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REVIEW

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The risk of postoperative respiratory complications following adenotonsillar surgery in children with or without obstructive sleep apnea: A systematic review and meta-analysis

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Abstract

Objectives: Obstructive sleep apnea (OSA) appears in 2%–5% of children, with first-line treatment being adenotonsillar (AT) surgery. Our aim was to examine the risk of postoperative respiratory complications (PoRCs) in non-OSA and the different OSA severity (mild, moderate, severe) groups.

Study Design: We conducted a systematic review and meta-analysis of studies comparing PoRCs following AT surgery in children with and without OSA.

Methods: Nineteen observational studies were identified with the same search key used in MEDLINE, Embase, and CENTRAL. The connection between PoRCs, the presence and severity of OSA, and additional comorbidities were examined. Odds ratios (OR) were calculated with 95% confidence intervals (CI).

Results: We found that PoRCs appeared more frequently in moderate ($p = 0.048$, OR: 1.79, CI [1.004, 3.194]) and severe OSA ($p = 0.002$, OR: 4.06, CI [1.68, 9.81]) compared to non-OSA patients. No significant difference was detected in the appearance of major complications ($p = 0.200$, OR: 2.14, CI [0.67, 6.86]) comparing OSA and non-OSA populations. No significant difference was observed in comorbidities ($p = 0.669$, OR: 1.29, CI [0.40, 4.14]) or in the distribution of PoRCs ($p = 0.904$, OR: 0.94, CI [0.36, 2.45]) between the two groups.

Conclusion: Uniform guidelines and a revision of postoperative monitoring are called for as children with moderate and severe OSA are more likely to develop PoRCs following AT surgery based on our results, but no significant difference was found in mild OSA. Furthermore, the presence of OSA alone is not associated with an increased risk of developing major complications.

KEYWORDS

adenoidectomy, child, obstructive sleep apnea, postoperative complications, tonsillectomy

Abbreviations: AAP, American Academy of Pediatrics; AAO–HNS, The American Academy of Otolaryngology–Head and Neck Surgery; AHI, apnea–hypopnoea index; AT, adenotonsillar; CI, confidence interval; ERS, European Respiratory Society; ICSD, International Classification of Sleep Disorders; ICU, intensive care unit; IPOG, International Pediatric Otolaryngology Group; OR, odds ratio; OSA, obstructive sleep apnea; PoRCs, postoperative respiratory complications; PSG, Polysomnography; SDB, sleep disordered breathing; SpO_2, oxygen saturation.

1 | INTRODUCTION

According to the International Classification of Sleep Disorders, obstructive sleep apnea (OSA) syndrome is categorized as a sleep-related breathing disorder,[1] in which breathing is repetitively interrupted due to the partial or complete collapse and obstruction of the upper airway during sleep.[2] A diagnosis is based on the presence of either one or more obstructive events per hour of sleep or obstructive hypoventilation, manifested in partial pressure of carbon dioxide >50 mmHg for >25% of sleep time registered by polysomnography (PSG).[2] According to international studies, OSA presents in 2%–5% of the pediatric population, mostly occurring between the ages of 2 and 6 years.[3] Untreated OSA can cause daytime drowsiness and can lead to cardiovascular diseases (e.g., systemic hypertension or acute heart failure), neurocognitive and behavioral abnormalities (e.g., hyperactivity or aggression), and metabolic syndrome.[3]

As adenotonsillar (AT) hypertrophy is the most common cause of pediatric OSA, AT surgery has been accepted as a first-line treatment for the disease.[4] When OSA-like symptoms are not present, infectious indications, such as chronic adenoiditis, tonsillitis, recurrent upper airway infection, and otitis media, are most likely in the background of AT surgery. Mostly minor events can be registered postoperatively, including pain, vomiting, bleeding, and temporary desaturation; however, major complications can occur in some cases. Even though mortality is uncommon (between 1/16,000 and 1/50,000 events),[5] major respiratory complications, such as severe desaturation, pulmonary edema, laryngospasm, and bronchospasm, can lead to serious adverse events following acute respiratory failure. While primary postoperative bleeding only occurs in 0.2%–2.2% of cases, postoperative respiratory complications (PoRCs) are more common; indeed, they are present in around 9% of all cases.[6] Not only the frequent appearance but also the insidious onset can increase the risk of an unfavorable outcome as a consequence of hypoxemia and hypercapnia, such as reintubation, myocardial ischemia, cardiac arrythmia, hypoxic encephalopathy, and even death.[7]

Contradictions can still be found in the literature as to whether OSA increases the risk of PoRCs after AT surgery in pediatric patients. A number of articles discuss OSA and postoperative complications, suggesting a higher occurrence rate of postoperative complications among OSA children. Overall, most of these studies examined a small population or combined pediatric and adult patients, high-risk patients were not involved or analyzed separately, or the complications in the OSA group were not compared to those of non-OSA patients. Usually, each study had a unique conclusion listing a variety of postoperative complications, not limited to respiratory ones; minor and major complications were not separated or only the effectiveness of the different (AT) surgical approaches were compared. Some meta-analyses can also be found on the topic, but mostly with the same shortcomings noted above. However, a meta-analysis by De Luca Canto[6] separately examined complications by characteristics following AT in children and comparing the appearance rate in OSA children to a pediatric population without the disease; nevertheless, it does not provide data on the severity of the complications nor on the role of other comorbidities.

As children with OSA are still considered high-risk patients, independent of the severity of the disease or the presence of additional comorbidities, our aim was to clarify the relationship between the factors noted above by performing a systematic review and a meta-analysis of the currently available data. This is crucial as most otorhinolaryngology departments currently have their own individual protocols for monitoring children with OSA post-operatively. There are therefore no unified evidence-based guidelines to date, and the relation between PoRCs, the severity of OSA, and the need for closer postoperative observation is not yet well-defined. With a comprehensive meta-analysis, high-risk patients could be screened more effectively to prevent fatal PoRCs, adverse events, and unplanned intensive care unit (ICU) admissions.

2 | METHODS

2.1 | Protocol and registration; reporting

This meta-analysis was registered with PROSPERO under registration number CRD42020165517. No deviations were made from the protocol, except for an expansion in the search key: the preplanned search key ("postoperative complications" OR ICU OR desaturation OR mortality OR "respiratory failure") AND obstructive sleep apnea AND children AND (adenoidectomy OR tonsillectomy OR tonsillotomy) was expanded to ("postoperative complications" OR ICU OR ICU OR desaturation OR mortality OR "respiratory failure") AND (obstructive sleep apnea OR sleep disordered breathing [SDB]) AND (children OR child OR childhood OR pediatric) AND (adenoidectomy OR tonsillectomy OR tonsillotomy OR "tonsil surgery") in order not to miss any relevant articles. This study is reported in accordance with the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA) 2020 Statement.[8] Ethical approval is not required due to the nonindividualized character of the extracted and analyzed data, and primary data was not collected.

