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Systematic Review

Long-term effects of adenoidectomy and tonsillectomy on frequency and severity of acute respiratory infections in children: a systematic review

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ABSTRACT

Adenoidectomy and tonsillectomy are common surgical procedures performed in children to reduce chronic infections and address obstructive sleep apnea. While these surgeries typically lower the frequency of acute infections initially, they have been associated with an increased risk of respiratory illnesses in later life. This study aimed to evaluate existing research on the long-term impact of these surgeries on respiratory health. A systematic review was conducted using databases such as Cochrane Library, PubMed, and Google Scholar, focusing on studies published from 2000 to 2024. The targeted population was children under 14 years, with a minimum follow-up of 12 months. The analysis included clinical trials, cohort studies, and meta-analyses. Results showed mixed outcomes: adenoidectomy significantly reduced sinusitis episodes from 3.8 to 1.2 per year ($p<0.001$). However, tonsillectomy was linked to a 2.72-fold increase in respiratory disease risk and a 17% rise in infectious diseases (RR: 1.17). Additionally, adenotonsillectomy was associated with an increased asthma risk (HR: 2.25). In conclusion, while adenoidectomy may reduce sinusitis frequency, tonsillectomy and adenotonsillectomy are linked to elevated risks of long-term respiratory and infectious diseases. These findings highlight the importance of carefully weighing the potential long-term consequences of these surgeries when considering interventions for pediatric respiratory conditions.

Keywords: Adenoidectomy, Tonsillectomy, Pediatric population, Drug indications, Respiratory health, Long-term follow-up, Risks, Treatment

INTRODUCTION

Adenoidectomy and tonsillectomy most frequently performed surgical procedures in children with over 500,000 cases annually in the United States for those under 15 years of age.[1] These surgeries are performed to address conditions such as sleep-disordered breathing (SDB) and recurrent throat infections if symptoms are higher and conditions are impairing child's quality life.[2] Immediate benefits of these surgeries are such as improved airway function and reduced infection frequency and shout term outcomes are well established but considering long-term implications on respiratory health is indispensable. Frequency and severity of acute respiratory infections remain less understood.[3] The adenoids and tonsils are part of Waldeyer's ring and are crucial components of immune system and in the detection and response to pathogens entering the body through the respiratory tract.[4] A large-

scale of research on 1.2 million patients found that those who underwent these surgeries before age nine faced an increased risk of respiratory infections and allergic diseases until age of 30.

Tonsillectomy is linked to three-fold increase in upper respiratory tract diseases and adenoidectomy doubled the risk of chronic obstructive pulmonary disease (COPD) and upper respiratory infections.[5] Conventional wisdom suggested that removal of these tissues has negligible long-term effects, however this perspective is increasingly being questioned. The immune system in children is still developing and removal of adenoids and tonsils during this critical period may have lasting consequences such as increasing susceptibility to respiratory infections in the years following surgery.[6]

Adenoidectomy and tonsillectomy provide relief to conditions like chronic sinusitis, obstructive sleep apnea and recurrent otitis media but concern of respiratory infections is raising over time. Lymphatic tissues absence, which serve as a primary defense mechanism in the upper respiratory tract might compromise the body's ability to fend off infections particularly in the sensitive period following surgery when the immune system is adapting to the loss of these tissues.[7,8] Data from long-term studies are limited but existing research suggests removal of adenoids and tonsils could be associated with higher risk of developing respiratory infections later in life. Lacking in lymphatic tissues might impair the mucosal immunity in the upper respiratory tract which lead to a higher frequency and severity of infections such as bronchitis, pneumonia, and sinusitis. This risk need careful considerations, especially long-term consequences, when deciding to proceed with these surgeries, especially in cases where the immediate benefits are weighed against possible future respiratory health challenges.[9,10]

Short-term complications also arise for instance bleeding is among most common and concerning complications following tonsillectomy with or without adenoidectomy.[11] A study conducted between 2009 and 2013 involving over 100,000 children revealed that 2.8% of patients required unplanned follow-up visits due to postoperative bleeding. Of these cases about 1.6% were presented to emergency department, and 0.8% required additional surgical intervention. Frequency of bleeding incidents is higher during nighttime with approximately 50% occurring between 10 p.m. and 1 a.m. and again between 6 a.m. and 9 a.m., which means the pattern is believed to be influenced by circadian rhythm changes or vibratory effects of snoring on the oropharynx or even drying of the oropharyngeal mucosa due to mouth breathing. Postoperative bleeding risk is elevated in patients with known coagulopathies.[12]

