THROAT study: tertiary hospital retrospective observational audit of tonsillectomy

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STATEMENT OF ORIGINALITY

This is to certify that to the best of my knowledge the content of this thesis is my own work. This thesis has not been submitted for any degree or other purpose. The project builds upon the original THROAT study published by Ng et al, but contains no common results, and all statistical analyses were performed de novo.

I certify that the intellectual content of this thesis is the product of my own work and that all the assistance received in preparing this thesis and sources have been acknowledged.

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AUTHORSHIP ATTRIBUTION STATEMENT

The work presented here was developed by the candidate with support from the research team including Professor Alan Cheng and Professor Karen Waters who assisted with development of research questions and gaining ethics approval through the Sydney Children's Hospital Network Ethics Committee. As the candidate, I was responsible for reviewing literature, submitting ethics applications, data collection, statistical analysis and writing of the manuscript.

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As primary supervisor for the candidature upon which this thesis is based, I can confirm that the authorship attribution statements above are correct.

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No content produced by generative AI tools has been used in the preparation of this thesis

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ABSTRACT

Background

Adenotonsillectomy is the most common surgical treatment for paediatric obstructive sleep apnoea (OSA). Evolving patient demographics, diagnostic strategies, and surgical techniques have prompted the need to reassess complication risks and outcome predictors in contemporary practice.

Aims

To evaluate trends in patient characteristics, surgical techniques, and outcomes in paediatric adenotonsillectomy over time; and to identify risk factors for post-operative complications and both reported obstructive sleep disordered breathing (oSDB) cure and PSG-confirmed OSA cure in order to develop a predictive tool for adenotonsillectomy outcomes.

Methods

This retrospective cohort study reviewed 1,716 children undergoing adenotonsillectomy at a tertiary paediatric hospital across two time-separated cohorts. Data were analysed for demographic trends, operative variables, post-operative complications and predictors of OSA resolution, using multivariable regression and subgroup analysis.

Results

The second cohort featured more complex patients, including higher rates of obesity, American Society of Anesthesiologists (ASA) score ≥3, and pre-operative OSA diagnoses. Partial tonsillectomy and coblation use increased, while cold dissection

and oral antibiotic use declined. Despite the increase in patient complexity, general complication rates remained stable. Risk factors for complications included age <2, ASA ≥3, neuromuscular and syndromic conditions, developmental delay and local anaesthetic use. Adenoidectomy increased both complication risk and OSA cure likelihood. Reported oSDB cure rate remained stable while PSG-proven OSA cure rate increased by 38% over time with age 2-6, large tonsils, and absence of comorbidities predicting better outcomes.

Conclusions

Adenotonsillectomy remains an effective treatment for paediatric OSA. Outcomes are influenced by both patient and operative factors. Risk stratification tools such as the proposed STARS model may improve clinical decision-making and resource allocation. These findings support a tailored approach to adenotonsillectomy, balancing benefit and risk based on individual patient profiles.

Keywords

Tonsillectomy; paediatric otolaryngology; post-tonsillectomy haemorrhage; risk analysis; obstructive sleep apnoea.

LIST OF ABBREVIATIONS

AHI – apnoea-hypopnoea index

ASA – American Society of Anesthesiologists

ATs – adenotonsillectomy

BMI – body mass index

CHW – Children's Hospital at Westmead

CPAP – continuous positive airway pressure

EMR – electronic medical record

ENT – Ear, Nose and Throat

IVAB – intravenous antibiotics

LOS – length of stay

NSAIDs – non-steroidal anti-inflammatory drugs

OSA – obstructive sleep apnoea

oSDB – obstructive sleep disordered breathing

PICU – paediatric intensive care unit

PNS – post-nasal space

POAB – (per) oral antibiotics

PRAEs – peri-operative respiratory adverse events

PSG – polysomnogram

PT – partial tonsillectomy

PTH – post-tonsillectomy haemorrhage

TT – total tonsillectomy

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

Tonsillectomy, often accompanied by adenoidectomy, is one of the most commonly performed surgical procedures in children worldwide, and it is considered a routine operation for any Ear, Nose and Throat (ENT) surgeon. Despite its prevalence, there is still much to be learned about the risk factors associated with this procedure, particularly in terms of its impact on medically complex children's health outcomes and how these change over time as diagnostic techniques and operative methods are adapted. Working as an ENT registrar for five years, I have to date been the primary operator on more than 600 tonsillectomy surgeries, and I have seen and managed many cases of complications arising from this type of surgery. Complications affecting children often carry a heavy burden for the patient, their carers and healthcare professionals, not just in a physical sense but also emotionally and financially.

While much research has been done to investigate risk factors for post-tonsillectomy complications in children, there remains controversy in the literature due to conflicting evidence on the safety and efficacy of particular surgical techniques and peri-operative medications, especially as they pertain to specific patient groups. Previous studies have examined risk factors in paediatric populations undergoing tonsillectomy, but these groups often do not include children with significant co-morbidities who require tertiary paediatric centre level care. At our centre at the Children's Hospital at Westmead (CHW), the patient population is made up of those who fall into the geographical catchment area as well as those with complex medical backgrounds who are referred from out of area. Thus, our clinical population covers the spectrum from

otherwise normal children to those with complex medical co-morbidities. Examining the perioperative features of this group enables us to examine how factors specific to certain patients and aspects of the surgical procedure interplay to result in tonsillectomy complications.

Recurrent tonsillitis and obstructive sleep apnoea (OSA) are the two commonest indications for tonsillectomy in children in Australia, with the latter increasing in frequency within the last two decades. The most feared of post-tonsillectomy complications is haemorrhage, described as primary bleeding if occurring within 24 hours of the operation, or secondary bleeding if occurring thereafter. Post-operative respiratory distress is also of significant concern especially in children with OSA, despite the tissue thought to be responsible for the obstruction being removed - evidence that the physiological impact of pre-existing OSA is the major driver for a patient's immediate post-operative respiratory dysfunction. A comprehensive review of the available literature is presented in chapter 2 of the thesis.

This work builds on the previous THROAT study[1], using not just a larger cohort of patients and broadening the variables included in data collection and analysis, but including a second more contemporary cohort. The primary aim of this thesis is to observe the trends in adenotonsillectomy between the two cohorts – cohort 1 from 2010-2014 and cohort 2 from 2023 (12 months) – in terms of patient trends, operative trends and how these have affected outcomes including complications and resolution of OSA. Factors included in the analyses included patient factors such as demographics and co-morbidities as well as operative factors such as surgical

technique and peri-operative medications. The secondary aim is to develop a risk assessment tool based on data gleaned from cohort 1 to pre-operatively identify children who might be most at risk of complication from tonsillectomy as well as those who might have the most to gain in terms of OSA resolution. Using data from the first cohort, binomial logistic regression modelling was used to predict likelihood of post-tonsillectomy complications based on patient and procedure related factors, as well as factors identified that may influence the success rate of tonsillectomy for management of OSA. The model was then tested in the second cohort. These results will enable us to compile guidelines for peri-operative tonsillectomy care for use at CHW, with possible further applications in non-paediatric tertiary centres and even primary care settings in Australia and beyond.

By stratifying patients and predicting outcomes based on their risk factors, we may potentially be able to reduce morbidity associated with the procedure, reduce inpatient admission and recovery time, and overall reduce the burden of complications while identifying children who have the most to gain from the procedure. It allows researchers to better understand the interplay between several uncommon conditions and surgical outcomes using a paediatric tertiary hospital patient population, which has not yet been examined and reported in the literature.

CHAPTER 2: LITERATURE REVIEW

Tonsillectomy is one of the most commonly performed surgical procedures in children worldwide. Each year, an estimated 40,000 tonsillectomies with or without adenoidectomies are performed in children under the age on 15 in Australia[1], with that figure estimated to be over 530,000 in the United States of America (USA)[2]. Techniques and tools have changed significantly over time, and the increase in childhood obesity as well as advancements in pharmacotherapy over the last few decades have seen a shift in the most common indication for paediatric tonsillectomy moving from recurrent acute tonsillitis to obstructive sleep apnoea (OSA)[3]. As a result, the goals of tonsil surgery have changed from managing infective complications to a renewed focus on reducing unnecessary morbidity from post-operative complications[4]. The question remains as to which tonsillectomy method will produce the optimal result for individual patients, and what risk factors need to be identified and managed before children undergo this procedure. This review of the literature aims to provide an overview of paediatric tonsillectomy, to describe common post-tonsillectomy complications and to explore risk factors for these including patient factors such as demographics and co-morbidities as well as operative factors including tonsillectomy technique and peri-operative medications.

2.1 HISTORY AND OVERVIEW OF TONSILLECTOMY

Tonsillectomy involves the surgical removal of the palatine tonsils under general anaesthetic, often accompanied by the removal of the adenoids in children[2]. The earliest tonsillectomies date back to Rome in 40 AD, when Cornelius Celsus described

removal of the tonsil by blunt finger dissection[5]. The Victorian era saw many advancements in instrumentation for tonsil removal, including the early tonsillotome by Physick and the Beck-Mueller's ring, soon leading to the development of Sluder's guillotine[5]. The first widespread tonsil surgeries of the 19th and early 20th Centuries were aimed at removing as much tonsillar tissue in the shortest time possible in what was referred to as a *tonsillotomy*[5]. The indication for these surgeries was predominantly recurrent infection, so it stands to reason that once general anaesthesia was more widely available surgeons began developing methods for removal of the entire infected tonsil. With the aforementioned rise in pharyngeal obstruction as indication for surgery, especially in children, a trend towards tonsillar debulking procedures has emerged[3].

Terminology between methods in contemporary studies varies greatly. Terms such as *extra-capsular tonsillectomy* or *total tonsillectomy* are used to describe the removal of all tonsillar tissue including the fibrous capsule from the overlying pharyngeal constrictor muscle. When a cuff of tonsillar tissue including the fibrous capsule is left, this is referred to as either *tonsillotomy*, *intra-capsular tonsillectomy* or *partial tonsillectomy*. For the purposes of this literature review, 'tonsillectomy' will be used as a general term to refer to the removal of the tonsils and where specified, 'total tonsillectomy' (TT) and 'partial tonsillectomy' (PT) will be used to differentiate between the two methods.

2.2 COMPLICATIONS OF TONSIL SURGERY

Complications from tonsillectomy in children can be categorised by their frequency, severity or affected system. Johnson et al classified common complications by their time of onset[6], namely primary events occurring immediately or within the first 24 hours, delayed events occurring up to two weeks post-operatively, and longer term complications occurring after more than two weeks. This review of the literature will focus on common primary and delayed complications, which include bleeding, anaesthetic and respiratory issues, pain, infection and dehydration. In Australia, the majority of children undergoing tonsillectomy will be admitted overnight for observation[7] especially where the indication for surgery is OSA, however this is not the case in the USA where most procedures are done in an ambulatory setting[2], possibly reducing the visibility of primary complications.

Bleeding

One of the most clinically significant post-tonsillectomy complications is post-tonsillectomy haemorrhage (PTH). Primary PTH occurs in the first 24 hours following surgery, while secondary PTH occurs after 24 hours[8] and represents the majority of bleeding following tonsillectomy[2]. It is hypothesised that primary PTH occurs due to ineffective haemostasis often correlated to lower experience levels of the operating surgeon[9], while secondary PTH may occur as a result of necrotic slough dislodging from the tonsillar fossae, post-operative site infection or idiopathic causes[10]. Rates vary across the literature from 1.6-6.7%[11, 12], with Lowe et al reporting an overall 3.5% bleeding rate using the National Prospective Tonsillectomy Audit (NPTA) of 34,000 patients in England and Northern Ireland[10]. This is the largest primary study to date that

has encompassed all events of bleeding, including those requiring a return to the operating theatre and those managed conservatively. A 2008 review by Blakley proposed that the maximum acceptable rate of PTH should be no more than 2 standard deviations above the mean rate in the literature[13]. The mean was calculated to be 4.5%, and the proposed maximum acceptable rate was deemed to be 13.9%[13].

There is wide variability in what is reported as a PTH throughout the literature[14]. Sarny et al proposed the Stammberger classification for PTH in 2011[15], where the post-operative day (X) on which the bleeding occurred is denoted by T_X and the severity of the bleed is graded from A (blood stained sputum or coagulum with dry underlying mucosa) to E (death as a result of haemorrhage). Unfortunately, its application has been limited in subsequent research, possibly due the retrospective nature of the majority of research in this area which relies on written medical records, making it difficult to classify individual events. Many larger study designs can only accurately capture PTH events if they require readmission or reoperation[9, 16, 17], whereas smaller studies that are able to capture conservatively managed bleeds are subject to bias and not able to carry the same statistical power or generalisability[10]. Studies using reoperation to define PTH are likely to report lower rates than those also including non-operatively managed bleeds, making comparison across the literature difficult[7].

Anaesthetic and respiratory issues

The most frequent peri-operative anaesthetic complications of tonsillectomy include tissue trauma and respiratory events. Laryngoscopy during intubation can cause dental trauma, temporo-mandibular joint (TMJ) dislocation and pharyngeal soft tissue injury,

while the Boyle-Davis gag – used to provide visualisation to the oropharynx during tonsillectomy – can contribute to the same injuries as well as accidental extubation and impaired ventilation by compression of the endotracheal tube (ETT)[6]. Peri-operative respiratory adverse events (PRAEs) may occur such as upper airway obstruction, post-obstructive pulmonary oedema or hypoxaemia[18, 19], and these may require interventions ranging from supplemental oxygen to re-intubation and ventilatory support requiring admission and monitoring in a paediatric intensive care unit (PICU)[20].

Post-operative infection

Lower respiratory tract infections (LRTIs) can occur due to aspiration of blood or secretions or atelectasis from decreased alveolar recruitment[21]. Surgical oedema may cause Eustachian tube dysfunction, particularly when adenoidectomy is performed which can cause a secondary otitis media, either acute or with effusion[2]. Surgical site infection following tonsillectomy is rare but remains a common mis-diagnosis due to the sloughy appearance of the tonsillar fossae during the first two weeks of recovery. Routine post-operative per-oral antibiotics (POAB) were once frequently prescribed to prevent these infections, however the rates of antibiotic prescriptions have fallen since the release of the American Academy of Otolaryngology-Head and Neck Surgery's (AAO-HNS) 2011 Clinical Practice Guideline: Tonsillectomy in Children[22, 23], where routine use was discouraged.

Pain

Effective management of post-operative pain is imperative in patients recovering from tonsillectomy, as the flow on effects of pain in this region include limited oral intake,

dehydration, sleep disturbance, behavioural changes and readmission to hospital[24]. Identification of pain in paediatric patients can be challenging for caregivers due to communication barriers and emotional distress, and several pain rating scales such as the Wong-Baker FACES scale and the FLACC pain scale have been developed and validated as a result[25, 26]. Pain management is further complicated by parental concerns or understanding regarding analgesia and children's refusal of oral medications[2]. Many patients recovering from tonsillectomy experience not just the immediate post-operative pain, but a delayed worsening of pain often around days 5-7 referred to in the literature as the pain peak or post-operative dip[27], the exact cause of which is not well understood.

Dehydration

It is crucial that children recovering from tonsillectomy are able to manage adequate oral intake, facilitated by effective analgesia, to prevent dehydration and need for readmission[28]. Dehydration can also lead to increased pain, developing a vicious cycle when children are unable to manage oral intake due to oropharyngeal pain. Hypovolaemia, whether due to blood loss or decreased oral intake, can be particularly severe in children due to their lower circulating volume compared to adults and vital signs are a poor marker for the degree of volume deficit[28].

2.3 RISK FACTORS FOR COMPLICATIONS

PATIENT FACTORS

Age

Age has been demonstrated to affect the rates of post-tonsillectomy complications in several ways. Lawlor et al. demonstrated a 50% increased risk of total post-operative complications in children under 3 years of age compared to those between the ages of 3-6 years, with a 3 times higher chance of experiencing a complication in the first 24 hours[29]. Cooper et al found that the overall complication rate for children under 2 years was 38% compared to 22% for those between 2-3 years old[30], and that younger children experienced higher rates of respiratory distress in the first 24 hours post-operatively. Hession-Labard et al found that the median age of children readmitted for dehydration was significantly lower than those undergoing tonsillectomy[28].

Multiple studies have shown an increase in both primary and secondary post-tonsillectomy bleeding risk with increasing age on logistic regression[31, 32]. A US national database study by Leung et al identified that children between 5-11 years of age and those over 12 years old were 1.5 and 3 times more likely to experience a bleed than those less than 5 years old[11]. Tomkinson found that patients over 12 years old had 1.5 times increased risk of primary and 3.3 times risk of secondary bleeding compared to those under 12 years of age[9]. Achar et al found a bimodal distribution of age groups experiencing PTH, with a peak at 6-7 years old and another in teenage years[33]. In a patient population where the median age was 7 years old, Goncalves et al found a 3.4 times increased PTH rate for adults compared to children[34], and Harju et al identified that the increased risk of bleeding faced by patients over 15 years of age was consistent

across all surgical indications[35]. Even in a cohort of children under the age of 12, Buckhardt found that the 7-12 year age group had nearly double the risk of PTH than younger children[36].

Gender

It is well established that male patients will experience higher rates of bleeding up to 1.8 times those of their female counterparts[7, 9, 11, 35, 37], despite the underlying reasons being poorly understood. In a 2019 nationwide German database study, Windfuhr et al identified that while rates of PTH requiring a return to theatre were similar between genders under the age of 15, males aged 15-20 years old had haemorrhage rates on average 1.7 times higher than those of female patients[38]. Male gender was not shown to significantly affect rates of other post-tonsillectomy complications.

Ethnicity

Ethnic and cultural factors have shown interesting impacts on a child's post-tonsillectomy complication rate, mainly in populations from the USA. Lavin et al. showed an association between the rate of readmission to hospital for pain following tonsillectomy and having Hispanic ethnicity or speaking Spanish as primary language[39]. In a study by Lloyd et al on demographics of all-cause readmissions following tonsillectomy, African-American children were more likely to be readmitted for pain and dehydration than Caucasian children[40], and Bhattacharyya demonstrated increased readmission and pain rates for African-American and Hispanic children compared to Caucasians[37]. No studies have demonstrated an association between race or ethnicity and PTH. Heller et al identified that following the release of the 2011 guidelines where

polysomnography (PSG) was recommended for children with obstructive sleep disordered breathing (oSDB), higher proportions of Hispanic and Black children underwent tonsillectomy, and the proportion decreased for Caucasian children[41], however this study did not look at complications.

Socio-economic status

In a cross-sectional analysis of over 79,000 cases, increasing household income was associated with decreasing rates of all complications, including revisits to Emergency departments, bleeding, acute pain, fever and dehydration[37]. Lloyd et al examined socio-economic factors of 14,000 paediatric tonsillectomy patients over an 8 year period and identified that low levels of poverty and college educated parents were associated with lower rates of readmission for pain and dehydration[40]. An unexpected finding in Leung's national database study on the risk of PTH related to ibuprofen use was that compared to the Southern region of the USA where poverty rates are highest, the risk of PTH in the North-East region was 1.7 times higher despite this region having the lowest poverty rates[11]. This was not further explored in this study, and there are undoubtedly some confounders present.

Recurrent tonsillitis

While not strictly speaking a comorbidity so much an indication for tonsillectomy, recurrent acute tonsillitis as well as chronic or cryptic tonsillitis with Actinomyces infection has been shown to increase the risk of post-operative complications. Rates of PTH when tonsillectomy is performed for recurrent infection are 1.2-4.5 times higher than for non-infection indications[32, 35, 42, 43], though it is generally agreed that these

patients are on average older that those with oSBD and that this may confound the result. Johnson et al investigated whether pre-operative infection contributed to PTH in a cohort of 1500 children, and found that PTH rates were higher in children with infective symptoms in the 2 weeks prior to surgery[44]. Stephens et al identified that patients with positive bacterial tonsillar cultures pre-operatively had a PTH odds ratio of 3.8 compared to those with negative cultures, and recommended the use of beta-lactamase inhibiting antibiotics in cases of PTH[45]. Recurrent tonsillitis has been shown to be associated with multiple PTH in a case control study by Spektor et al[32], but not in a large retrospective cohort study by McKeon et al[14].

A study by Grasl et al investigated whether pre-operative serum inflammatory markers could be used as a predictor of PTH, and identified elevated fibrinogen level as a risk factor[46]. Elevated plasma fibrinogen can result from chronic oral inflammatory conditions such as Actinomyces infection, and Group A, C and G Streptococcus species can shift the clotting cascade towards fibrinolysis, increasing the tendency to bleed. In addition, they suggested chronic infections of the oral cavity may lead to elevated levels of serum cytokines responsible for hyperaemia and increased blood flow. They calculated a 65% “bleed-free survival” rate for those with elevated fibrinogen levels, compared to 90% for those with normal levels[46].

In a systematic review and meta-analysis by Daskalakis et al, it was proposed that the increased pain reported by children undergoing PT for recurrent tonsillitis rather than obstructive symptoms was due to disruption of the capsule by multiple infections prior to the operation despite the surgeon’s efforts to keep the capsule intact[47].

OSA

oSDB describes a spectrum of abnormalities in the pattern of respiration and oxygenation during sleep due to prolonged partial upper airway obstruction, with OSA representing the most severe cases where demonstrated intermittent complete obstruction of the upper airway occurs[48]. Polysomnogram (PSG) remains the gold standard for diagnosis of OSA, involving overnight monitoring of transcutaneous oxyhaemoglobin saturation, mouth and nasal airflow, electroencephalography (EEG), electrooculography (EOG), electromyography (EMG) and electrocardiography (ECG) [49]. In contrast, oSDB is a clinical diagnosis based on history from caregivers[2]. The apnoea-hypopnoea index (AHI) is defined as any apnoeic or hypopnoeic event lasting two or more consecutive breaths, and is reported as the number of events per hour of sleep[49], with AHI greater than one diagnostic of OSA in children. AHI between 1-5 indicates mild OSA, between 5-10 indicates moderate OSA and AHI>10 indicates severe OSA[48, 50]. These categories may be modified when the study is reported, for example when children with relatively low AHI have significant oxygen desaturation noted on PSG and vice versa[51]. For normal-weight children with oSDB and OSA, adenotonsillar hypertrophy is the leading cause and as such, adenotonsillectomy is recommended as first-line therapy especially when AHI >5 on PSG[48, 52]. Adenotonsillectomy has shown OSA cure rates of up to 80% in normal weight children[2] and while visual grading of tonsil size alone does not predict the degree of obstruction, the combined volume of adenoids and tonsils does predict severity of OSA[53], as demonstrated by Arens et al using magnetic resonance imaging in children with and without diagnosed OSA.

Children with OSA are at higher risk of post-operative complications than those without obstructive issues, with up to 20% experiencing respiratory compromise requiring intervention[54]. Despite removal of the presumed cause of obstruction, children with OSA have still been shown to experience higher rates of PRAEs following adenotonsillectomy[19, 55], with a meta-analysis by De Luca Canto et al identifying an overall odds ratio (OR) for post-tonsillectomy respiratory complications of 4.90 compared to children without OSA[56]. Nixon et al demonstrated marked sleep disturbance, desaturations and obstructive events on PSGs performed on the first night following adenotonsillectomy for OSA. Those with mild OSA (AHI between 1-5 on pre-operative PSG) had an average AHI of 6.9 on post-operative PSG the first night post-adenotonsillectomy compared to 4.4 pre-operatively, and for children with severe OSA the average AHI was 21.5, with no pre-operative scores published[57]. They noted that there was no significant difference in peri-operative medications or volume of adenotonsillar tissue removed between the mild and severe groups. De et al demonstrated that obese children with OSA showed similar obstructive and hypoxic parameters on PSG performed the night following tonsillectomy as their pre-operative studies[58]. While it is accepted that OSA cure rates from adenotonsillectomy are lower for obese children than normal weight (20% vs 80%[2]), the results of these studies suggest that there are other residual drivers of obstruction immediately post-tonsillectomy, such as increased airway collapsibility and abnormalities in arousal responses that are compounded by surgical site oedema[48]. Interestingly, the child with the most severe obstructive events post-operatively in the Nixon study went on to have normal nocturnal oximetry six weeks later[57].

Some predictors of post-tonsillectomy PRAEs for children with OSA have been identified in the literature. Billings et al demonstrated that children with PSG showing AHI>27 events per hour, >18.5 obstructive apnoeas or an oxygen saturation nadir of <72% were at higher risk of post-operative respiratory events requiring interventions such as supplementary oxygen or reintubation[50]. Xiao et al undertook PSG on the night following adenotonsillectomy and found that the McGill oximetry score (MOS, taken from the PSG data) predicted PRAEs better than AHI on the night following adenotonsillectomy, based on multivariate analysis including age[18]. Despite a MOS cutoff for post-tonsillectomy monitoring not specified, their study suggests that simple nocturnal oximetry may provide most of the essential information needed to identify those most in need of post-tonsillectomy monitoring, and strengthens the recommendation that children with moderate to severe OSA be admitted for continuous oxygen saturation monitoring following adenotonsillectomy.

Much of the literature on post-tonsillectomy complications experienced by children with OSA is regarding respiratory events, with far fewer studies focusing on other complications. De Luca Canto demonstrated in their meta-analysis that children with OSA were less likely to experience PTH than those without, calculating an odds ratio of 0.41 for this group[56]. Gerhke et al calculated a secondary PTH rate for children with OSA of 1.9% compared to 0.8% for non-OSA[55], however only complications within the first 24 hours were included, reducing the likelihood of capturing bleeding events and the raising questions regarding the classification of secondary bleeding in their study. Achar et al analysed a group of paediatric patients presenting with post-tonsillectomy complications, finding an increased risk of PTH in those operated on for OSA compared

to tonsillitis; however different data sources were used to identify the number of tonsillectomies performed and the number of PTH presentations in the study timeframe[33].

Obesity

Children with obesity, defined as body-mass index (BMI) greater than 2 standard deviations from the mean or over 95th percentile for age and gender[48], have twice the odds of undergoing adenotonsillectomy than healthy weight children, according to a nationwide-wide audit of perioperative obesity in the United Kingdom (UK) by Burton et al[59]. The authors identified that obese children have nearly 3 times higher rates of snoring and oSDB than even overweight children, likely an interplay between adenotonsillar hypertrophy and features of childhood obesity including increased neck adiposity, increased pharyngeal fat deposits, altered chest wall mechanics, altered respiratory drive and relative macroglossia, in keeping with OSA rates of up to 60% in obese children compared to up to 6% of the general paediatric population[48, 58]. Adenotonsillectomy has higher treatment failure in OSA when children are obese, however it remains first line treatment according to USA guidelines[48], possibly contributing to the over-representation of obese children undergoing the procedure[59].

Obesity not only increases the likelihood of undergoing tonsillectomy, but it also increases the risk of post-tonsillectomy complications such as bleeding, pain, PRAEs and weight gain. Obese and overweight children have higher rates of PTH than normal weight children[43, 44], with McKeon et al identifying an odds ratio for multiple PTH of 2.26 if BMI >85th percentile[14]. Martin et al identified BMI >85th percentile as a risk factor for

prolonged pain, with overweight children experiencing episodes of pain twice as long as healthy weight children[60]. Obese children experience increased rates of intra-operative desaturation, multiple laryngoscopy attempts, difficult mask ventilation and airway obstruction in recovery than non-obese children according to a study by Nafiu et al[61], with the authors also demonstrating a positive correlation between BMI score and the post-operative length of stay. In a randomised controlled trial (RCT) by Katz et al, children across all weight categories showed accelerated weight gain post-adenotonsillectomy compared to watchful waiting for management of OSA[62]. However, a greater proportion of overweight children randomized to surgical management became obese compared to controls (52% versus 21%), leading the authors to suggest that weight gain should be discussed as a significant post-operative complication of adenotonsillectomy in children who are already overweight or obese[62].

Craniofacial and syndromic disorders

Multiple studies have highlighted the increased risks faced by children with complex medical conditions or disorders undergoing tonsillectomy. The presence of complex chronic conditions puts children at nearly double the risk of readmission for dehydration[28]. Children with Trisomy 21 or Down syndrome have a higher risk of OSA, but following tonsillectomy had a morbidity rate of up to 31.5% and a PTH rate of 17.9% in a chart review study by Cottrell et al[63]. It is estimated that only 30-40% of children with Down syndrome will have resolution of OSA symptoms after adenotonsillectomy[48], with some even demonstrating worsening OSA on post-operative PSG[64]. In medically complex children, identified predictors of PRAEs include craniofacial conditions (OR 4.97), cardiac abnormalities (OR 2.07-2.09), airway anomalies (OR 3.19-3.48),

neurological conditions (OR 2.36), genetic disorders (OR 2.04) and a history of prematurity (OR 6.23)[20, 65]. Prematurity and Down syndrome were also associated with increased readmission rates for pain and dehydration[39].

