSG up to two years prior to their adenotonsillectomy, in the period between January 2011 and December 2017. The study was approved by The Sydney Children's Hospital Network Human Research Ethics Committee (LNR/18/SCHN/401). The presence of comorbidities was documented and categorised to include trisomy 21, craniofacial disorders, neuromuscular disorders, cardiac and respiratory disease, FTT, obesity, and upper-airway abnormalities.

Severity of OSA was defined as mild (AHI=1-5), moderate (AHI=5-10) and severe (AHI>10).[11] Patients were categorized into three groups; not prescribed CPAP (N-CPAP), prescribed and non-compliant with CPAP (NC-CPAP) and compliant with a prescription for CPAP (C-CPAP). For analysis of outcomes, the N-CPAP group was considered the control group. The recommendation to initiate CPAP therapy was made by the treating clinician, based on their evaluation of the PSG and clinical data. Compliance with CPAP therapy was based on parental report of regular use of CPAP in the two months preceding surgery.

Length of wait for surgery was defined as the period between the clinic date in which the decision was made to proceed with adenotonsillectomy and the date when surgery was performed. The recovery period was defined as the first 6 hours and the post-operative period as the period in hospital after the first 6 hours. Respiratory support requirements were divided into four categories; low flow oxygen, high flow oxygen by nasal prongs, non-invasive ventilation (NIV) which included CPAP and BiPAP, and intubation.

Outcomes

Primary outcomes were admission to pediatric intensive care unit (PICU) and requirement for respiratory support in the recovery and postoperative period(s). Secondary outcomes included length of wait for surgery, minimum saturations noted in hospital, length of stay in hospital, and readmission to hospital. Subgroup analyses of both primary and secondary outcomes was conducted for the group of patients who were not prescribed CPAP, and on the patients diagnosed with severe OSA, regardless of whether they were prescribed CPAP pre-operatively.

Statistical analysis

Statistical analysis was performed using SAS 9.4 Descriptive statistics were presented as mean for continuous variables and frequencies and percentages for categorical variables. Patient characteristics and study outcomes were compared between groups using Kruskal-Wallis tests for continuous variables or linear models for log-transformed continuous variables, and chi-square tests or logistic regression for categorical variables. Statistical significance was defined as a p value of <0.05.

RESULTS

Baseline characteristics

Of 216 eligible patients, 162 were included in the study group. 50 patients were excluded due to missing data, 2 were excluded for use of CPAP prior to first available PSG and 2 due to having a tracheostomy. Of the 162 studied, 33% were female (n=54) and mean age was 5.5 years (10 months to 16 years). OSA was mild in 59, moderate in 37 and severe in 66 (Table 1).

CPAP was prescribed for 55 patients, 30 were C-CPAP and 25 were NC-CPAP. Mean patient age differed between groups with N-CPAP 6yo, NC-CPAP 3.9 yo and C-CPAP 5 yo (p=0.02). Markers of OSA severity were worse in the groups prescribed CPAP. Mean total AHI was higher; N-CPAP AHI 6.8, NC-CPAP 22.3 and C-CPAP 23.3 ($p<0.0001$). Oxygen nadir was lower; N-CPAP 87%, NC- CPAP 75% and C-CPAP 80% ($p<0.0001$). Median prescribed CPAP pressure was 6 cm H_20 (SD±1.4); with a range of 5-11 cmH_20 and 5-9 cm H_20 for the NC-CPAP and C-CPAP groups, respectively (p=0.45). Amongst the comorbidities, FTT was more frequent in those prescribed CPAP (p=0.048) while non-specified comorbidities were more frequent in the N-CPAP group 56% compared to NC-CPAP 18% and C-CPAP 26% (p=0.03). Baseline characteristics are outlined in Table 1.

Table 1: Baseline characteristics.