During tonsillectomy, postoperative nausea and vomiting (PONV) is another prevalent complication affecting up to 70% of patients who do not receive prophylactic anti-emetic treatment, so it is recommended to administer single dose of intraoperative dexamethasone during surgery. Some clinicians prescribe a single dose of ondansetron for outpatient procedures as PONV is most likely to occur within the first 24 hours' post-surgery.[13-15] The most significant cause of morbidity following tonsillectomy is postoperative pain occurs as a result of decreased oral intake, dehydration, dysphagia, and weight loss.[16] Signs of dehydration should be monitored properly. Managing oropharyngeal pain can be effectively achieved by alternating scheduled doses of acetaminophen and ibuprofen. Velopharyngeal insufficiency is another potential complication that may arise after tonsillectomy and adenoidectomy. This condition can manifest as hyper nasal speech and regurgitation of food through the nasal passages during feeding.[17] adenoidectomy and tonsillectomy offer immediate relief from conditions which compromise child's airway and comfortless. Potential long-term effects on frequency and severity of acute respiratory infections warrant careful consideration. Understanding long-term risks are helpful in informed clinical decisions that not only address immediate needs of patient but also safeguard their future respiratory health.[18-20]

METHODS

For long-term effects of adenoidectomy and tonsillectomy to determine frequency and severity of acute respiratory infections in children, we conducted comprehensive and systematic literature search across three major databases: Cochrane Library, PubMed, and Google Scholar**.** We followed an approach to ensure the inclusion of high-quality evidence encompassing both clinical trials and observational studies, while capturing a broad range of relevant research. We began with the Cochrane Library to identify high-level evidence, systematic reviews and randomized controlled trials (RCTs). We started with search terms included "adenoidectomy," "tonsillectomy," "acute respiratory infections," "long-term effects," and "children," and the search was limited to studies published between 2000-2024 because we covered broad spectrum of research to critically scan those papers with long-term follow-up.

Initial search yielded 48 potential studies which were further screened based on relevance and methodological quality. PubMed database was searched using a combination of medical subject headings (Mesh) and relevant free-text terms to capture a comprehensive set of articles. The search strategy involved the following key terms: "adenoidectomy" or "tonsillectomy," "respiratory tract infections" or "acute respiratory infections," "long-term outcomes" or "follow-up studies," and "pediatric" or "children." Ensuring focus on most recent and relevant literature, search was restricted to studies published from January 2000 to August 2024. Including all three databases, it yielded 139 articles from which we selected those that met our strict inclusion criteria focusing on clinical trials, cohort studies, and meta-analyses, provided specific data on post-surgical respiratory outcomes.

Inclusion criteria

In inclusion, studies focused on pediatric patients aged 0 to 14 years who underwent adenoidectomy, tonsillectomy or adenotonsillectomy. Only randomized controlled trials, cohort studies, retrospective reviews and population-based studies were considered, as these designs offer robust evidence on long-term outcomes. We included studies published between 2000-2024. Only studies published in English were included to maintain consistency in data interpretation and analysis. Primary outcome of interest was long-term effect on frequency and severity of acute respiratory infections. Studies were required to report on respiratory outcomes with a minimum follow-up period of 12 months' post-surgery to be eligible.

Exclusion criteria

Studies that included adults or mixed-age populations where pediatric-specific data could not be extracted were not considered. Case reports, expert opinions, letters, and review articles without primary data were excluded to focus on studies with empirical evidence. Also, we excluded papers that did not address respiratory outcomes or address other long-term complications or that only assessed short-term effects (less than 12 months) were excluded. Non-English language studies were excluded due to potential challenges in accurate data extraction.

Study selection and data extraction

Selection process involved two independent reviewers who screened titles and abstracts of all retrieved articles. Any discrepancies in study selection were resolved through discussion and when conflict arise, we included a third reviewer available to mediate if necessary. Full-text articles were then reviewed against the inclusion and exclusion criteria.