Other comorbidities: asthma, reflux, ADHD, coagulopathies

A number of other comorbid conditions can lead to worse outcomes following adenotonsillectomy in children. Asthma increases the likelihood of readmission for pain and dehydration[39], but was not identified as a predictor for PRAEs following tonsillectomy. Gastro-oesophageal reflux disease (GORD), estimated to affect 7.9% of children undergoing tonsillectomy, increases children's risk of PRAEs including aspiration pneumonitis, hypoxaemia and the need for reintubation[66], while laryngo-pharyngeal reflux (LPR) increases the risk of delayed pain, PTH and longer post-operative stay[67]. Attention deficit hyperactivity disorder (ADHD) was identified as a significant risk factor for PTH with a relative risk (RR) of 8.7[32], however multivariate analyses in other studies have shown a decreased risk, suggesting that other factors were likely to be contributing to bleeding risk in that study[43]. ADHD is associated with increased readmission for pain and dehydration[39]. Pre-operative abnormalities on coagulation blood tests were shown to increase the risk of PTH, however these studies generally include adult patients where medications may be a factor[34]. Pre-operative coagulopathies were identified as a risk factor for readmission in a large retrospective cohort study by Khoury et al[68], but the exact nature of the readmissions associated with coagulopathy was outside the scope of their study.

OPERATIVE FACTORS

Methods of dissection and haemostasis

Perhaps the most contentious area of tonsillectomy research is which method and tools should be used for dissection and how haemostasis should be optimally achieved. Trends in technique and instruments have changed significantly over the past century and despite the vast quantity of studies available, there remains insufficient evidence to declare any single option universally superior. “Cold” methods of tonsillectomy utilise steel instruments such as scissors and the Gwyneth Evans dissector for removal of the tonsils and ligatures or suture ties for haemostasis, while “hot” methods use electrocautery devices or other similarly powered instruments for dissection and haemostasis. These include monopolar diathermy wands, bipolar scissors, bipolar forceps, coblation, and less commonly, laser, harmonic scalpel and radiofrequency ablation.

Several large retrospective studies have reported increased rates of primary PTH with all hot methods when compared to cold dissection[9, 10], with some even reporting higher likelihood of PTH if cold dissection is accompanied with bipolar haemostasis rather than ties[15]. A 2011 Cochrane review by Pinder et al analysed two RCTs comparing cold dissection with monopolar cautery or bipolar cautery, and demonstrated reduced intra-operative bleeding but increased post-operative pain in the cautery arms[69]. The studies were not powered to detect a difference in secondary PTH rates. Despite multiple studies demonstrating lower secondary PTH risk with cold methods, the increased intra-operative blood loss and higher rates of primary PTH are considered hard to rationalise in the younger or small-for-age paediatric patients who have comparatively

lower blood volumes[17]. Cautery methods were associated with increased readmission rates for pain and dehydration when compared to cold dissection and coblation tonsillectomies[39]. In a retrospective cohort study, Shotts et al investigated whether a very low energy transfer (VLET) monopolar of 8 watts would confer a lower risk of PTH requiring reoperation, and found an OR of 0.155 for total PTH and 0.114 for secondary bleeds compared to standard monopolar at 25w[17]. While these results were impressive, the authors noted that the VLET group was around 2 years younger than the standard group, and had differing indications for surgery as well as increased ibuprofen use, potentially confounding results. They also noted that few studies examining the use of cautery actually report the wattage used[17].

The coblation method of tonsillectomy utilises a saline plasma field to degrade cells within target tissues at a low temperature of 40-70°C, and combines ablation with saline irrigation, suction and bipolar cautery in a single wand. Studies have shown increased secondary PTH with coblator compared to cold dissection[9, 10], as well as compared to monopolar cautery[9]. A 2017 Cochrane review by Pynnonen et al analysed RCTs of tonsillectomy by coblation versus other methods, and identified low quality evidence for reduced pain on day 1 post-operatively, no difference in delayed pain, no difference in primary PTH and a modest increase in secondary PTH using coblation with an OR 1.39 and absolute risk of 5% compared to 3.6% for controls[70], far lower than the 13 fold increase reported by Tomkinson[9]. Due to the low quality of evidence reported, the authors remain uncertain of whether or not coblation confers any advantage over traditional techniques, or difference in adverse events.

Total or partial tonsillectomy

PT began to regain popularity in the early 2000s when Koltai et al reintroduced the technique to reduce oropharyngeal obstruction from the tonsils while retaining a barrier over underlying tissues as a means of preventing pain, expediting recovery and reducing complications such as bleeding and infection[71]. They described use of an endoscopic microdebrider to shave away the tonsillar tissue until only a thin layer remained, reporting less pain compared to standard monopolar TT but more intra-operative bleeding and no difference in post-operative complications such as PTH[71]. Since then, the coblator and other instruments such as laser, bipolar and radiofrequency sling have been utilised in PT[72]. Several systematic reviews have been performed comparing PT to TT outcomes, but meta-analyses are limited due to heterogeneity of reported data with multiple methods of both PT and TT included in analyses. A 2020 Cochrane review by Blackshaw et al concluded that PT probably conferred a lower risk of post-operative complications, but the study was unable to determine a difference in clinical effectiveness compared to TT due to the quality of available studies.

By preventing exposure and injury to the pharyngeal constrictor muscles, PT appears to improve pain outcomes for children post-operatively. Systematic reviews by Walton, Zhang and Acevedo have each demonstrated shorter duration of reported pain, fewer doses of analgesia and a quicker return to normal diet compared to TT[72-74]. In the most recent systematic review on the topic which addressed only coblation methods, Daskalakis et al found no difference in severity of early pain but found that PT appeared to prevent the post-operative dip[47]. With regards to bleeding, neither Walton nor Zhang found a difference in primary PTH rates, but both reported significantly reduced rates of

secondary PTH in PT groups[72, 74]. When comparing specific methods of PT , coblator PT had reduced secondary PTH compared to coblator TT, but microdebrider PT showed no difference in secondary PTH compared to cold steel TT[72]. Acevedo et al's systematic review found that low quality studies demonstrated significant differences in PTH rates, but this was not seen in higher quality studies[73]. Sathe et al reported an association between PT and increased post-operative surgical site infections compared to TT in 3 out of 4 RCTs included in their analysis[75], however this was not reported in other reviews.

Zhang et al concluded that PT appears to be as effective in TT in the management of OSA in children[74], however this statement was not supported by other systematic reviews. PT will reduce soft tissue collapse should there be circumferential collapse at the level of the velopharynx, however does not affect the position of the muscular anterior and posterior tonsil pillars, as seen in TT. A drawback of PT is the possibility of tonsil regrowth and need for definitive TT. Rates of regrowth vary from 2-6%[76-78] and appear to be associated with younger age[78] and acute tonsillitis post-operatively[77]. Reoperation puts children at risk of general complications associated with anaesthesia and surgery, as well as specific procedure-related risks. In a Swedish national patient registry cohort study, Odhagen et al demonstrated that the risk of post-operative complications from completion tonsillectomy following PT was greater than that of TT performed as a primary procedure, with a PTH rate of 4% for secondary completion versus 2.5% for primary TT[79]. Bagwell et al studied the cost-effectiveness of tonsillectomy methods and concluded that PT would only become the more cost effective option for management of childhood OSA compared to TT when the regrowth

rate requiring completion tonsillectomy fell below 3.1%, despite its increased rates of readmission form TT[80].

With or without adenoidectomy

The addition of adenoidectomy to tonsillectomy in children is often out of necessity, either due to nasal obstruction at the posterior choanae from adenoidal hypertrophy or the combined contribution of adenotonsillar tissue to velopharyngeal obstruction in OSA[53]. However, it appears to provide some protection from the risk of PTH, according to multivariable analysis[79]. It is worth keeping in mind, however, that children undergoing adenotonsillectomy rather than tonsillectomy may be doing so for management of OSA rather than recurrent tonsillitis, placing them at an already reduced risk of bleeding.

Surgeon factors

The evidence regarding surgeon seniority and complications remains inconclusive. Sarny et al showed a lower PTH rate when performed by registrars in training compared to senior surgeons[15], however the reverse has been demonstrated in studies by Tomkinson with regards to primary PTH rates[9] and others have not found significant differences[10, 31, 34, 35]. Masalha et al investigated whether the surgeon's hand preference influenced the risk of bleeding and concluded that when PTH occurred, it was 9 times more likely to be on the side of the surgeon's non-dominant hand[81]. This study did not consider surgeons' level of experience, so the question remains whether less experienced operators find greater difficulty with their non-dominant hand compared to senior surgeons and whether this affects PTH risk.

Admission criteria

Day-stay, or ambulatory tonsillectomy, is commonplace in the USA with the majority of paediatric procedures being performed on an outpatient basis[2]. In Australia, a steady increase in the proportion of tonsillectomies performed as day-stay procedures has been noted over the past two decades from 2.7% in 2000 to 14.2% in 2020[7]. In Germany, however, inpatient tonsillectomy remains the mainstay with patients admitted for 2-3 days post-operatively[82] , a reduction since the early 2000s where admissions of up to 6 days were routine[42]. It is unclear whether healthcare related costs influence the recommended length of stay post-tonsillectomy across countries.

The decision to perform day-stay over inpatient tonsillectomy is not necessarily a causative factor for outcomes, and according to a nationwide cohort study in the USA children undergoing tonsillectomy as an inpatient have a higher rate of PTH than ambulatory patients[11]. This result suggests that the effect may lie in patient selection and that those selected for day-stay tonsillectomy are appropriately identified as having less risk factors for complications. In addition, the lower rates of primary PTH with contemporary methods compared with cold steel reduces the burden of complications in the first 24 hours. There is the possibility of course that without close monitoring, some post-operative complications occurring in day-stay patients are not recorded or reported to providers, skewing the rate of complications via an observer bias. The higher rates of PRAEs experienced by younger children and those with OSA remain a significant concern, leading to an update in the 2019 American clinical guidelines recommending overnight admission for children under 3 years of age and those with AHI >10 or oxygen

saturation nadir <80%[2]. This highlights the importance for individual patient risk assessment when making the decision to perform day-stay procedures.

Choice of analgesia

Another area of controversy within the literature is the choice of analgesics in post-tonsillectomy pain management. Prior to 2013, codeine was routinely prescribed for post-operative pain control until a US Food and Drug Administration (FDA) report identified 24 codeine-related deaths from respiratory depression, 10 of which were confirmed to be children under the age of 9 years old who had received weight-appropriate doses of codeine post-tonsillectomy[2]. In the majority of these cases, children had a genetic predisposition to ultra-rapid metabolism of codeine to morphine which in combination with a diagnosis of OSA significantly increased the risk of respiratory depression[2, 65]. Since this report, clinical guidelines strongly recommend against use of codeine as well as tramadol and hydrocodone – other opioids metabolised by the same pathway – post-tonsillectomy, but alternate opioid agents are available such as oxycodone have been shown to produce effective pain relief with less sedation[83]. In addition to respiratory complications, opioid analgesia regimens have been shown to increase vomiting and readmissions for constipation in children following tonsillectomy[84, 85]. When reviewing post-tonsillectomy readmission events, Lavin identified that 36% of paediatric patients returning to Emergency departments due to pain had not been compliant with analgesia recommendations, with non-compliance rates higher among those receiving opioid analgesia[39].

Adequate use of paracetamol (acetaminophen in the USA) and non-steroidal anti-inflammatory drugs (NSAIDs) can reduce the need for opioid analgesia post-tonsillectomy. However, concerns regarding increased risk of PTH with ibuprofen use persist despite high levels of evidence advising of their safety[2]. Ibuprofen is a non-selective cyclooxygenase (COX) inhibitor with demonstrated effects on platelet aggregation posing a theoretical increased risk of bleeding, and a 2013 Cochrane review by Lewis et al concluded that there was insufficient evidence to exclude an increased risk of bleeding[85]. The authors found that NSAIDs such as ibuprofen had an OR 1.6 for PTH requiring surgical intervention, but this did not show statistical significance. In a later systematic review encompassing over 300,000 patients, Stokes et al identified a small but statistically significant increased risk of PTH with use of ibuprofen (OR 1.38), and claimed less heterogeneity in their included studies than the Cochrane review[86]. However, 7 out of 12 included studies did not control for age, with some evidence to suggest that ibuprofen use is more common in older children. In a national database study published in 2021, Leung et al identified an upward trend in ibuprofen use post-tonsillectomy from 2% in 2010 to 30% in 2015, alongside an increased rate of PTH from 1.33-1.91% in the same timeframe[11]. This coincided with the release of the 2011 clinical guidelines where evidence was presented demonstrating no significant increase in PTH rates from ibuprofen[22], prompting Leung to propose that the increased ibuprofen use may have come as a result of this evidence, and that use may increase further following the inclusion of a key activity statement in the 2019 clinical guidelines strongly recommending its routine use[2].

An Australian study by Kwok et al found an increase in PTH rates for ibuprofen compared to celecoxib, an oral selective COX-2 inhibitor that does not have the same impact on platelet aggregation but is not recommended for children under 12[31]. Parecoxib is a long-acting COX-2 inhibitor which can be given as a single dose on induction of general anaesthesia for tonsillectomy, with evidence to suggest significantly reduced early post-operative pain, opioid requirement and post-operative nausea and vomiting (PONV) [87], and no increase in the risk of primary or secondary PTH[88]. However, its use is not yet routine in the USA[89] and it is unable to be used as post-operative analgesia owing to its intravenous (IV) route of administration.

Steroids

A single dose of IV steroid is routinely used as part of general anaesthesia for tonsillectomy in children[89], and this been strongly recommended in the US clinical guidelines since 2011[2, 22]. Intra-operative dexamethasone has been shown to decrease rates of PONV by 50%, decrease severity of pain and increase progression to normal diet according to a 2011 Cochrane review[90]. No adverse events were reported in the included studies. The use of post-operative oral steroids has not been routinely recommended, and the evidence for their effectiveness is inconclusive with limited high-quality studies available suggesting no difference in pain scores compared to other analgesia or placebo[91], and no difference in rates of PTH requiring surgical intervention[92]. Other complications from oral steroid use post-tonsillectomy have not yet been assessed.

Antibiotics

Perioperative antibiotic use is strongly discouraged for children undergoing tonsillectomy[2], having been demonstrated to provide no meaningful benefit in terms of infection, PTH or pain in a 2012 Cochrane review[93]. While some included studies reported a reduced incidence of fever with antibiotic use, the authors concluded that this may be a result of positive bias introduced by weaknesses in study design rather than any real effect. When weighed against potential harms of routine antibiotic use such as allergy, gastrointestinal upset, financial cost and antimicrobial resistance, the evidence for reduced incidence of fever was not considered strong enough to justify routine use[2]. Since these recommendations were first made in 2011, antibiotic use has fallen from 42% in 2010 to 16% in 2015[11].

Local anaesthetic

The current guidelines do not provide specific recommendations for intra-operative local anaesthetic in the management of post-tonsillectomy pain, despite high quality evidence supporting its use. A meta-analysis by Sun et al demonstrated less severe pain in children given local injection of bupivacaine to the tonsillar fossae compared to placebo with saline, as well as reduced analgesia requirements and no difference in complications[94]. This finding was supported in a later meta-analysis by Stramiello et al which examined other agents such as lignocaine and ropivacaine. They found similar improvements in immediate post-operative pain scores with local anaesthetic use, as well as pain scores 24 hours later despite duration of action of these agents not expected to last past 6 hours[25]. The authors also found improvement in pain scores regardless of whether infiltration was done before or after dissection[25]. In a systematic

review by the same group, administration of local anaesthetic was associated with longer time until first analgesia dose and reduced need for multiple doses of opioid analgesia[95]. A Cochrane review assessing topical preparations for post-tonsillectomy pain control found that lignocaine-containing sprays appeared more effective than saline sprays in reducing the severity of pain up to 3 days post-tonsillectomy[96], but noted poor quality of reporting in the included studies.

Intravenous fluids

Dehydration remains a common cause for readmission post-tonsillectomy in children[39], and it is confounded by post-operative pain. A quality improvement study by Hession-Laband et al demonstrated an absolute reduction in readmission for dehydration by 82% following the implementation of a peri-operative hydration protocol for ambulatory tonsillectomy in healthy children[28]. Their protocol involved delivering a combined oral and IV volume of at least 1.5 times the standard maintenance fluid rate calculated for the time spent nil by mouth, undergoing tonsillectomy and post-operatively, with discharge criteria not being met until adequate fluids were delivered and children were able to demonstrate ongoing adequate oral intake. Readmissions within 72 hours were seen to fall from 1% to 0.2% across the study period[28], suggesting a prolonged benefit of increased hydration at admission on a child's ability to maintain oral intake following discharge.

2.4 ADENOTONSILLECTOMY AS TREATMENT FOR OSA

Physical health sequelae of OSA in children which have been shown to resolve following tonsillectomy include systemic hypertension[97], pulmonary hypertension[98, 99], cardiomyopathies[100] and failure to thrive[101, 102]. Additionally, obese children with OSA have higher risks of developing diabetes and metabolic syndrome than obese children without OSA[103-105]. The cognitive and behavioural consequences of OSA include nocturnal enuresis, daytime somnolence, irritability, inattention, hyperactivity and learning delays, and tonsillectomy has been demonstrated to significantly improve these quality of life and behaviour measures in children with OSA, even more so than for children suffering from recurrent acute tonsillitis[106].

2.5 CONCLUSION

Though there has been much research done on risk factors for complications of paediatric tonsillectomy in terms of patient-factors, such as demographics and comorbidities, and procedure-related factors, such as technique, instruments and peri-operative medications, there are many areas where the evidence remains conflicted. An area of controversy of most relevance to this research project is which tonsillectomy method confers the greatest advantage to specific patient groups. However, the literature does appear congruent on several points, namely that male gender and increasing age are associated with increased risk of PTH, recurrent tonsillitis as an indication for surgery may result in more pain and higher rates of PTH, and that while cold steel tonsillectomy contributes to less secondary PTH than cautery methods, the increased intra-operative blood loss with cold steel in children cannot be ignored. While

further high-quality studies need to be performed to definitively answer remaining questions, ENT surgeons and other healthcare providers need to be able to draw their own conclusions from the available evidence in terms of what methods will achieve optimal results for their patients. As a mentor once said to me, “the best method is the one that is safest in my hands”.

CHAPTER 3: METHODS

The study follows a retrospective observational design, using data obtained from the electronic medical record to observe the shifting trends in paediatric adenotonsillectomy over time. Data analysed included patient demographics and comorbidities, operative methods and perioperative management, and how these affect the documented complications and the rates of complication and OSA resolution results. The primary outcome measured was the occurrence of post-operative complications, which included subcategories of unplanned admission to PICU, delayed discharge for any reason and readmission for any reason within 2 weeks of surgery. The secondary outcome of interest was resolution of OSA following tonsillectomy, both parent reported and PSG-proven.

Ethical approval

This study was first reviewed and approved by the Sydney Children's Hospital Network (SCHN) ethics board on 3/11/22 (2022/ETH01082) with site specific approval granted by the Children's Hospital at Westmead (CHW) ethics board on 9/1/23 (2022/STE03348). Approval for further data collection was granted by SCHN ethics board on 4/7/24 (2024/ETH00819) with site specific approval granted by CHW on 26/8/24 (2024/STE01988). Letters of approval are supplied as appendices.

DATA COLLECTION

Setting

This study was conducted at CHW, a 340-bed tertiary hospital in Western Sydney, New South Wales, Australia. CHW is the largest paediatric hospital in NSW and is part of the Sydney Children's Hospital Network (SCHN). Data were collected for all cases of tonsillectomy performed between January 2010 and December 2014 for cohort 1, and between January 2023 and December 2023 (inclusive) for cohort 2. The follow-up period was limited to 5 years post-operatively for cohort 1 and to 2 years post-operatively for cohort 2.

Data were collected from January 2023 to May 2023 for cohort 1 and from December 2024 to February 2025 for cohort 2, following ethical board approval. Data collection was performed using the shared SCHN PowerChart electronic medical record (EMR) program, developed by Cerner (Copyright 2022 Cerner Corporation).

Participants

Participants were eligible for inclusion in the study if they were a patient undergoing tonsillectomy at CHW within the relevant study period(s). Participants were identified using Discern Analytics 2.0 (Version 3.36.12), an auditing tool extension of PowerChart. Once identified, participants' clinical information related to their operative encounter was extracted from EMR and collected in a password protected database at the CHW, only available to research team members. Once variables of interest were collected, participants were assigned a study number, and all subsequent analyses used deidentified data.

Table 3.1 – Description of variables collected

Category	Variables collected
Demographics	Age at procedure
	Gender
Co-morbidities	Weight BMI *Z-score for age* *Weight category – underweight, normal, obese*
	OSA severity *AHI* *Severity category – nil, mild, moderate, severe*
	Significant medical conditions *Syndromes, neurological conditions, CPAP requirement etc* *Comorbidity severity category – non-significant, significant* *ASA class*
	Indication for surgery *oSDB* *Recurrent tonsillitis*
Tonsillectomy details	Type of tonsillectomy *Total* *Partial*
	Tonsil size *Brodsky Grade I-IV*[107]
	Tonsillectomy technique *Hot techniques – monopolar diathermy, coblation, bipolar* *Cold techniques – cold steel dissection, microdebrider*
	Haemostasis method *Hot techniques – monopolar, bipolar* *Cold techniques – ties*
	With or without adenoidectomy
	Type of adenoidectomy *Total* *Partial*
	Adenoid size *ACE criteria A0-A4*[108]
	Adenoidectomy technique *Hot techniques – suction monopolar diathermy, coblation* *Cold techniques – curette, microdebrider*
	Local anaesthetic infiltration *If used, pre- or post-excision*
	Dexamethasone
	Intravenous antibiotics
Postoperative stay and discharge details	Length of stay *Planned length of stay* *Actual nights spent in hospital* *If delayed, reason – fevers, pain, poor oral intake, bleeding*
	Admission to PICU *Elective* *Unplanned*
	Oral antibiotics on discharge
Readmission and follow-up details	Readmission *Reason – fevers, poor oral intake, bleeding,*
	Post-tonsillectomy bleed *Primary (<24hr postoperatively) or secondary (>24hr)* *Operative or conservative management*
	OSA cure *Proven OSA cure from sleep study (post-operative AHI)* *Reported oSDB cure from caregiver history*

Demographics

Age in months, body mass index (BMI) z-score and apnoea-hypopnoea index (AHI) score were collected in both continuous numerical score for analysis as well as categorised to allow for tests of association. Age was grouped into 0-2, 2-6 and >6 years old. Gender was recorded as male or female as documented on EMR.

Comorbidities

Weight was grouped into underweight (BMI Z-score <-1.6449 or <5th centile), normal (-1.6449 to 1.6449 or 5th-95th centile) and obese (>1.6449 or >95th centile). Not all children had weight and height recorded at time of surgery, limiting calculation of BMI. In these cases, weight below 1st centile for age was classified as underweight, and above 99th centile was classified as obese. Children with obstructive sleep apnoea (OSA) confirmed on polysomnography (PSG) had their AHI score recorded and a categorised as nil (AHI 0-1), mild (1-5), moderate (5-10) and severe (>10) based on guidelines. Those who underwent oxycapnography screening studies without AHI scoring were assigned to their category based on the physician's report. OSA cure was defined as AHI score <5/hr on postoperative PSG or determined on history from caregivers at follow-up if PSG was not available and only classified as cured if their snoring had stopped completely. Change in AHI was calculated by subtracting pre-operative AHI from post-operative AHI. Comorbidities in addition to OSA that were present at the time of surgery were collected from anaesthetic charts or admission paperwork. In particular, data were collected on syndromic conditions, neuromuscular disorders, craniofacial or airway abnormalities, developmental delay and morbid obesity (with BMI Z-score of 3 or higher). American Society of Anesthesiologists (ASA) class 1-4 was collected from anaesthetic charts or

calculated based on current classification guidelines[109] if absent. The primary indication for surgery was collected from admission documentation, anaesthetic charts or operation reports and classified as obstructive sleep disordered breathing (oSDB) or recurrent tonsillitis.

Tonsillectomy details

Procedural details were collected from documentation in the operations reports. Type of tonsillectomy was recorded as total if described as extracapsular tonsillectomy, or partial if recorded as intracapsular tonsillectomy or tonsillotomy. Tonsil size was recorded according to Brodsky classification, with tonsils considered grade I if filling 0-25% of the posterior oropharynx, grade II if filling 25-50%, grade III if filling 50-75% and grade IV if filling over 75% of the posterior oropharynx[107]. Technique used for tonsillectomy was collected and classified into hot and cold techniques, with hot techniques including monopolar diathermy, bipolar diathermy and coblation and cold techniques including cold steel dissection or microdebrider. Haemostasis method was also collected and classified into hot and cold, with hot including monopolar or bipolar forceps, suction monopolar diathermy or bipolar function of the coblator wand, and cold including ties or packing. If adenoidectomy was performed, further details were recorded including whether this was total or standard adenoidectomy with removal of all adenoidal tissue, or partial adenoidectomy if some adenoidal tissue was preserved to reduce the risk of velopharyngeal insufficiency (VPI). If adenoid size was documented, this was recorded using the A subcomponent of the ACE criteria, with adenoids considered A0 if absent, A1 if filling 1-25% of the nasopharyngeal airway, A2 if filling 26-50%, A3 if filling 51-75% and A4 if filling 76-100% of the nasopharyngeal

airway[108]. Technique used for adenoidectomy was collected and classified into hot and cold techniques, with hot techniques including monopolar suction diathermy and coblation and cold techniques including curettage or microdebrider. Intraoperative medications used were recorded, including local anaesthetic and whether this was infiltrated pre- or post-excision of the tonsils, as well as intravenous dexamethasone and antibiotics, which were given by the anaesthetic team and recorded on anaesthetic charts.

Postoperative stay and discharge details

Information was collected regarding the complications of delayed discharge, admission to paediatric intensive care unit (PICU), unplanned readmission and post-tonsillectomy haemorrhage (PTH, including timing of bleed), as well as a pooled complication outcome hence referred to as "general complication". These outcomes were identified based on clinical documentation either recorded during admission to a hospital within the SCHN or included in documentation from follow-up assessments. If PTH occurred, captured details included primary or secondary bleeds, and whether or not a return to operating theatre was required. Failure of OSA cure was identified when patients had a post-operative sleep study showing persisting OSA with AHI >1, or parents reported no improvement in oSDB symptoms. Proven OSA cure was identified when patients had a sleep study showing AHI <1, while reported oSDB cure was recorded when parents reported no symptoms of oSDB at follow-up. All outcome measures were recorded in categorical form aside from the post-operative AHI.

All patients in the study had length of stay (LOS) recorded as number of nights spent in hospital. Planned LOS was recorded as 'day only' and assigned a value of 0 if patients were deemed suitable for same day discharge, and recorded as overnight if routine post-operative course was expected, with a value of 1. For patients where planned PICU admission was arranged or more than 1 night stay was anticipated, planned LOS was recorded as 'longer than overnight' and given a value of 2. However, significantly comorbid children whose admissions went past 2 nights due to their pre-existing conditions but who experienced no post-operative complications had their planned LOS given the same value as their actual LOS.

For categorical variables with more than two groups such as co-morbidities, tonsillectomy method and reason for delayed discharge, subgroup analyses were performed where possible as well as overall association tests with categories defined as presence or absence of grouping variable. For the outcome measures of any complication and resolution of OSA, only statistically significant analyses were reported in full unless non-statistically significant results were considered clinically relevant.

DATA ANALYSIS

Bias and management of missing data

Given the broad inclusion criteria, this study has a low risk of sampling bias however the retrospective design increases the risk of measurement bias by way of an incomplete medical record leading to potential missing data. Thanks to reliable clinical frameworks at CHW, all tonsillectomy patients receive a follow-up phone call at 2-3 week post-

operatively where major complications such as bleeding are discussed and recorded, as well as in person clinic review if required. However, for the outcome measure of OSA cure, failure of treatment could only be defined if ongoing apnoeas were reported at follow-up with CHW staff, or patients underwent postoperative sleep study or completion tonsillectomy within SCHN, viewable to CHW staff. Given that a subset of children undergoing tonsillectomy at CHW did so out of necessity due to comorbidities requiring tertiary level perioperative care rather than falling within the catchment area, it is possible that long term follow-up for issues related to OSA may have taken place outside of SCHN, raising the possibility of attrition bias for this outcome within our study. Missing data were highlighted and noted in the results where analyses took place using incomplete data sets.