2.2 | Eligibility criteria

Observational studies that examined PoRCs in pediatric patients (aged 0–18 years) undergoing any kind of AT surgery were considered. Only studies that provided adequate data on PoRCs in both the OSA and non-OSA groups were eligible. No other restriction was put in place.

Eligibility was based on the following PECO:

P—Population: Studies that examined pediatric patients (aged 0–18 years) undergoing any kind of AT surgery.

E—Exposure: Children with a diagnosis of OSA undergoing AT surgery.

C—Comparator: Children undergoing AT surgery without OSA.

O—Outcome: The presence of PoRCs following AT surgery in the pediatric OSA and non-OSA population.

In addition, the connection between the appearance rate of PoRCs, the severity of OSA, the severity of respiratory complications and presence of other comorbidities were examined.

2.3 | Systematic search and selection

The systematic search was conducted in MEDLINE (via PubMed), Embase and the Cochrane Library (CENTRAL) using the search key described above. The date of the last systematic search was March 3, 2021. No language restriction was applied.

Citations were imported to a citation management program (EndNote X9) as a shared pool, and duplicates were removed first automatically by the software, then manually. Following screening by title and abstract, full texts were reviewed. Each step of the selection process was taken independently by two review authors (F. K. and V. A. J.) using the inclusion criteria noted above. If there were any disagreements, an independent third party made the decision as to whether to include a study (M. F. J.). The rate of agreement was calculated and documented at each stage of the selection process and expressed using Cohen's kappa coefficient (κ).[9] Exclusions determined in the full text phase were documented. We used the PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only to demonstrate the steps of the selection.

2.4 | Data extraction

For both groups (OSA and non-OSA), extracted data from the eligible articles contained first author, publication year, study design, number of patients, age and gender distribution, PoRCs (minor and major), and patients' characteristics, such as comorbidities and severity of OSA. Subgroups were formed to be able to decide whether children with OSA (at a mild, moderate or severe stage) or with additional comorbidities carry a higher risk for developing respiratory complications following AT surgeries. As regards PoRCs, two subgroups were formed: major and minor complications. Based on the included articles, desaturations for any reason without the need for intervention were listed as minor complications, while desaturation, laryngospasm, bronchospasm, pulmonary edema, or pneumonia requiring interventions, such as reintubation, naso- or oropharyngeal airway management, or ventilation were listed as major complications in the postoperative period before discharge. As this is a meta-analysis, only data provided by individual studies on preoperative PSG and the diagnosis or classification of OSA could be used: when a patient did not have positive anamnesis for obstructive sleep apnea and not OSA-like symptoms stands in the background of performing AT surgery, PSG was not necessarily carried out. According to The European Respiratory Society (ERS) statement on obstructive SDB in 1- to 23-month-old children[10] and obstructive SDB in 2- to 18-year-old children: diagnosis and management,[11] PSG is needed when a child is at risk for SDB (symptoms of upper airway obstruction, findings on exam, objective findings related to SDB, prematurity, or family history of SDB).

In the OSA group, three subgroups were created based on severity according to a categorization established by Kaditis et al.[11]: mild and moderate (apnea–hypopnoea index [AHI]: 5–10) and severe (AHI: >>10). In comparing the presence of PoRCs in mild, moderate, and severe OSA, we only included studies with sufficient data on the severity of OSA defined by preoperative PSG. Investigating the prevalence of comorbidities affecting the craniofacial region or the respiratory system (such as 21 trisomy, asthma, Chiari malformation, chronic pulmonary disease, Crouzon's disease, Fragile-X, Franceschetti–Klein syndrome, Joubert's syndrome, microcephaly, mucopolysaccharidosis and Pierre–Robin sequence) as potential risk factors for the examined outcome among OSA compared to non-OSA patients, we only analyzed studies that provided precise data on the characteristics of the abnormalities.

2.5 | Risk of bias assessment

The studies included in our meta-analysis were analyzed using the Quality in Prognostic Studies modified table to assess risk of bias. The results are summarized in the Supporting Information: Table S1.

2.6 | Statistical analysis

Odds ratios (OR) were calculated, with 95% confidence intervals (CI) and $p < 0.05$ indicating statistical significance. If at least three articles reported on the same outcome in a comparable manner, a meta-analysis was performed using the DerSimonian–Laird random effects model.[12] Results of the meta-analyses are displayed graphically with forest plots. Heterogeneity was tested with the χ^2 test (with $p < 0.1$ indicating statistically significant heterogeneity) and the I^2 statistic, where an I^2 value of 30%–60% represents a moderate risk of heterogeneity, 50%–90% indicates a substantial risk and 75%–100% suggests a considerable risk.[13] All meta-analytical calculations were performed using the Stata 15 data analysis and statistical software (Stata Corp LLC).

3 | RESULTS

3.1 | Systematic search and selection

The number of studies in the search and selection process are detailed in the PRISMA flowchart (Figure 1).

The systematic search yielded 672 hits, of which 474 studies were screened after removing duplicates. One hundred and ninety-eight studies were also excluded by title, leaving 276 for screening based on abstracts and leading to the exclusion of a further 190

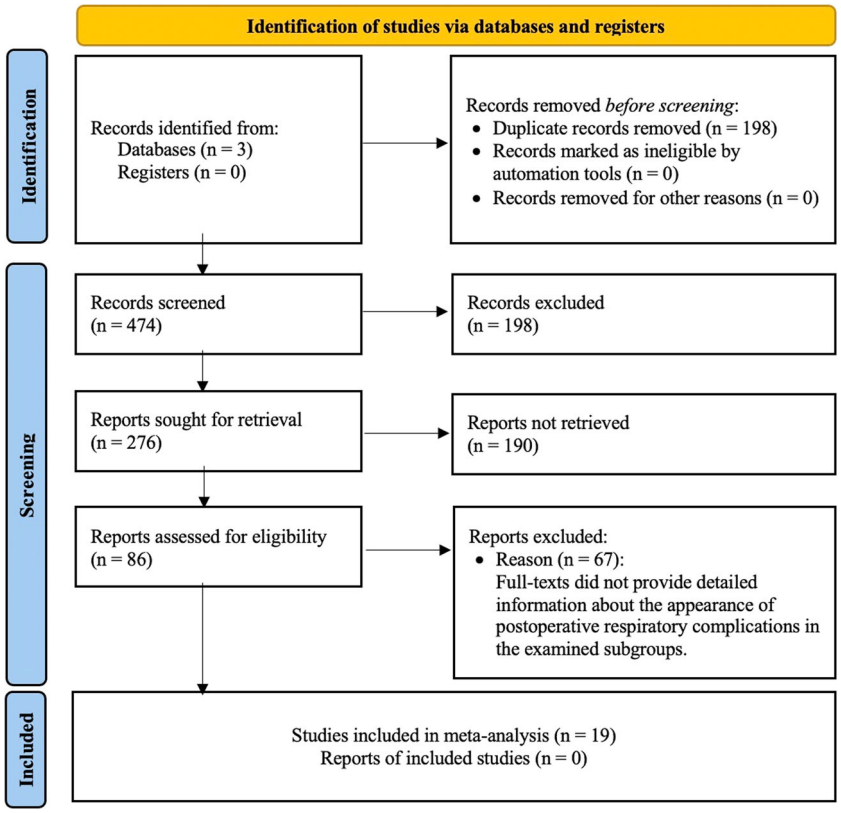

FIGURE 1 Preferred reporting items for systematic reviews and meta-analyses 2020 flow diagram for study selection [Color figure can be viewed at wileyonlinelibrary.com]

papers. Out of the remaining 86 studies, based on a review of the full texts, 19 were included for this meta-analysis. Studies were excluded mostly because the full texts did not provide detailed information about the appearance of PoRCs in the subgroups. (Cohen's κ was 0.69 and showed substantial agreement by title and abstract, and 0.83 was calculated with a substantial agreement during the full text selection).