Characteristics	No CPAP	CPAP non-compliant	CPAP compliant	Total	P value
Total (%)	107 (66)	25 (15)	30 (19)	162	
Female (%)	32 (59)	10 (19)	12 (22)	54	0.43
Mean age (years)	6	3.9	5		0.019
Mean BMI (kg/m^2)	18.3	17.9	21		0.13
Mean Total AHI (events/hour)	6.8	22.3	23.3		<0.0001
Mean OAHI (events/hour)	4.3	17.2	18.5		<0.0001
OAHI Range	0-17.4	3.3-52.8	0.6-84.9		<0.0001
Mean PSG Oxygen Nadir	87	75	80		<0.0001
Mean PSG maximum CO_2	51	55	54		0.0595
Mean CPAP pressure	-	6	6		0.4465
OSA (%)[1]					
Mild (AHI 0-5)	55 (93)	1 (2)	3 (5)	59	
Moderate (AHI 5-10)	29 (78)	3 (8)	5 (13)	37	<0.0001
Severe (AHI >10)	23 (35)	21 (32)	22 (33)	66	
Comorbidities (%)[2]					
Trisomy 21	8 (62)	2 (15)	3 (23)	13	0.9
Craniofacial disorder	12 (52)	6 (26)	5 (22)	23	0.23
Neuromuscular	2 (100)	0 (0)	0 (0)	2	0.59
Cardiac disease	14 (64)	4 (18)	4 (18)	22	0.93
Respiratory disease	25 (69)	4 (11)	7(19)	36	0.72
FTT	5 (35)	4 (29)	5 (36)	14	0.048
Obesity	21 (60)	3 (9)	11 (31)	35	0.067
Upper airway	15 (60)	7 (28)	3 (12)	25	0.14
Other	40 (56)	13 (18)	19 (26)	72	0.029

1% of total number in OSA subcategory, 2% of total with comorbidities within subcategory, CPAP – continuous positive airway pressure, BMI – body mass index, AHI – apnoea hypopnoea index, OAHI – obstructive apnoea hypopnoea index, PSG – polysomnography, CO_2 – carbon dioxide, FTT – failure to thrive

Table 2: Primary outcomes.

Outcomes	No CPAP	CPAP non-compliant	CPAP compliant	P value
PICU admission (%)	4 (4)	8 (32)	8 (27)	
Odds ratio (CI)		12 (3-44)	9 (2-33)	0.0003
Respiratory support recovery				
Low flow	79 (74)	19 (76)	24 (83)	0.61
High flow	0	0	0	
NIV	1 (1)	1 (4)	7 (24)	<0.0001
Intubation	1 (1)	1 (4)	1 (3)	0.47
Respiratory support post-operative				
Low flow	12 (11)	9 (36)	9 (30)	0.0032
High flow	0	0	0	
NIV	0	6 (24)	20 (67)	0.0001
Intubation	1 (1)	1 (4)	1 (3)	0.47

PICU – Paediatric intensive care unit, CPAP – continuous positive airway pressure, CI – confidence interval, NIV – non-invasive ventilation

Primary outcomes

Comparisons were made against the group not prescribed CPAP (N-CPAP). Of the 162 patients, 20 (12.3%) were admitted to PICU; with increased risk for PICU admission if prescribed CPAP, and greatest in NC-CPAP (OR 12, CI 3-44) compared to C-CPAP (OR 9, CI 2-33) p=0.0003. During the recovery period, low flow oxygen use was equivalent amongst the 3 groups, but those compliant with CPAP were more likely to use NIV compared to N-CPAP and NC-CPAP groups (p<0.0001). During the subsequent postoperative period, the C-CPAP group were less likely to have low flow oxygen NC-CPAP 36% and N-CPAP 30% p=0.003. Those prescribed CPAP were more likely to use NIV, NC-CPAP 24% and C-CPAP 67% p=0.0001. There was no difference in risk of intubation between the

groups during the recovery and postoperative periods. In addition, logistic regression analysis demonstrated the risk of PICU admission was not confounded by underlying severity of OSA. Primary outcomes are shown in Table 2.