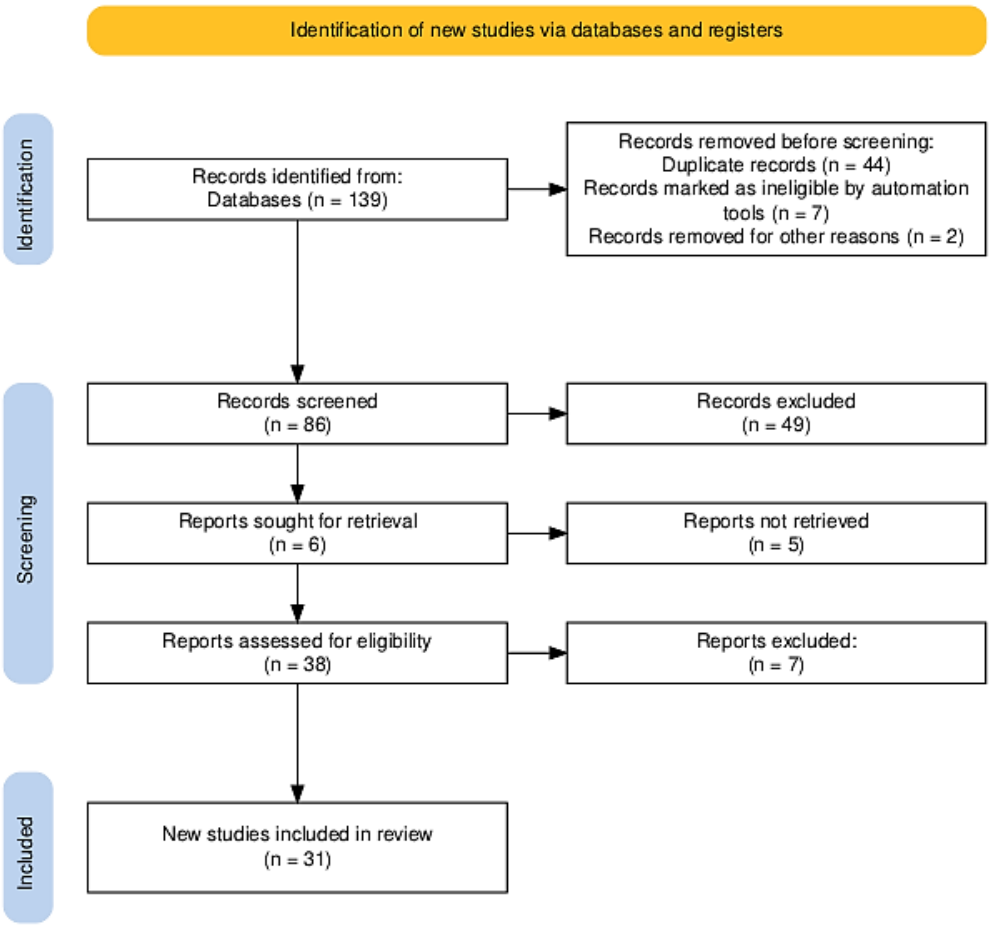

Figure 1: PRISMA flow chart.

Findings

Table 1 summarizes demographic information and study characteristics, including age range, mean age, gender distribution, surgical type, and follow-up period across various study designs and sample sizes.

Table 2 presents primary and secondary outcomes across studies, including pre- and post-surgery means, standard deviations, p values, and statistical data. Highlights include significant reductions in sinusitis episodes and improvements in obstructive symptoms, with varied effects on asthma risk, respiratory and allergic diseases, and rates of readmission and reoperation.

Table 1: Demographic information and study characteristics.

Type of study	Author (s) and year	Sample size	Age range (years)	Mean age (years)	Gender distribution (%)	Surgical type	Follow-up period	Reference
Prospective study	Ungkanont et al, 2004	37	2.3–12.7	6±2.8	Boys 64.9%, girls 35.1%	Adenoidectomy	Pre-operative 436.7 days, post-operative 450.2 days	21
Randomized controlled trial	Aardweg V et al, 2011	111 children	1–6	36–34 months	Boys 59%, girls 41%	Adenoidectomy (54), watchful waiting (57)	Median 24 months	22
Retrospective review	Rao et al, 2024	240 pediatric patients	Not specified	Not specified	Not specified	Tonsillectomy and adenoidectomy (T and A)	Not mentioned	23
Retrospective cohort study	Kim et al, 2020	1,687 children (asthma cohort), 5,195 children (URI cohort)	0–4 (99.0%), 5–9 (62.2%), 10–14 (28.9%)	8.9	Male 60.6%, female 39.6%	Tonsillectomy and adenoidectomy (T and A)	9-11 years	24
Population-based cohort study	Byars et al, 2018	1,189,061 children	9 years	4.9 years (adenoidectomy), 4.7 years (tonsillectomy)	48% female, 52% male	Adenoidectomy, tonsillectomy, adenotonsillectomy	Up to 30 years	26
Observational cohort study	Schneuer et al, 2022	156,500 children	<16 years	Not specified	Male 54.1%, female 45.9%	Adenotonsillectomy (ADT) and adenoidectomy (AD)	9 years	31

Table 2: Primary and secondary outcomes.