Statistical methods

Statistical analysis was performed using IBM SPSS Statistics version 29.0.1.0 (171), copyright IBM Corporation. Normality of distribution was tested using Shapiro-Wilk test, with normality assumed if $p>0.05$. For non-normally distributed variables with sample size greater than 30, mean and standard deviation were used as measures of central tendency. Figures were presented with one decimal place except where significant differences were found between similar values, and up to two significant figures were presented. Pearson's r was used for correlation of normally distributed variables, and Kendall's tau-b for non-normally distributed variables, with $p<0.01$ used for statistical threshold. For variables that were either normally distributed or where $N>30$, Student's t-test was used to compare means of two groups using $p<0.05$ and 95% confidence intervals as thresholds for significance. Levene's test was used to check homogeneity

of variances, and if violated the Welch's test was used in place of Student's t-test. For variables that were not normally distributed and N<30, Mann-Whitney U test was utilised as a comparator with the same significance thresholds. One-way ANOVA was used to compare means of more than two groups, using $p<0.05$ as statistical threshold. If homogeneity of variances was violated on Levene's test ($p>0.05$), Welch's ANOVA was utilised assuming unequal variances, otherwise Fisher's ANOVA was used. If distribution was not normal, non-parametric one-way ANOVA was performed using Kruskal-Wallis test. For categorical variables, tests of association were performed using Pearson's χ^2, with Fisher's exact test used if groups contained frequencies less than 5, using $p<0.05$ as significance threshold.

DEVELOPMENT OF PREDICTIVE TOOLS

Binomial logistic regression was utilised to predict log odds of categorical outcomes (general complication rate, reported oSDB cure rate, proven OSA cure rate) of cohort 1, using McFadden's R^2 to assess variance and $p<0.05$ as significance threshold. Factors identified in earlier tests of association were inputted into the model, with confounding factors removed if they fell out of significance. Once final factors were selected, predicted probability was calculated and recorded for each participant. The log odds for each risk factor were transformed into the lowest numeric whole number value. For each identified risk factor in a model, participants scored 0 if a particular risk factor was absent or scored the value of the transformed log odds score if present, and the sum of all factors in each model was referred to as their score for that calculator. Complication score (CS), reported oSDB cure score (RS) and PSG-proven OSA cure score (PS) were then calculated for each participant in cohort 1. Score ranges for low, medium and high

likelihood of outcome were defined by the cutoff between lower and middle thirds and middle and upper thirds of the cohort's CS, RS and PS. The actual outcome rate for each calculator's low, medium and high likelihood group was calculated, and compared to the predicted probability of outcomes from the binomial regression model.

Validation of these models was performed by running a binomial logistic regression model on cohort 2 participants, using inputting identified significant factors as identified in cohort 1. McFadden's R^2 was again to assess variance and $p<0.05$ as significance threshold, and predicted probability was calculated and recorded. Using the same transformed log odds scoring as cohort 1, all participants in cohort 2 had CS, RS and PS calculated, and were then assigned to the same low, medium and high likelihood groups as cohort 1. Actual outcome rate was again compared to predicted probability for each calculator per score range group.

CHAPTER 4: RESULTS – shifting trends in adenotonsillectomy

A total of 1409 patients underwent tonsillectomy at the Children's Hospital at Westmead (CHW) between January 2010 and December 2014, and a total of 307 between January 2023 and December 2023.

4.1 PATIENT AND DEMOGRAPHIC TRENDS

A summary of patient factors is presented in Table 4.1, and cohort data is presented separately for the purposes of comparative analyses.

Table 4.1 – Summary of patient factors

Patient factors	Cohort 1 N	Cohort 1 % of cohort (% of group)	Cohort 1 Mean	Cohort 2 N	Cohort 2 % of cohort	Cohort 2 Mean
Age (months)	1409		78.6	307		79.5
Age group (years)						
<2	49	*3.5*		12	*3.9*	
2-6	698	*49.5*		140	*45.6*	
>6	662	*47.0*		155	*50.5*	
Male gender	782	*55.5*		202	65.8	**
Weight category						*
Underweight	77	*5.5*		22	7.8	
Normal	1012	*71.8*		194	*63.2*	
Obese	320	*22.7*		91	*29.6*	
BMI Z-score	525		0.7	279		0.6
Main indication for surgery						***
oSDB	925	*65.6*		271	*88.3*	
Tonsillitis	484	*34.4*		36	*11.7*	
Pre-op sleep study done	479	*34.0*		138	*45.0*	***
OSA category						**
Nil^	949	*67.4*		178	*58.0*	
Mild	116	*8.2*		39	*12.7*	
Moderate	132	*9.4*		27	*8.8*	
Severe	212	*15.0*		63	*20.5*	
Preoperative AHI	379		17.3	110		22.7*
CPAP prescribed	49	*3.5*		50	*16.3*	***
Comorbidities present	345	*24.5*		77	*25.1*	
ASA class						***
1	588	*41.7*		58	*18.9*	
2	618	*43.9*		172	*56.0*	
3	200	*14.2*		77	*25.1*	
4	3	*0.2*		0	*0*	
5+	0	*0*		0	*0*	
Tonsil grade						**
1-2	309	*21.9*		93	*30.3*	
3-4	1100	*78.1*		214	*69.7*	
Adenoid grade						***
1-2	306	*(24.8)*		175	*57.0*	
3-4	923	*(75.2)*		132	*43.0*	

SD = standard deviation, BMI = body mass index, oSDB = obstructive sleep disordered breathing, ASA = American Society of Anesthesiologists, OSA = obstructive sleep apnoea, AHI = apnoea-hypopnoea index, CPAP = continuous positive airway pressure

^Includes those who did not undergo sleep study

* $p<0.05$

** $p<0.01$

*** $p<0.001$

Demographics

The average age of patients undergoing tonsillectomy at CHW was 78.6 months (SD 41.5, range 6-212) in cohort 1, and 79.5 months (SD 42.2, range 15-237) in cohort 2, with no difference in any age groups between cohorts: 3.5% of children in cohort 1 vs 3.9% in cohort 2 were under 2 years of age, 49.5% vs 45.6% were between 2-6, and 47.0% vs 50.5% were over 6 years of age. Age showed a non-normal distribution for both cohorts with a skew of 0.87 for cohort 1 and 1.04 for cohort 2 (Figure 4.1). 55.5% vs 65.8% were male in cohort 1 and 2 respectively ($p<0.001$, $\chi^2(1)=10.9$).

Results for weight

71.8% vs 63.2% of children were considered normal weight in cohort 1 and 2 respectively, but children in cohort 2 were more than three times as likely to be morbidly obese, defined as Z-score greater than 3.0, compared to cohort 1 (3.3% vs 1.1%, RR=3.1, $\chi^2(1)=8.4$, $p=0.004$). 5.5% vs 7.2% were underweight in cohort 1 vs cohort 2 and 22.7% vs 29.6% were obese in cohort 1 vs 2 ($\chi^2(2)=9.0$, $p=0.01$), outlined in Figure 4.2. 525 children in cohort 1 and 279 in cohort 2 had a BMI and corresponding Z-score recorded, with no difference in mean BMI Z-score between groups (0.67 for cohort 1 (SD 1.5, range -5.8-6.3) vs 0.60 in cohort 2 (SD 1.5, range -5.3-5.1), NS). BMI Z-score for both cohorts showed non-normal distribution with a skew of -0.44 for cohort 1 and -0.35 for cohort 2 (Figure 4.3). Z-score showed a mildly positive correlation with age for cohort 1 (Kendall's Tau-b(525) = 0.20, $p<0.001$) and cohort 2 (Kendall's Tau-b(279) = 0.11, $p=0.009$). Mean Z-score did not differ between genders for either cohort.

Figure 4.1 – Distribution of age in months by cohort

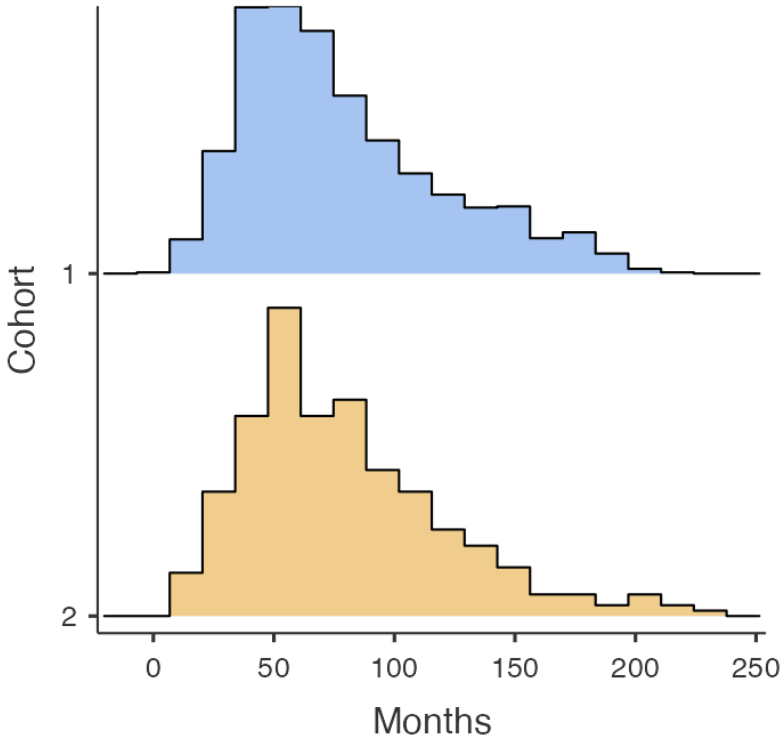
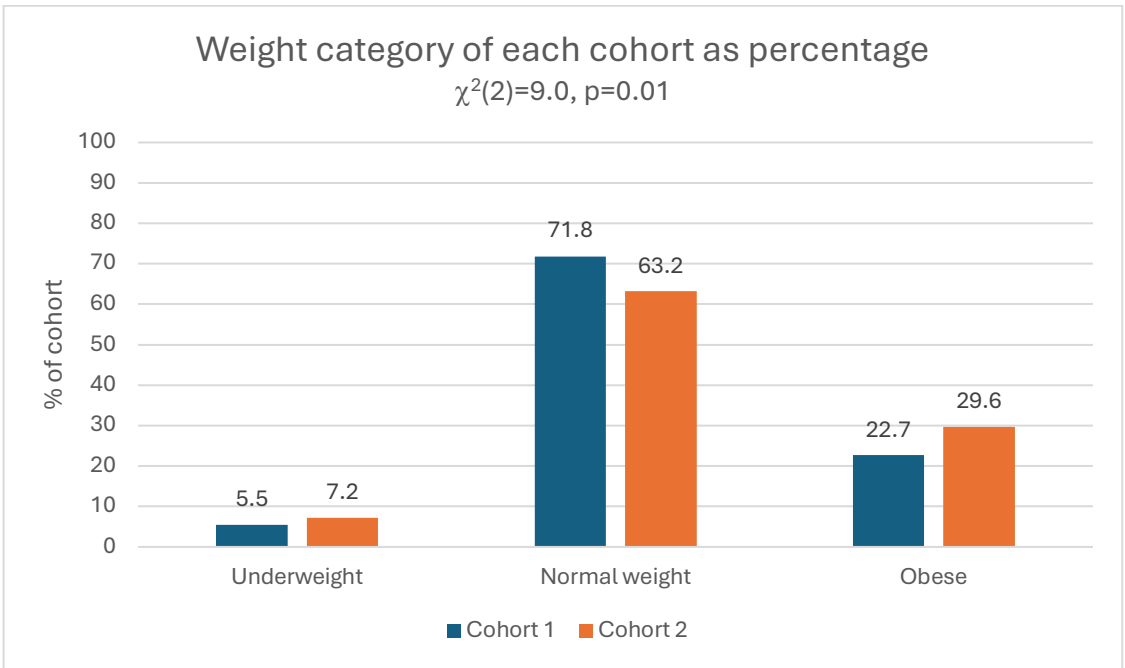


Figure 4.2 – Weight category by cohort



Results for indication for surgery

Obstructive sleep disordered breathing (oSDB) was the most common primary indication for surgery in both cohorts compared to recurrent tonsillitis, increasing from 65.6% in cohort 1 to 88.3% in cohort 2 ($\chi^2(1)=61.1$, $p<0.001$). In cohort 1, those undergoing surgery for oSDB were on average 21.2 months younger than those having surgery for tonsillitis (71.3 vs 92.5 months, Welch's t=-8.9, $p<0.001$), and oSDB was more than three times as likely to be the indication for surgery in children under 2 than recurrent infection (4.6% vs 1.2%, RR=3.8, $\chi^2(1)=11.0$, $p<0.001$). There was no relationship between age and indication for surgery seen in cohort 2. Underweight children in cohort 1 were more likely to undergo surgery for oSDB than normal weight or obese children (76.6% vs 65.0%, RR=1.2, ($\chi^2(1)=4.4$, p-0.04), but this was not observed in cohort 2.

Results for OSA

34.0% vs 45.0% of children underwent pre-operative sleep study in the form of polysomnography (PSG) or screening study in cohort 1 and 2 respectively (RR=1.3, $\chi^2(1)=13.1$, $p<0.001$), but the proportion of positive studies between cohorts was unchanged. 32.6% in cohort 1 vs 42.0% in cohort 2 had a pre-operative diagnosis of OSA (RR 1.3, $\chi^2(1)=9.8$, $p=0.002$), with OSA categories in cohort 1 and cohort 2 as follows: mild OSA 8.2% vs 12.7%; moderate OSA 9.4% vs 8.8%; severe OSA 15.0% vs 20.5% ($\chi^2(2)=13.8$, $p=0.003$), outlined in Figure 4.4. Average AHI in cohort 1 was 17.3 (SD 20.1, range 0-210) vs 22.7 in cohort 2 (SD 28.0, range 0.2-185, NS). AHI showed non-normal distribution with a skew of 3.9 for cohort 1 and 2.8 for cohort 2 (Figure 4.5). The prescription of continuous positive airway pressure (CPAP) increased from 3.5% to

16.3% in cohort 1 vs 2 ($\chi^2(1)=76.1$, $p<0.001$), with a corresponding increase (10.7 vs 38.8%) in the proportion of children with a diagnosis of OSA being prescribed pre-operative CPAP in cohort 1 vs 2 ($\chi^2(1)=56.9$, $p<0.001$). Boys in cohort 1 had a higher rate of OSA overall compared to girls (34.9% vs 29.7%, RR=1.18, $\chi^2(1)=4.4$, $p=0.04$), not observed in cohort 2. Those with OSA in cohort 1 were on average 11.6 months younger than those without (70.7 vs 82.3, $p<0.001$, 95% CI: 7.0-16.2), with children under 2 years of age in cohort 1 being more than twice as likely to have a diagnosis of OSA than those over 2 (65.3% vs 31.5%, RR=2.1, $\chi^2(1)=24.6$, $p<0.001$), and nearly four times as likely to require CPAP than older children (12.2% vs 3.2%, RR=3.9, $\chi^2(1)=11.6$, $p<0.001$).

Results for comorbidity

40.0% vs 64.5% of children were listed as having a comorbidity in cohort 1 vs 2 respectively ($\chi^2(1)=61.1$, $p<0.001$). This was matched by the proportions of children categorised into higher American Society of Anesthesiologists (ASA) classes. ASA classes in cohort 1 vs cohort 2 were as follows: ASA 1 41.7% vs 18.9%; ASA 2 43.9% vs 56.0%; ASA 3 14.2% vs 25.1%; ASA 4+ 0.2% vs 0.0% ($\chi^2(3)=62.2$, $p<0.001$), outlined in Figure 4.6. ASA class 3+ was considered to represent significant comorbidities and children were separated into significant (ASA 3+) and non-significant (ASA 1-2) groups. Children in cohort 2 were nearly 75% more likely to be classified as having a significant ASA score than those in cohort 1 (25.1% vs 14.4%, $\chi^2(1)=21.0$, $p<0.001$).

Figure 4.3 – Distribution of BMI as Z-score by cohort

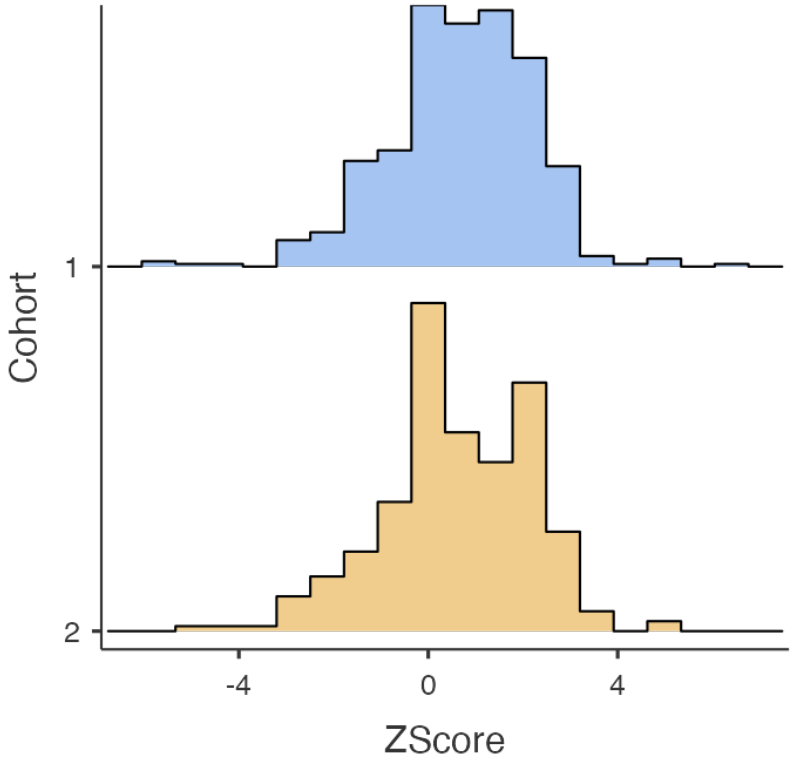


Figure 4.4 – OSA severity by cohort

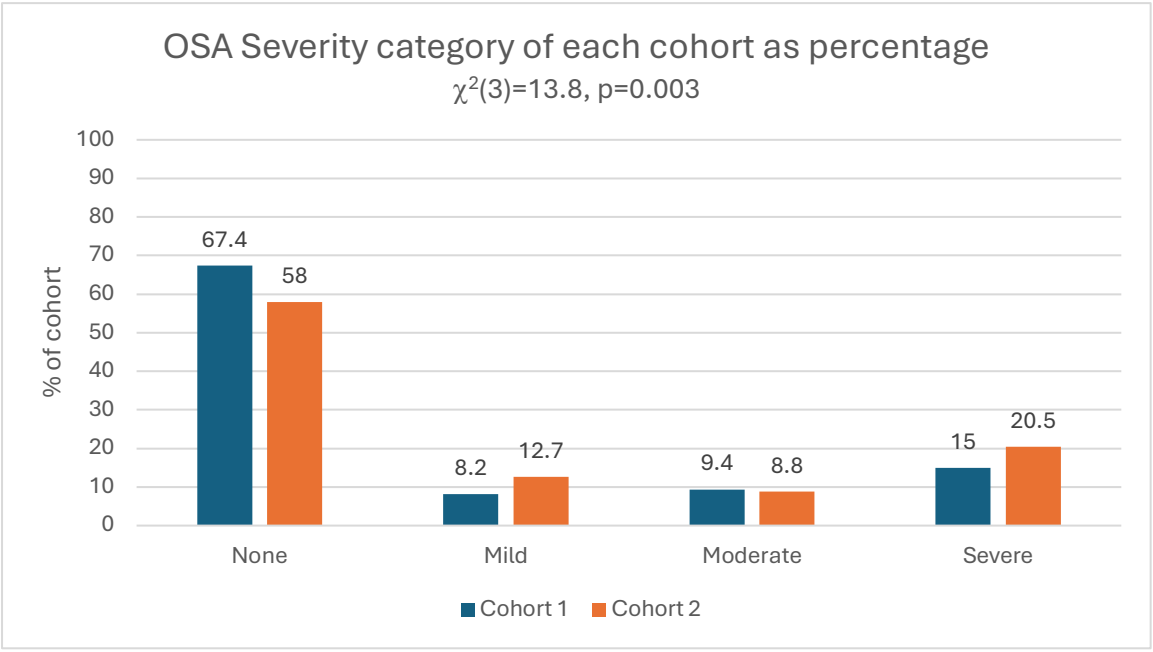


Figure 4.5 – Distribution of AHI by cohort

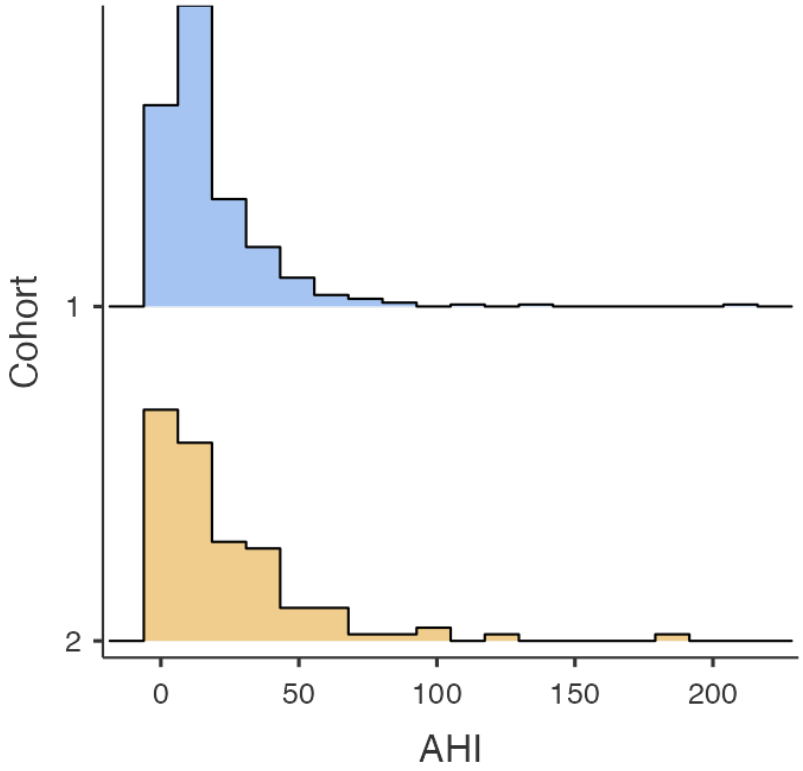
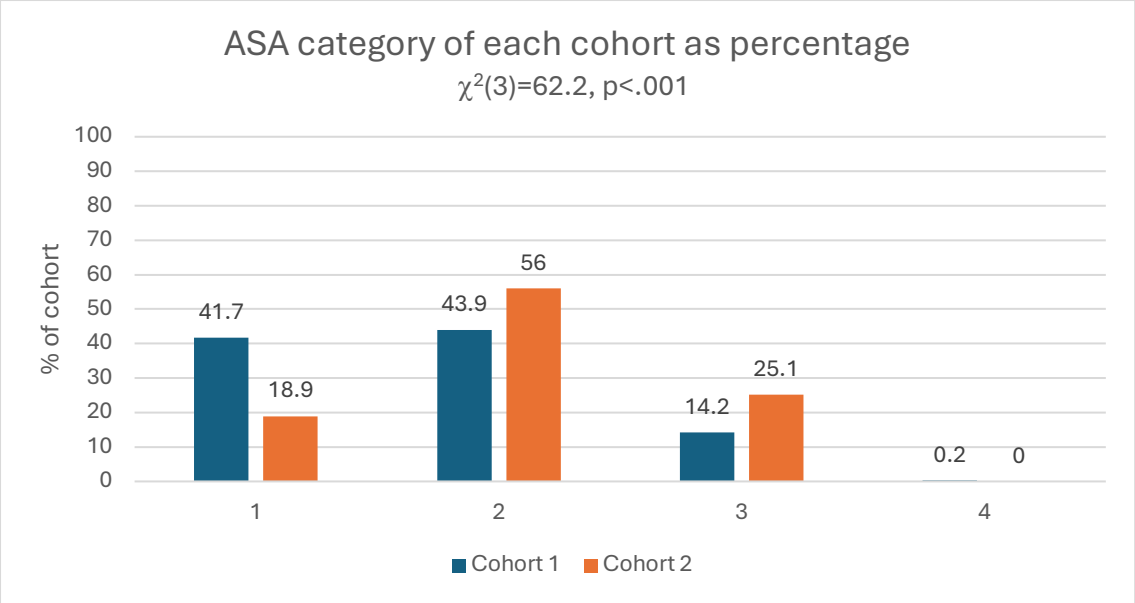


Figure 4.6 – ASA category by cohort



The most commonly reported comorbidities in cohort 1 and 2 are displayed in Table 4.2. For the purposes of analysis, OSA was not considered to be a comorbidity unless its severity was such that CPAP was prescribed, nor was obesity unless the BMI Z-score was 3 or above, both of which have been described above. However, this was confounded by the fact that children with severe OSA not requiring CPAP were assigned ASA class 3 as per guidelines[109]. Between cohort 1 and 2, the proportion of children undergoing tonsillectomy with a history of premature birth more than doubled (1.9% vs 4.9%, $\chi^2(1)=9.3$, RR=2.6, p=.002) while the proportion of children with ADHD increased more than four times (1.1% vs 5.2%, $\chi^2(1)=24.4$, RR=4.7, p<0.001). Children with ASA 3-4 were 40% more likely to be undergoing tonsillectomy for oSDB compared to those with ASA 1-2 in cohort 1 (86.7% vs 62.1%, $\chi^2(1)=46.6$, p<0.001), and 16% more likely in cohort 2 (98.7% vs 84.8%, Fisher's exact p<0.001). Comorbid children were twice as likely to have a diagnosis of OSA than non-comorbid children in both cohort 1 (46.3% vs 23.6%, $\chi^2(1)=79.4$, p<0.001) and cohort 2 (52.0% vs 23.9%, $\chi^2(1)=22.9$, p<0.001), and had higher mean AHI scores than those without in cohort 1 (20.8 vs 12.7, p<0.001, MD=8.2, 95% CI: 4.4-11.9).

Results for tonsillar and adenoidal hypertrophy

Tonsillar size by cohort was as follows (Cohort 1 vs Cohort 2): Brodsky grade I 2.1% vs 2.6% ; grade II 19.9% vs 27.7% ; grade III 56.6% vs 57.6% ; grade IV 21.4% vs 12.1% ($\chi^2(3)=18.9$, p<0.001) (Figure 4.7). Grades I-II were considered not enlarged and grades III-IV were considered large or hypertrophic, with the rate of tonsillar hypertrophy decreasing over time (78.1% in cohort 1 vs 69.7% in cohort 2, $\chi^2(1)=9.8$, p=0.002). Interestingly, there was no observed association between age and tonsillar hypertrophy

in either cohort. Tonsillar hypertrophy was 17% more common in those with oSDB as primary indication compared to recurrent tonsillitis in cohort 1 (82.2% vs 70.2%, $\chi^2(1)=26.3$, $p<0.001$). There was no difference in the rates of tonsillar hypertrophy for children with or without a pre-operative diagnosis of OSA in either cohort, however children with severe OSA were 71% more likely to have grade IV tonsils than those without severe OSA in cohort 1 (33.2% vs 19.4%, $\chi^2(1)=20.3$, $p<0.001$), and nearly three times as likely in cohort 2 (25.4% vs 8.6%, $\chi^2(1)=13.3$, $p<0.001$). A positive correlation was seen between tonsil grade and AHI in cohort 1 (Kendall's Tau-B(379) = 0.15, $p<0.001$), while mean AHI for children with grade IV tonsils was 22.1 compared to 15.9 for those with grades I-III (MD=6.2, p=0.01, 95% CI: 1.4-11.0).