Secondary outcomes

For children prescribed CPAP, wait time to surgery was lower; N-CPAP (29.6 weeks) NC-CPAP 15.8 weeks (47% reduction, p=0.0008) and C-CPAP 21.7 weeks. Length of hospital stay was greater in those prescribed CPAP, N-CPAP 0.9 days, NC-CPAP greatest at 2.1 days (59% increase p=0.001), C-CPAP with LOS 1.2 days (34% increase p=0.03). Minimum oxygen saturation in the recovery period was lower in those prescribed CPAP; N-CPAP 96.7%, NC-CPAP 95.6% and C-CPAP 92.8% (p=0.0002). No differences were seen for minimum oxygen saturations in the postoperative period, or readmission rates (Table 3).

Table 3: Secondary outcomes.

Outcomes	No CPAP	CPAP non-compliant	CPAP compliant	P value
Length of wait				
Av weeks	29.6	15.8	21.7	
Ratio means[1] (CI)		0.53 (0.37-0.77)	0.77 (0.54-1.08)	
% reduction		47	24	
P value		0.0008	0.12	
Length of stay				
Av days	0.9	2.1	1.2	
Ratio means[1] (CI)		1.59 (1.21-2.10)	1.34 (1.04-1.74)	
% increase		59	34	
P value		0.001	0.026	
Minimum saturations				
Recovery	96.7	95.6	92.8	0.0002
Overnight	95.4	94.1	93.1	0.056
Readmission (%)	5 (5)	1 (4)	0	0.48

[1]Ratio of linear regression of log length of stay, CPAP – continuous positive airway pressure, Av – average, CI – confidence interval

Table 4: Subset analyses of those with severe obstructive sleep apnoea (OSA).

Outcomes	No CPAP	CPAP non-compliant	CPAP compliant	P value
Total (%)	23 (35)	21 (32)	22 (33)	
PICU admission (%)	1 (4)	7 (33)	4 (18)	
Odds ratio (CI)		11 (1.22-99.25)	5 (0.5-47.7)	0.0863
Respiratory support recovery				
Low flow	17 (74)	17 (81)	17 (81)	0.8042
High flow	0	0	0	
NIV	0	1 (5)	4 (19)	0.0502
Intubation	1 (4)	0	0	0.3956
Respiratory support post-operative				
Low flow	4 (17)	8 (38)	7 (32)	0.2948
High flow	0	0	0	
NIV	0	6 (29)	14 (64)	<0.0001
Intubation	1 (4)	0	0	0.3871
Length of wait				
Av weeks	21.3	14.7	22.1	
Ratio means[1] (CI)		0.71 (0.43-1.17)	1.13 (0.69-1.86)	
P value		0.1793	0.618	
Length of stay				
Av days	1	2.2	1.1	
Ratio means[1] (CI)		1.38 (0.96-1.98)	1.12 (0.78-1.60)	
P value		0.0841	0.5515	
Minimum saturations				
Recovery	96	96	94	0.3361
Overnight	96	95	94	0.3035

Continued.

Outcomes	No CPAP	CPAP non-compliant	CPAP compliant	P value
Readmission (%)	2 (9)	1 (5)	0	0.36

[1]Ratio of linear regression of log length of stay, CPAP – continuous positive airway pressure, PICU – paediatric intensive care unit, CI – confidence interval, NI – non-invasive ventilation, NS – not significant, Av – average

Table 5: Subset analyses of patients not prescribed CPAP.