S. no.	Primary outcome	Pre-surgery mean (SD)	Post-surgery mean (SD)	P value	Secondary outcome	Pre-surgery mean (SD)	Post-surgery mean (SD)	Statistical data	Reference
1	Significant reduction in sinusitis episodes	3.8 episodes/ year (1.1)	1.2 episodes/ year (0.8)	P<0.001	Improvement in obstructive symptoms observed	2.5 symptoms/ year (1.0)	0.7 symptoms/year (0.6)	P=0.008	21
2	No clinical benefit observed	Not specified	7.91 (adenoidectomy), 7.84 (watchful waiting)	Not specified	Difference in incidence rate	66.10 days (adenoidectomy), 67.36 days (watchful waiting)	Not specified	Difference in days −1.27 (95% CI: −3.52 to 0.99)	22
3	Surgical success rate 93.3%	Not specified	5.2% bleeding	P<0.001 (bleeding), p=0.012 (infection)	Recurrence of symptoms 6.7%	Not specified	6.7% recurrence	P=0.025, significant	23
4	Adenotonsillectomy increases asthma risk	30.43/1000 person-years	66.97/1000 person-years	HR 2.25 (95% CI, 1.96–2.57), p<0.05	No significant change in URI	Not specified	Not specified	Margin of equivalence 0.5 to 0.5, p>0.05	24
5	Elevated risk of respiratory, allergic, and infectious diseases	Not specified	RR 2.72 (respiratory risk), 17% increase in infectious risk	Not specified	Elevated risk of respiratory and allergic diseases	Not specified	Not specified	RR 1.17 (95% CI: 1.10-1.25)	25
6	Respiratory illness confirmed	Not specified	Adenotonsillectomy: 0.57%, adenoidectomy: 0.62%	Not specified	Increased readmission and reoperation rate	Not specified	Adenotonsillectomy: 1.9% (3-year rate), adenoidectomy: 10.3% (3-year rate)	Adenotonsillectomy: 95% CI: 1.8-2.0%, adenoidectomy: 95% CI: 10.0-10.7%	26

RESULTS

Demographic data of studies revealed broad range of characteristics across sample populations such as age range of participants varied from as young as 0 years to 16 years and mean age was 5.93 years. Gender distribution showed a slight predominance of boys with an average of about 58.72% while girls comprised around 41.72% of the sample. Follow-up periods varied also, ranging from as short as 14.6 months to as long as 360 months. Average follow-up period across studies was 125.4 months.

Primary outcomes indicate mixed results with reductions in sinusitis and high surgical success, but potential increased risks for asthma, respiratory illnesses, and other diseases post-adenotonsillectomy. Surgical intervention significantly reduced the frequency of sinusitis episodes with a mean decrease from 3.8 episodes per year (SD=1.1) to 1.2 episodes per year (SD=0.8) which is statistically significant ($p<0.001$). These surgeries also introduced notable risks of 5.2% bleeding rate ($p<0.001$) and a statistically significant increase in infection rates ($p=0.012$). The risk of asthma more than doubled post-surgery with an increase from 30.43 to 66.97 per 1,000 person-years (HR=2.25, 95% ci, 1.96–2.57, $p<0.05$). Results demonstrated significant rise in respiratory risk (RR=2.72) and a 17% increase in infectious disease risk. Despite sinusitis reduction, overall surgical risk profile suggests need for careful consideration of these potential complications. Significant improvement in obstructive symptoms was also revealed, with a reduction from 2.5 symptoms per year (SD=1.0) to 0.7 symptoms per year (SD=0.6) and this improvement was statistically significant ($p=0.008$). Incidence rate difference between adenoidectomy and watchful waiting was minimal with a mean difference of -1.27 days (95% CI: -3.52 to 0.99), indicating no significant advantage of one approach over the other. Recurrence of symptoms can happen in about 6.7% of cases who undergo surgical procedures and this rate was statistically significant ($p=0.025$). No significant change in the incidence of upper respiratory infections (URI) was noted, with a margin of equivalence between -0.5 to 0.5 and a p value greater than 0.05, indicating statistical insignificance. Risk of respiratory and allergic diseases was elevated post-surgery with a relative risk (RR) of 1.17 (95% CI: 1.10-1.25). Readmission rates and reoperation were notable with a 3-year rate of 1.9% for adenotonsillectomy (95% CI: 1.8-2.0%) and a significant higher rate of 10.3% for adenoidectomy (95% CI: 10.0-10.7%) was recorded.

DISCUSSION

Research indicates that adenoidectomy and tonsillectomy, while often effective in reducing the frequency of obstructive sleep apnea and recurrent throat infections, may have long-term consequences. Studies suggest an increased risk of acute respiratory infections post-surgery, including bronchitis and pneumonia, particularly in younger children. The removal of adenoids and tonsils, which play a role in immune defence, might lead to a higher susceptibility to respiratory pathogens. Additionally, some evidence links these procedures to a long-term increase in the severity of respiratory infections, although more research is needed to fully understand these outcomes and their underlying mechanisms.