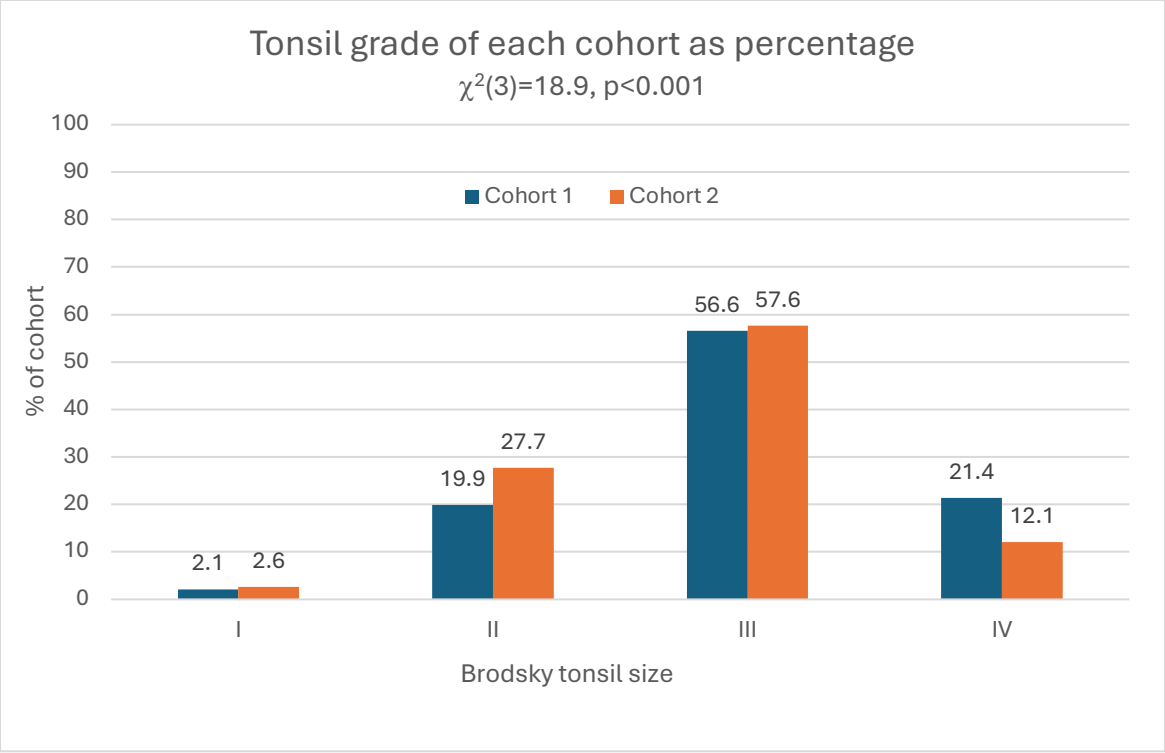
Adenoidal hypertrophy (ACE A3-A4) was 75% more common in cohort 1 than cohort 2 (75.2% vs 43.0%, $\chi^2(1)=118.8$, $p<0.001$). Those with adenoidal hypertrophy in cohort 1 were on average 9.4 months younger than those without (72.1 vs 81.5 months, $p<0.001$, 95% CI: 4.3-14.5), and children under 6 were more likely to have larger adenoids than those over 6 (78.6% vs 70.9%%, RR=1.1, $\chi^2(1)=9.6$, p=0.002), in keeping with physiological involution of the adenoids with age. Adenoidal hypertrophy was 8% more common in those with oSDB as primary indication compared to recurrent tonsillitis in cohort 1 (77% vs 71.2%, $\chi^2(1)=4.8$, $p<0.03$), but over three times as likely in cohort 2 (46.9% vs 13.9%, $\chi^2(1)=14.1$, $p<0.001$). Children in cohort 2 with OSA were 30% more likely to have enlarged adenoids than those without OSA (49.6% vs 38.2%, $\chi^2(1)=4.0$, $p<0.05$), increasing to 68% in those with severe OSA compared to no OSA (63.5% vs 38.2%, $\chi^2(1)=13.6$, $p<0.001$).

Table 4.2 – Frequency of comorbidities in cohorts 1 and 2 (as percentage of cohort)

Comorbidity	Cohort 1	Cohort 2	
Craniofacial or airway abnormality	10.1	8.8	
Developmental delay	8.2	9.1	
Syndromic condition	6.8	9.8	
Neuromuscular disorder	4.2	2.2	
OSA requiring CPAP	3.5	16.3	***
Premature	1.9	4.9	**
Morbid obesity	1.1	3.3	**
ADHD	1.1	5.2	***
Diabetes	0.7	0.3	
ASA 3-4	*14.4*	*25.1*	***

*p<0.05
**p<0.01
***p<0.001

Figure 4.7 – Tonsil grade by cohort



4.2 OPERATIVE TECHNIQUE TRENDS

A summary of perioperative factors is presented in Table 4.3.

Table 4.3 – Summary of perioperative factors

Perioperative factors	*Cohort 1* N	% of cohort (% of group)	*Cohort 2* N	% of cohort (% of group)	
Tonsillectomy type					***
Standard/total	1374	*97.5*	278	*90.6*	
Intracapsular/partial	35	*2.5*	29	*9.4*	
Tonsillectomy method					***
Monopolar diathermy	1258	*89.3*	260	*84.7*	
Coblation	4	*0.3*	47	*15.3*	
Cold methods	146	*10.3*	*0*	*0*	
Hot tonsillectomy	1263	*89.8*	*307*	*100*	
Haemostasis method					***
Mono/bipolar diathermy	1285	*98.2*	260	*84.7*	
Coblation	4	*0.3*	47	*15.3*	
Cold methods	15	*1.1*	0	*0*	
Adenoidectomy type					
Nil	180	*12.8*	35	*11.4*	
Total	1190	*84.5*	266	*86.6*	
Partial	39	*2.8*	6	*2.0*	
Adenoidectomy method	1229		272		***
Suction monopolar	836	*(68.0)*	235	*(86.4)*	
Coblator	3	*(0.3)*	*36*	*(13.2)*	
Cold methods	390	*(31.7)*	1	*(0.4)*	
Local anaesthetic used	834	*59.2*	230	*74.9*	***
Dexamethasone given	1392	*98.8*	302	*98.4*	
IV antibiotics given	81	*5.7*	31	*10.1*	**
Oral antibiotics given	764	*54.2*	27	*8.8*	***

IV = intravenous
* p<0.05
** p<0.01
*** p<0.001

Tonsillectomy factors

The rate of partial tonsillectomy (PT) increased by nearly four-fold from cohort 1 to cohort 2 (2.5% vs 9.4%, $\chi^2(1)=34.0$, $p<0.001$), with remaining procedures performed as total tonsillectomies (TT). Between cohort 1 and 2, PT rates increased by more than five times for children under the age of 2 (8.2% vs 41.7%, $\chi^2(1)=8.6$, $p<0.001$) and nearly tripled for children with oSDB (3.7% vs 10.7%, $\chi^2(1)=20.7$, $p<0.001$). Despite the 3-times higher PT rates seen in cohort 1 for children ASA 3-4 compared to those ASA 1-2 (5.9% vs 1.9%, $\chi^2(1)=11.5$, $p<0.001$), this association was not observed in cohort 2. This is likely due to the 4-fold increase in PT in ASA 1-2 children from cohort 1 to cohort 2 (1.9% vs 8.7%, $\chi^2(1)=30.6$, $p<0.001$) while no increase in PT was observed for those ASA 3-4 across cohorts.

Despite a mild reduction in use over time, monopolar diathermy remained the most common method of tonsillectomy (89.3% vs 84.7%, $\chi^2(1)=5.2$, $p=0.02$) while the use of coblation increased 50-fold (0.3% vs 15.3%, $\chi^2(1)=197.4$, $p<0.001$); both methods categorised as “Hot tonsillectomy”. Use of “Cold tonsillectomy” techniques such as steel dissection and microdebrider reduced from 10.2% to 0% between cohorts ($\chi^2(1)=34.3$, $p<0.001$). Coblation TT increased from 0.1% to 6.5% (RR=65.0, $\chi^2(1)=77.4$, $p<0.001$), while coblation PT increased from 5.7% to 100% across cohorts (RR=17.5, $\chi^2(1)=56.5$, $p<0.001$). Hot methods of haemostasis were the most common, increasing from 98.5% in cohort 1 to 100% in cohort 2 ($\chi^2(1)=4.6$, $p=0.03$), and included bipolar forceps, monopolar forceps, suction diathermy, coblation and a combination of bipolar and ties. The remaining 1.5% of cases from cohort 1 used cold methods such as ties alone or had no haemostasis method recorded.

Adenoidectomy factors

Adenoidectomy rate did not differ across cohorts (87.2% vs 88.6%, NS). Adenoidectomy was associated with younger age in cohort 1, with an average age difference of 32.8 months between those undergoing adenoidectomy and those not (74.4 vs 107.2, $p<0.001$, 95% CI: 24.9-40.8) and an increased likelihood of adenoidectomy performed for children less than 6 years old (92.2% vs 81.6%, $\chi^2(1)=35.8$, $p<0.001$). No association with age was seen in cohort 2, likely impacted by increasing rates of adenoidectomy for children over 6 across cohorts (81.6% vs 89%, $\chi^2(1)=5.0$, $p=0.03$). Adenoidectomy was more likely if the indication for surgery was oSDB in compared to recurrent tonsillitis (cohort 1: 91.9% vs 78.3%, RR=1.2, $\chi^2(1)=52.6$, $p<0.001$; cohort 2: 90.4% vs 75.0%, RR=1.2, $\chi^2(1)=7.5$, $p=0.006$). In cohort 1, diagnosis of OSA was associated with a 5.5% higher adenoidectomy rate (90.4% vs 85.7%, $\chi^2(1)=6.3$, $p=0.01$) and those undergoing adenoidectomy had higher mean AHI than those having tonsillectomy alone (17.8 vs 12.1, $p=0.03$, 95% CI: 0.5-10.9). Children with ASA 3-4 were less likely to undergo adenoidectomy than ASA 1-2 in cohort 1 (82.8% vs 88.0%, RR=0.9, $\chi^2(1)=4.3$, p-0.04), but by cohort 2, adenoidectomy rates did not differ between ASA classes. Adenoidectomy was more likely for children with larger tonsils in cohort 1 (89.0% vs 80.9%, RR=1.1, $\chi^2(1)=14.2$, $p<0.001$) and more likely for children with large adenoids in cohort 2 (98.5% vs 81.1%, RR=1.2, $\chi^2(1)=22.4$, $p<0.001$), though an association in cohort 1 could not be identified as adenoid size not recorded for this group unless adenoidectomy was performed.

Partial adenoidectomy rate did not differ between cohorts (3.2% in cohort 1 vs 2.2% in cohort 2, NS). Children with comorbidities were more than 5 times more likely to have

partial adenoidectomy than those without in cohort 1 (6.5% vs 1.2%, RR=5.5, $\chi^2(1)=26.2$, $p<0.001$), while all children who underwent partial adenoidectomy in cohort 2 had comorbidities but small numbers precluded statistical significance. No other patient factors were associated with partial adenoidectomy. Suction diathermy was the most common tool for adenoidectomy, and its use increased by 27% across cohorts (68.0% vs 86.4%, $\chi^2(1)=69.2$, $p<0.001$) while coblator use increased by nearly 70-fold (0.2% vs 13.6%, Fisher's exact $p<0.001$), both methods classed as "Hot adenoidectomy". Meanwhile, "Cold adenoidectomy" methods such as curettage and microdebrider decreased from 31.7% to 0.4% (Fisher's exact $p<0.001$).

Perioperative medications

The rate of local anaesthetic use increased by 26.5% between cohort 1 and cohort 2, (59.2% vs 74.9%, $\chi^2(1)=26.5$, $p<0.001$), with no difference in administration rates over time for those under 2 years, but a 21.5% increase for children between 2-6 years old (58.2% vs 70.7%, $\chi^2(1)=7.7$, $p=0.006$) and a 34.2% increase for those over 6 years old (60.6% vs 81.3%, $\chi^2(1)=23.5$, $p<0.001$). As such, an association was seen between increasing age and higher rates of local anaesthetic use in cohort 2 that was not observed in cohort 1 ($\chi^2(2)=11.7$, $p=0.003$). In cohort 1, factors associated with increased likelihood of receiving local anaesthetic were: recurrent tonsillitis (62.4% vs 53.1%, RR=1.2, $\chi^2(1)=11.3$, $p<0.001$), larger tonsils (61.0% vs 52.8%, RR=1.2, $\chi^2(1)=6.8$, $p<0.001$) and comorbidities (65.8% vs 54.8%, RR=1.2, $\chi^2(1)=16.9$, $p<0.001$), but these associations were not observed in cohort 2. Pre-excision local anaesthetic infiltration increased from 4.7% in cohort 1 to 77.4% in cohort 2 (RR=16.5, $\chi^2(1)=550.1$, $p<0.001$), and there was no association with timing of local anaesthetic use and any patient or

operative factors for either cohort. Dexamethasone was given as a single intravenous (IV) dose on induction of general anaesthesia in 98.8% of tonsillectomies in cohort 1 and 98.4% in cohort 2, with no difference observed over time, nor any association with any patient or operative factors in either cohort.

IV antibiotic (IVAB) use increased by 77% from cohort 1 to cohort 2 (5.7% vs 10.1%, RR=1.8, $\chi^2(1)=7.8$, p=0.005), with administration rates increasing by 85% for children classified as ASA 1-2 (4.7% vs 8.7%, RR=1.9, $\chi^2(1)=6.0$, p=0.01). This is despite those classes as ASA 3-4 being 2.5 times more likely to receive IVAB intra-operatively compared to ASA 1-2 in cohort 1 (11.8% vs 4.7%, RR=2.5, $\chi^2(1)=16.1$, p<0.001), and resulting in no association between ASA class and IVAB use in cohort 2. The addition of adenoidectomy was associated with nearly three times higher IVAB use in cohort 1 (6.3% vs 2.2%, $\chi^2(1)=4.7$, p=0.03), but lower use in cohort 2 (8.8% vs 20.0%, RR=0.4, $\chi^2(1)=4.3$, p=0.04), with the rate of IVAB administration for those having tonsillectomy alone increasing 9-fold between cohorts (2.2% vs 20.0%, $\chi^2(1)=19.1$, p<0.001).

The rate of oral antibiotics (POAB) being given on discharge decreased by 84% between cohort 1 and cohort 2 (54.2% vs 8.8%, $\chi^2(1)=209.4$, p<0.001). Those undergoing tonsillectomy for recurrent infection in cohort 1 were 17% more likely to be discharged on POAB than those with oSDB (59.9% vs 51.2%, $\chi^2(1)=9.6$, p=0.002), while children in cohort 2 were more likely to be given POAB on discharge if they were graded ASA 3-4 than those ASA 1-2 (15.6% vs 6.5%, RR=2.4, $\chi^2(1)=5.9$, p=0.02). Patients with smaller tonsils were 22% more likely to be prescribed POAB than those with larger tonsils in cohort 1 (63.1% vs 51.7%, $\chi^2(1)=12.6$, p<0.001).

4.3 POSTOPERATIVE OUTCOME TRENDS

A summary of postoperative outcomes for cohort 1 and 2 is displayed in Table 4.4.

Table 4.4 – summary of postoperative outcomes for cohort 1 and 2

Outcomes	Cohort 1			Cohort 2		
	N	*% of cohort (% of group)*	Mean	N	*% of cohort (% of group)*	Mean
Length of stay	1409		1.2	307		1.2
Day stay	136	*9.7*		29	*9.4*	
Overnight	1088	*77.2*		234	*76.2*	
2+ nights	185	*13.1*		185	*14.4*	
Delayed discharge	155	*11.0*		42	*13.7*	
Reason for delay						
Respiratory distress	55	*(35.5)*		12	*(28.6)*	
Fevers	48	*(31.0)*		7	*(16.7)*	
Poor intake	39	*(25.2)*		14	*(13.3)*	
N&V	6	*(3.9)*		2	*(4.8)*	
Post-op bleed	3	*(1.9)*		5	*(11.9)*	**
Other	4	*(2.5)*		2	*(4.8)*	*
PICU admission	51	*3.6*		20	*6.5*	*
PICU type						
Planned	46	*(90.2)*		18	*(90.0)*	
Unplanned	5	*(9.8)*		2	*(10.0)*	
Readmitted	128	*9.1*		35	*11.4*	
Readmission reason						
Fevers	25	*(19.5)*		8	*(22.9)*	
Poor intake	27	*(21.1)*		13	*(37.1)*	*
N&V	12	*(9.4)*		1	*(2.9)*	
Post-op bleed	49	*(38.3)*		13	*(37.1)*	
Other	15	*(11.7)*		0	*(0.0)*	
PTH bleed	57	*4.0*		15	*4.9*	
Rate of PTH by type						
Primary bleed	3	*0.2*		2	*0.7*	
Secondary bleed	54^	*3.8*		13	*4.2*	
Operative bleed	6	*0.4*		3	*1.0*	
Conservative bleed	51	*3.6*		12	*3.9*	
General complication	269	*19.1*		72	*23.5*	
OSA status known	752	*53.4*		154	*50.2*	
Reported cure	631	*(83.9)*		131	*(85.1)*	
Post-op sleep study	170	*12.1*		36	*11.7*	
Proven OSA status[#]	146	*10.4*		29	*9.4*	
Proven cure	84	*(57.5)*		23	*(79.3)*	*
Post-operative AHI	36		8.2	32		5.7
Change in AHI score	25		-19.8	23		-28.4

N&V = nausea and vomiting, PICU = paediatric intensive care unit, PTH = post-tonsillectomy haemorrhage, OSA = obstructive sleep apnoea, AHI = apnoea-hypopnoea index

^5 secondary bleeds were not readmitted, but reported on follow-up

[#]Proven OSA on sleep study pre-operatively and sleep study repeated post-operatively

* $p<0.05$

** $p<0.01$

Length of stay including delayed discharge

There was no observed difference in length of stay (LOS) between cohorts, with 9.7% of children in cohort 1 vs 9.4% in cohort 2 being discharged the same day, 77.2% in cohort 1 vs 76.2% in cohort 2 staying for 1 night and 13.1% in cohort 1 vs 14.4% in cohort 2 staying longer than 1 night. The average LOS in cohort 1 was 1.17 days with range 0-22 days, statistically unchanged for cohort 2 with average LOS 1.21 days and range 0-14 days. There was no difference in the proportion of children experiencing an unplanned delay in their discharge (11.0% in cohort 1 vs 13.7% in cohort 2, NS). The most common reasons for delayed discharge were respiratory distress (35% of delays in cohort 1 vs 28.6 in cohort 2, NS), fevers (31% in cohort 1 vs 16.7% in cohort 2, NS), poor oral intake (25.2% in cohort 1 vs 13.3% in cohort 2, NS), nausea and vomiting (3.9% in cohort 1 vs 4.8% in cohort 2, NS) and bleeding including PTH and epistaxis (1.9% in cohort 1 vs 11.9% in cohort 2, Fisher's exact p=0.006).

Admission to Paediatric Intensive Care Unit (PICU)

Total post-operative admissions to PICU increased from 3.6% in cohort 1, to 6.5% in cohort 2 (RR=1.8, $\chi^2(1)=5.3$, p=0.02). Emergency PICU admission rate did not differ across cohorts (0.4% in cohort 1 vs 0.7% in cohort 2, NS).

Readmission

9.1% of children in cohort 1 and 11.4% in cohort 2 were readmitted within the first two postoperative weeks (NS). Reasons for readmission included post-operative bleeding including epistaxis and PTH (38.3% vs 37.1% in cohort 1 vs cohort 2, NS), poor oral intake due to pain (21.1% in cohort 1 vs 37.1% in cohort 2, $\chi^2(1)=5.9$, p=0.02), post-

operative infection and fevers (19.5% in cohort 1 vs 22.9% in cohort 2, NS), vomiting and diarrhoea (9.4% in cohort 1 vs 2.9% in cohort 2, NS), and other causes in cohort 1 which included exacerbation of pre-existing asthma, a choking episode and otorrhoea post-grommets.

Post-tonsillectomy haemorrhage

The overall post-tonsillectomy haemorrhage (PTH) rate was 4.0% in cohort 1 and 4.9% in cohort 2 (NS). There were no differences in the proportion of bleeds classified as primary PTH (5.3% in cohort 1 vs 13.3% in cohort 2), proportion of bleeds managed operatively (10.5% in cohort 1 vs 20% in cohort 2, NS), overall primary bleed rate (0.2% in cohort 1 vs 0.7% in cohort 2), overall secondary bleed rate (3.8% in cohort 1 vs 4.2% in cohort 2), overall operative bleed rate (0.4% in cohort 1 vs 1.0% in cohort 2), nor overall conservative bleed rate (3.6% in cohort 1 vs 3.9% in cohort 2).

Reported oSDB cure rate

The limited availability of PSG in Australia for formal pre-operative OSA diagnosis necessitates the use of other measures to identify patient and operative factors contributing to resolution of symptoms post-tonsillectomy. For this reason, parent reported oSDB cure was used in this study and analysed separately from sleep study proven OSA cure. 752 (53.3%) of children in cohort 1 and 154 (50.2%) in cohort 2 had confirmed follow-up where their post-operative snoring status was discussed (NS), and were included in the analyses for reported oSDB cure rate. Of these, 83.9% in cohort 1 and 85.1% in cohort 2 reported resolution of their oSDB symptoms, (NS).

Proven OSA cure rate

10.4% of children in cohort 1 vs 9.4% in cohort 2 had both pre-operative OSA diagnosis and underwent post-operative sleep study (NS) and were therefore included in the analysis for proven OSA cure. All patients with sleep study proven OSA cure had reported oSDB cure, however post-operative sleep studies were only undertaken in 15.4% and 22.6% from cohort 1 and 2. The mean post-operative AHI for children with pre-operative OSA was lower in cohort 2 versus cohort 1 (6.2 (range 0-56) vs 8.3 (range 0.9-32) U=311, p=0.001). Only 25 children in cohort 1 and 23 in cohort 2 had both pre- and post-operative AHI scores, and the average change in AHI score was -19.7 in cohort 1 (range -49-8.1) and -28.4 in cohort 2 (range -129-7.4, NS). For children who underwent post-operative sleep study, the rate of proven OSA cure increased from 57.5% to 79.3% in cohort 1 vs cohort 2 ($\chi^2(1)=4.8$, p=0.03).

General complication rate

A child was defined as having a general complication if they experienced a delayed discharge, emergency admission to PICU, readmission within 2 weeks and/or PTH. The general complication rates were 19.1% in cohort 1 and 23.5% in cohort 2 (NS).

4.4 RISK FACTORS FOR COMPLICATIONS

Delayed discharge

A summary of patient factors and relative risk of delayed discharge per cohort is presented in Table 4.5, and a summary of operative factors and relative risk of delayed discharge per cohort is presented in Table 4.6.

Table 4.5 – Patient factors and risk of delayed discharge for cohort 1 and 2

Patient factors	Cohort 1		Cohort 2	
	RR	p-value	RR	p-value
Gender (M:F)	-	NS	-	NS
Age (<2:>2)	3.0	<0.001	-	NS
Age (>6:<6)	0.5	<0.001	-	NS
Obese (Y:N)	-	NS	-	NS
Morbidly obese (Y:N)	-	NS	-	NS
Underweight (Y:N)	2	0.005	-	NS
Indication (oSDB:RT)	1.9	<0.001	-	NS
ASA class 3+ (Y:N)	1.8	<0.001	2	0.01
Neuromuscular (Y:N)	2.1	0.006	4.5	0.008
Craniofacial (Y:N)	1.8	0.004	-	NS
Dev. delay (Y:N)	2	<0.001	-	NS
Syndromic (Y:N)	2.6	<0.001	2.5	0.006
OSA (Y:N)	1.7	<0.001	2	0.01
Severe OSA (Y:N)	1.7	0.002	-	NS
On CPAP (Y:N)	2.9	<0.001	2.1	0.02
Big tonsils (Y:N)	-	NS	0.7	0.02
Big adenoids (Y:N)	-	NS	-	NS

RR = relative risk, Y = yes, N = no, M = male, F = female, ASA = American Society of Anesthesiologists, oSDB = obstructive sleep disordered breathing, RT = recurrent tonsillitis, Dev. = developmental, OSA = obstructive sleep apnoea, CPAP = continuous positive airway pressure, NS = not significant

Table 4.6 - Operative factors and risk of delayed discharge for cohort 1 and 2

Operative factors	Cohort 1		Cohort 2	
	RR	p-value	RR	p-value
Total:partial tonsil	(11.3 vs 0%)	0.03	-	NS
Monopolar tonsil (Y:N)	2.0	0.003	-	NS
Coblator tonsil (Y:N)	-	NS	-	NS
Ads done (Y:N)	2.4	0.006	-	NS
Standard:partial Ads	-	NS	-	NS
Monopolar adenoids (Y:N)	1.8	0.001	-	NS
Coblator adenoids (Y:N)	-	NS	-	NS
LA used (Y:N)	1.7	<0.001	-	NS
Dexamethasone (Y:N)	-	NS	-	NS
IVABs (Y:N)	-	NS	-	NS
POABs (Y:N)	-	NS	-	NS

RR = relative risk, Y = yes, N = no, LA = local anaesthetic, Ads = adenoidectomy, IVABs = intravenous antibiotics, POABs = per oral antibiotics, NS = not significant

Patient factors associated with delayed discharge included younger age (particularly age < 2 years), being underweight, oSDB as the indication for surgery, pre-operative prescription of CPAP and the presence of comorbidities, especially the presence of neuromuscular and craniofacial disease. Younger age was associated with increased risk of delayed discharge in cohort 1 only, with children experiencing a delayed discharge being on average 20.8 months younger than those who went home as planned (60.1 vs 80.9 months, $p<0.001$, 95% CI: 14.3-27.3). Age less than 2 increased the risk of delayed discharge by three times (30.6% vs 10.3%, RR=3.0 $\chi^2(1)=19.9$, $p<0.001$), while age over 6 reduced the risk by half (6.9% vs 14.6%, RR=0.5, $\chi^2(1)=20.9$, $p<0.001$). Being underweight in cohort 1 doubled the risk of delayed discharge (20.8% vs 10.4%, RR=2.0, $\chi^2(1)=8.0$, $p=0.005$) but other weight parameters did not affect length of stay in either cohort. oSDB as indication for surgery doubled the risk of delayed discharge compared to recurrent tonsillitis in cohort 1 (13.9% vs 7.2%, RR=1.9, $\chi^2(1)=13.9$, $p<0.001$), while OSA increased the likelihood by 70% in cohort 1 (15.2% vs 9.0%, RR=1.7, $\chi^2(1)=12.4$, $p<0.001$) and more than doubled the risk in cohort 2 (19.4% vs 9.6%, RR=2.0, $\chi^2(1)=6.1$, $p=0.01$). Pre-operative CPAP prescription increased the risk of delayed discharge by three times in cohort 1 (30.6% vs 10.3% RR=3.0, $\chi^2(1)=19.9$, $p<0.001$) and more than twice in cohort 2 (24.0% vs 11.7%, RR=2.1, $\chi^2(1)=5.4$, $p=0.02$).

Comorbid children experienced higher rates of delayed discharge in both cohorts, with those classed ASA 3-4 having 79% increased risk compared to ASA 1-2 in cohort 1 (17.7% vs 9.9%, RR=1.8, $\chi^2(1)=11.0$, $p<0.001$), and more than double the risk in cohort 2 (22.1% vs 10.9%, RR=2.0, $\chi^2(1)=6.1$, $p=0.01$). Neuromuscular disorders more than doubled the risk of delayed discharge in cohort 1 (22.0% vs 10.5%, RR=2.1, $\chi^2(1)=7.7$,

p=0.006) and increased the risk by more than four times in cohort 2 (57.1% vs 12.7%, RR=4.5, Fisher's exact p=0.008), while syndromic conditions more than doubled the risk in both cohorts (26.0% vs 9.9% in cohort 1, RR=2.6, $\chi^2(1)=23.8$, $p<0.001$; 30.0% vs 11.9% in cohort 2, RR=2.5, $\chi^2(1)=7.5$, p=0.006). Craniofacial abnormalities increased the risk of delayed discharge only in cohort 1 (18.2% vs 10.2%, RR=1.8, $\chi^2(1)=8.4$, p=0.004) as did developmental delay (20.7% vs 10.1%, RR=2.0, $\chi^2(1)=12.1$, $p<0.001$). Smaller tonsils grades I-II were associated with 90% increased chance of delayed discharge compared to grade III-IV in cohort 2 (20.4% vs 13.7%, RR=1.9, $\chi^2(1)=5.1$, p=0.02), and the risk of delayed discharge for those with small tonsils increased by 70% between cohort 1 and 2 (20.4% vs 12.0%, RR=1.7, $\chi^2(1)=4.3$, p=0.04).

Perioperative factors associated with delayed discharge included total tonsillectomy, monopolar tonsillectomy, adenoidectomy, suction monopolar adenoidectomy and administration of local anaesthetic. No children having PT in cohort 1 experienced a delay in discharge, compared to 11.9% of children undergoing TT (Fisher's exact p=0.03), and monopolar tonsillectomy was associated with nearly three times the likelihood of delayed discharge than other methods in cohort 1 (11.8% vs 4.0%, RR=3.0, $\chi^2(1)=8.5$, p=0.003). Adenoidectomy more than doubled the likelihood of delayed discharge than tonsillectomy alone in cohort 1 (11.9% vs 5.0%, RR=2.4, $\chi^2(1)=7.6$, p=0.006), while suction monopolar adenoidectomy increased the risk of delayed discharge by 75% compared to other adenoidectomy methods in cohort 1 (14.4% vs 8.2%, RR=1.8, $\chi^2(1)=10.8$, p=0.001). Local anaesthetic administration increased delayed discharge risk by 73% in cohort 1 (13.3% vs 7.7%, RR=1.7, $\chi^2(1)=11.1$, $p<0.001$) and no association with other perioperative medications was observed.

