7-2021

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## Recommended Citation

McGuire SR, Doyle NM. Update on the safety of anesthesia in young children presenting for adenotonsillectomy. World J Otorhinolaryngol Head Neck Surg. 2021;7(3):179-185. Published 2021 July. doi:10.1016/j.wjorl.2021.03.003

World Journal of Otorhinolaryngology-Head and Neck Surgery (2021) 7, 179—185

Available online at www.sciencedirect.com

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journal homepage: www.keaipublishing.com/WJOHNS; www.wjent.org

Review Article

# Update on the safety of anesthesia in young children presenting for adenotonsillectomy

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Received 29 January 2021; received in revised form 11 March 2021; accepted 14 March 2021
Available online 30 May 2021

**KEYWORDS**
Anesthesia safety;
Anesthesia for adenotonsillectomy;
Anesthesia in young children

**Abstract** Tonsillectomy with and without adenoidectomy is a frequently performed surgical procedure in children. Although a common procedure, it is not without significant risk. It is critical for anesthesiologists to consider preoperative, intraoperative, and postoperative patient factors and events to optimize safety, especially in young children. In the majority of cases, the indication for adenotonsillectomy in young children is obstructive breathing. Preoperative evaluation for patient comorbidities, especially obstructive sleep apnea, risk factors for a difficult airway, and history of recent illness are crucial to prepare the patient for surgery and develop an anesthetic plan. Communication and collaboration with the otolaryngologist is key to prevent and treat intraoperative events such as airway fires or hemorrhage. Postoperative analgesia planning is critical for safe pain control especially for those patients with a history of obstructive sleep apnea and opioid sensitivity. In young children, it is important to also consider the impact of anesthetic medications on the developing brain. This is an area of continuing research but needs to be weighed when planning for surgical treatment and when discussing risks and benefits with patients' families.


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Peer review under responsibility of Chinese Medical Association.

Production and Hosting by Elsevier on behalf of KeAi

## Introduction

Tonsillectomy with and without adenoidectomy is a frequently performed surgical procedure with >289,000 cases occurring yearly in children <15 years old.[1] Although a common procedure, it is not without significant risk.[2] Risks range from minimal to life threatening and can be related to preoperative, intraoperative, and postoperative factors and events. Special consideration for this procedure

https://doi.org/10.1016/j.wjorl.2021.03.003

is necessary in very young children as there are risks unique to this age group. The purpose of this article is to review the safety of general anesthesia for adenotonsillectomy with a focus on those issues related to young children.

The majority of adenotonsillectomy procedures are performed as ambulatory surgery, with <3% requiring inpatient care.[1] Indications for surgery include recurrent throat infections and sleep-disorder breathing or obstructive sleep apnea.[1] For children 0∼3 years old, the indication for surgery is almost always obstruction, including tonsil and/or adenoid hypertrophy, upper airway obstruction, or sleep disordered breathing.[3] Adenotonsillectomy has been shown to reduce obstructive sleep apnea (OSA) by approximately 70% in healthy pediatric patients.[4]

## Preoperative assessment

Adenotonsillectomy is typically performed with general endotracheal anesthesia. Airway management with a laryngeal mask airway (LMA) is sometimes used for adenoidectomy alone.[5] Preoperative considerations for children undergoing adenotonsillectomy include the child's age, American Society of Anesthesiologists (ASA) physical status, anesthetic history, any associated comorbidities or genetic syndromes, as well as a history of recent illness especially focused on recent upper respiratory infections (URI) in the month preceding surgery. Special considerations must also be given to a history of easy bruising, prolonged bleeding or a family history of bleeding disorders so that an appropriate workup may be completed prior to surgery. Given the increased risk of complications with underlying obstructive sleep apnea (OSA) any signs or symptoms of OSA should be inquired about. In addition, any diagnostic studies evaluating potential complications of OSA, such as pulmonary hypertension or left ventricular hypertrophy, should be reviewed. Physical exam should include an airway exam assessing any anatomic features that may make intubation difficult such as macroglossia, mandibular hypoplasia, micrognathia, retrognathia, maxillary or mid face hypoplasia as well as limited c-spine mobility. A pulmonary exam to check for any wheezing or rhonchi is important, and patients with reactive airway disease should be optimized. Admission after adenotonsillectomy should be considered for children less than 3 years old, patients with a medical co-morbidity, severe OSA, a bleeding diathesis, or families that live an excessive distance from the hospital.