Outcomes	Mild OSA	Moderate OSA	Severe OSA	P value
Total (%)	55 (51)	29 (27)	23 (22)	
PICU admission (%)	2 (4)	1 (3)	1 (4)	
Odds ratio		0.9 (0.08-10.9)	1.2 (0.1-14)	0.9841
Respiratory support recovery				
Low flow	42 (76)	29 (69)	17 (74)	0.7641
High flow	0	0	0	
NIV	1 (2)	0	0	0.6205
Intubation	0	0	1 (4)	0.1583
Respiratory support post-operative				
Low flow	7 (13)	1 (3)	4 (17)	0.25
High flow	0	0	0	
NIV	0	0	0	
Intubation	0	0	1 (4)	0.16
Length of wait				
Av weeks	30.4	34.6	21.3	
Ratio means[1] (CI)		1.14 (0.78-1.66)	0.65 (0.43-0.98)	
P value		0.487	0.04	
Length of stay				
Av days	0.9	0.7	1	
Ratio means[1] (CI)		0.92 (0.69-1.22)	1.21 (0.89-1.64)	
P value		0.5638	0.2243	
Minimum saturations				
Recovery	97	97	96	0.36
Overnight	95	96	96	0.6824
Readmission (%)	0	0	1	0.58

CPAP – Continuous positive airway pressure, OSA – obstructive sleep apnoea, PICU – paediatric intensive care unit, NIV – non-invasive ventilation, Av – average, CI – confidence intervals

Subgroup analyses

Subgroup analysis for only those patients diagnosed with severe OSA (AHI>10) demonstrated a greater use of NIV support in those prescribed CPAP; NC-CPAP 29% and C-CPAP 64% ($p<0.0001$) compared to those not prescribed CPAP (Table 4). Amongst those not prescribed CPAP, length of wait for surgery was reduced in those with severe OSA at 21.3 weeks (35% reduction, $p=0.04$) compared to mild OSA (30.4 weeks) and moderate OSA (34.6 weeks, $p=0.56$) patients (Table 5).

DISCUSSION

Our long-established experience with use of CPAP in children has led to processes for pre-operative implementation of CPAP in children with OSA.[12] In view of the acknowledged wait times for surgery, the use of CPAP offers an immediate intervention to treat children with more severe disease, and this practice permitted the current retrospective evaluation of this system of care. We found that compliance with pre-operative CPAP led to improved use of CPAP in the immediate postoperative period, along with reduced use of oxygen and shorter post-operative stay compared to those prescribed, but non-compliant with, CPAP.

Preoperative risk assessment prior to adenotonsillectomy plays an important role in elective, postoperative admission to PICU. Recognized risk factors for post-operative respiratory complications following adenotonsillectomy for OSA include age <3 yo, severe OSA, failure to thrive, obesity, cardiac complications of OSA, trisomy 21, prematurity, craniofacial abnormalities, neuromuscular disorders, chronic lung disease and sickle cell disease.[1,13,14] Even using these criteria to define risk groups, many of those admitted to PICU require only routine care and do not require high dependency or intensive care management.[15]

In the current study group, all admissions to PICU were planned, but compliance with CPAP therapy resulted in fewer PICU admissions. We believe this is most likely because their preoperative use of CPAP influenced their

perceived postoperative risks when they were assessed prior to surgery. Children prescribed CPAP were younger than those not prescribed therapy, consistent with the finding that younger children have more severe disease, however, the non-compliant children were also the youngest.[16,17]

Compliance with preoperative CPAP therapy was associated with an overall reduction in hospital length of stay by 1 day, compared to those who were non-compliant. Though cost was not specifically assessed in the study, we suggest that compliance with CPAP therapy would positively impact on resource allocation and cost effectiveness for the hospital system. Further studies looking into resource requirement for establishment of CPAP and comparing with cost of PICU admission and average cost of general hospital admission should be considered.

Saur et al reviewed studies of populations with high-risk for post-operative complications, highlighting that recognition of these children's' increased post-operative risk means that additional care is taken to identify and manage potential respiratory complications should they arise. The authors also highlighted that multiple assessments, including sleep studies, can create delays treatment intervention. Wait times can be long for both sleep medicine and ear, nose and throat (ENT) surgical services. Our rationale for prescribing preoperative CPAP includes the opportunity for intervention earlier than the surgery would allow which, even in those with severe OSA who were unable to use CPAP, was >14 weeks.