Admission to Paediatric Intensive Care Unit (PICU)

A summary of patient factors and risk of unplanned PICU admission is presented in Table 4.7, and a summary of operative factors and risk of unplanned PICU admission is presented in Table 4.8. Elective planned admission to PICU was not considered an outcome of interest and was not included in further analysis.

Patient factors associated with unplanned PICU admission included younger age, ASA 3-4, OSA especially if severe, syndromic conditions, neuromuscular disorders and developmental delay. Children under 2 in cohort 1 had more than 18-times higher risk of emergency PICU admission than those over 2 (4.1% vs 0.2%, Fisher's exact p=0.01), and patients emergently admitted had lower mean age than those not (U=1036.5, p=0.006). Interestingly, no children emergently admitted to PICU in cohort 2 were under 2. Other factors in cohort 1 included ASA 3-4 vs 1-2 (1.5% vs 0.2%, RR=8.9, Fisher's exact p=0.02), presence of syndromic conditions (3.1% vs 0.2%, RR=20.5, Fisher's exact p=0.003), and pre-operative diagnosis of OSA (0.9% vs 0.1%, RR=8.3, Fisher's exact p=0.04) especially if severe OSA vs not (1.4% vs 0.2%, RR=8.5, Fisher's exact p=0.03). Neither cohort showed an association between pre-operative CPAP requirement and emergency PICU admission. In cohort 2, neuromuscular disorders increased the risk by more than 40-fold (14.3% vs 0.3%, RR=42.9, Fisher's exact p<0.001), while all children emergently admitted had developmental delay (7.1% vs 0%, Fisher's exact p=0.008).

The only operative factor associated with increased risk of unplanned PICU admission was partial adenoidectomy, showing a 40-fold higher rate compared to standard adenoidectomy in cohort 2 (16.7% vs 0.7%, RR=44.3, Fisher's exact p=0.04).

Table 4.7 - Patient factors and risk of unplanned PICU admission for cohort 1 and 2

Patient factors	Cohort 1		Cohort 2	
	RR	p-value	RR	p-value
Gender (M:F)	-	NS	-	NS
Age (<2:>2)	18.5	0.01	-	NS
Age (>6:<6)	-	NS	-	NS
Obese (Y:N)	-	NS	-	NS
Morbidly obese (Y:N)	-	NS	-	NS
Underweight (Y:N)	-	NS	-	NS
Indication (oSDB:RT)	-	NS	-	NS
ASA class 3+ (Y:N)	8.9	0.02	-	NS
Neuromuscular (Y:N)	-	NS	42.9	<0.05
Craniofacial (Y:N)	-	NS	-	NS
Dev. delay (Y:N)	-	NS	(7% vs 0)	0.008
Syndromic (Y:N)	20.5	<0.001	-	NS
OSA (Y:N)	8.3	0.04	-	NS
Severe OSA (Y:N)	8.5	0.03	-	NS
On CPAP (Y:N)	-	NS	-	NS
Big tonsils (Y:N)	-	NS	-	NS
Big adenoids (Y:N)	-	NS	-	NS

RR = relative risk, Y = yes, N = no, M = male, F = female, ASA = American Society of Anesthesiologists, oSDB = obstructive sleep disordered breathing, RT = recurrent tonsillitis, Dev. = developmental, OSA = obstructive sleep apnoea, CPAP = continuous positive airway pressure, NS = not significant

Table 4.8 - Operative factors and risk of unplanned PICU admission for cohort 1 and 2

Operative factors	Cohort 1		Cohort 2	
	RR	p-value	RR	p-value
Total:partial tonsil	-	NS	-	NS
Monopolar tonsil (Y:N)	-	NS	-	NS
Coblator tonsil (Y:N)	-	NS	-	NS
Ads done (Y:N)	-	NS	-	NS
Standard:partial Ads	-	NS	0.04	0.04
Monopolar adenoids (Y:N)	-	NS	-	NS
Coblator adenoids (Y:N)	-	NS	-	NS
LA used (Y:N)	-	NS	-	NS
Dexamethasone (Y:N)	-	NS	-	NS
IVABs (Y:N)	-	NS	-	NS
POABs (Y:N)	-	NS	-	NS

RR = relative risk, Y = yes, N = no, LA = local anaesthetic, Ads = adenoidectomy, IVABs = intravenous antibiotics, POABs = per oral antibiotics, NS = not significant

Readmission

A summary of patient factors and risk of readmission is presented in Table 4.9, and summary of operative factors and risk of readmission is presented in Table 4.10. The presence of neuromuscular disorder was the only patient factor associated with readmission in either cohort, increasing the readmission rate by 94% in cohort 1 (16.9% vs 8.7%, RR=1.9, $\chi^2(1)=4.6$, p=0.032) and by over 4 times in cohort 2 (42.9% vs 10.7%, RR=4.0, Fisher's exact p=0.04).

Regarding operative factors, monopolar adenoidectomy doubled the risk of readmission compared to other methods in cohort 1 (11.4% vs 5.6%, RR=2.0, $\chi^2(1)=12.0$, p<0.001), while no patient given IVAB intra-operatively was readmitted in cohort 2, compared to 12.7% who were not (Fisher's exact p=0.03).

Post-tonsillectomy haemorrhage

A summary of patient factors and risk of PTH is presented in Table 4.11, and summary of operative factors and risk of PTH is presented in Table 4.12. Patient factors associated with PTH included older age, neuromuscular disorders and tonsil size. Older age was associated with increased PTH risk only in cohort 1, with an average age 22.8 months greater for those who bled (100.5 vs 77.6 months, p<0.001, 95% CI: 11.9-33.8) and logistic regression demonstrating 1.1% increased odds of PTH for every additional month of age (OR = 1.011, p<0.001, 95% CI: 1.006-1.017), or 12.1% increased odds for every additional year. Children over 6 years old had more than double the PTH rate than younger children in cohort 1 (6.0% vs 2.3%, RR=2.7, ($\chi^2(1)=12.8$, p<0.001), and there was no difference in bleed risk for any age group across cohorts.

Table 4.9 - Patient factors and risk of readmission for cohort 1 and 2

Patient factors	Cohort 1		Cohort 2	
	RR	p-value	RR	p-value
Gender (M:F)	-	NS	-	NS
Age (<2:>2)	-	NS	-	NS
Age (>6:<6)	-	NS	-	NS
Obese (Y:N)	-	NS	-	NS
Morbidly obese (Y:N)	-	NS	-	NS
Underweight (Y:N)	-	NS	-	NS
Indication (oSDB:RT)	-	NS	-	NS
ASA class 3+ (Y:N)	-	NS	-	NS
Neuromuscular (Y:N)	1.9	0.03	4.0	0.04
Craniofacial (Y:N)	-	NS	-	NS
Dev. delay (Y:N)	-	NS	-	NS
Syndromic (Y:N)	-	NS	-	NS
OSA (Y:N)	-	NS	-	NS
Severe OSA (Y:N)	-	NS	-	NS
On CPAP (Y:N)	-	NS	-	NS
Big tonsils (Y:N)	-	NS	-	NS
Big adenoids (Y:N)	-	NS	-	NS

RR = relative risk, Y = yes, N = no, M = male, F = female, ASA = American Society of Anesthesiologists, oSDB = obstructive sleep disordered breathing, RT = recurrent tonsillitis, Dev. = developmental, OSA = obstructive sleep apnoea, CPAP = continuous positive airway pressure, NS = not significant

Table 4.10 - Operative factors and risk of readmission for cohort 1 and 2

Operative factors	Cohort 1		Cohort 2	
	RR	p-value	RR	p-value
Total:partial tonsil	-	NS	-	NS
Monopolar tonsil (Y:N)	-	NS	-	NS
Coblator tonsil (Y:N)	-	NS	-	NS
Ads done (Y:N)	-	NS	-	NS
Standard:partial Ads	-	NS	-	NS
Monopolar adenoids (Y:N)	2.0	<0.001	-	NS
Coblator adenoids (Y:N)	-	NS	-	NS
LA used (Y:N)	-	NS	-	NS
Dexamethasone (Y:N)	-	NS	-	NS
IVABs (Y:N)	-	NS	(0 vs 12.7%)	0.03
POABs (Y:N)	-	NS	-	NS

RR = relative risk, Y = yes, N = no, LA = local anaesthetic, Ads = adenoidectomy, IVABs = intravenous antibiotics, POABs = per oral antibiotics, NS = not significant

Table 4.11 - Patient factors and risk of PTH for cohort 1 and 2

Patient factors	Cohort 1		Cohort 2	
	RR	p-value	RR	p-value
Gender (M:F)	-	NS	-	NS
Age (<2:>2)	-	NS	-	NS
Age (>6:<6)	2.7	<0.001	-	NS
Obese (Y:N)	-	NS	-	NS
Morbidly obese (Y:N)	-	NS	-	NS
Underweight (Y:N)	-	NS	-	NS
Indication (oSDB:RT)	-	NS	-	NS
ASA class 3+ (Y:N)	-	NS	-	NS
Neuromuscular (Y:N)	-	NS	6.7	0.04
Craniofacial (Y:N)	-	NS	-	NS
Dev. delay (Y:N)	-	NS	-	NS
Syndromic (Y:N)	-	NS	-	NS
OSA (Y:N)	-	NS	-	NS
Severe OSA (Y:N)	-	NS	-	NS
On CPAP (Y:N)	-	NS	-	NS
Big tonsils (Y:N)	1.8 (IV vs I-III)	0.02	0.4 (III-IV vs I-II)	<0.05
Big adenoids (Y:N)	-	NS	-	NS

RR = relative risk, Y = yes, N = no, M = male, F = female, ASA = American Society of Anesthesiologists, oSDB = obstructive sleep disordered breathing, RT = recurrent tonsillitis, Dev. = developmental, OSA = obstructive sleep apnoea, CPAP = continuous positive airway pressure, NS = not significant

Table 4.12 - Operative factors and risk of PTH for cohort 1 and 2

Operative factors	Cohort 1		Cohort 2	
	RR	p-value	RR	p-value
Total:partial tonsil	-	NS	-	NS
Monopolar tonsil (Y:N)	-	NS	-	NS
Coblator tonsil (Y:N)	-	NS	-	NS
Ads done (Y:N)	-	NS	-	NS
Standard:partial Ads	-	NS	-	NS
Monopolar adenoids (Y:N)	-	NS	-	NS
Coblator adenoids (Y:N)	-	NS	-	NS
LA used (Y:N)	-	NS	-	NS
Dexamethasone (Y:N)	-	NS	-	NS
IVABs (Y:N)	-	NS	-	NS
POABs (Y:N)	-	NS	-	NS

RR = relative risk, Y = yes, N = no, LA = local anaesthetic, Ads = adenoidectomy, IVABs = intravenous antibiotics, POABs = per oral antibiotics, NS = not significant

The presence of neuromuscular disorders in cohort 2 increased PTH risk by 6 times (28.6% vs 4.3%, Fisher's exact p=0.04). PTH rate by tonsil size (cohort 1 vs cohort 2) were as follows: Brodsky grade I 3.4% vs 12.5%; grade II 3.6% vs 8.2%; grade III 3.4% vs 2.3%; grade IV 6.3% vs 8.1% (NS, Figure 4.8). While there was no difference in PTH for individual tonsil grades across cohorts, grade IV tonsils were associated with 83% increased risk of PTH than grades I-III combined in cohort 1 (6.3% vs 3.4%, RR=1.8, $\chi^2(1)=5.0$, p=0.02), while grades I-II were associated with more than double PTH risk compared to grades III-IV in cohort 2 (8.6% vs 3.3%, RR=2.6, $\chi^2(1)=4.0$, $p<0.05$). Adenoid size did not show any association with overall PTH rate in either cohort.

No operative factors or perioperative medications recorded in this study demonstrated any association with PTH in either cohort.

The only patients experiencing primary PTH in cohort 1 were obese (0.9% vs 0%, Fisher's exact p=0.01), while the only patients experiencing PTH requiring operative management in cohort 2 were those with small tonsils (3.2% grade I-II vs 0% grades III-IV, Fisher's exact p=0.03). There were no other patient or operative factors associated with timing of PTH nor whether operative management was required or not.

General complication rate

A summary of patient factors and risk of general complication is presented in Table 4.13, and summary of operative factors and risk of general complication is presented in Table 4.14.

Figure 4.8 – PTH rates by tonsillar size across cohorts

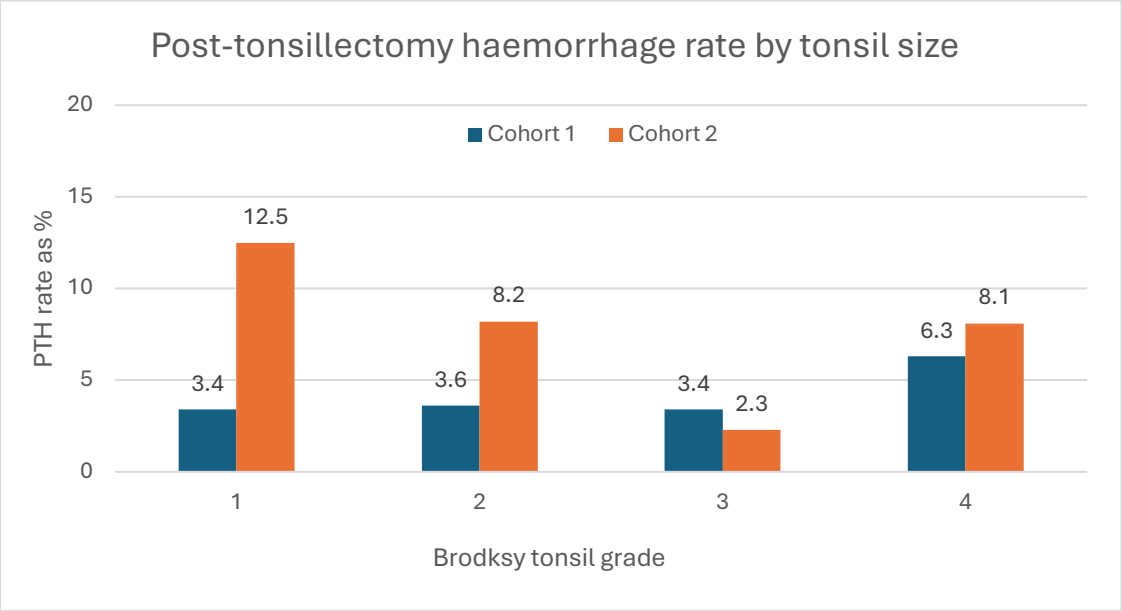


Table 4.13 - Patient factors and risk of general complication for cohort 1 and 2

Patient factors	Cohort 1		Cohort 2	
	RR	p-value	RR	p-value
Gender (M:F)	-	NS	-	NS
Age (<2:>2)	2.0	0.001	-	NS
Age (>6:<6)	0.7	0.002	-	NS
Obese (Y:N)	-	NS	-	NS
Morbidly obese (Y:N)	-	NS	-	NS
Underweight (Y:N)	1.5	0.03	-	NS
Indication (oSDB:RT)	-	NS	-	NS
ASA class 3+ (Y:N)	1.6	<0.001	1.8	0.005
Neuromuscular (Y:N)	1.9	<0.001	3.9	<0.001
Craniofacial (Y:N)	-	NS	-	NS
Dev. delay (Y:N)	1.5	0.03	-	NS
Syndromic (Y:N)	1.7	0.004	1.8	0.02
OSA (Y:N)	1.3	0.02	1.5	0.04
Severe OSA (Y:N)	1.4	0.02	-	NS
On CPAP (Y:N)	1.9	0.005	1.6	<0.05
Big tonsils (Y:N)	-	NS	-	NS
Big adenoids (Y:N)	-	NS	-	NS

RR = relative risk, Y = yes, N = no, M = male, F = female, ASA = American Society of Anesthesiologists, oSDB = obstructive sleep disordered breathing, RT = recurrent tonsillitis, Dev. = developmental, OSA = obstructive sleep apnoea, CPAP = continuous positive airway pressure, NS = not significant

Table 4.14 - Operative factors and risk of complication for cohort 1 and 2

Operative factors	Cohort 1		Cohort 2	
	RR	p-value	RR	p-value
Total:partial tonsil	-	NS	-	NS
Monopolar tonsil (Y:N)	1.7	0.02	-	NS
Coblator tonsil (Y:N)	-	NS	-	NS
Ads done (Y:N)	1.4	0.05	-	NS
Standard:partial Ads	-	NS	-	NS
Monopolar adenoids (Y:N)	1.9	<0.001	-	NS
Coblator adenoids (Y:N)	-	NS	-	NS
LA used (Y:N)	1.5	<0.001	-	NS
Dexamethasone (Y:N)	-	NS	-	NS
IVABs (Y:N)	-	NS	-	NS
POABs (Y:N)	-	NS	-	NS

RR = relative risk, Y = yes, N = no, LA = local anaesthetic, Ads = adenoidectomy, IVABs = intravenous antibiotics, POABs = per oral antibiotics, NS = not significant

Patient factors associated with general complication risk included younger age, underweight, OSA especially if severe and requiring CPAP, ASA class 3+, neuromuscular disorders, developmental delay and syndromic conditions. Younger age was associated with increased risk of general complication in cohort 1 (36.7% age <2 vs 18.5% age>2, RR=2.0, $\chi^2(1)=10.2$, p=0.001; 15.7% age >6 vs 22.1% age <6, RR=0.7, $\chi^2(1)=9.2$, p=0.002), as was being underweight vs normal weight or obese (28.6% vs 18.5%, RR=1.5, $\chi^2(1)=4.7$, p=0.03). OSA increased the risk of general complication by 30% in cohort 1 (22.6% vs 17.4%, $\chi^2(1)=5.5$, p=0.02) and 54% in cohort 2 (29.5% vs 19.1%, $\chi^2(1)=4.5$, p=0.04), with severe OSA increasing the risk by 40% but only in cohort 1 (25.1% vs 18.1%, $\chi^2(1)=5.8$, p=0.02) while a CPAP requirement increased complication risk by 87% in cohort 1 (34.7% vs 18.5%, $\chi^2(1)=8.0$, p=0.005) and 59% in cohort 2 (34.0% vs 21.4%, $\chi^2(1)=3.7$, p<0.05). Children classed as ASA 3-4 had 60% higher complication rates than ASA 1-2 in cohort 1 (28.1% vs 17.6%, $\chi^2(1)=12.4$, p<0.001) and 79% higher in cohort 2 (35.1% vs 19.6%, $\chi^2(1)=7.7$, p=0.005). Neuromuscular disorders increased the risk of complication by 94% in cohort 1 (35.6% vs 18.4%, $\chi^2(1)=0.9$, p<0.001) and by nearly 4 times in cohort 2 (85.7% vs 22.0%, $\chi^2(1)=15.5$, p<0.001). Syndromic conditions increased the rate by 65% in cohort 1 (30.2% vs 18.3%, $\chi^2(1)=8.2$, p=0.004) and by 85% in cohort 2 (40.0% vs 21.7%, $\chi^2(1)=5.1$, p=0.02). Developmental delay increased complication rate by 45% in cohort 1 only (26.7% vs 18.4%, $\chi^2(1)=4.8$, p=0.03).

Perioperative factors associated with increased complication rate in cohort 1 did not show the same associations in cohort 2, these being monopolar tonsillectomy vs other methods (20.0% vs 11.9%, RR=1.7, $\chi^2(1)=5.6$, p=0.02), addition of adenoidectomy vs

tonsillectomy alone (19.9% vs 13.9%, RR=1.4, $\chi^2(1)=3.6$, $p<0.05$), monopolar adenoidectomy vs other methods (24.2% vs 13.4%, RR=1.8, $\chi^2(1)=21.8$, $p<0.001$) and use of local anaesthetic vs not (22.1% vs 14.8%, RR=1.5, $\chi^2(1)=11.7$, $p<0.001$).

4.5 PREDICTIVE FACTORS FOR REPORTED oSDB CURE

A summary of patient factors and likelihood of reported oSDB cure is presented in Table 4.15, and a summary of operative factors and likelihood of reported oSDB cure is presented in Table 4.16.

Patient factors associated with reported oSDB cure included age, morbid obesity, indication for surgery, OSA especially if severe and requiring CPAP, ASA 3+, neuromuscular disorders, craniofacial abnormalities, syndromic conditions, developmental delay and adenotonsillar size. Age below 2 and morbid obesity were associated with lower likelihood of reported oSDB cure in cohort 1 only (age <2: 65.6% vs 84.7%, RR=0.8, $\chi^2(1)=8.3$, $p=0.004$; morbid obesity: 52.9% vs 85.4%, RR=0.6, $\chi^2(1)=25.3$, $p<0.001$), as were oSDB as primary indication for surgery vs tonsillitis (80.8% vs 92.2%, RR=0.9, $\chi^2(1)=14.6$, $p<0.001$), pre-operative OSA (73.6% vs 91.5%, RR=0.8, $\chi^2(1)=43.5$, $p<0.001$), severe OSA (66.0% vs 88.5%, RR=0.7, $\chi^2(1)=45.6$, $p<0.001$) and CPAP prescription (69.7% vs 84.6%, RR=0.8, $\chi^2(1)=5.2$, $p=0.02$). ASA 3-4 was associated with reduced likelihood of reported oSDB cure compared to ASA 1-2 in both cohorts (cohort 1: 62.3% vs 89.1%, RR=0.7, $\chi^2(1)=62.5$, $p<0.001$; cohort 2: 77.4% vs 89.1%, RR=0.9, $\chi^2(1)=3.8$, $p<0.05$), as was developmental delay (cohort 1: 63.2% vs 86.6%, RR=0.7, $\chi^2(1)=31.2$, $p<0.001$; cohort 2: 62.5% vs 87.7%, RR=0.7, $\chi^2(1)=7.2$, $p=0.007$).

Table 4.15 - Patient factors and risk of reported oSDB cure for cohort 1 and 2

Patient factors	Cohort 1		Cohort 2	
	RR	p-value	RR	p-value
Gender (M:F)	-	NS	-	NS
Age (<2:>2)	0.8	0.004	-	NS
Age (>6:<6)	-	NS	-	NS
Obese (Y:N)	-	NS	-	NS
Morbid obesity (Y:N)	0.6	<0.001	-	NS
Underweight (Y:N)	-	NS	-	NS
Indication (oSDB:RT)	0.9	<0.001	-	NS
ASA class 3+ (Y:N)	0.7	<0.001	0.9	<0.05
Neuromuscular (Y:N)	0.7	<0.001	-	NS
Craniofacial (Y:N)	0.7	<0.001	-	NS
Dev. delay (Y:N)	0.7	<0.001	0.7	0.007
Syndromic (Y:N)	0.7	<0.001	-	NS
OSA (Y:N)	0.8	<0.001	-	NS
Severe OSA (Y:N)	0.7	<0.001	-	NS
On CPAP (Y:N)	0.8	0.02	-	NS
Big tonsils (Y:N)	1.2	<0.001	-	NS
Big adenoids (Y:N)	1.1	0.01	-	NS

RR = relative risk, Y = yes, N = no, M = male, F = female, ASA = American Society of Anesthesiologists, oSDB = obstructive sleep disordered breathing, RT = recurrent tonsillitis, Dev. = developmental, OSA = obstructive sleep apnoea, CPAP = continuous positive airway pressure, NS = not significant

Table 4.16 - Operative factors and risk of reported oSDB cure for cohort 1 and 2

Operative factors	Cohort 1		Cohort 2	
	RR	p-value	RR	p-value
Total:partial tonsil	1.3	0.006	-	NS
Monopolar tonsil (Y:N)	1.2	0.001	-	NS
Coblator tonsil (Y:N)	-	NS	-	NS
Ads done (Y:N)	1.3	<0.001	1.2	<0.05
Standard:partial Ads	-	NS	-	NS
Monopolar adenoids (Y:N)	-	NS	-	NS
Coblator adenoids (Y:N)	-	NS	-	NS
LA used (Y:N)	-	NS	-	NS
Dexamethasone (Y:N)	-	NS	-	NS
IVABs (Y:N)	-	NS	-	NS
POABs (Y:N)	-	NS	-	NS

RR = relative risk, Y = yes, N = no, LA = local anaesthetic, Ads = adenoidectomy, IVABs = intravenous antibiotics, POABs = per oral antibiotics, NS = not significant

Other factors shown to reduce the likelihood of reported cure in cohort 1 only included neuromuscular conditions (62.5% vs 85.4%, RR=0.7, $\chi^2(1)=17.4$, $p<0.001$), craniofacial abnormalities (59.4% vs 87.7%, RR=0.7, $\chi^2(1)=51.9$, $p<0.001$), syndromic conditions (60.5% vs 86.5%, RR=0.7, $\chi^2(1)=34.2$, $p<0.001$), larger tonsils (87.0% vs 72.1%, RR=1.2, $\chi^2(1)=20.1$, $p<0.001$) and larger adenoids (87.5% vs 79.5%, RR=1.1, $\chi^2(1)=6.3$, $p=0.01$)

Operative factors associated with reported oSDB cure included TT, monopolar tonsillectomy and addition of adenoidectomy. In cohort 1, TT was associated with a 32% higher reported cure rate than PT (84.6% vs 64.0%, $\chi^2(1)=7.6$, $p=0.006$) and monopolar tonsillectomy was associated with a 32% higher reported cure rate than other methods (85.6% vs 72.3%, $\chi^2(1)=10.7$, $p=0.001$), with neither showing an association with reported cure in cohort 2. When adenoidectomy was performed in addition to tonsillectomy, reported cure rate increased by 26% in cohort 1 (85.6% vs 68.1%, $\chi^2(1)=14.8$, $p<0.001$), and by 22% in cohort 2 (87.2% vs 71.4%, $\chi^2(1)=3.6$, $p<0.05$).

4.6 PREDICTIVE FACTORS FOR PROVEN OSA CURE

A summary of patient factors and likelihood of proven OSA cure is presented in Table 4.17, and summary of operative factors and likelihood of proven OSA cure is presented in Table 4.18.

Table 4.17 - Patient factors and risk of proven OSA cure for cohort 1 and 2

Patient factors	Cohort 1		Cohort 2	
	RR	p-value	RR	p-value
Gender (M:F)	-	NS	-	NS
Age (<2:>2)	-	NS	-	NS
Age (>6:<6)	0.7	0.04	-	NS
Obese (Y:N)	-	NS	-	NS
Morbidly obese (Y:N)	-	NS	-	NS
Underweight (Y:N)	-	NS	-	NS
Indication (oSDB:RT)	0.6	0.02	-	NS
ASA class 3+ (Y:N)	0.7	0.003	-	NS
Neuromuscular (Y:N)	-	NS	-	NS
Craniofacial (Y:N)	0.7	0.02	-	NS
Dev. delay (Y:N)	0.7	0.03	-	NS
Syndromic (Y:N)	0.7	0.04	-	NS
OSA (Y:N)*	n/a	NS	n/a	NS
Severe OSA (Y:N)	-	NS	-	NS
On CPAP (Y:N)	-	NS	-	NS
Big tonsils (Y:N)	1.9	<0.001	-	NS
Big adenoids (Y:N)	-	NS	-	NS

RR = relative risk, Y = yes, N = no, M = male, F = female, ASA = American Society of Anesthesiologists, oSDB = obstructive sleep disordered breathing, RT = recurrent tonsillitis, Dev. = developmental, OSA = obstructive sleep apnoea, CPAP = continuous positive airway pressure, NS = not significant
*analysis only included those with pre-operatively diagnosed OSA on sleep study

Table 4.18 - Operative factors and risk of proven OSA cure for cohort 1 and 2

Operative factors	Cohort 1		Cohort 2	
	RR	p-value	RR	p-value
Total:partial tonsil	-	NS	-	NS
Monopolar tonsil (Y:N)	-	NS	-	NS
Coblator tonsil (Y:N)	-	NS	-	NS
Ads done (Y:N)	2.5	0.007	-	NS
Standard:partial Ads	-	NS	-	NS
Monopolar adenoids (Y:N)	-	NS	-	NS
Coblator adenoids (Y:N)	-	NS	-	NS
LA used (Y:N)	-	NS	-	NS
Dexamethasone (Y:N)	-	NS	-	NS
IVABs (Y:N)	-	NS	-	NS
POABs (Y:N)	0.8	<0.05	-	NS

RR = relative risk, Y = yes, N = no, LA = local anaesthetic, Ads = adenoidectomy, IVABs = intravenous antibiotics, POABs = per oral antibiotics, NS = not significant

Patient factors associated with proven OSA cure included age, indication for surgery, ASA 3+, craniofacial abnormalities, developmental delay, syndromic conditions and tonsillar size. No patient nor operative factors showed any association with proven OSA cure in cohort 2. In cohort 1, age over 6 years was associated with reduced likelihood of proven OSA cure (46.3% vs 64.1%, RR=0.7, $\chi^2(1)=4.8$, p=0.04), as were oSDB as primary indication vs recurrent tonsillitis (55.4% vs 100%, RR=0.6, Fisher's exact p=0.02), ASA 3-4 compared to ASA 1-2 (46.1% vs 70.0%, RR=0.7, $\chi^2(1)=8.6$, p=0.003), presence of developmental delay (41.7% vs 62.7%, RR=0.7, $\chi^2(1)=4.9$, p=0.04), craniofacial abnormality (43.8% vs 64.3%, RR=0.7, $\chi^2(1)=5.6$, p=0.02) and syndromic conditions (43.9% vs 62.9%, RR=0.7, $\chi^2(1)=4.3$, p=0.04). Larger tonsils increased the likelihood of proven OSA cure by 89% in cohort 1 compared to smaller tonsils (66.0% vs 35.0%, RR=1.9, $\chi^2(1)=11.5$, p<0.001).