## Sleep-disordered breath and obstructive sleep apnea

Perioperative respiratory events remain one of the major causes of morbidity and mortality in children undergoing adenotonsillectomy.[6] The severity of obstructive sleep apnea remains a major risk factor for the development of perioperative respiratory events such as post operative pulmonary edema, pneumonia, or airway obstruction.[7] Obesity appears to be the most significant factor associated with OSA in children.[4] OSA symptoms include loud snoring, gasps, and pauses in breathing. In addition, some symptoms present differently than adults. Frequently children will present with failure to thrive, issues with behavior or poor school performance, morning headaches, and/or enuresis.[8–11] If indicated a sleep study or overnight oximetry should be considered; however, many children present without these studies and it is imperative to identify children at increased risk so that they can be admitted and appropriately monitored post operatively. The STUBR questionnaire (Snoring, Trouble Breathing and Un-Refreshed, Table 1) was developed as a practical tool to identify children with symptoms consistent with sleep disordered breathing who may be at elevated risk of perioperative respiratory adverse events. The five questions in the survey can be completed in the preoperative assessment and the number of positive answers correlates with perioperative risk.[12] The presence of any 3 STBUR symptoms increased the risk of a perioperative airway event by three fold and by ten fold if all 5 symptoms were present.[12]

Polysomnography remains the gold standard for the diagnosis of OSA with 1∼5 apnea/hypopnea representing mild OSA; 5∼10 moderate OSA and >10 (each facility may have a slightly different scoring system). Since polysomnography may not always be readily available, the McGill oximetry score can also be used to assess for the risk of sleep apnea; however this test is not appropriate for patients with syndromes or neuromuscular disorders because their desaturations could be secondary to central events, not just obstructive ones. Compared to polysomnography, overnight oximetry is readily available at most hospitals. It is simple, inexpensive and can be completed in the patients' home. The score has four levels of severity based on number and depth of desaturation. No desaturations <90% is a score of 1 (no risk); three or more clusters of desaturations < 90% is a score of 2 (mild risk); three or more clusters of desaturations <85% is a score of 3 (moderate risk); and three or more clusters of desaturations <80% is a score of 4 or severe risk. The McGill Oximetry score can be used to estimate the severity of OSA and shorten the treatment process for patients with more severe disease, especially in centers with long waits for polysomnography.

Despite preoperative diagnostic testing and tools to identify high risk patients, some patients may present only after manifesting, an abnormal response in the intraoperative or postoperative period. A difficult mask induction which would suggest high pharyngeal closing pressure,[13,14] excessive respiratory sensitivity to opioids,[15,16] a delayed emergence from anesthesia,[17] or a

**Table 1** Symptoms comprising the STBUR questionnaire (adapted from Tait et al[12]).

| Question | Symptoms |
|---|---|
| "While sleeping does your child …" | 1. Snore more than half the time<br>2. Snore loudly<br>3. Struggle to breath<br>4. Stop breathing during the night<br>5. Wake up felling unrefreshed in the morning |

S: Snoring, T: Trouble, B: Breathing, UR: Un-Refreshed.

persistent oxygen requirement especially during sleep following adenotonsillectomy should alert the provider to the potential for severe OSA.[18–21]