3.2 | Study characteristics

A total of 19 studies were included in this meta-analysis, examining PoRCs following AT surgery in 120,544 patients, with 59,323 of them involving OSA. Thirteen of the included studies were retrospective observational (Allareddy et al.,[14] Camacho et al.,[15] Castano et al.,[16] Dalesio et al.,[17] Ekstein et al.,[18] Kang et al.,[19] Kieran et al.,[20] Lalakea et al.,[21] Marsollier et al.,[22] Patel et al.,[23] Rodriguez-Catalán et al.,[24] Tweedie et al.,[25] and Ali et al.),[26] two retrospective case–control (Gehrke et al.[27] and Riaz et al.),[28] one ambidirectional (Muninnobpamasa et al.),[29] one prospective (Sanders et al.)[30] and two cross-sectional (Kou et al.[31] and Martins et al.).[32] The number of patients examined in the various studies included were as follows: four of the studies[23,28,30,32] had fewer than 100 patients participating, another four[16,18,21,22] consisted of 100–200, five studies[15,17,24,26,29] comprised 200–500, two[19,20] involved 500–1000, and four[14,25,27,31] had over 1000. Most of the studies randomly examined selected pediatric patients from the population in the chosen period. Riaz et al.[28] was the only study to divide the selected children into two equal groups, enrolling a matched control group of children without OSA, possibly leading to the high heterogeneity found in some of our statistical analyses. The presence of any comorbidity other than OSA was an exclusion criterion in Camacho et al.,[15] Dalesio et al.,[17] Martins et al.,[32] Riaz et al.,[28] and Sanders et al.,[30] A study by Gherke et al.,[27] excluded children who had undergone additional surgeries. Detailed information on each study can be found in the study characteristics table (Table 1).

3.3 | Outcomes

3.3.1 | Primary outcomes

PoRCs in pediatric patients following AT surgery shows higher occurrence in OSA than in non-OSA

Based on our analysis of all 19 included studies,[14–32] PoRCs following AT surgery show a significantly higher occurrence rate in children with OSA (OR: 2.24, 95% CI [1.60, 3.15], $p < 0.001$). However, it must be noted that the statistical heterogeneity was high (I^2 65.4%, χ^2 test $p < 0.001$), most likely due to a case–control study with significantly different results.[28] A leave-one-out analysis was conducted in which that study was omitted, showing statistical homogeneity while retaining the significant difference between groups, as seen in Figure 2. Detailed statistical information can be found in the Supporting Information: Table S2 and Figure S1.

TABLE 1 Study characteristics of the 19 selected studies

	Publication data			Demography											Outcome: PoRCs			
								Age							PoRCs among children without OSA		PoRCs among children with OSA	
Study number	First author	Year of publication	Design	Country	Population	Exclusion criteria	No of patients	Mean (years)	Range (years)	Gender Female %	No of pediatric patients with OSA	No of pediatric patients with comorbidity other than OSA	N0 of pediatric patients with mild OSA	N0 of pediatric patients with moderate OSA	N0 of pediatric patients with severe OSA	total	major	total	major
1	Allareddy[14]	2015	Retrospective	USA	Children undergoing tonsillectomy	ND	141,599	ND	0–21	41.9	37,382	120,486	ND	ND	ND	total number of PoRCS (95% CI): 1,25 (0,91–1,69)[a]			
2	Camacho[15]	2014	Retrospective	Spain	Children undergoing AT surgery	Neuro-muscular disease, syndrome, or malformation in the craniofacial region	229	4.97	0–18	43.8	93	196	7	33	53	2	ND	3	ND
3	Castano[16]	2016	Retrospective medical record view	USA	Children undergoing AT surgery	Intracapsular tonsillectomy, no planned admission, concurrent airway procedure, syndromic, bleeding disorder, bleeding disorder, seizure disorder, lack of data	188	29.5 (months)	0–3	36.7	183	ND	ND	ND	ND	0	0	7	2
4	Dalesio[17]	2015	Retrospective	USA	Children undergoing AT surgery	Children without preoperative PSG, genetic abnormalities	319	5	0.5–17	47.3	279	ND	106	59	114	3	ND	17	ND
5	Ekstein[18]	2019	Retrospective review	Israel	Children undergoing AT surgery with planned PICU admission	Children with lack of medical data, intubated PICU admittance	179	43 ± 37 (months)	0–16	29.6	158	ND	33	45	71	10	0	102	6

(Continues)

TABLE 1 (Continued)

	Publication data			Demography											Outcome: PoRCs			
								Age							PoRCs among children without OSA		PoRCs among children with OSA	
Study number	First author	Year of publication	Design	Country	Population	Exclusion criteria	No of patients	Mean (years)	Range (years)	Gender Female %	No of pediatric patients with OSA	No of pediatric patients with comorbidity other than OSA	N0 of pediatric patients with mild OSA	N0 of pediatric patients with moderate OSA	N0 of pediatric patients with severe OSA	total	major	total	major
6	Gehrke[27]	2019	Retrospective case–control study	Germany	Children undergoing AT surgery	Additional surgeries	1995	3.85	0–18	38.9	528	139	ND	ND	ND	27	10	27	9
7	Kang[19]	2017	Retrospective	Taiwan	Children undergoing AT surgery	None	610	7.2 ± 3.3	2–18	28.5	528	ND	228	97	203	9	0	100	6
8	Kieran[20]	2013	Retrospective	USA	Children undergoing AT surgery	None	662	60.0 ± 48.6	0–18	ND	545	327	ND	ND	ND	27	ND	267	ND
9	Kou[31]	2018	Cross-sectional study	USA	Children undergoing AT surgery	Native Americans, small sample size	30617	5.2	0–18	41	17863	11515	ND	ND	ND	595	ND	1385	ND
10	Lalakea[21]	2018	Retrospective chart view	USA	Children undergoing AT surgery	Planned inpatient admission, insufficient follow-up	127	6.1 ± 2.6	0.9–12,6	37.3	116	ND	ND	ND	ND	0	ND	7	ND
11	Marsollier[22]	2017	Retrospective	France	Children undergoing AT surgery	Planned PICU admission	128	ND	2–18	ND	110	ND	ND	ND	ND	0	ND	25	ND
12	Martins[32]	2014	Cross-sectional cohort study	Brazil	Children referred to PICU following AT surgery	Cardiac, pulmonary, neuromuscular, chromosomal, craniofacial abnormalities, additional surgeries	53	5.3 ± 2.6	1–12	47.1	37	ND	ND	ND	ND	8	8	13	6
13	Muninnobpamasa[29]	2012	Retrospective and prospective	Thailand	Children undergoing AT surgery	ND	481	ND	3–18	60.7	113	ND	ND	ND	ND	8	ND	0	ND