In terms of operative factors, only the addition of adenoidectomy and the provision of POAB showed association with proven OSA cure, and only in cohort 1. Adenoidectomy more than doubled the likelihood of proven OSA cure (61.5% vs 25.0%, RR=2.5, Fisher's exact p=0.007), while children who received POAB on discharge had 25% lower likelihood of cure than those who did not (50.0% vs 66.7%, RR=0.75, Fisher's exact p<0.05).

4.7 SUMMARY OF SHIFTING TRENDS

Amongst patient factors, children in cohort 2 were more likely to be male (65.8% vs 55.5%), obese (29.6% vs 22.7%), and to have oSDB (88.3% vs 53.3%), an ASA of ≥3

(23.2% vs 13.3%), and smaller tonsils and adenoids than those in cohort 1. Rates of pre-operative PSG increased by 32%, and pre-operative OSA diagnosis increased by 29%, however the proportion of positive sleep studies and proportion of studies diagnosing severe OSA remained constant. Average pre-operative AHI scores increased from 17.3 in cohort 1 to 22.7, indicating higher degree of OSA severity in the later cohort.

Between cohorts, operative factors showed a more than threefold increase in PT, a more than 40-fold increase in coblation, and a complete reduction in cold dissection tonsillectomy. Local anaesthetic use rose by 27%, and pre-incision infiltration increased 16-fold. IV antibiotic use increased, particularly in ASA 1–2 children and those with larger tonsils, while PO antibiotics decreased sixfold, particularly in children undergoing surgery for recurrent tonsillitis.

Despite higher medical complexity of patients in cohort 2, major complication rates remained stable with no difference noted between cohorts for delayed discharge (11.0% vs 13.7%), emergency PICU admission (0.4% vs 0.7%), readmission (9.1% vs 11.4%) or PTH (4.0% vs 4.9%). An increase in post-operative bleeding delaying discharge was noted, as was poor oral intake as cause for readmission. Regarding operative outcomes, similar proportions of children in cohorts 1 and 2 had documented follow-up (53.3% vs 50.2%) and reported oSDB cure rates did not differ (83.9% in cohort 1 vs 85.1% in cohort 2). A similar proportion underwent post-operative sleep studies (12.1% vs 11.1%), and 10.3% of children in cohort 1 and 9.4% of children in cohort 2 had both pre- and post-operative studies available, with the proven OSA cure rates increasing from 57.5% in cohort 1 to 79.3% in cohort 2.

Adherence to clinical practice guidelines

The 2019 update for the American clinical practice guidelines for tonsillectomy in children recommended PSG for children with symptoms of sleep disordered breathing who were under the age of 2, were obese or had Down syndrome[2]. In this study where cohort 1 data collection ended more than 4 years prior to the release of the updated guidelines, PSG was performed prior to tonsillectomy for oSDB in 71.7% of children under the age of 2, 55.3% of children with obesity and 82% of children with syndromic conditions including Down syndrome. The 2019 update also recommended overnight admission for children under the age of 3 and for those with a diagnosis of severe OSA[2]. Pleasingly, 99.5% of children in this study who were under the age of 3 and 98.3% who were known to have severe OSA were admitted for post-operative overnight monitoring.

CHAPTER 5: RESULTS – development of predictive tools

Predictive tools were developed for three outcomes: general complication rate, reported obstructive sleep disordered breathing (oSDB) cure and proven obstructive sleep apnoea (OSA) cure. Built on data from cohort 1, binomial logistic regression modelling was performed using the risk factors identified against each of the three outcomes, summarised in Table 5.1.

Table 5.1 – Identified risk factors for general complication, reported oSDB cure and proven OSA cure and respective risk ratios for cohort 1

Risk factor (comparators)	RR for general complication	RR for reported oSDB cure	RR for proven OSA cure
Age (<2:>2)	2.0	0.8	-
Age (>6:<6)	0.7	-	0.7
Morbid obesity (Y:N)	-	0.6	-
Underweight (Y:N)	1.5	-	-
Indication (oSDB:RT)	-	0.9	0.6
ASA class 3+ (Y:N)	1.6	0.7	0.7
Neuromuscular (Y:N)	1.9	0.7	-
Craniofacial (Y:N)	-	0.7	0.7
Dev. delay (Y:N)	1.5	0.7	0.7
Syndromic (Y:N)	1.7	0.7	0.7
OSA (Y:N)	1.3	0.8	-
OSA severe (Y:N)	1.4	0.7	-
On CPAP (Y:N)	1.9	0.8	-
Big tonsils (Y:N)	-	1.2	1.9
Big adenoids (Y:N)	-	1.1	-
Total:partial tonsil	-	1.3	-
Monopolar tonsil (Y:N)	1.7	1.2	-
Adenoids done (Y:N)	1.4	1.3	2.5
Monopolar adenoids (Y:N)	1.9	-	-
LA used (Y:N)	1.5	-	-
POABs (Y:N)	-	-	0.8

RR = relative risk, Y = yes, N = no, M = male, F = female, ASA = American Society of Anesthesiologists, oSDB = obstructive sleep disordered breathing, RT = recurrent tonsillitis, Dev. = developmental, OSA = obstructive sleep apnoea, CPAP = continuous positive airway pressure, LA = local anaesthetic, IVABs = intravenous antibiotics, POABs = per oral antibiotics, NS = not significant

5.1 DEVELOPMENT OF PREDICTIVE TOOL FOR COMPLICATION

Binomial regression modelling for complication (cohort 1)

Binomial regression modelling was performed for the dependent variable of general complication with the reference level defined as “no complication”. Independent variables included in the analysis were those identified as individual risk factors for general complication occurring (displayed in Tables 4.13 and 4.14), with the reference levels set to the lowest identified risk factor for each parameter, for example age greater than 6. The measures for overall model fit are presented in Table 5.2, with model 1 including all listed dependent variables identified on univariate analysis as being associated with general complication rate and model 2 refines the analysis by excluding variables that are correlated and thus confounding the multivariate analysis.

Model 2 was selected based on superior relative likelihood test using the Akaike information criterion (AIC), with the remaining variables presented in Table 5.3 as predictors alongside their respective log odds estimates and p-values, as calculated by the regression model.

Predictive measures for general complication model are displayed in Table 5.4, and classification table with predicted versus observed complication is presented in Table 5.5. A sensitivity-specificity plot with cut-off value set to 0.2 is presented in Figure 5.1, and receiver operating characteristic (ROC) curve is presented in Figure 5.2.

Table 5.2 – Regression model fit measures for general complication, models 1 & 2

Model	Deviance	AIC	R^2_{McF}	χ^2	df	p
1	1296.7	1326.7	0.056	77.2	14	< .001
2	1301.8	1317.8	0.052	72.1	7	< .001

AIC = Akaike information criterion, R^2_{McF} = McFadden's pseudo R-squared, df = degrees of freedom

Table 5.3 – Dependent variables used in regression model 2 for general complication

Predictor	Estimate*	p
Intercept	*-3.190*	*< .001*
Age 0-2 vs 6+	1.012	0.002
Age 2-6 vs 6+	0.314	0.031
ASA 3-4 vs 1-2	0.423	0.027
Neuromuscular disorder vs no	0.708	0.024
Local anaesthetic used vs no	0.433	0.004
Monopolar tonsillectomy vs no	0.759	0.005
Monopolar adenoidectomy vs no	0.713	< .001

*Estimate represents the log odds of complication occurring vs not

Table 5.4 – Predictive measures for general complication regression model

Specificity	Sensitivity	Accuracy	AUC
0.632	0.632	0.632	0.67

AUC = area under the curve

Table 5.5 – Classification table for predicted versus observed complication

	Predicted		
Observed	Yes	No	% correct
Yes	170	99	63.2
No	419	721	63.2

Figure 5.1 – Sensitivity-specificity chart for complication regression model, with cut-off point set to 0.2

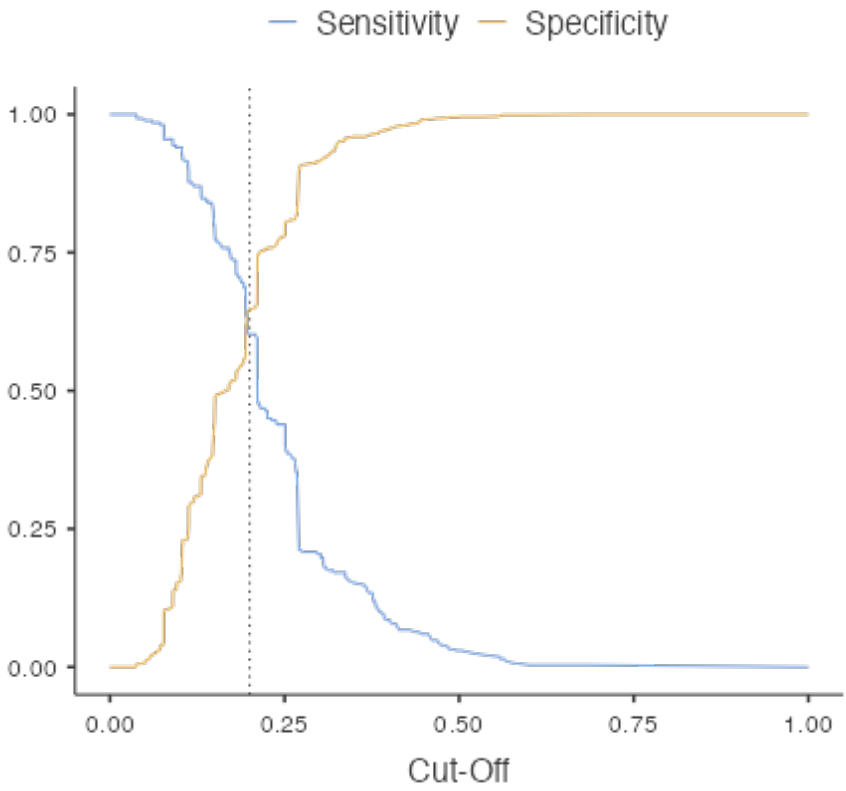
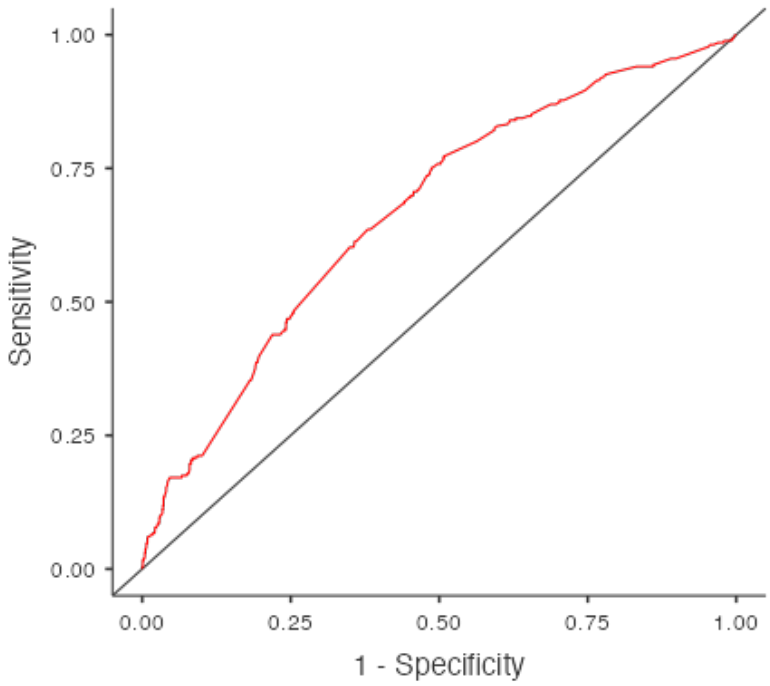


Figure 5.2 – ROC curve for complication regression model, AUC = 0.67



Application of complication regression model to risk assessment tool for cohort 1

In order to develop the binomial regression model into a risk assessment tool, assigned scores for each risk factor were developed from the log odds estimate calculated by the regression analysis. Log odds was selected over odds to prevent overpowering of a single factor in the combined score calculation, while retaining a relative ranking of scores for identified risk factors. To provide the smallest possible whole number, each log odds value was adjusted by dividing by the lowest log odds in the model and multiplying by 5, as presented in Table 5.6. The term "Complication Score" (CS) was given to the sum of adjusted scores for risk factors for general complication and was calculated and recorded for each participant.

Based on the calculated values, the lowest overall CS possible is 0, and would apply to a child who is over the age of 6 with an ASA class less than 3 and no neuromuscular disorder, who will not receive local anaesthetic and will undergo non-monopolar techniques of tonsillectomy and adenoidectomy. Conversely, the highest CS possible is 67, representing a child under the age of 2 with an ASA of 3 or above and a neuromuscular disorder, who will receive local anaesthetic and have both tonsillectomy and adenoidectomy performed using monopolar diathermy techniques.

Three categories were selected to represent groups at low, medium or high risk of complication, with cut-off values selected by calculating 33.3rd and 66.7th percentile groups. The low risk group therefore included those with calculated CS between 0-27, medium risk between 28-45 and high risk between 46-67. Observed complication rates for the respective groups were calculated using Chi-squared independent samples test

of association, and demonstrated significant differences in the proportions of children experiencing complications between the low (10.5% complications), medium (26.0%) and high risk (50.0%) groups ($\chi^2(2)=77.8$, $p<0.001$). These correlated well to the mean predicted probability of a complication was calculated for low, medium and high risk groups using binomial regression prediction modelling, with the low risk group having a mean predicted probability of 11.8%, medium risk group of 24.8% and high risk of 47.6%. Non-parametric one-way ANOVA using Kruskal-Wallis H test demonstrated significant differences between mean probabilities of low, medium and high risk groups ($H(2)=1080$, $p<0.001$). The observed rates and mean predicted probability of complication rates for low, medium and high groups are presented in Table 26, and in bar graph form in Figure 5.3.

Validation of the risk calculator (cohort 2)

To validate CS as a scoring tool, the same score ranges were tested for defining low, medium and high risk groups in cohort 2 and compared against the observed complication rate in those respective groups. Using Chi-squared independent samples test of association, significant differences were demonstrated in the proportions with complications from the low (16.0%), medium (23.5%) and high risk groups ($\chi^2(2)=9.0$, $p=0.01$), of children in the low risk group, of those in the medium risk group and of those in the high risk group. This was compared against mean predicted probabilities for each risk group as calculated using binomial regression model based on cohort 1 and displayed in Table 5.8 and in bar graph form in Figure 5.4.

Table 5.6 – Adjusted scores per risk factor for general complication model

Risk factor	Category	Estimate	Adjusted score
Age	<2	1.012	16
	2-6	0.314	5
	6+	0	0
ASA class	1-2	0	0
	3-4	0.423	7
Neuromuscular disorder	Yes	0	0
	No	0.708	11
Local anaesthetic used	Yes	0.433	7
	No	0	0
Monopolar tonsillectomy	Yes	0.759	12
	No	0	0
Monopolar adenoidectomy	Yes	0.713	11
	No	0	0

Table 5.7 – Observed and predicted complication rate for low, medium and high risk groups in cohort 1

Risk group	Low	Medium	High
Complication score (CS) range	0-27	28-45	46-67
Observed complication rate (%)	10.5	26.0	50.0
Predicted probability of complication (%)	11.8	24.8	47.6

Figure 5.3 – Bar graph showing the observed complication rate against predicted probability of complication for low, medium and high risk groups in cohort 1

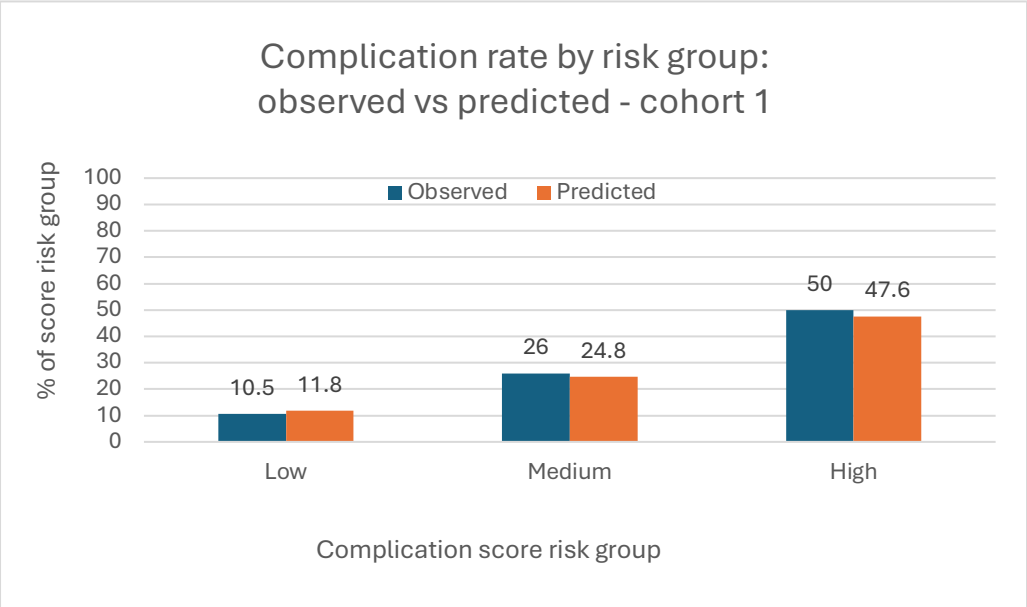
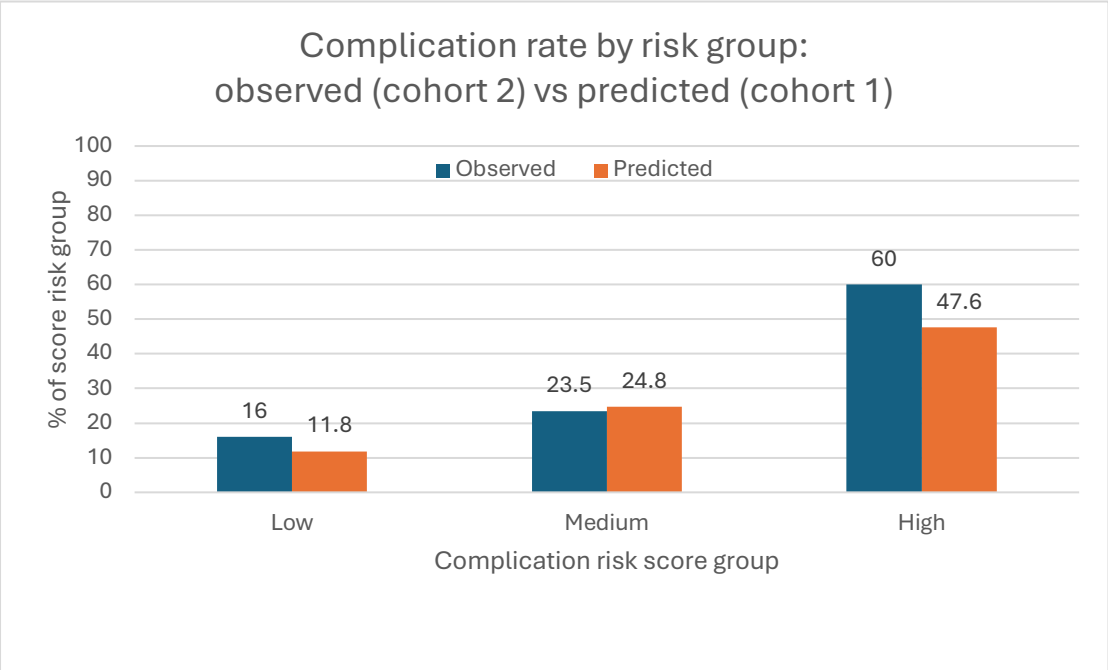


Table 5.8 - Observed complication rate for low, medium and high-risk groups in cohort 2 alongside predicted probability calculated from cohort 1

Risk group	**Low**	**Medium**	**High**
Complication score (CS) range	0-27	28-45	46-67
Observed complication rate (%)	16.0	23.5	60.0
Predicted probability of complication (%)	*11.8*	*24.8*	*47.6*

Figure 5.4 – Bar graph showing observed complication rate from cohort 2 alongside predicted probability for low, medium and high risk groups



5.2 DEVELOPMENT OF PREDICTIVE TOOL FOR REPORTED oSDB CURE

Binomial regression modelling for reported oSDB cure (cohort 1)

Binomial regression modelling was performed for the dependent variable of parent reported oSDB cure, with the reference level defined as “cure not reported”. Independent variables included in the analysis were those identified as predictive factors (i.e. positive statistical association) for reported oSDB cure (displayed in Tables 4.15 and 4.16), with the reference levels set to the highest likelihood of cure, for example adenoidectomy performed versus not. Overall model fit measures are presented in Table 5.9, with model 1 including all listed dependent variables identified as being associated with reported oSDB cure on univariate analysis and model 2 excluding variables identified as correlated and therefore confounding the multivariate analysis.

Model 2 was selected based on the superior relative likelihood test using the Akaike information criterion (AIC), with the remaining variables presented in Table 5.10 as predictors alongside their respective log odds estimates and p-values.

Predictive measures for reported oSDB cure model are displayed in Table 5.11, and classification table with predicted versus observed reported cure is presented in Table 5.12. A sensitivity-specificity plot with cut-off value set to 0.85 is presented in Figure 5.5, and receiver operating characteristic (ROC) curve is presented in Figure 5.6.

Table 5.9 – Regression model fit measures for reported oSDB cure, models 1 & 2

Model	Deviance	AIC	R^2_{McF}	χ^2	df	p
1	537.4	569.4	0.19	126.1	15	< .001
2	551.0	565.0	0.17	112.6	6	< .001

AIC = Akaike information criterion, R^2_{McF} = McFadden's pseudo R-squared, df = degrees of freedom

Table 5.10 – Dependent variables used in regression model 2 for reported oSDB cure

Predictor	Estimate*	p
Intercept	*2.747*	*< .001*
Tonsils grade 1-2 vs 3-4	-0.833	< .001
Adenoidectomy not done vs done	-0.806	0.012
ASA 3-4 vs 1-2	-0.650	0.015
OSA severe vs not	-1.086	< .001
Morbidly obese vs no	-1.148	0.004
Craniofacial/airway abnormality vs no	-1.074	< .001

*Estimate represents the log odds of OSA cure reported vs not

Table 5.11 – Predictive measures for reported oSDB cure regression model

Specificity	Sensitivity	Accuracy	AUC
0.702	0.729	0.725	0.77

AUC = area under the curve

Table 5.12 – Classification table for predicted versus observed reported oSDB cure

	Predicted		
Observed	Yes	No	% correct
Yes	460	171	72.9
No	36	85	70.2

Figure 5.5 – Sensitivity-specificity chart for reported oSDB cure regression model, with cut-off point set to 0.85

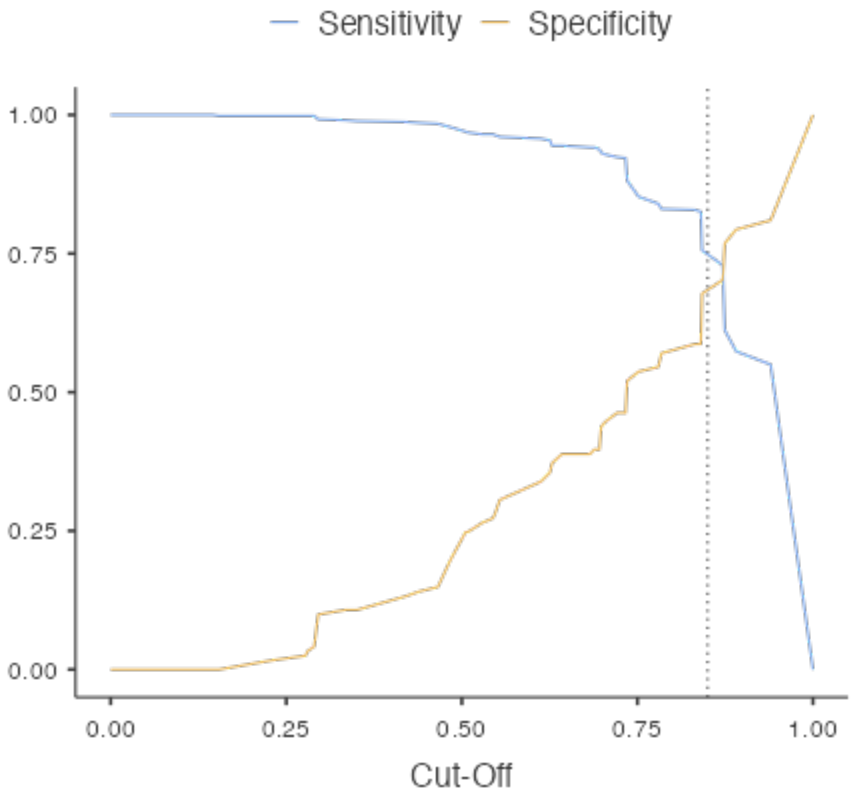
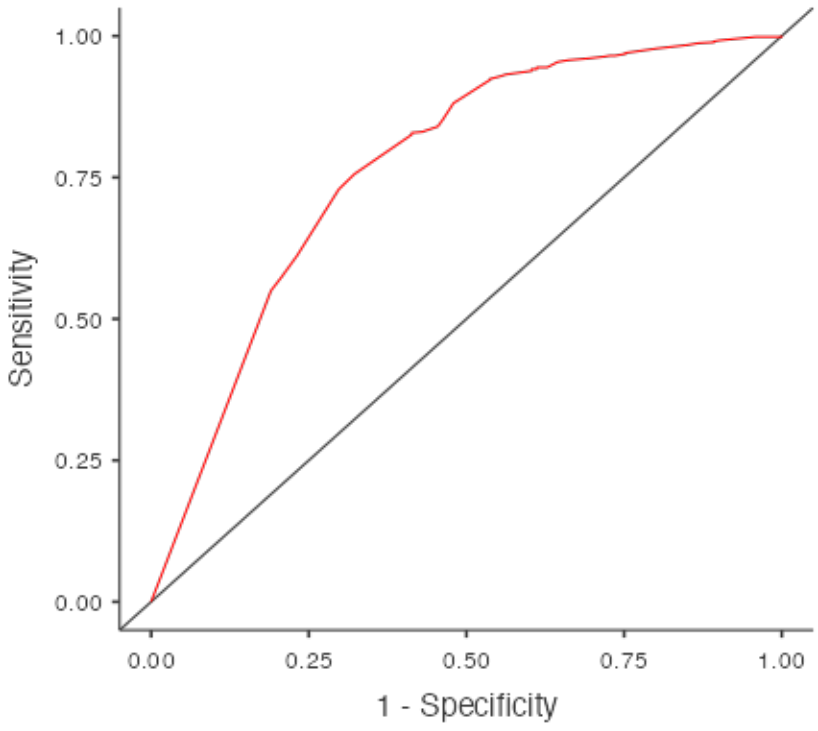


Figure 5.6 – ROC curve for reported oSDB cure regression model, AUC = 0.77



Application of the predictor for reported oSDB cure (cohort 1)

As for the risk assessment tool for complications, scores were changed to whole numbers. The assigned scores were developed from the log odds estimate calculated by the regression analysis, and adjusted by dividing by the lowest log odds in the model, this time multiplying by 10 to reach smallest possible whole number, as presented in Table 5.13. The term "Reported oSDB cure Score" (RS) was given to the sum of adjusted scores for predictive factors for reported oSDB cure and was calculated and recorded for each participant.