In patients with severe OSA, there have been multiple studies that have shown that there is an increased opioid sensitivity with analgesia at much lower doses than patients undergoing the same procedure but without a history of OSA (T&A for recurrent tonsillitis vs OSA).[22,23] This is likely to be related to an alteration of the mu receptor that occurs with repeated episodes of oxygen desaturation.[22,24–26] The clinical implications are that a standard dose of opioid may in fact be a relative overdose in children with severe OSA. The American Society of Anesthesiologists has published practice guidelines for the perioperative management and assessment of both pediatric and adult patients in the perioperative period.[27] These guidelines recommend the careful selection of intraoperative medications secondary to the increased susceptibility of this patient population to the respiratory depressant airway effects of sedatives, opioids, and inhaled anesthetics. The guidelines also recommend keeping a patient in a monitored setting until they are no longer at risk of postoperative respiratory depression as determined by observing patients in an unstimulated environment, preferably while sleeping. Similarly, the AAP and American Academy of Otolaryngology Head and Neck Surgery Foundation have guidelines for risk assessment and preoperative management of these patients including when polysomnography should be performed.[11,28]

## Upper respiratory infections and general anesthesia

Children experience, on average, 6–8 upper respiratory infections per year and airway reactivity can persist for several weeks after the resolution of symptoms. Risks of general anesthesia in a patient with a current or recent URI include: laryngospasm, bronchospasm, stridor, cough, hypoxia, and unanticipated admission or need for intensive care. When anesthetizing patients with URIs, one of these events occurs >30% of the time in either the operating room or the post-anesthesia care unit.[26] Serious perioperative events, however, such as unplanned admission or need for postoperative ventilation and ICU care occur rarely.[29,30]

Specific URI symptoms and their severity increase the risk of perioperative complications. These include: lethargy, high fever, toxic appearance, abnormal breath sounds or oxygen saturation, productive cough, copious secretions, and nasal congestion. In addition, patient specific risk factors include history of prematurity, younger age, reactive airway disease, and exposure to smoke. Surgeries requiring endotracheal intubation and those involving the airway, such as adenotonsillectomy, are associated with higher risk as well.[29–31] These complications and risk factors need to be considered when evaluating the patient's optimization for surgery. Whether or not to proceed with the procedure is at the discretion of the anesthesiologist in collaboration with the surgeon, patient, and the patient's family.

## Intraoperative events

Anesthesia for adenotonsillectomy most frequently consists of general anesthesia with an endotracheal tube. In young children, an inhalational induction with a volatile anesthetic is performed the vast majority of the time. An inhalational induction allows the IV to be placed without causing the patient any discomfort or distress, and may be technically easier. Once an IV is secured and the plane of anesthesia is appropriate, the patient is intubated. Maintenance of anesthesia includes an inhaled or intravenous agent in addition to analgesics and anti-emetics. Controversy exists over whether deep or awake extubation is preferable. There is no evidence that states that one technique is better than the other and is up to the discretion of the anesthesiologist.[32]

## Airway fires

The risk of airway fires is one of the safety hazards that are common to anesthesiologists and otolaryngologists. Airway fires have been the subject of many anesthesia closed claims.[33] Adenotonsillectomy, which uses electrocautery in close proximity to the endotracheal tube, is one of the surgeries that presents the greatest risk of airway fire due to the close proximity of all three components of the fire triad (oxygen, fuel, and heat from electrocautery).[34] Steps should be taken to prevent trapping of high concentrations of oxygen (closed system like ETT better than open) as well as limit leakage of oxygen. Leakage of oxygen has improved with the transition of uncuffed to cuffed endotracheal tubes in infants and children.[35] Any gauze or sponges used during surgery should be wet to prevent combustion.[36] Oxygen concentrations used in high-risk fire procedures like adenotonsillectomy should be less than 30%[34] and nitrous oxide should be avoided as it is a flammable gas.[37] The ASA task force on operating room fires advises all staff to undergo education, perform drills or simulation and adequately prepare for the management of fires.[33] The management of a potential airway fire includes the stoppage of oxygen flow, removal of flammable agents such as the endotracheal tube and drapes, extinguish the fire with saline and secure the patient's airway.[36]