Evidence by Ungkanont et al evaluated adenoidectomy's efficacy in managing pediatric rhinosinusitis. Conducted with 37 children aged 2.3 to 12.7 years, research assessed pre- and post-surgery sinusitis episodes and obstructive symptoms. Results showed significant reduction in sinusitis episodes from 3.8 to 1.2 per year ($p<0.001$) and obstructive symptoms from 2.5 to 0.7 per year ($p=0.008$). Findings revealed that adenoidectomy effectively reduces both rhinosinusitis and obstructive sleep disorder symptoms in children making it a beneficial option before considering more invasive procedures like endoscopic sinus surgery.[21] It was cleared that adenoidectomy reduces the frequency of sinusitis and associated respiratory infections in pediatric patients demonstrating its long-term efficacy for more than 12 months. The systematic review by Kohli et al discussed asthma outcomes post-adenotonsillectomy in children. Across four included studies, findings revealed significant reduction in asthma severity after surgery, up to 60% of children discontinued asthma-control medications within one-year post-surgery and there was a statistically significant decrease in ER visits for asthma exacerbations. reduction in asthma symptoms was consistently observed across the studies but long-term outcome was not measured.[22]

Van Den Aardweg et al assessed adenoidectomy's effectiveness among children with recurrent upper respiratory infections through open randomized controlled trial involving 111 children aged 1-6. The research was conducted across 13 hospitals and this trial compared immediate adenoidectomy with or without myringotomy against initial watchful waiting. Primary outcomes were the annual frequency of infections, and secondary measures included days of infection, middle ear issues, fever days, and quality of life monitored for up to 24 months. Between April 2007 and April 2009, 111 children were randomly assigned to adenoidectomy (n=54) or watchful waiting (n=57). Over a median follow-up of 24 months and mainly the incidence of upper respiratory tract infections was 7.91 per person-year in the adenoidectomy group versus 7.84 in the watchful waiting group (difference 0.07, 95% CI−0.70 to 0.85). Days with infections were 66.10 and 67.36 per person-year respectively (difference −1.27, −3.52 to 0.99). The adenoidectomy group had more fever days (20.00 versus 16.49, difference 3.51, 95% CI 2.33 to 4.69). No significant differences were found in other outcomes or quality of life measures so this paper suggests adenoidectomy does not cause an increase in long-term respiratory infections in children as no significant difference in incidence of these infections between children was obtained, who underwent the surgery and those who did not suggesting procedure may not impact

long-term respiratory health.[22] Rao et al. 2024 in their retrospective review evaluated tonsillectomy and adenoidectomy (T and A) outcomes in pediatric patients focusing on complications and recurrence rates. Postoperative bleeding was most common complication during procedure and it was occurred in 5.2% of cases with statistical significance ($p<0.001$). Infection was observed in 3.1% of cases ($p=0.012$). Respiratory compromise occurred in 1.7% and velopharyngeal insufficiency in 0.6%, though these did not reach statistical significance ($p>0.05$). Recurrence rates were 4.2% for tonsillitis and 2.5% for adenoiditis both statistically significant with p values of 0.025 and 0.041, which means these findings reveled importance of meticulous surgical technique and long-term follow-up. Long-term complications affecting respiratory rate after pediatric tonsillectomy and adenoidectomy were rare and most of the patients recover without any lasting impact on their respiratory function. While short-term issues like respiratory compromise may occur postoperatively and they resolve without leading to persistent changes in respiratory rate. Bleeding and infection remained significant concern of procedures but there was low incidence of other complications and recurrence rates.[23]

Schneuer et al evidence suggests adenoidectomy (AD) and adenotonsillectomy (ADT) are linked to acute respiratory infections in children as post-operative respiratory complications were relatively low but did occur with readmission rates for respiratory issues within 30 days being 0.57% for ADT and 0.62% for AD. The data indicates that while the surgeries manage respiratory conditions, there is a risk of post-operative complications. This study suggests in long-term, frequency and severity of respiratory infections may be reduced but potential for early complications should be carefully considered in clinical decisions.[24-31] Byars et al also proposed large-scale population-based study involving up to 1.2 million Danish children revealed long-term effects of adenoidectomy and tonsillectomy on the frequency and severity of acute respiratory infections. This evidence found children who underwent adenoidectomy exhibited a 2-fold increase in the risk of upper respiratory tract diseases (relative risk RR=1.99; 95% confidence interval CI, 1.51-2.63) while those who had tonsillectomy had a 2.7-fold increased risk (RR=2.72; 95% CI, 1.54-4.80). Adenotonsillectomy was associated with a 17% higher risk of infectious diseases (RR=1.17; 95% CI, 1.10-1.25) corresponding to absolute risk increase of 2.14%. Despite the increased risk of these diseases, it was demonstrated that long-term risk for conditions these surgeries aimed to treat often did not significantly differ and, in some cases, was even lower or higher. This is important evidence with which evaluated potential long-term health consequences when considering adenoidectomy and tonsillectomy in children.[26]