Based on calculated values, the lowest overall RS possible is 0, and would apply to a child who has large tonsils, an ASA of less than 3, no history of craniofacial or airway abnormality, severe OSA or of morbid obesity who is planned for adenoidectomy as well as tonsillectomy. Conversely, the highest RS possible is 87, representing a child with an ASA of 3 or above who has a craniofacial or airway abnormality, is morbidly obese and has severe OSA and small tonsils who is not planned for adenoidectomy.

Three categories were selected to represent groups with high, medium or low likelihood of reported oSDB cure, with cut-off values selected by calculating 33.3rd and 66.7th percentile groups. The high likelihood group therefore included those with calculated RS between 0-30, medium likelihood between 31-50 and low likelihood between 51-87. The observed rates for parent reported cure rate was calculated for each of the respective groups using Chi-squared independent samples test of association, and demonstrating significant differences in proportions between high (89.1%), medium (47.5%) and low (33.3%) likelihood of cure groups ($\chi^2(2)=118.3$, $p<0.001$). The mean

predicted probability of parent reported cure was then calculated for high (88.7%), medium (53.4%) and low (28.1%) likelihood groups using binomial regression prediction modelling. Non-parametric one-way ANOVA using Kruskal-Wallis H test demonstrated significant differences between the groups (mean probabilities of high, medium and low likelihood) ($H(2)=257.7$, $p<0.001$). Observed reported cure rate and mean predicted probability of reported cure for high, medium and low likelihood groups is presented in Table 5.14, and in bar graph form in Figure 5.7.

Validation of predicting parent reported oSDB cure (cohort 2)

The same score ranges were used to define high, medium and low likelihood groups in cohort 2 as in cohort 1. The observed rates of parent reported oSDB cure for the respective groups in cohort 2 was again calculated using Chi-squared independent samples test of association, demonstrating significant differences in proportions between high (89.1%), medium (66.7%) and low (50%) likelihood groups ($\chi^2(2)=9.9$, $p=0.007$). This was compared against mean predicted probabilities for each likelihood group as calculated using binomial regression model based on cohort 1 and displayed in Table 5.15 and in bar graph form in Figure 5.8.

Table 5.13 – Adjusted scores per risk factor for reported oSDB cure model

Risk factor	Category	Estimate	Adjusted score
Adenoidectomy done	**Yes**	**0**	0
	No	-0.806	12
ASA class	1-2	0	0
	3-4	-0.650	10
Craniofacial/airway disorder vs no	Yes	-1.074	17
	No	0	0
Morbid obesity vs no	Yes	-1.148	18
	No	0	0
Severe OSA vs no	Yes	-1.086	17
	No	0	0
Tonsils grade	1-2	-0.833	13
	3-4	0	0

Table 5.14 – Observed and predicted reported oSDB cure rate for high, medium and low likelihood groups in cohort 1

Likelihood group	High	Medium	Low
Reported cure score (RS) range	0-30	31-50	51-87
Observed reported cure rate (%)	89.1	47.5	33.3
Predicted probability of reported cure (%)	88.7	53.4	28.1

Figure 5.7 – Bar graph showing observed reported cure rate against predicted probability of reported oSDB cure for high, medium and low likelihood groups in cohort 1

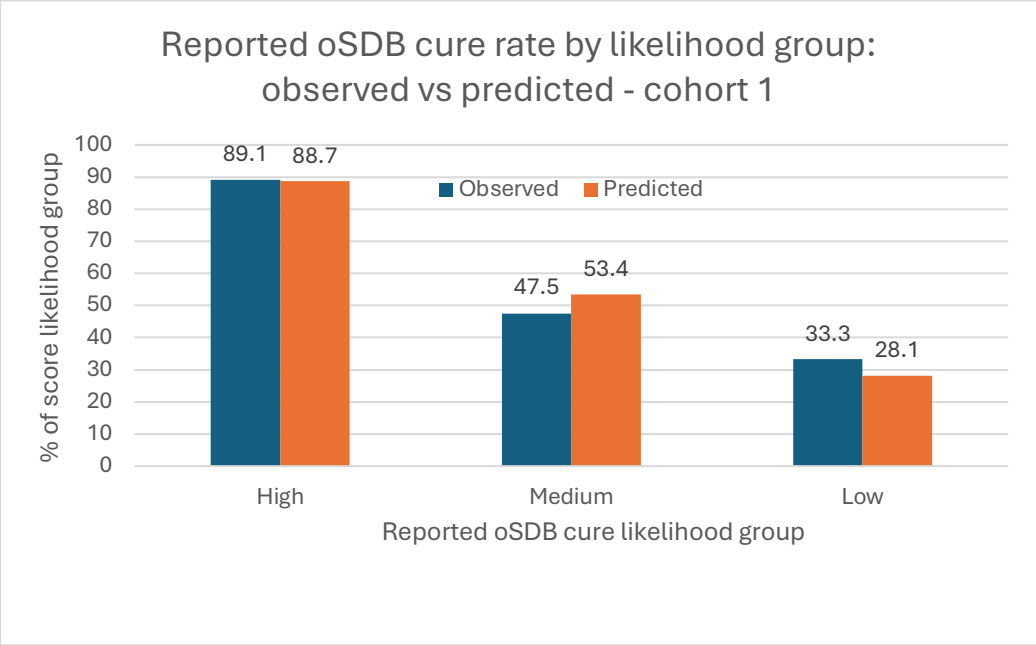
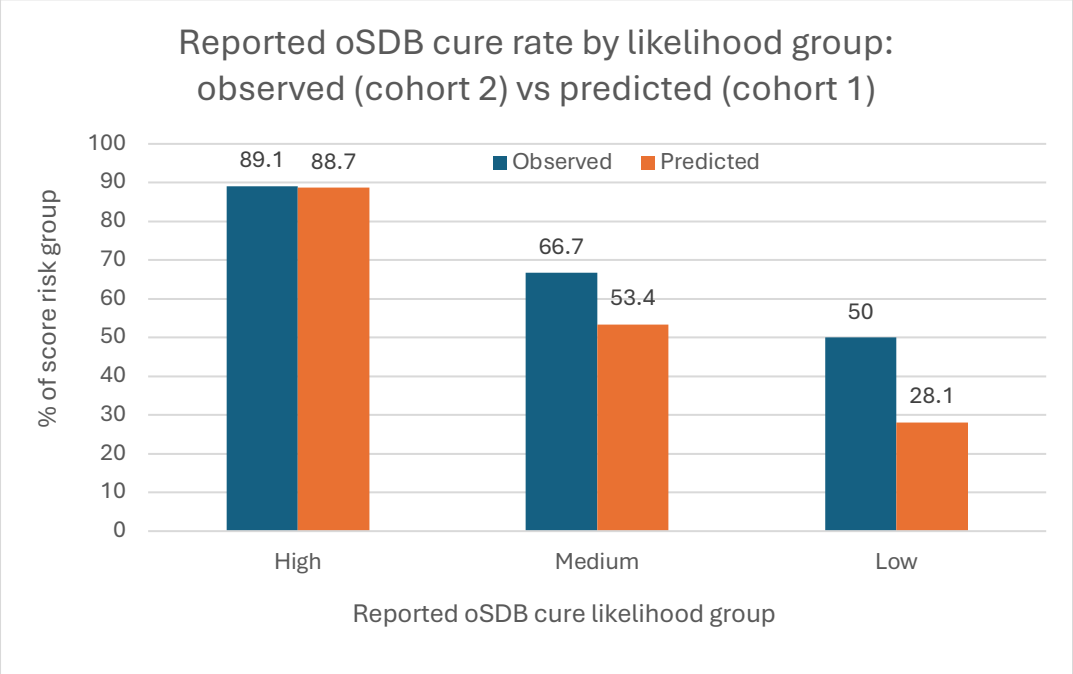


Table 5.15 - Observed reported oSDB cure rate for high, medium and low likelihood groups in cohort 2 alongside predicted probability calculated from cohort 1

Likelihood group	**High**	**Medium**	**Low**
Reported oSDB cure score (RS) range	0-30	31-50	51-87
Observed reported oSDB cure rate (%)	89.1	66.7	50.0
Predicted probability of reported cure (%)	*88.7*	*53.4*	*28.1*

Figure 5.8 – Bar graph showing observed reported cure rate from cohort 2 alongside predicted probability for high, medium and low likelihood groups



5.3 DEVELOPMENT OF PREDICTIVE TOOL FOR PROVEN OSA CURE

Binomial regression modelling for proven OSA cure (Cohort 1)

Binomial regression modelling was performed for the dependent variable of sleep study proven OSA cure, with the reference level defined as “cure not reported”. Independent variables included in the analysis were those identified as predictive factors for proven OSA cure (displayed in Tables 4.17 and 4.18), with the reference levels set to the highest likelihood of cure, for example age less than 6. The measures of overall model fit are presented in Table 5.16, with model 1 including all listed dependent variables identified as being associated with proven OSA cure on univariate analysis and model 2 having excluded variables identified as correlated and thus confounding the multivariate analysis.

Model 2 was selected due to multiple variables falling out of statistical significance in model 1, despite inferior relative likelihood test using the Akaike information criterion (AIC). The variables remaining in model 2 are presented in Table 5.17 as predictors alongside their respective log odds estimates and p-values.

Predictive measures for proven OSA cure model are displayed in Table 5.18, and classification table with predicted versus observed proven cure are presented in Table 5.19. A sensitivity-specificity plot with cut-off value set to 0.85 is presented in Figure 5.9, and receiver operating characteristic (ROC) curve is presented in Figure 5.10.

Table 5.16 – Regression model fit measures for proven OSA cure, models 1 & 2

Model	Deviance	AIC	R^2_{McF}	χ^2	df	p
1	153.9	173.9	0.23	45.1	9	<. 001
2	171.1	181.1	0.14	28.0	4	< .001

AIC = Akaike information criterion, R^2_{McF} = McFadden's pseudo R-squared, df = degrees of freedom

Table 5.17 – Dependent variables used in regression model 2 for proven OSA cure

Predictor	Estimate*	p
Intercept	*1.556*	*< .001*
Tonsils grade 1-2 vs 3-4	-1.005	0.006
Adenoidectomy not done vs done	-1.447	0.018
ASA 3-4 vs 1-2	-0.705	0.024
Age >6 vs <6	-0.876	0.035

*Estimate represents the log odds of proven OSA cure vs not

Table 5.18 – Predictive measures for proven OSA cure regression model

Specificity	Sensitivity	Accuracy	AUC
0.694	0.679	0.685	0.74

AUC = area under the curve

Table 5.19 – Classification table for predicted versus observed proven cure

	Predicted		
Observed	Yes	No	% correct
Yes	57	27	67.9
No	19	43	69.4

Figure 5.9 – Sensitivity-specificity chart for proven OSA cure regression model, with cut-off point set to 0.65

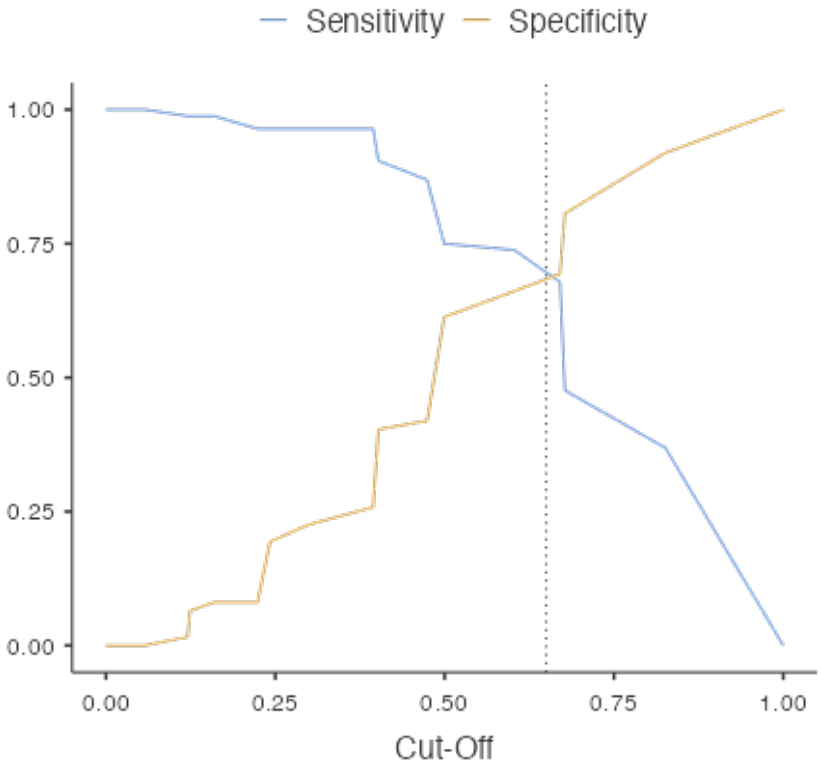
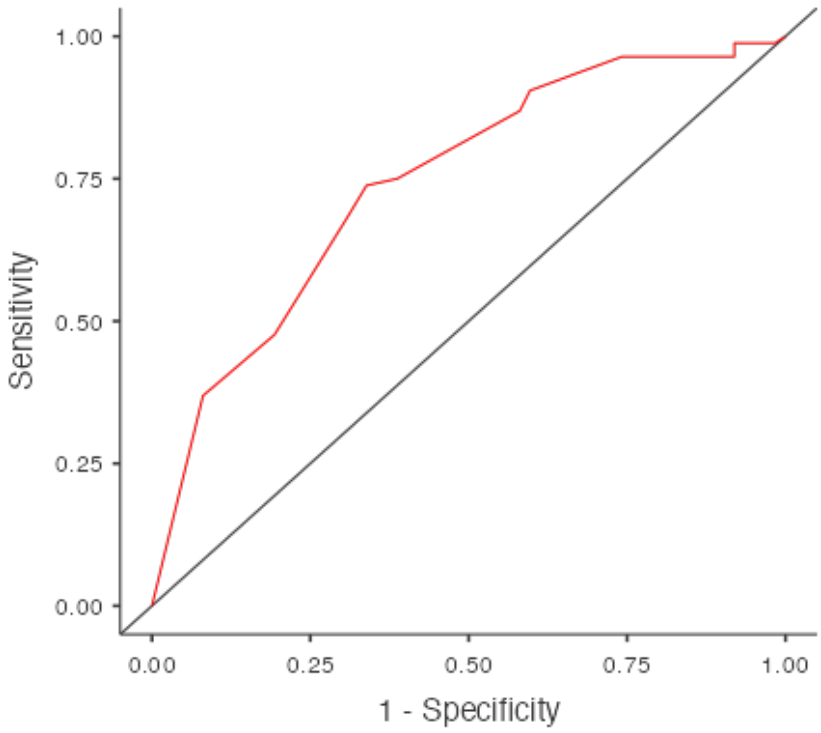


Figure 5.10 – ROC curve for proven OSA cure regression model, AUC = 0.74



Application of predictive score for sleep study proven OSA cure (cohort 1)

As with above previous risk assessment tools, assigned scores for predictive factors for proven cure factor were developed from the log odds estimate calculated by the regression analysis, and adjusted by dividing by the lowest log odds in the model, in this case multiplying by 10 to reach smallest possible whole numbers as presented in Table 5.20. The term "Proven cure Score" (PS) was given to the sum of adjusted scores for predictive factors for proven OSA cure and was calculated and recorded for each participant.

Based on calculated values, the lowest overall PS possible is 0, and would apply to a child who is under the age of 6 who has large tonsils, an ASA of less than 3 and who is planned for adenoidectomy as well as tonsillectomy. Conversely, the highest PS possible is 57, representing a child over the age of 6 with an ASA of 3 or above and small tonsils who is not planned for adenoidectomy.

Three categories were again selected to represent groups with high, medium or low likelihood of proven OSA cure, with cut-off values selected by calculating 33.3rd and 66.7th percentile groups. The high likelihood group therefore included those with calculated PS between 0-15, medium likelihood between 16-30 and low likelihood between 31-57. Observed proven cure rate for respective groups was calculated using Chi-squared independent samples test of association, demonstrating significant differences in proportions between high (74.4%), medium (43.2%) and low (15.8%) likelihood groups ($\chi^2(2)=27.3$, $p<0.001$). Mean predicted probability of reported cure was calculated for high (73.4%), medium (39.9%) and low (17.2%) likelihood groups

using binomial regression prediction modelling. Non-parametric one-way ANOVA using Kruskal-Wallis H test demonstrated significant differences between mean probabilities of high, medium and low likelihood groups ($H(2)=866.7$, $p<0.001$). Observed proven cure rate and mean predicted probability of proven cure for high, medium and low likelihood groups are presented in Table 5.21, and in bar graph form in Figure 5.11.

Validation testing of predictive score for (sleep study) proven OSA cure (cohort 2)

The same score ranges were used to define high, medium and low likelihood groups in cohort 2 as in cohort 1. The observed rate of proven OSA cure for the respective groups in cohort 2 was again calculated using Chi-squared independent samples test of association, demonstrating significant differences in proportions between high (92.9%), medium (87.5%) and low (42.9%) likelihood groups ($\chi^2(2)=7.6$, $p=0.02$). This was compared against mean predicted probabilities for each likelihood group as calculated using binomial regression model based on cohort 1, and displayed in Table 5.22 and in bar graph form in Figure 5.12.

Table 5.20 – Adjusted scores per risk factor for proven OSA cure model

Risk factor	Category	Estimate	Adjusted score
Adenoidectomy done	Yes	0	0
	No	-1.447	20
ASA class	1-2	0	0
	3-4	-0.705	10
Age	<6	0	0
	>6	-0.876	12
Tonsils grade	1-2	-1.005	15
	3-4	0	0

Table 5.21 – Observed and predicted reported cure rate for high, medium and low likelihood groups in cohort 1

Likelihood group	High	Medium	Low
Proven cure score (PS) range	0-15	16-30	30-57
Observed Proven cure rate (%)	74.7	43.2	15.8
Predicted probability of proven cure (%)	73.4	39.9	17.2

Figure 5.11 – Bar graph showing observed proven cure rate against predicted probability of proven cure for high, medium and low likelihood groups in cohort 1

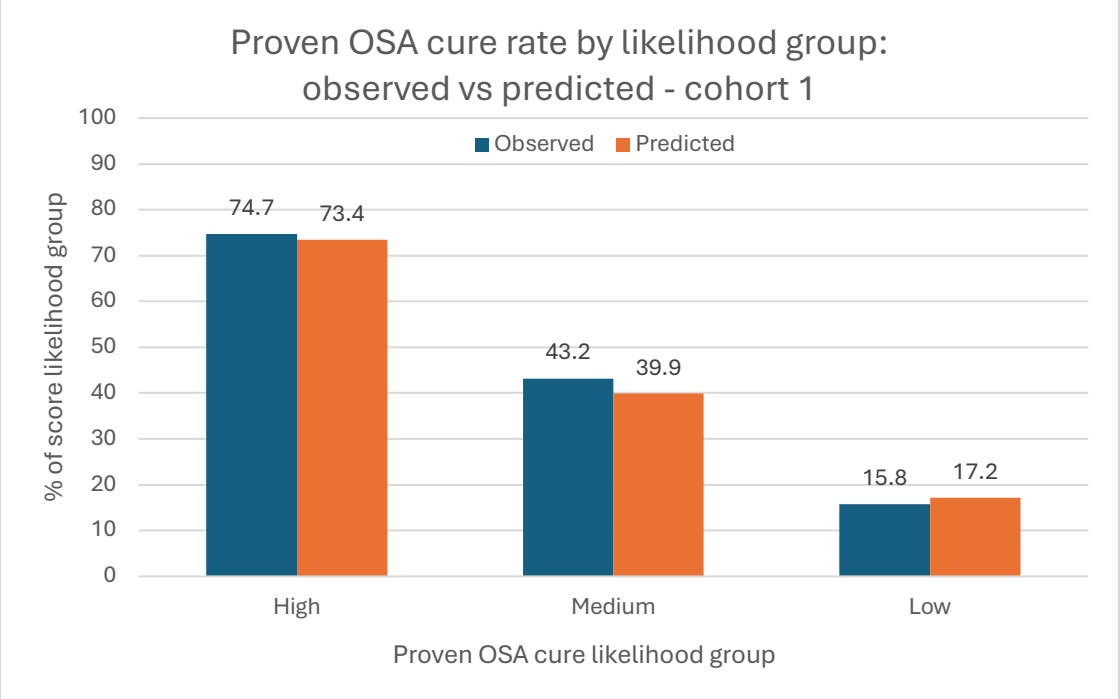
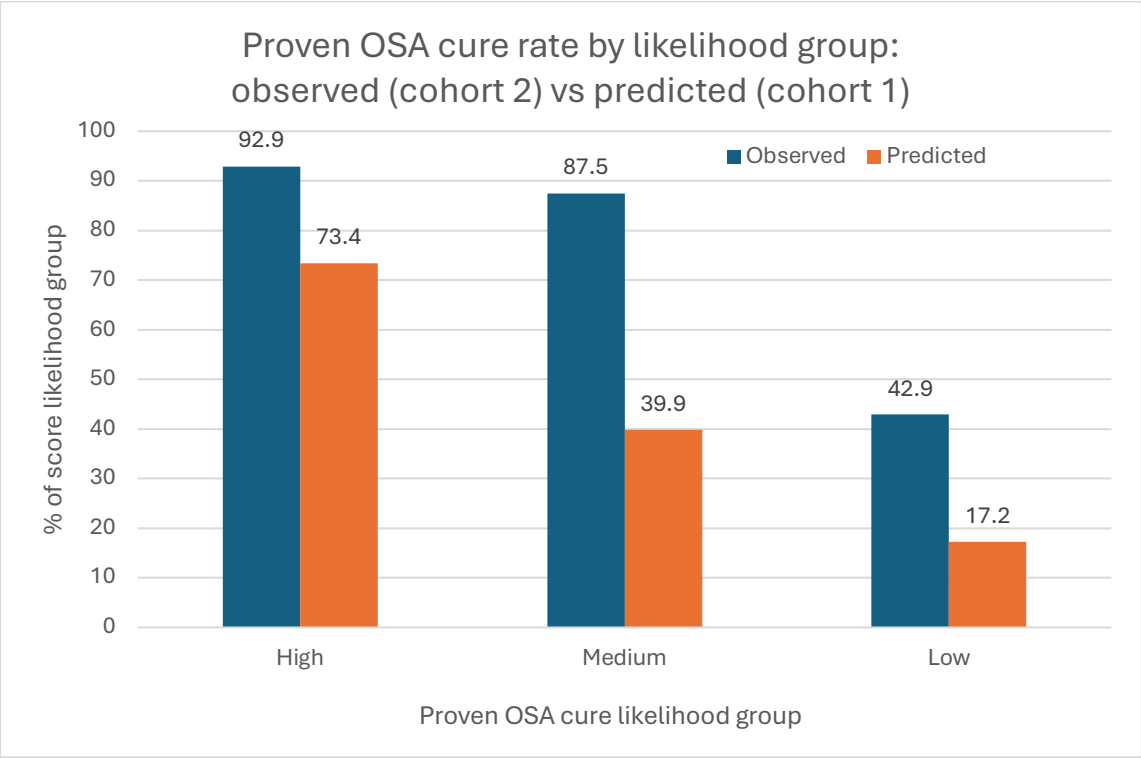


Table 5.22 - Observed reported cure rate for high, medium and low likelihood groups in cohort 2 alongside predicted probability calculated from cohort 1

Likelihood group	**High**	**Medium**	**Low**
Proven cure score (RS) range	0-15	16-30	30-57
Observed proven cure rate (%)	88.9	80	50
Predicted probability of proven cure (%)	*73.4*	*39.9*	*17.2*

Figure 5.12 – Bar graph showing observed proven OSA cure rate from cohort 2 alongside predicted probability for high, medium and low likelihood groups



5.4 DEVELOPMENT OF A COMBINED PREDICTIVE TOOL

All three risk assessment tools were combined into a single table with the purpose of providing clinicians a pre-operative risk profile for children they are considering for tonsillectomy, covering the risk of complications the child may experience and the likelihood of OSA cure (reported and sleep study proven). It was designed with a column listing all patient and operative factors, a column for marking whether factor present, and a column for each CS, RS and PS value per factor. A row was allocated for totalling respective CS, RS and PS, and below this a section for interpretation of results with each low, medium and high risk or likelihood category and their respective probability of outcome. The final tool was named the Scoring Tool for Adenotonsillectomy Risk and Sleep-apnoea outcome (STARS) and is displayed in Table 5.23, based on data from cohort 1 and validated on data from cohort 2.

As demonstrated, complication score and reported oSDB cure score correlated well when validated on cohort 2, while proven OSA cure appeared to correlate the least. The explanation is likely due to the fact complication rates and reported oSDB cure rates were unchanged across cohorts, while proven OSA cure rate was higher in cohort 2. A simple to use and cost-effective tool such as STARS is necessary to guide clinicians and caregivers in identifying whether adenotonsillectomy is a viable option for management of paediatric OSA and oSDB both in terms of risk of complications and the likelihood of parents noticing a change in their child's breathing as well as objective cure of OSA by means of sleep study.

Table 5.23 – Scoring Tool for Adenotonsillectomy Risk and Sleep-apnoea outcome (STARS) for complication, reported oSDB cure and proven OSA cure scores

Factor	Tick if present	Complication score (CS)	Reported oSDB cure score (RS)	Proven OSA cure score (PS)
Patient factors				
Age <2		16		
Age 2-6		5		
Age >6				12
Morbid obesity (Z-score>3)			18	
Neuromuscular disorder		11		
Craniofacial abnormality			17	
ASA 3+		7	10	10
Severe OSA on pre-op PSG			17	
Tonsils grade 1-2			13	15
Operative factors				
Monopolar tonsillectomy		12		
No adenoidectomy			12	20
Monopolar adenoidectomy		11		
Local anaesthetic given		7		
Score per column:				
		0-27 = 10.5% risk	0-30 = 89.1% cure	0-15 = 74.7% cure
		28-45 = 26.0% risk	31-50 = 47.5% cure	16-30 = 43.2% cure
		46+ = 50.0% risk	51+ = 33.3% cure	31+ = 15.8% cure

CHAPTER 6: DISCUSSION

Adenotonsillectomy remains one of the most commonly performed surgical procedures on paediatric patients and this study offers a detailed evaluation of trends, outcomes, and risk factors associated with paediatric adenotonsillectomy at a tertiary paediatric hospital, comparing two time-separated cohorts. Through this comparative analysis, key shifts in patient demographics, surgical techniques, and post-operative outcomes were identified, alongside predictors of both surgical complications (unplanned admission to paediatric intensive care unit (PICU), delayed discharge for any reason, post-tonsillectomy haemorrhage (PTH) and readmission for any reason within 2 weeks of surgery) and resolution of obstructive sleep apnoea (OSA). Using binomial logistic regression analysis, this retrospective cohort study identified key risk factors for post-operative complications as well as predictive factors of both reported and sleep study proven OSA cure following tonsillectomy, using these factors to develop the Scoring Tool for Adenotonsillectomy Risk and Sleep-apnoea outcome (STARS) tool.

Other significant and original findings demonstrated in this study include an association between tonsil size and risk of PTH, an increased risk of delayed discharge and overall risk for complications with local anaesthetic use, an increased risk of PTH and general complication association with neuromuscular disorders, small tonsils being associated with reduced reported and proven OSA cure rates and the addition of adenoidectomy increasing the likelihood of both reported and proven OSA cure.

6.1 SHIFTING TRENDS IN PATIENT, OPERATIVE AND OUTCOME CHARACTERISTICS

Major patient-related changes in adenotonsillectomy trends identified in this study include a higher proportion of patients who are male, obese, comorbid, and who suffer from obstructive sleep-disordered breathing (oSDB) but lower rates of adenotonsillar hypertrophy over time. Several large-scale database studies collecting data prior to 2015 reported cohorts made up of 49-59% male paediatric patients[11, 23, 28, 37, 68, 110], while studies reporting data from 2019 onwards reported higher proportions between 59-63%[111, 112], perhaps indicating a global shift towards higher proportions of paediatric male patients requiring tonsillectomy. The increase in the proportion of obese patients undergoing tonsillectomy in this study is 2.5 times higher than the increase in childhood obesity in Australia[113], in keeping with obese children having twice the odds of undergoing adenotonsillectomy than healthy weight children according to previous studies[59, 61]. It is well recognised that obesity is a significant contributor to paediatric OSA[48, 114, 115], so higher rates of childhood obesity may contribute to even higher rates of obstructive symptoms necessitating referral for tonsillectomy. The increased proportion of children undergoing pre-tonsillectomy sleep studies may be explained by increased services available at our centre in recent times, it may also represent a response to the recommendation for pre-operative sleep study being performed prior to tonsillectomy if children are under 2 years, obese or have comorbidities, or if the need for tonsillectomy was uncertain or discordance existed between clinical symptoms and physical examination, as per the 2019 update to the Clinical Practice Guideline: Tonsillectomy in Children[2]. Most epidemiological studies report rates of paediatric OSA to be between 1-5%[116, 117], but no high quality data is currently available to confirm increasing prevalence

of OSA among children. Adenotonsillar hypertrophy is widely considered to be the leading cause of OSA in children[2, 48], suggesting that the increased rate of OSA (including severe OSA) observed in cohort 2 is more likely to be a reflection of increased medical complexity[48, 118, 119], given the reduced rates of adenotonsillar hypertrophy seen in cohort 2. It has been suggested that the increased prescription of continuous positive airway pressure (CPAP) observed in cohort 2 is a result of the increased waitlist time for adenotonsillectomy at the Children's Hospital at Westmead observed by clinicians, with interim treatment using CPAP required to avoid clinical deterioration in these children while they await definitive management. The higher proportion of patients with significant comorbidities is unlikely to be a result of increased comorbidity rates in children in general but rather lower rates of otherwise well children being referred to our tertiary centre (and possibly undergoing tonsillectomy elsewhere).