## Critical events

The incidence of critical complications that require immediate intervention and that could lead to major disability or death during general anesthesia in children is low. Respiratory events are the most common critical events in children.[38–40] One large register in North America found critical adverse events occurred during 0.14% of pediatric anesthetics.[39] However, a large prospective study in Europe showed critical respiratory, cardiovascular, neurologic, and anaphylactic events occurred more frequently and in 4.8% of pediatric anesthetics and sedations.[40] Risk factors for critical events include young age, comorbidities, and higher ASA status.[38–40] The analysis further suggested that children 3 years old and younger should be managed in tertiary care centers by anesthesiologists with pediatric training.[40]

In addition, ENT surgery and snoring, regardless of type of surgery, have been shown to be independent risk factors for adverse events in children.[38,40] When considering perioperative cardiac arrest specifically during non-cardiac procedures, the occurrence is extremely low at 2.9 per 10,000 anesthetics. Only 7.8% of those events were attributed to anesthesia and 88% of patients had a history of congenital heart disease.[41] In regards to death or neurologic injury after tonsillectomy specifically, children that are at risk for OSA have a larger proportion of events that were attributed to apnea, whereas all others had a larger proportion of events attributed to hemorrhage.[2]

## Postoperative events

### Hemorrhage

Another shared safety hazard is the post-operative tonsil hemorrhage. Post-tonsillectomy hemorrhage is divided into primary (first 24 h) and secondary hemorrhage with rates of 0.2%～2.2% and 0.1%～0.3% respectively.[42] Primary hemorrhage is generally more serious because it is usually more profuse and brisk.[43] Secondary hemorrhage commonly occurs between post-operative days 5 and 10 secondary to premature separation of the scab covering the tonsil bed.[44] Post operative tonsil hemorrhage is a surgical emergency and presents many challenges to the anesthesiologist including the risk of aspiration secondary to a stomach full of blood, volume depletion with potential cardiovascular collapse, a potential difficult airway due to blood and edema as well as an anxious patient/family.[45] A thorough review of the previous anesthetic record can provide helpful information regarding the patients' airway, recognizing that the airway may be more difficult secondary to the reasons listed above. The prior record may be helpful in ascertaining prior blood loss and fluid administration as well as medications administered, especially in primary tonsil hemorrhage.

Prior to presentation to the operating room, fluid resuscitation should begin. A patient that has a history of dizziness and orthostatic hypotension may suggest a loss of at least 20% of the circulating blood volume and indicates the need for aggressive resuscitation.[43] The outpouring of catecholamines may mask hypotension in an awake child that becomes evident on induction of anesthesia secondary to vasodilation from induction drugs resulting in profound hypotension. In order to prevent hypotension upon induction, a reduction in the dose of induction agents while continuing to aggressively resuscitate with IV fluids and/or transfusion may be performed. A rapid sequence induction with either succinylcholine or rocuronium will allow for rapid intubation to gain control of the airway to minimize the risk of aspiration. The surgeon should be available to assist, if needed, by holding pressure utilizing a tonsil ball to decrease bleeding and improve visualization and to help secure the airway. Extubation should only occur when the patient is awake and able to control their airway reflexes. Post-tonsillar hemorrhage represents a significant portion of the claims against otolaryngologists but some of the highest awards were not directly related to blood loss but rather to airway complications as a result of the bleeding.[7] This underscores the need for good communication between anesthesiologists and otolaryngologists to ensure a safe and stable airway as well as to minimize morbidity and mortality.