TABLE 1 (Continued)

Study number	Publication data			Demography											Outcome: PoRCs			
	First author	Year of publication	Design	Country	Population	Exclusion criteria	No of patients	Age		Gender Female %	No of pediatric patients with OSA	No of pediatric patients with comorbidity other than OSA	N0 of pediatric patients with mild OSA	N0 of pediatric patients with moderate OSA	N0 of pediatric patients with severe OSA	PoRCs among children without OSA		PoRCs among children with OSA	
								Mean (years)	Range (years)							total	major	total	major
14	Patel[23]	2021	Retrospective	USA	Children undergoing AT surgery	Additional surgeries	76	17.8 ± 3.7 (months)	0–2	26.3	36	37	ND	ND	ND	2	0	5	4
15	Riaz[28]	2009	Retrospective case–control study	Saud Arabia	Children undergoing AT surgery	Additional surgeries	60	6.13 ± 2.01 (OSA); 7.06 ± 1.52 (non-OSA)	3–10	42	30	ND	ND	ND	ND	3	0	26	7
16	Rodriguez-Catalán[24]	2019	Retrospective	Spain	Children undergoing AT surgery	Craniofacial or neuromuscular abnormalities	418	5.5 ± 3.2	0–18	43.8	181	ND	26	61	94	1	ND	5	ND
17	Sanders[30]	2006	Prospective	USA	Children undergoing AT surgery	ASA »3, additional surgeries, craniofacial malformation, Down syndrome, asthma, congenital heart disease, previous AT surgery, contraindication to general anesthesia	82	6.5 (OSA), 7.0 (non-OSA)	2–16	44	61	ND	ND	ND	ND	1	ND	17	ND
18	Tweedie[25]	2012	Retrospective	UK	Children undergoing AT surgery	None	1735	46 (months)	0.3–16.5	ND	999	1328	951		48	1	1	14	9
19	U. Ali[26]	2012	Retrospective review	UK	Children undergoing tonsillectomy	ND	309	ND	3–16	ND	81	ND	ND	ND	ND	0	0	2	1

Abbreviations: AT, adenotonsillar; ND, not defined; $N^{0,}$ number; OSA, obstructive sleep apnea; PICU, paediatric intensive care unit; PoRCs, Postoperative respiratory complications; PSG, polysomnography.

[a]Calculated data from statistical results of the original article.

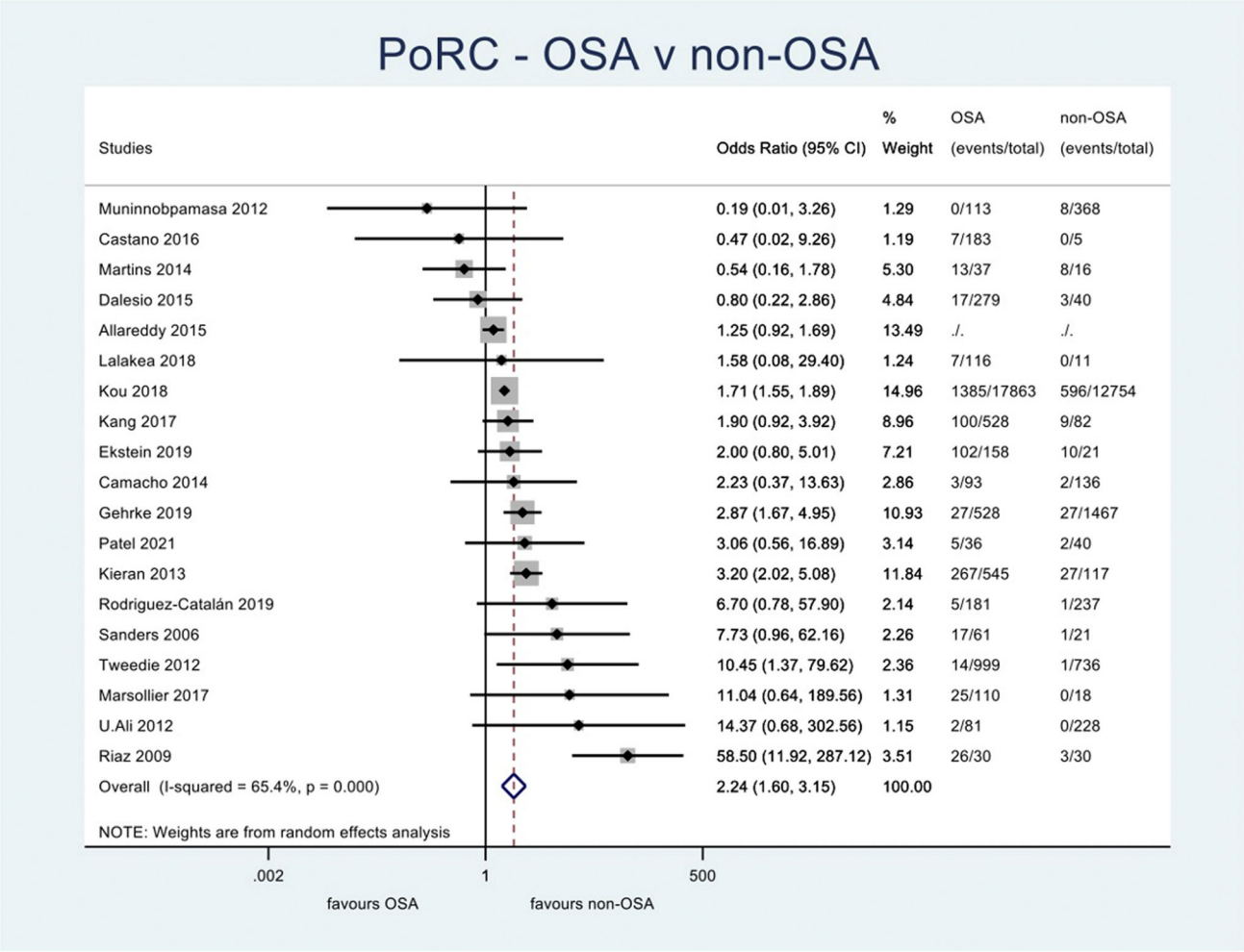

FIGURE 2 PoRCs in pediatric patients following AT surgery in OSA and non-OSA. AT, adenotonsillar; OSA, obstructive sleep apnea; PoRCs, postoperative respiratory complications. [Color figure can be viewed at wileyonlinelibrary.com]

Moderate and severe OSA is associated with a higher risk of PoRCs in pediatric patients following AT surgery