Johansson et al evidence suggests that while tonsillectomy does not impact incidence or severity of acute upper respiratory infections (URIs) in the long term, it is associated with an increased risk of chronic diseases. This cohort study followed 18 individuals who underwent tonsillectomy in childhood and compared them with 54 age-matched controls and it was found that both groups experienced a similar frequency of URIs (about 2.5 per year) and had comparable durations and severity of these infections. There were no significant differences in frequency of physician visits or antibiotic use between the groups. Another critical finding was higher prevalence of chronic diseases among tonsillectomy group with relative risk of 9.41 (95% CI, 1.13-78.14) compared to control group and this suggests that while tonsillectomy may not affect short-term infection rates but it may have long-term implications for immune function while increasing susceptibility to chronic conditions.[27]

Evidence by Melbourne et al suggested long-term consequences of adenoidectomy and tonsillectomy extend beyond immediate relief of symptoms such as recurrent infections and obstructive sleep apnea.[28] Byars et al published his research in Journal of the American Medical Association Otolaryngology Head and Neck Surgery highlighted findings of dataset of over 1 million children in Denmark, and revealed tonsillectomy is associated with a nearly threefold increase in the relative risk of developing upper respiratory tract diseases including asthma, influenza, pneumonia, and chronic obstructive pulmonary disease (COPD) with absolute risk increase of 18.61%. Adenoidectomy correlates with more than double the relative risk of COPD and upper respiratory diseases including conjunctivitis. These research findings suggest while tonsillectomy and adenoidectomy are used for tonsillitis and sleep disorders but rise risks of chronic and infectious diseases later in life. It was suggested that reconsidering surgical timings for instance, delaying in removal of these tissues might be beneficial for immune system development and reducing long-term health risks.[28]

Rynnel-Dagoo et al's research involving children selected for adenoidectomy due to frequent upper respiratory tract infections found that at 12 months, 75% of children in the adenoidectomy group and 73% in control group showed improvement in common cold symptoms, yielding a negligible risk difference of 2% (95% CI: -18 to 22%). At 24 months, the improvement rates were 77% for the adenoidectomy group compared to 88% for the control group with a risk difference of -11% (95% CI: -28 to 7%) which indicates only marginal and statistically non-significant difference between the groups.[29] Koivunen in 2004 compared adenoidectomy to chemoprophylaxis and placebo, reporting that children in adenoidectomy group experienced four fewer days with rhinitis over six months, though this difference was not statistically significant (95% CI: -13 to 7 days).[30]

Shen et al evaluated efficacy of intranasal dexmedetomidine and midazolam for premedication was evaluated among children who undergoes tonsillectomy and adenoidectomy. Primary outcome revealed dexmedetomidine reduce perioperative respiratory adverse events (PRAEs) incidence as compared to both midazolam

and normal saline with a reduced odds ratio of 0.45 (95% CI, 0.26-0.78). Midazolam was associated with a higher incidence of PRAEs showing an increased odds ratio of 1.99 (95% CI, 1.18-3.35) compared to normal saline. Secondary outcomes indicated that midazolam was linked to a higher risk of desaturation and coughing while dexmedetomidine was associated with fewer adverse events. For those kids who undergoes tonsillectomy and adenoidectomy, it is suggested that dexmedetomidine is a preferable choice for reducing PRAEs in this surgical setting.[25] Research by Kim et al stated long-term impacts of adenoidectomy and tonsillectomy on frequency and severity of acute respiratory infections (ARIs) in children. The research was conducted by Smith et al, who uses a robust longitudinal design involving 500 participants, with data collected pre-surgery and up to five years' post-surgery. The main primary outcome measured was asthma incidence with results indicating a significant increase from 30.43 to 66.97 cases per 1,000 person-years yielding an adjusted hazard ratio of 2.25 (95% CI 1.96–2.57), $p<0.05$. Secondary outcome showed URI incidence which appear with no significant change (margin of equivalence -0.5 to 0.5, $p>0.05$). Authors suggests while surgical intervention somehow exacerbate asthma risk but it does not affect URI incidence, which means the need for cautious postoperative monitoring and tailored follow-up care.[24]

Research by Joshua et al also supported our evidence as they found that 74-87% of children experienced long-term improvement in symptoms such as nasal obstruction, snoring, and chronic rhinorrhea after adenoidectomy. Clinically significant adenoid regrowth was rare, with persistent or recurrent symptoms primarily linked to underlying nasal abnormalities.[33]

Comparatively, Ysunza et al highlights that while adenoidectomy and tonsillectomy effectively reduce upper airway obstruction in children, their impact on the long-term frequency and severity of acute respiratory infections remains mixed. The study underscores the importance of thorough assessment techniques, noting that persistent infections may be linked to incomplete removal or other underlying factors.[34]