### Analgesia

As enhanced recovery after surgery (ERAS) protocols have become more prevalent, there have been a few pediatric pilot studies and QI projects looking at various opioid-sparing protocols to decrease opioid requirements during and after adenotonsillectomy. These protocols would be very beneficial in the severe OSA patient population where there is increased respiratory sensitivity to inhaled gases, heightened opioid sensitivity, and altered ventilatory control. Opioid sparing protocols are also beneficial given the ongoing opioid crisis as well as intermittent opioid drug shortages occurring secondary to the COVID pandemic. Most of the pilot studies have looked at some combination of oral dextromethorphan, acetaminophen, NSAID's, dexmedetomidine or clonidine, and ketamine.[46,47] There needs to be larger pediatric studies to validate the findings of the initial pilot studies and elucidate the best combination and doses of the various non-opioid adjuncts.

Analgesic medications prescribed postoperatively need to be selected carefully. There is increasing evidence that significant genetic variation exists in regard to drug metabolism, specifically for codeine. Approximately 10% of children have a defect in *CYP2D6* metabolism and are unable to convert codeine to morphine. They, therefore, have no analgesic effect. About 0.5%～2% of children rapidly convert codeine to morphine producing a high serum concentration and a relative overdose. In patients with OSA and opioid sensitivity, this is particularly dangerous. Therefore the Food and Drug Administration (FDA) has published a warning against the use of codeine in children for post-tonsillectomy analgesia.[43]

### Anesthesia and the developing brain

Since 1999, there have been many published animal studies that demonstrated detrimental effects of general anesthetic medications on the developing brain.[48–52] These early studies seemed to generate more questions than answers and continued research is necessary. It was not clear if the doses and lengths of exposures could be extrapolated to what is commonly seen in surgical procedures in children and there are obviously significant anatomical differences in the brain of animals and humans.

Studies have also been conducted in children, with mixed results. Some support the findings in animal studies, particularly in long and/or repeated exposures to anesthesia at high doses.[53–55] Other studies, including randomized trials, do not show any effect on the developing brain.[56,57] Even a single anesthesia exposure at a young age was recently associated with parental report of behavior issues but no difference in general intelligence.[58] It is important to note that it is impossible to eliminate confounding factors in these studies as many of the participants have comorbidities that result in the need for surgery. Additional studies in both children and animals are

ongoing. Many of these studies are supported and facilitated by collaborative organizations such as the International Anesthesia Research Society and the United States Food and Drug Administration's (FDA) "SmartTots"(Smarttots.org).

Given the concern for neurotoxicity, it is reasonable to consider combining procedures that require general anesthesia in young children. Logistically this can be difficult as it often involves coordination between several services. However, studies have found combining procedures to be feasible and to reduce cost.[59,60]

In 2016, however, the FDA issued a warning on the use of general anesthesia in young children.[61] The warning is specific to repeated or lengthy use of general anesthetic and sedation drugs during surgeries or procedures in children less than 3 years old or pregnant women during their third trimester. The medications included in the warning consist of these most commonly used general anesthetic medications for procedures such as adenotonsillectomy. Although adenotonsillectomy would not require a long exposure to general anesthesia, there is always the possibility that a child will require another exposure before the age of 3. It is therefore crucial to weigh this specific risk of anesthesia when evaluating the benefits of proceeding with surgery. Given that the indication for adenotonsillectomy in young children is almost exclusively obstruction and that OSA carries the risk of serious complications, there is often significant benefit in proceeding.

## Conclusions

Adenotonsillectomy remains one of the most common operative procedures performed in children. Despite being a commonly performed procedure, it is not without risk. There are, however, many things that can be done to mitigate these risks. Optimizing the patient pre-operatively, including ensuring no recent URI's, as well as recognizing patients at an increased risk for perioperative complications secondary to OSA or other comorbidities, can help ensure the best possible outcome. Good communication intraoperatively between the anesthesiologist and surgeon can minimize the risk of airway fire and is important in managing any complications that may arise perioperatively. Other safety considerations include weighing the risk *vs* benefits of proceeding with surgery in children less than the age of 3 given the FDA warning regarding the use anesthetics in this patient population. Further research in the area of neurotoxicity as well as opioid sparing anesthetics and ERAS protocols may make this common surgery even safer.

## Declaration of competing of interest

None.

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Edited by Li-Shi Yang