With the inclusion of five studies[15,17–19,24] that supplied precise information about the severity of OSA, the PoRCs rate was analyzed in each OSA severity subgroup and compared individually to non-OSA patients. Based on the analysis, no significant difference was found in the case of mild OSA ($p = 0.619$, OR: 1.15, 95% CI [0.651, 2.058]), but a significantly higher probability of PoRCs was observed in moderate ($p = 0.048$, OR: 1.79, 95% CI [1.004, 3.194]) and severe OSA ($p = 0.002$, OR: 4.06, 95% CI [1.68, 9.81]) compared to non-OSA patients. Even though our statistical analysis shows that children with severe OSA carry a significantly higher risk for PoRCs than children without the disease, it must be noted that statistical heterogeneity was high (I^2 58.1%, χ^2 test $p = 0.036$) and Tweedie et al.[25] showed a relatively higher OR for PoRCs in patients with severe OSA compared to the other studies included (OR: 85.47, 95% CI [9.77, 747.74]). A leave-one-out analysis was performed with the same significant difference, but without statistically significant heterogeneity (Figure 3). Detailed statistical information can be found in the Supporting Information: Tables S3–S5 and Figure S2.

Major PoRCs in pediatric patients following AT surgery in OSA and non-OSA

Nine studies[16,18,19,23,25–28,32] with sufficient data on major PoRCs were examined. No significant difference was found in the rate of major PoRCs in pediatric patients with OSA compared to children without it ($p = 0.200$, OR: 2.14, 95% CI [0.67, 6.86]) (I^2 61.7%, χ^2 test $p = 0.008$) (Figure 4), suggesting that OSA does not elevate the risk for major respiratory complications postoperatively. Detailed statistical information can be found in the Supporting Information: Table S6.

3.3.2 | Secondary outcomes

The role of comorbidities in PoRCs in OSA and non-OSA pediatric patients following AT surgery

A statistical analysis of four studies[20,21,23,25] showed no significant differences ($p = 0.669$, OR: 1.29, 95% CI [0.40, 4.14]) in additional comorbidities in children with OSA compared to children without it in the PoRCs group (Figure 5). Based on our results, the presence of

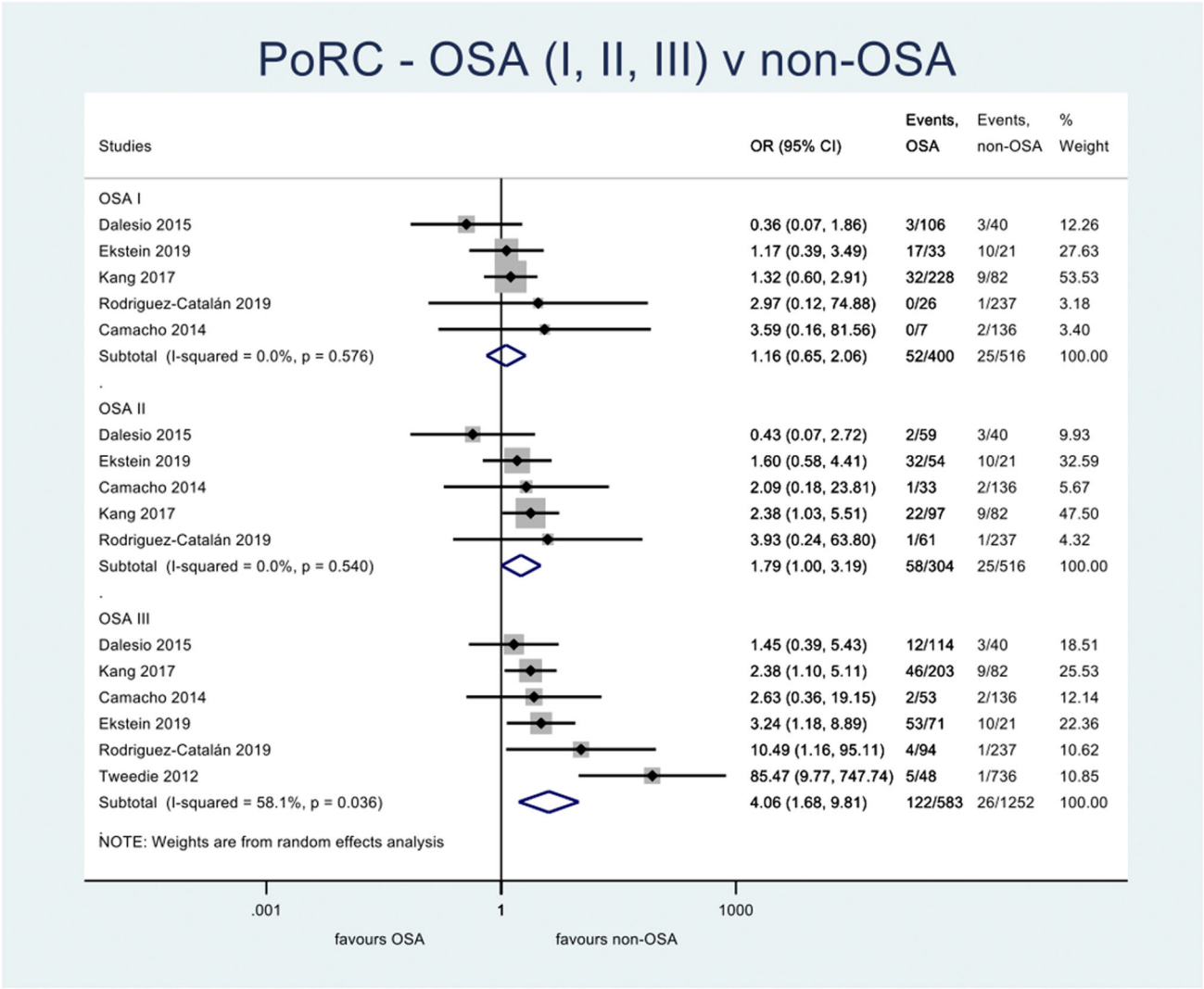

FIGURE 3 Risk for PoRCs in mild (OSA I), moderate (OSA II), and severe OSA (OSA III) in pediatric patients following AT surgery. AT, adenotonsillar; OSA, obstructive sleep apnea; PoRCs, postoperative respiratory complications. [Color figure can be viewed at wileyonlinelibrary.com]

other comorbidities was not more common in the OSA group among pediatric patients with respiratory complications postoperatively, strengthening our hypothesis that OSA alone can increase the risk of respiratory complications after AT surgery. Only comorbidities associated with craniofacial malformations or affecting the respiratory system (e.g., obesity, Down syndrome, and bronchial asthma) were collected. Detailed statistical information can be found in the Supporting Information: Table S7.

3.3.3 | Additional outcomes

Major and minor PoRCs in pediatric patients following AT surgery in OSA and non-OSA

To compare the appearance of major and minor PoRCs from the first nine studies included[16,18,19,23,25–28,32] after data extraction, two were excluded[16,26] because no PoRCs were registered in the entire non-OSA group. No statistically significant difference ($p = 0.904$, OR: 0.94, 95% CI [0.36, 2.45]) was found in the likelihood of the complication being major among children experiencing PoRCs in the OSA group compared to the non-OSA groups (Figure 6), suggesting that mostly minor events occur.