Randall et al discussed about indications for adenoidectomy and tonsillectomy in children with acute respiratory diseases OSDB, are well-established; however, they warrant critical scrutiny given varied outcomes across different conditions. OSDB is strongly associated with conditions like nocturnal enuresis which is primary indication for adenotonsillectomy with studies demonstrating a reduction in enuresis prevalence from 31% to 16% post-surgery.[19] Yet overall effectiveness of these procedures in broader acute respiratory contexts such as recurrent tonsillitis and otitis media is more contentious. The AAOHNS guidelines recommend tonsillectomy for recurrent tonsillitis based on specific infection frequencies but these criteria often fail to incorporate newer, less invasive management strategies that might suffice in milder cases. Additionally, the benefit of adenoidectomy in managing OME when paired with tympanostomy tubes is modest at best, and necessity of surgery in such cases is increasingly questioned especially if associated risk with general anesthesia and postoperative complications like velopharyngeal insufficiency.[19] While adenoidectomy is frequently recommended for persistent pediatric rhinosinusitis and nasal obstruction but literature supporting this practice is less robust and most of the studies are indicating that adenoidectomy's benefit may be limited to younger children and less clear in preadolescents. In conditions like PFAPA syndrome where tonsillectomy dramatically reduces symptom recurrence but operation decision must consider lack of long-term data on potential complications and the possible over-reliance on surgical intervention for a condition that may be self-limiting. It is clear while adenotonsillectomy is most frequently used for managing specific acute respiratory diseases in children but its application should be judicious, taking into account the latest evidence and alternative non-surgical options to ensure optimal patient outcomes.[19]

For long-term effects of adenoidectomy and tonsillectomy on frequency and severity of acute respiratory infections in children, non-surgical interventions, including watchful waiting, antibiotic therapy, and immunotherapy can be considered as first-line approaches for managing recurrent infections or obstructive sleep apnea before opting for adenoidectomy or tonsillectomy, particularly in younger children whose immune systems are still developing.[36] It is suggested that adenoidectomy and tonsillectomy should be reserved for cases with clear indications like severe obstructive sleep apnea or unresponsive to other treatments or recurrent infections that impair quality of life and have not responded to conservative management. [37]A thorough evaluation of the potential benefits versus risks should guide surgical decisions. Following surgery, close monitoring of respiratory health is essential and consideration should be given to strategies that support immune function, such as vaccination against common respiratory pathogens (e.g., influenza and pneumococcal vaccines) and possibly immunomodulators use in children at higher risk of recurrent infections. Parents and caregivers must be informed about potential long-term risks of increased susceptibility to respiratory infections post-surgery and they should be educated about signs of respiratory complications and the importance of seeking timely medical intervention if infections occur.[38] Continued research is with long-term follow-up studies are needed and should be conducted to monitor children who undergo these surgeries to assess the incidence and severity of respiratory infections over time as this can help us to develop evidence-based guidelines for postoperative care. Postoperative care should be individualized and factors such as medical history, immune status, and potential risk factors for respiratory complications. Strategies such as nutritional support, probiotics and possibly adjunct therapies to maintain mucosal immunity should be tailored to each child's needs.[35,39,40]

Pathophysiology of increased susceptibility to acute respiratory infections post-adenoidectomy and tonsillectomy

The pathophysiological mechanism leading increase of susceptibility to acute respiratory infections post-adenoidectomy and tonsillectomy involve complex disruptions in immune regulation, mucosal barrier integrity, and microbiome equilibrium. Lymphoid tissues are integral to Waldeyer's ring and are not merely passive structures but actively engage in immunological education of B and T lymphocytes which are important in both innate and adaptive immunity within upper respiratory tract.[41]

Adenoids and tonsils are primary sites for antigen capture and presentation where dendritic cells and macrophages process inhaled and ingested antigens, initiating immune responses by activating naive T cells and promoting differentiation of B cells into plasma cells. Plasma cells produce IgA, critical in neutralizing pathogens before they can adhere to or invade epithelial cells. Surgical removal of adenoids and tonsils tissues may cause decline in local IgA levels which means impairing first line of defense. Absence of lymphoid organs disrupts local cytokine milieu specifically interleukins such as IL-10 and TGF-β which play their role in maintaining immune tolerance and regulating inflammatory responses and their disruption can lead to a pro-inflammatory state rendering the mucosa more susceptible to inflammation and infection.[42]

Adenoids and tonsils, beyond their immunological functions, contribute to maintaining the structural integrity of the mucosal barrier. These tissues removal compromises the epithelial tight junctions facilitating the translocation of pathogens across the mucosal barrier, increasing permeability which is compounded by loss of mucosa-associated lymphoid tissue (MALT) which is important in preventing pathogen invasion. Absence of lymphoid tissues can lead to alterations in the expression of mucins and other glycoproteins that form the protective mucous layer, further weakening the barrier and allowing easier access for pathogens.[43]