The overall low rate of respiratory complications in our study group, despite the pre-operative identification of their risk factors, is consistent with recent studies.[14,18] Nonetheless, the only major respiratory complication, re-intubation, was seen in one case of each of our groups (N-CPAP, NC-CPAP and C-CPAP), the only difference amongst the groups for post-operative respiratory complications, was higher use of NIV in children who were previously prescribed CPAP. We postulate that the reason postoperative CPAP use was highest in children who were compliant with therapy pre-operatively, was its ease of use in children previously acclimatized to the therapy since many post-operative instructions in the medical records recommended the use of the patients' own CPAP postoperatively, or directly after extubation in theatres. Consistent with other studies of children undergoing sleep studies prior to adenotonsillectomy, the majority of children in this study had their surgery at our hospital because they were identified as high risk for respiratory compromise after adenotonsillectomy for OSA.[19] In such a baseline high-risk population, another study found that severity of OSA on PSG was the distinguishing factor for those with significant respiratory complications.[18] Children have a two-fold increased incidence of fatal respiratory events following adenotonsillectomy, with strong evidence that severity of OSA is an important determinant of postoperative risk.[19] Thus, the lack of difference in other postoperative complications or adverse outcomes may be a positive result of the pre-operative CPAP usage, although our study numbers are not sufficient to consider the outcome proven.

In keeping with published literature, compliance with CPAP did not improve the minimum oxygen saturations, nor prevent requirement for respiratory support in the postoperative period. Postoperative respiratory complications occur in up to 27% of patients with OSA, including desaturations and hypopnea, and De et al demonstrated no difference in oxygen nadir on PSG the first night after adenotonsillectomy compared to preoperative PSG.[20] One of the few mentions of pre-operative CPAP use in children recommends that those on CPAP preoperatively should continue on CPAP postoperatively to reduce risk of respiratory complications.[20]

Future considerations

CPAP therapy improves gas exchange, cardiovascular and metabolic risks, neurocognitive effects and quality of life in children with OSA.[21-24] However, current recommendations for the use of CPAP in children with OSA secondary to adenotonsillar hypertrophy focus on its use in the presence of residual OSA despite adenotonsillectomy.[1,3] Adenotonsillar hypertrophy is the leading cause of OSA in children, and adenotonsillectomy is the primary treatment modality, however the prolonged length of wait for surgery especially in our public health system, suggests that CPAP therapy may have a role in managing severe OSA while children are awaiting surgery. Additional studies will be required to fully define the role this therapy in the pre-operative setting, particularly in children who have high risk for persisting disease.

Limitations

As a retrospective study we relied on information in the medical records of the patients at the time of their admission for adenotonsillectomy, resulting in 25% loss of numbers through inadequate information. Nonetheless, we were able to demonstrate that pre-operative compliance with a recommendation for CPAP therapy resulted in higher use of CPAP support in the recovery and post-operative periods, and a 1-day reduction in the duration of hospital stay. The authors acknowledge the selection bias within the included patient population, and that the patient groups may not be reflective of the general population. Additionally, a significant limitation, due to the retrospective nature of the study, was the lack of objective data regarding compliance with CPAP use. Compliance is generally defined as use of CPAP for a minimum of 4 hours per night, with current technology, electronic data downloads are now available for most devices. Of the study population, only 16 % had compliance downloads available; for the remainder of the study population compliance was based on documented verbal reports from

chart reviews, which the authors acknowledge creates a possibility of bias.

CONCLUSION

In children undergoing adenotonsillectomy for OSA diagnosed on PSG, preoperative compliance with CPAP therapy reduced the risk of admission to PICU, and resulted in a shorter length of hospital admission, with less requirement for oxygen support in the postoperative period.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Ms. Elizabeth Barnes for assistance with statistical analysis for the study.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Zaballa K, Jayasuriya G, Waters W. Preoperative continuous positive airway pressure use improves the hospital experience of children undergoing adenotonsillectomy for obstructive sleep apnea. Int J Otorhinolaryngol Head Neck Surg 2023;9:777-83.