Detailed statistical information on each outcome can be found in the Supporting Information: Table S8.

4 | DISCUSSION

OSA is a common disorder in childhood, that without treatment can have severe consequences (behavioral, cardiovascular, or neurocognitive).[3] Since in the pediatric population OSA has come to be the primary indication for AT surgeries where adverse respiratory events

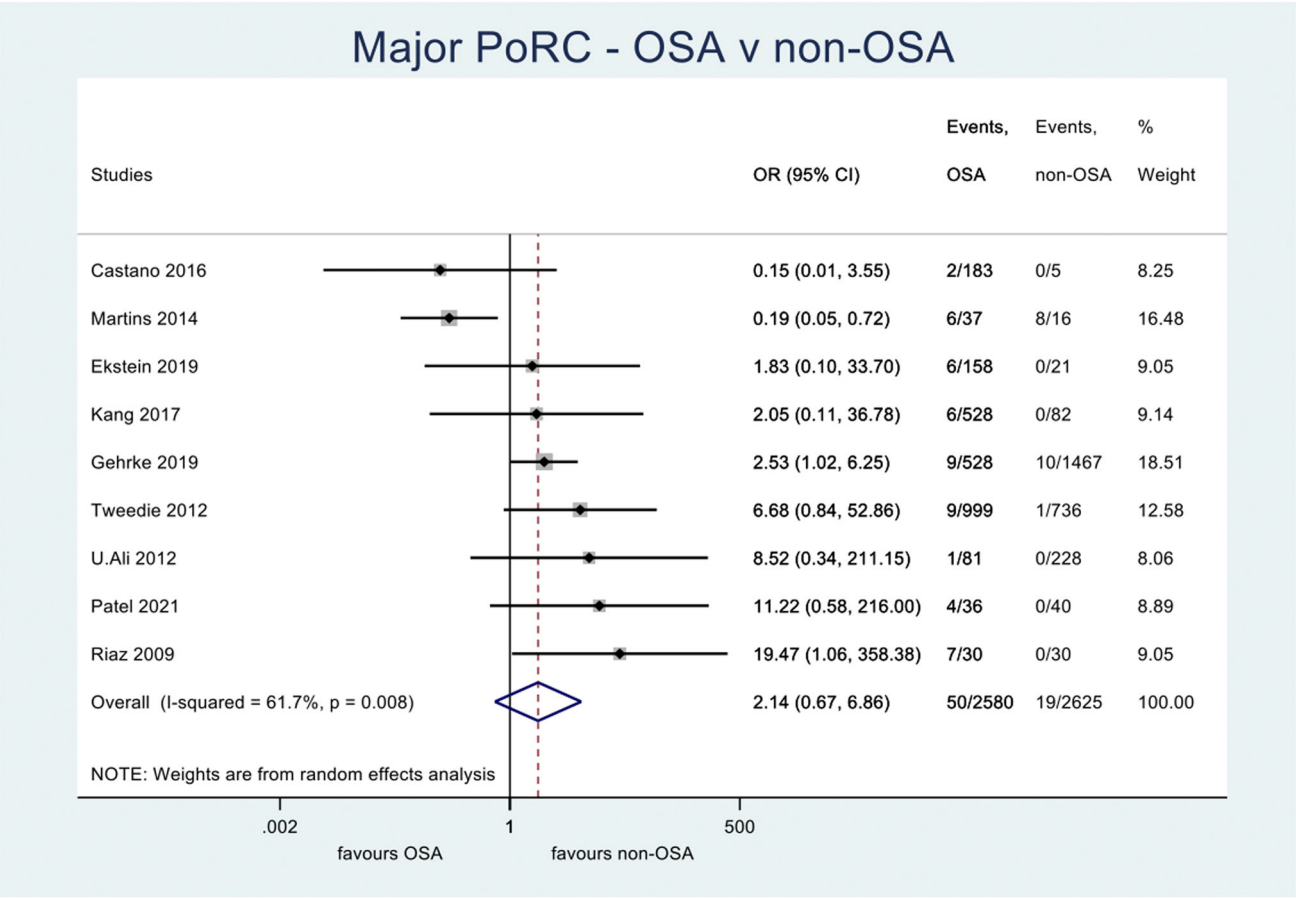

FIGURE 4 Major PoRCs in pediatric patients following AT surgery in OSA and non-OSA. AT, adenotonsillar; OSA, obstructive sleep apnea; PoRCs, postoperative respiratory complications. [Color figure can be viewed at wileyonlinelibrary.com]

are a known side effect, postoperative monitoring should be planned precisely.[17]

Intermittent hypoxia in OSA can activate different molecular pathways leading to the downregulation of genes responsible for identifying and reacting to hypoxia and hypercapnia. The resultant desensitization of the respiratory system can lead to serious adverse events postoperatively (reintubation, myocardial ischemia, cardiac arrythmia, hypoxic encephalopathy, or even death), especially if respiratory complications are not promptly recognized.[33] Certain studies have concluded that the use of continuous positive airway pressure preoperatively can help to handle obstructive apnea during sleep and also to aid in the resensitization and upregulation of the respiratory system and to prevent adverse events occurring for lack of reaction to hypoxia and hypercapnia.[34] Although PoRCs are common after AT surgery in children, correlation with the presence and severity of OSA still remain unsubstantiated. There is not a single consensus for routine overnight observation postoperatively; only regional protocols can be found.

According to the consensus statement issued by the International Pediatric Otolaryngology Group (IPOG), postoperative monitoring should be performed in children under 2 years of age regardless of OSA stage and in patients with Down syndrome or craniofacial malformation with moderate or severe OSA. The IPOG consensus statement declares that otherwise healthy patients with mild OSA do not need overnight observation.[35] According to the American Academy of Pediatrics (AAP), when none of the following risk factors are present—including age <3 years, severe OSA, obesity, cardiac complication, failure to thrive or the presence of upper respiratory tract infection—AT surgery can be safely performed on an outpatient basis. The children noted above or children with an oxygen saturation (SpO_2) nadir <80% or an AHI ≥ 24/h should be observed as inpatients postoperatively. Children with comorbidities were not included in their guidelines.[3] The American Academy of Otolaryngology–Head and Neck Surgery (AAO–HNS) updated their recommendations on the pre-, intra- and postoperative care and management of children 1–18 years of age and suggested inpatient monitoring of children after tonsillectomy if age <3 years or they have severe OSA; that is, if AHI is more than 10 events/h or the SpO_2 nadir <80% or both.[36] The ERS also published their statement (based on expert opinion) on the management of OSA patients after AT surgery. They state that risk factors for PoRCs include patients under 3 years of age, patients with severe OSA who have AHI of more than 26 events/h, and patients with obesity or low weight, or neuromuscular, craniofacial, or genetic disorders.[11] According to these