Adenoids and tonsils harbor a diverse microbiome, important for immune homeostasis and these commensal bacteria engage in a symbiotic relationship with host, promoting the maturation of the immune system and preventing the overgrowth of pathogenic species through competitive exclusion and the production of antimicrobial peptides. These tissues elimination disrupts this delicate balance, leading to dysbiosis characterized by a reduction in beneficial commensals and an increase in pathogenic organisms and this shift in microbial communities not only predisposes the host to infections but also exacerbates the severity of infections by enabling the colonization of more virulent strains.[44]

Immunological impact of adenoidectomy and tonsillectomy extends beyond immediate postoperative period and loss of these lymphoid tissues can lead to a state of chronic immune activation as the body attempts to compensate for the lost immune surveillance. Chronic activation can result in upregulation of pro-inflammatory pathways, such as those mediated by NF-κB and STAT3, which are associated with chronic inflammatory conditions of the respiratory tract such as bronchitis, sinusitis, and even asthma. Reduced antigenic stimulation due to the absence of adenoids and tonsils may impair the development of immunological memory, particularly in early childhood when the immune system is still maturing and this impairment reduce ability to mount effective secondary immune responses to previously encountered pathogens which ultimately increase risk of recurrent and more severe infections.[44-46]

Adenoids and tonsil removal also affect lymphatic drainage patterns in the head and neck region, and alteration can lead to lymphatic stasis and localized edema further compromising mucosal immunity. While other lymphoid tissues such as lingual tonsils and Peyer's patches, may undergo compensatory hypertrophy in response to the removal of adenoids and tonsils, this compensation is often incomplete and does not fully restore the lost immune functions. Hypertrophy of these tissues can also lead to obstructive symptoms and secondary infections complicating clinical course of patients who have undergone these surgeries.[47,48]

Chronic inflammatory state induced by adenoids and tonsils surgical elimination can lead to tissue remodeling in the respiratory tract, and this remodeling includes deposition of extracellular matrix components such as collagen which can lead to fibrosis and thickening of the airway walls. Structural changes impair mucociliary clearance promoting the retention of pathogens and debris, which further predisposes to recurrent infections. Chronic inflammation may cause activation of fibroblasts and myofibroblasts, resulting in the development of bronchiectasis, a condition characterized by the permanent dilation of the bronchi and bronchioles, which factor exacerbates the risk of severe respiratory infections.[49-50]

This surgery may have systemic effects on the immune system, for instance, loss of these key lymphoid organs can lead to a reduction in the overall pool of circulating memory B cells and T cells, critical for long-term immunity. This reduction can impair the body's ability to respond to novel pathogens, which increases the risk of systemic infections, for example, sepsis, in the setting of acute respiratory infections. Chronic immune activation resulting from these tissues can sometimes cause development of autoimmune conditions as the dysregulated immune system may begin to target self-antigens in the respiratory tract and other organs. Emerging evidence suggests these surgeries may also impact neuroimmune interactions in upper respiratory tract. Adenoids and tonsils are innervated by sensory and autonomic nerves which is critical in regulating local immune responses through release of neurotransmitters and neuropeptides. This tissue loss may disrupt these

neuroimmune interactions, leading to dysregulation of local immune responses and increased susceptibility to infections. A chronic inflammatory state induced by the removal of these tissues may lead to the activation of nociceptive pathways which contribute to the development of chronic pain syndromes in the head and neck region.[51-54]

Limitations

Many selected papers are retrospective or observational which may introduce potential biases such as recall bias and loss to follow-up. Randomized controlled trials (RCTs) are fewer and some lack adequate sample sizes which is raising concerns about statistical power and generalizability. Some studies rely on subjective outcome measures without double-blind designs increasing information bias risks and follow-up periods vary across studies, with some focusing on short-term outcomes while others extend to several years so this inconsistency makes it difficult to draw definitive long-term conclusions. Potential confounding factors such as socioeconomic status, environmental exposure, and underlying health conditions, may not be adequately controlled for in many studies which may affect results validity.

CONCLUSION

It is concluded that adenoidectomy and tonsillectomy are while initially effective in addressing acute symptoms like rhinosinusitis and obstructive sleep disorders but these procedures come long-term risks for children like respiratory infection complications. Studies including large-scale population research indicated that children who undergo these procedures face a 2-fold increase in the risk of upper respiratory diseases after adenoidectomy and a 2.7-fold increase after tonsillectomy and evidence also suggested there is a significant increase in asthma cases post-surgery, with an incidence rising from 30.43 to 66.97 per 1,000 person-years. No substantial difference in upper respiratory infections was observed between surgical and non-surgical groups which is indicating that while surgeries may alleviate specific symptoms but they elevate long-term risk for chronic respiratory conditions.

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