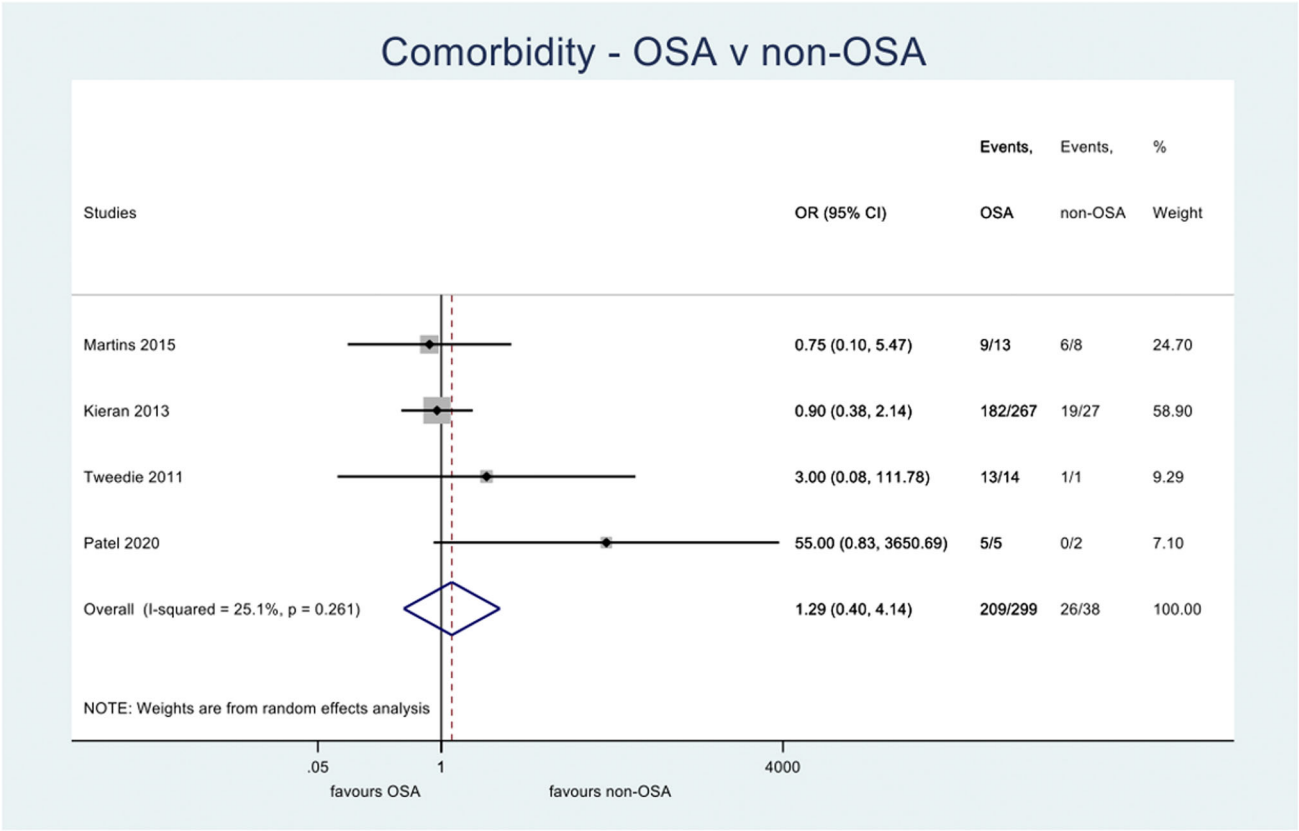

FIGURE 5 The role of comorbidity in PoRCs in pediatric patients following AT surgery in OSA and non-OSA. AT, adenotonsillar; OSA, obstructive sleep apnea; PoRCs, postoperative respiratory complications. [Color figure can be viewed at wileyonlinelibrary.com]

consensus statements, children with comorbidities are suspected of being at a higher risk for PoRCs.

Our statistical finding on comparing the prevalence of abnormalities affecting the respiratory system and craniofacial region between the OSA and non-OSA groups showed no significant differences, thus potentially also suggesting that the association found in the main outcome on PoRCs in OSA compared to non-OSA: the presence of OSA alone could be a risk factor for respiratory complications following AT surgery. However, due to the observed high heterogeneity in PoRC rate in the OSA groups between studies, we performed a leave-one-out analysis, which suggested that the omission of any single study would not influence the overall statistical significance of our results; further research should be carried out to examine the rate PoRCs in specific subpopulations of OSA patients. Although the results may be affected by the characteristics of the studies under examination and deviate in retro- and prospective studies, our main outcome is not likely to be influenced by this. The appearance rates of PoRCs following AT surgeries in pediatric patients with OSA in retrospective studies are consistent with the statistical findings provided by Sanders et al.[30] the only prospective study included in our analysis. According to our results, the severity of OSA is associated with a higher risk for PoRCs: 1.79 times higher in moderate OSA and 4.06 times higher in severe OSA compared to non-OSA patients, in contrast to mild OSA, with a 0.5 times higher occurrence rate for PoRCs. Therefore, no significant difference was found. Additionally, our statistical analysis showed that the risk of major PoRCs is not significantly higher in the OSA group compared to non-OSA children: minor and major respiratory complications occur in the same proportion among OSA and non-OSA children following AT surgery.

In conclusion, an integrated, uniform postoperative monitoring protocol for children with OSA is called for. Our finding that major PoRCs can occur with the same incidence following AT surgery among children with OSA and among those without it along with the statistical finding that the appearance rate of PoRCs is not significantly higher in mild OSA could also suggest a revision of postoperative monitoring and planned ICU admittance to minimize waiting lists and inpatient admittance.

Although each of the consensus statements noted above issued by the IPOG, AAP, AAO–HNS, and ERS take preoperative PSG findings or AHI or SpO_2 values into account to identify high-risk patients and define postoperative care following AT surgeries, their protocols are not identical. Based on our findings, that children with moderate and severe OSA are at higher risk for postoperative adverse events, the severity of OSA should be defined preoperatively. Since PSG is expensive and not widely accessible, quicker informative assets should be defined to obtain more precise information on patients and to be able to form a plan for preoperative

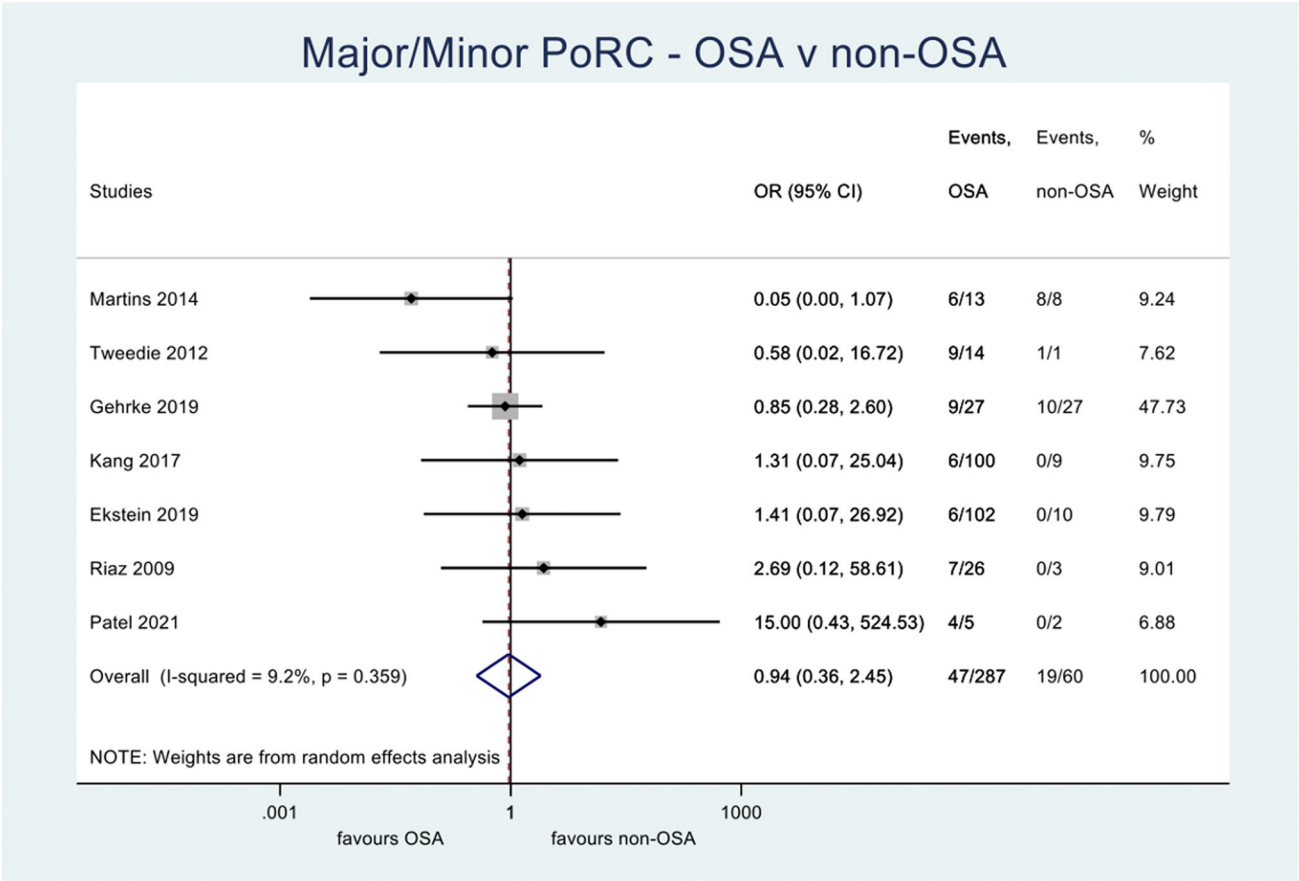

FIGURE 6 Major and minor PoRCs in pediatric patients following AT surgery in OSA and non-OSA. AT, adenotonsillar; OSA, obstructive sleep apnea; PoRCs, postoperative respiratory complications. [Color figure can be viewed at wileyonlinelibrary.com]

investigations and postoperative monitoring. Although there are contradictions regarding unattended screening of pediatric population for OSA, according to Álvarez et al.[37] nocturnal oximetry and the meta-analysis performed by Certal et al.[38] unattended sleep studies could be used to accurately diagnose and predict the severity of OSA in children. With easily accessible and reliable preoperative screening tests not only the waiting period could be shortened, but also PoRCs could be prevented in pediatric population with OSA. Future studies examining the reliability of unattended screening should be performed such as the possible role of preoperative PSG in predicting the severity of PoRCs. Further research should also focus on whether the presence of OSA only requires closer postoperative monitoring or rather a planned ICU admission following AT surgery.

4.1 | Strengths and limitations

To our knowledge, this is the largest systematic review to compare the risk of PoRCs after AT surgery in children with OSA compared to children without it.

This meta-analysis summarizes data on more than 120,000 patients undergoing AT surgery, among them more than 59,000 patients with OSA. We have performed additional analyses according to the severity of OSA and PoRCs to identify the exact groups at risk and to determine how seriously they impact the postoperative period. Although most of the studies did not adjust for confounding factors, we showed that other comorbidities in PoRCs patients were not more common in the OSA group in the included studies, strengthening our hypothesis that OSA alone can increase the risk of complications after AT surgery.

Although numerous studies were included in this meta-analysis, it also has its limitations. Most of the studies are retrospective and did not examine the exact same population or provide sufficient data on the population under examination or any complications. However, all of the included studies used the same classification for moderate and severe OSA (moderate OSA: AHI 5–10; severe OSA: AHI>>10), although the criteria for the diagnosis were different in some of them (mild OSA: AHI 1–5 according to Dalesio[16] and Kang[18]; AHI 2–5 according to Ekstein[17] and Rodriguez-Catalán[23]; and AHI 3–5 according to Camacho).[14] Still, since the appearance rate of PoRCs showed no significant difference in mild OSA compared to non-OSA patients, no further modification was required. Also, it should be noted that the system for individually monitoring OSA children, which can vary from close postsurgery monitoring to a planned

ICU admittance to prevent accidental adverse events, can influence the investigated outcomes. These could have resulted high heterogeneity in some of our statistical analyses, but by conducting a leave-one-out analysis, it was determined that omitting studies that cause heterogeneity does not change the outcome. While an analysis of additional comorbidities suggests that OSA alone can elevate the risk of PoRCs, only four studies provided data for this analysis, thus lowering our confidence in this finding.

Implications for practice: PoRCs are more common after AT surgery in children with OSA, especially in those with moderate or severe disease. At the same time, OSA was not associated with an increased risk of major PoRCs. This affects the monitoring of this population in the postoperative period and suggests a revision of planned ICU admittance by minimizing the waiting list and inpatient admittance.

Implications for research: Interventional studies of postoperative monitoring strategies should be able to minimize the PoRC rate after AT surgery in children, taking into account the severity of OSA, the presence of comorbidities other than OSA and the fact that major complications showed no significant differences in children with OSA compared to children without it.

AUTHOR CONTRIBUTIONS

The roles of authors and contributors have been defined, according to the International Committee of Medical Journal Editors.[12] All the authors have contributed to the concept of the study, and they have read, critically reviewed, and approved the final version of the manuscript. Additional roles include: Fanni Keserű: Preparation of the manuscript, selection of the studies, data extraction and risk of bias assessment; Zoltán Sipos: Statistical analysis; Nelli Farkas: Statistical analysis; Péter Hegyi: Contributed to the concept and design of the investigation and revision of the manuscript; Pálma Edina Benedek: Expert in the field of pediatric sleep medicine, preparation, and revision of the manuscript; Márk Félix Juhász: Preparation of the study protocol and preparation of the data collection sheet; Viktória Adrienn Jászai: Selection of studies and risk of bias assessment; Andrea Párniczky: Preparation of the study protocol.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Additional supporting information can be found online in the Supporting Information section at the end of this article.

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