Major operative changes in adenotonsillectomy trends identified in this study include an increased proportion of partial tonsillectomy (PT), increased coblator use and reduced cold dissection methods for both tonsillectomy and adenoidectomy, increased local anaesthetic use especially pre-excision, increased use of intravenous antibiotics (IVABs) intra-operatively and decreased use of per-oral antibiotics (POABs) on discharge. The increase in partial tonsillectomies in this study may be in response to increased acceptance of the technique for management of OSA in children as summarised in a 2020 Cochrane review[4], especially for children under 2 years of age, while the increase in coblator use coincides with the release of a Cochrane review in 2017[70], which suggested decreased pain levels on day 1 post-tonsillectomy and decreased primary bleeding rates despite the low quality of included studies. The 2011

Cochrane review on dissection versus diathermy for tonsillectomy, which reported no method being clearly superior but suggested lower intraoperative bleeding with diathermy[69], may have contributed to the observed reduction in cold tonsillectomies. The use of local anaesthetic in cohort 2 is supported by many studies recommending local anaesthetic use in paediatric tonsillectomy[25, 95, 120], however there is little data on the benefits of pre- or post-excision infiltration, with no difference in outcomes between the two in this study. Despite reiterated recommendations in updated clinical practice guidelines, intravenous antibiotic use increased in cohort 2 with no identified reason, however the routine use of POAB on discharge reduced in accordance with recommendations[2].

Despite significant changes in patient and operative factors, there were few differences in outcome measures between the two studied cohorts, with no change in rates of general complication, delayed discharge, emergency PICU admission, readmission, PTH or reported oSDB cure, but there was an increase in proven OSA cure rate in cohort 2. The general complication rates in this study differ from complication rates reported by other studies[30, 121] however the definition of overall post-tonsillectomy complication varies greatly throughout the literature, with some studies including a smaller number of complications and reporting lower rates[121], and others a longer list or broader definition of complications and reporting higher rates[30]. While the emergency PICU admission rate did not increase, the increase in elective PICU admissions may represent a response to multiple studies recommending planned PICU admission following tonsillectomy in children with significant comorbidities and severe OSA[122, 123]. Readmission to hospital was constant across cohorts, but was higher than other

studies in the literature which saw rates of 3.6-8.1%[36, 37, 40, 68], however definitions of readmission varied between studies with some excluding cases where children were discharged directly from the emergency department. The rates of overall PTH, primary PTH and operative PTH remained constant across cohorts, despite the increased proportion of male patients in cohort 2 and the well-recognised association between male gender and PTH[8, 11, 15, 37, 82, 110]. Reported oSDB cure rate did not change over time, however the rate of proven OSA cure increased by 38% across cohorts despite similar proportions of children in each cohort undergoing both pre- and post-operative sleep studies, with the cohort 2 proven cure rate of 73.5% exceeding that of previous large scale studies[115].

6.2 RISK FACTORS FOR COMPLICATIONS

Risk factors for complication

Younger age was associated with increased risk of any complication (unplanned admission to PICU, delayed discharge for any reason and readmission for any reason within 2 weeks of surgery) as well as delayed discharge and emergency admission to PICU in this study. Cooper et al observed an overall complication rate of 38% for children under 2[30], in keeping with our findings. Multiple studies in the literature have identified younger age as a risk factor for respiratory distress and re-intubation[20, 30, 54, 124], which then requires admission to PICU. Increasing age on the other hand demonstrated a strong association with PTH in this study in keeping with multiple studies in the literature[9, 11, 36]. In this study, the 12.1% increased odds per additional year of age of PTH was greater than the 3-10% increased odds reported previously[31, 32]. Underweight

children were at higher risk of any complication and for delayed discharge than normal weight or obese children, in contrast to previous studies identifying higher body mass index (BMI) to be a risk factor for prolonged pain[60] and demonstrating a positive correlation with BMI and length of stay in days[61].

American Society of Anesthesiologists (ASA) class 3 or higher, a marker for significant comorbidity, was associated with increased risk of general complication, delayed discharge and higher risk of unplanned admission to PICU, supported by multiple studies in the literature[63, 123, 125]. Neuromuscular disorders were associated with all outcome measures of complication in this study, and while previous studies have identified association with complications leading to increased length of stay, admission to PICU and readmission[19, 20, 68, 126], ours is the first to identify an increased risk of PTH in children with neuromuscular conditions. This contrasts with a previous national database study demonstrating a lower PTH rate for children with paralysis and other neurological disorders[110]. Syndromic conditions were associated with general complication, delayed discharge and emergency PICU admission, as previously reported in various studies[63, 127]. Developmental delay was associated with increased general complication rate as well as delayed discharge and emergency PICU, however comparison to available literature was limited due to various definitions of developmental delay[126, 128]. Where conditions were explicitly defined, the literature supported our findings of increased length of stay and higher risk of PICU admission in the presence of these conditions[128].

Pre-operative OSA diagnosis was associated with increased general complication rate, delayed discharge and emergency PICU admission, while CPAP prescription was associated with increased general complication rate and delayed discharge in this study. The increased risk of postoperative respiratory distress in children with OSA has been well demonstrated in the literature[20, 30, 56] including higher rates of peri-operative respiratory adverse events (PRAEs) associated with increasing apnoea-hypopnoea index (AHI)[65], with no surprise that similar results were demonstrated in our study regarding delayed discharge often caused by respiratory distress. Higher PICU admission rates have been demonstrated for children with pre-operative AHI greater than 10[123], while severe OSA has been identified as an independent risk factor for reintubation or post-obstructive pulmonary oedema requiring PICU admission following tonsillectomy[50].

Operative factors had less of an impact on post-tonsillectomy complications than patient factors in this study. Monopolar techniques for tonsillectomy and adenoidectomy were associated with increased risk of general complication and delayed discharge in cohort 1, while monopolar adenoidectomy was also linked to increased readmission rates in cohort 1. Pinder et al's Cochrane review suggested that cautery methods for adenotonsillectomy increased the risk of severe post-operative pain compared to dissection[69], which could lead to poor oral intake delaying discharge as well as leading to readmission, while Stramiello's meta-analysis demonstrated a reduced impact of local anaesthetic in reducing pain if tonsillectomy was performed by cautery rather than cold dissection techniques[25]. The addition of adenoidectomy in addition to tonsillectomy was associated with increased general complication and

delayed discharge, however few studies have reported on complication rates of adenotonsillectomy versus tonsillectomy alone. It is possible that the additional complications specific to adenoidectomy may play a role, including epistaxis, an increased surgical wound delaying healing, local infection and Grisel's syndrome, otherwise known as atraumatic atlanto-axial subluxation[129].

The use of local anaesthetic was associated with increased general complication rate and delayed discharge, specifically delay caused by poor oral intake due to pain. This not only goes against the intended effect of intraoperative local anaesthetic infiltration in preventing pain and improving oral intake, but is also in contrast with other studies in the literature including meta-analyses demonstrating less pain at 24 hours postoperatively[25] and reduced analgesia requirements[94, 95]. This raises the possibility that prolonged time between doses of opioid given intraoperatively during general anaesthetic and those given postoperatively results in higher analgesic requirement by the time local anaesthetic has worn off. Total analgesic requirements and choice of oral analgesia were not in the scope of this study but are a consideration for future research.

Risk factors for specific complications (but not general complication rate)

Some factors did not increase the risk of general complication but were strongly associated with specific complications, some for the first time in the available literature. Children whose indication for surgery was recorded as oSDB were more likely to have a delayed discharge than those with recurrent tonsillitis in cohort 1, which is very likely confounded by the increased rates of delayed discharge for children with pre-operatively diagnosed OSA found in this study and supported by the literature[56].

Children with craniofacial abnormalities had increased risk of delayed discharge, which is supported by multiple studies showing greater odds of PRAEs leading to delayed discharge in children with craniofacial or airway abnormalities[20, 55]. PT was associated with lower rate of delayed discharge compared to total tonsillectomy (TT), in keeping with the findings from multiple systematic reviews demonstrating that PT is associated with reduced pain scores and quicker resumption of normal diet[72-74, 130], suggestive of earlier discharge. Partial adenoidectomy was associated with increased emergency PICU admission rates, however may be confounded by this procedure being generally reserved for comorbid children and similar findings were not found in the literature. Interestingly, there was no increased rate of emergency PICU admission in either cohort for children who required CPAP prior to tonsillectomy, and given the higher risk of PRAEs experienced by children with severe OSA, this raises the possibility that preoperative CPAP use mitigated these risks and prevented significant deterioration postoperatively. The preoperative provision of CPAP to these children also means ward staff have an effective way of providing respiratory support than may have otherwise required PICU and suggests that routine PICU admission on the basis of preoperative CPAP use may not continue to be relevant[131, 132]. Monopolar adenoidectomy was associated with increased risk of readmission compared to other adenoidectomy methods, with no precedent available in the literature. Surprisingly, the only operative factor in cohort 2 that influenced readmission rates was the use of intra-operative IVABs, where no children who received IVABs were readmitted following surgery. While no clear explanation for this trend was identified, it certainly warrants further research.

The risk of PTH was higher in the presence of grade IV tonsils, which appears to be the first demonstration of this association and calls for further research in this area. No previous studies have linked larger tonsils to increased risk of PTH, with the assumption being that larger tonsils are often associated with oSDB as indication for surgery – a finding verified in both cohorts included in this study – which in itself is meant to carry a lower risk of bleeding compared to recurrent tonsillitis according to available evidence from a 2015 meta-analysis[56]. Perhaps larger tonsils have increased size or number of blood vessels present, or may result in more inflammation given the larger raw surface area following removal, predisposing to PTH. The finding of smaller tonsils being associated with increased PTH risk in cohort 2 is likely confounded by a smaller group of children with grade I tonsils compared to other grades, and an overestimated PTH rate for this group calculated from one episode of bleeding. Neither gender nor weight were seen to increase the risk of PTH in either cohort in this study, despite many previous studies demonstrating increased bleeding rates for males[7, 9, 11, 35, 37] and children who are obese[43, 44, 133, 134]. In the context of a higher male population in the second cohort with no increased PTH rate, this suggests other protective factors at play that further research could identify. No association was seen between children undergoing tonsillectomy for recurrent tonsillitis and increased rates of PTH in either cohort in this study. This is in contrast to multiple sources in the literature demonstrating PTH risk ratios of up to 4.5 for recurrent tonsillitis compared to children having surgery for oSDB[32, 35, 42, 43], including a meta-analysis by De Luca Canto et al showing higher PTH rates in children without OSA[56]. The literature suggests this finding may be confounded by bleeding rates increasing with advancing age, however when analysing children over the age of 6, those with oSDB had marginally higher but statistically non-significant PTH rates than

those with recurrent tonsillitis in both cohorts. Despite these results not meeting significance threshold, this supports our finding of no increased risk of bleeding for children with recurrent infections. In this study, there was no association between any operative factors and risk of PTH particularly when comparing cold steel versus hot tonsillectomy techniques, in keeping with Pinder et al's 2011 Cochrane review[69]. While previous studies have been able to demonstrate lower PTH rates with lower energy cautery[17, 135], the wattage used for monopolar tonsillectomies in this cohort was not reliably recorded and analysis could not be conducted. Coblation tonsillectomy showed no increased risk of PTH in either cohort, in contrast to previously published literature[70].

6.3 PREDICTORS OF REPORTED AND PROVEN OSA CURE

Factors for reported oSDB cure

Reported oSDB cure was more likely in children over 2 who had an ASA score of 2 or less and large tonsils and adenoids, without morbid obesity or other comorbidities including neuromuscular conditions or pre-operatively diagnosed OSA. There remains a paucity in the literature regarding alternative metrics to polysomnography (PSG) when analysing OSA cure, making direct comparison to our findings difficult. However, multiple studies have reported that younger patients were more likely to have residual symptoms of oSDB following tonsil surgery and more likely to undergo further operations than older children[73, 77, 78, 136, 137]. There are limited studies on the effectiveness of adenotonsillectomy in the literature that do have included children with significant comorbidities, so it is no surprise that there is no published data on reported oSDB cure

rates for children with comorbidities. Pre-operative OSA diagnosis, especially if severe and requiring pre-operative CPAP, was associated with reduced likelihood of reported oSDB cure in this study. While it could be assumed at face value that those without a pre-operative PSG demonstrating OSA do not have OSA, less than half of children in this study with oSDB were able to undergo pre-operative sleep study, despite 96.3% of these studies being diagnostic for OSA. It is unlikely that the same proportion of children with oSDB who did not have sleep studies would have been diagnosed with OSA had a study been undertaken, however it is possible that a number of OSA diagnoses were missed due to lack of pre-operative PSG. As shown in this study as well as those in the literature, severe OSA is associated with reduced likelihood of reported oSDB cure compared to mild or moderate cases[138], and it could be reasoned that severe cases are more likely to undergo pre-operative sleep studies due to the magnitude of clinical symptoms. It is therefore possible that a cohort of children with undiagnosed mild to moderate OSA exist in this study who will have benefited greatly from tonsillectomy without objective measures to confirm this, and without their patient or carer reported oSDB status being used as a measure of improvement their results would be overlooked. More than half of children having post-operative sleep studies were those with a diagnosis of severe OSA pre-operatively, compared to only 15% of the cohort as a whole. It could then be suggested that the children in our study who underwent follow-up PSG were the ones for whom treatment success was least likely, implying that the children who did not have a follow-up PSG may have had higher magnitudes of improvement following tonsillectomy, and that sleep study proven OSA cure rates may be significantly higher if more children were able to access a post-operative study. This highlights the need for alternative OSA screening methods including validated

questionnaires to better identify those most in need of treatment, an area of possible future research in subsequent cohorts at our centre.

In terms of operative factors, TT, monopolar tonsillectomy technique and the addition of adenoidectomy were associated with increased likelihood of reported oSDB cure. Other studies in the literature have shown similar rates of reported symptom resolution between TT and PT[78], with our finding of lower reported cure associated with PT being likely confounded by higher proportions of children under 2 or with ASA 3 or higher undergoing this type of tonsillectomy – both factors independently associated with reduced reported cure. While there is no current evidence available to support our finding of increased reported oSDB cure with monopolar tonsillectomy compared to other methods, it is likely the scarring resulting from significant heat produced during monopolar cautery that stiffens the anterior and posterior pillars and soft palate, reducing the degree of upper airway obstruction contributing to snoring. This is in a similar fashion to the cautery-assisted palatal stiffening operation (CAPSO) described by Llewellyn et al, which was seen to reduce AHI scores by 41% when performed alone, and 61% when combined with tonsillectomy in adult patients[139]. The addition of adenoidectomy increased the rate of reported oSDB cure by compared to tonsillectomy alone in this study, and while adenoidectomy alone was seen to improve reported symptoms of oSDB in 43.5% of cases in a 2018 study on children under the age of 3[140], there remains a gap in the literature concerning the effectiveness of tonsillectomy compared to adenotonsillectomy for curing symptoms of OSA, both reported and proven on sleep study. Removing both adenoids and tonsils critically augments both nasal and oral sections of the velopharyngeal airway, which suggests that tonsillectomy

for treatment of OSA with and without formal diagnosis should be accompanied by adenoidectomy – an area for further research.

Factors for proven OSA cure

Proven OSA cure was associated with patient factors including age >6 years, recurrent tonsillitis as surgical indication, ASA class of 1-2, large tonsils and the absence of craniofacial abnormalities, developmental delay or syndromic conditions. Children <6 years most likely to have proven resolution of OSA, in keeping with the findings from several studies including Chen et al's systematic review and meta-analysis, identifying that those between 3-7 years old had the most to gain from tonsillectomy in terms of high OSA cure rates and low complication rates[141]. Children with pre-operatively diagnosed OSA but recurrent tonsillitis listed as the primary indication for surgery were more likely to have proven OSA cure than those with oSDB listed, likely confounded by these children having milder OSA than those identifying their obstructive symptoms as their main indication. Our finding of less severe OSA being associated with higher rates of cure is supported by multiple studies[127, 138]. Otherwise well children with ASA 1-2 had higher rates of proven OSA cure than comorbid children in this study, similar to Friedman et al's meta-analysis demonstrating 73.8% cure rate for otherwise well children compared to 38.7% in children with comorbidities [115], though their definition of comorbidity included all cases of obesity. In contrast to theirs and other studies[114], obesity alone did not lower the likelihood of OSA cure following tonsillectomy unless BMI Z-score was 3 or greater (and defined as morbid obesity), which was seen to be a significant contributing factor to treatment failure on multivariate analysis. Another study demonstrated that children with comorbidities did not show improvement from

central apnoeas following tonsillectomy despite improvement in obstructive apnoeas[142] suggesting factors other than adenotonsillar hypertrophy contribute to central apnoeas in comorbid children; however central apnoeas were not used as a metric in this study. Syndromic conditions, craniofacial abnormalities and developmental delay reduced the likelihood of proven OSA cure in this study, findings supported by previous studies[127, 143, 144]. While the combined volume of pharyngeal lymphoid tissue has previously been associated with severity of OSA[53], there are few studies demonstrating positive correlation between tonsil grade and AHI[145] and no studies to our knowledge demonstrating an association between visually graded tonsillar size and likelihood of proven OSA cure following tonsillectomy. A previous study by Tang et al demonstrated no difference in tonsil size and likelihood of OSA resolution but did not include any children with grade I tonsils[146], which may be explained by the fact that the study excluded children with comorbidities.

The only operative factors seen to affect proven OSA cure rates in this study were the addition of adenoidectomy to tonsillectomy and POAB prescription on discharge. Adenoidectomy alone has been shown to reduce AHI scores in other studies[147, 148], with the consensus being that adenoidectomy by itself can improve OSA in children with large adenoids and small tonsils, but that younger age was associated with the need for tonsillectomy at a later date[148]. Interestingly, adenoid size was not associated with either reported or proven OSA cure in this study. The link between POAB prescription and increased proven OSA cure rates is not supported by available literature, however it is likely confounded by POABs being given to children with recurrent tonsillitis at a higher rate than those with oSDB in cohort 1 where this phenomenon was seen.

6.4 CLINICAL IMPLICATIONS OF THIS STUDY

This study has several important clinical implications. First, it confirms the safety and effectiveness of adenotonsillectomy as first-line therapy for paediatric OSA, particularly in anatomically driven disease. Second, it highlights that outcomes are not uniform, and that careful consideration of patient-specific factors is essential for surgical planning. The STARS tool proposed from this data offers a practical method for pre-operative risk stratification. Incorporating age, ASA class, tonsil size, adenoid status, comorbidities, and surgical technique, and it provides clinicians with a decision-support framework that may inform perioperative planning and family counselling. The system was validated in our second cohort, and has potential to improve consistency and safety in surgical care, particularly in resource-constrained tertiary settings. The results also support routine adenoidectomy in the surgical management of paediatric OSA, even in cases without significant nasal symptoms or tonsillar hypertrophy. Similarly, PT appears to offer a favourable risk-benefit profile for appropriately selected patients, though its application in children with more severe disease should be carefully considered.

Risk-stratified care also has implications for hospital resource use. Identifying children at elevated risk of complications can help guide decisions regarding post-operative monitoring, overnight admission, or PICU booking, potentially reducing unplanned admissions and improving efficiency. At the same time, recognising children likely to achieve cure without complication can support more streamlined surgical pathways. Finally, the discrepancy between parent-reported and PSG-confirmed cure underscores

the importance of structured follow-up in children with residual symptoms or comorbidities. The use of validated tools like the OSA-18 or CAS-15, or access to simplified PSG protocols, may help ensure that clinically significant residual OSA is not missed.

6.5 LIMITATIONS AND FUTURE DIRECTIONS

This study has several limitations. As a retrospective review, it relied on the accuracy of documentation on the electronic medical record (EMR), which was user-dependent and inconsistent for some variables, such as tonsillectomy technique, local anaesthetic use, and patient height—limiting BMI Z-score calculation. Data from cohort 1 were extracted from scanned records, which may have introduced more missing data compared to the fully digital records of cohort 2. However, because all children undergoing adenotonsillectomy within the timeframes were included, the risk of sampling bias is low. While the time lapse between cohort 1 procedures and data collection could raise concerns about generalisability, it also enabled long-term follow-up, allowing outcomes such as revision surgery or delayed complications to be captured. By analysing cohorts separately, we were able to quantify changes over time, and findings with consistent results across both groups improve the generalisability of key associations.

Some findings did not reach statistical significance in cohort 2, likely due to the smaller sample size. A larger cohort would have improved statistical power, particularly for less common outcomes such as PTH. Our definition of comorbidities also differed from

some published studies: obesity only if ‘morbid’ with BMI Z-score exceeding 3, and OSA only if severe and requiring CPAP. These strict definitions allowed for more meaningful subgroup analyses but may limit direct comparison with broader literature. ASA class was used to provide a more objective marker of comorbidity severity.

OSA was only diagnosed if confirmed on pre-operative sleep study, and cure only if PSG was performed post-operatively, which limited the sample size and statistical power. However, this increased the strength of the associations identified. Pre-operatively, oSDB served as a surrogate marker for presumed OSA in children without formal testing, and parent-reported oSDB cure was used where PSG follow-up was unavailable. Although tonsillar regrowth was not formally assessed, the extended follow-up allowed us to confirm that no child in cohort 1 who underwent PT required revision tonsillectomy. Only one revision case occurred in a child with multiple comorbidities who underwent a PT prior to the first study period.

Associations involving local anaesthetic and antibiotic use must be interpreted cautiously as many factors determine their use. These interventions may have been more frequently applied in higher-risk or more symptomatic children, introducing confounding by indication. The suggestion that antibiotics or local anaesthetic use may negatively affect outcomes is intriguing, but requires prospective confirmation. Due to the overall low incidence of PTH, this study was underpowered to detect statistically significant differences in PTH rate between subgroups, despite observed variation in proportions. Given the relatively rare nature of this outcome, much larger multicentre cohorts would be required to explore this further and are a priority for future research.

CHAPTER 7: CONCLUSION

Through the results of this study, we have been able to identify for the first time in the known literature a direct association between tonsillar hypertrophy and both severity of obstructive sleep apnoea (OSA) and likelihood of polysomnography (PSG)-proven OSA cure as well as risk of post-tonsillectomy haemorrhage (PTH), an increased risk of general complication and delayed discharge with local anaesthetic use, an association between PTH with neuromuscular disorders and an increased likelihood of both reported and proven OSA cure with the addition of adenoidectomy to tonsillectomy. Multivariate analysis performed on data from cohort 1 was able to identify factors associated with general complication rates, reported and proven OSA cure. Factors associated with increased post-tonsillectomy complication include younger age, American Society of Anesthesiologists (ASA) class 3+, presence of a neuromuscular disorder, local anaesthetic use and monopolar techniques used for tonsillectomy and adenoidectomy. Reported obstructive sleep disordered breathing (oSDB) cure was associated with tonsillar hypertrophy, ASA class 1-2, addition of adenoidectomy, and absence of morbid obesity, severe OSA and craniofacial abnormalities. PSG-proven OSA cure was associated with age less than 6, tonsillar hypertrophy, ASA class 1-2 and addition of adenoidectomy. Findings from multivariate analyses were used to develop the Scoring Tool for Adenotonsillectomy Risk and Sleep-apnoea outcome (STARS) tool, which was then validated on cohort 2.

Areas of future research identified throughout the course of this project include further evaluation of the association between PTH and tonsil size, intravenous antibiotics

(IVABs) and reduced readmission rates and clinical validation of the STARS score, as well as expansion of the tool to other post-tonsillectomy outcomes. A critical future research direction in the context of limited PSG availability in Australia is the development and validation of alternative outcomes measures for OSA diagnosis and resolution, such as assessment tools including the OSA-18[149], OSA-5[150] and CAS-15[151] scores, or simpler overnight oximetry testing with metrics such as the McGill Oximetry Score (MOS) [152] used for classification of OSA rather than apnoea-hypopnoea index (AHI). An effective alternative to PSG must be developed and incorporated into local and national guidelines, ensuring we are offering the right surgery to the right patients and that children who would otherwise benefit greatly from tonsillectomy do not miss out on surgery due to the lack of pre-operative PSG. Using the results of this study, we hope to validate the STARS calculator in clinical practice, giving predictions of post-operative complication and OSA resolution rates and comparing these to observed rates. Following successful validation, we hope to incorporate it into local policy to better assist clinicians in recognising which patients have the most to gain from tonsillectomy with the least risk of complication, in order to continue to provide a safe and effective treatment for paediatric OSA in Australia.

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APPENDICES

ETHICS APPROVAL LETTER: 2022/ETH01082

Contact for this correspondence
Research Ethics Office
Research Ethics Support Officer
Phone: (02) 9845 1253
Facsimile: (02) 9845 1317
Email: SCHN-ethics@health.nsw.gov.au

3 November 2022

Professor Alan Cheng
ENT Surgery
The Children's Hospital at Westmead

Dear Professor Cheng,

HREC Reference: **2022/ETH01082**

Project title: **THROAT study: Tertiary Hospital Retrospective Observational Audit of Tonsillectomy**

Sites: **The Children's Hospital at Westmead**

Thank you for submitting the above project for single ethical and scientific review. This project was first considered by the Executive of the Sydney Children's Hospitals Network (SCHN) Human Research Ethics Committee (HREC) ("the Committee") at its meeting on 4 October 2022 and 31 October 2022.

The HREC has been accredited by the NSW Department of Health as a lead HREC under the model for single ethical and scientific review, and by the National Health and Medical Research Council as a certified committee in the review of multi-centre clinical research projects.

This HREC is constituted and operates in accordance with the National Health and Medical Research Council's National Statement on Ethical Conduct in Human Research and CPMP/ICH Note for Guidance on Good Clinical Practice.

I am pleased to advise that the Committee has granted ethical approval of this research project. Your approval is valid for five (5) years, effective the date of this letter.

This application has been assessed in accordance with, and meets the requirements of the National Statement on Ethical Conduct in Human Research (2007) (including all updates).

Please note the following conditions of approval:

1. The Coordinating Investigator will immediately report anything which may warrant review of ethical approval of the project in accordance with the NSW Health's monitoring and safety reporting requirements https://www.medicalresearch.nsw.gov.au/clinical-trial-safety-monitoring/ .

2. All proposed changes to the research protocol, including the conduct of the research, changes to site or personnel, or an extension to HREC approval, are to be provided to the HREC or its delegate for review before those changes can take effect.

3. The HREC will be notified, giving reasons, if the project is discontinued at a site before the expected date of completion.

4. The co-ordinating investigator will provide an annual report to the HREC on the anniversary of this approval letter, and a final report on completion of the study.

5. Your approval is valid for five (5) years from the date of the final approval letter. If your project extends beyond that five year period and you are still actively recruiting you will be required to submit an application for renewal for up to 5 years of ethics approval incorporating any amendments prior to the approval expiry date, and within six (6) months of the expiry date. If your project is in follow up, or analysis, please submit an application for amendment to extend the approval period. Ethics approval can be extended for a period of twelve (12) months at a time.

6. In the event of a project **not having commenced** within 12 months of its approval, the approval will lapse and reapplication to the HREC will be required.

7. This approval is restricted to research being conducted in accordance with the approved documents, and the review of the medical records you have nominated. There is to be no contact with patients, parents/guardians or other family members.

The documents reviewed and approved by the Committee are:

Document	Version	Date
HREA	2	7 October 2022
LNR HREC Project protocol - Jaensch - 2022ETH01082, THROAT study- Tertiary Hospital Retrospective Observational Audit of Tonsillectomy	2	October 2022
Response to Committee Form SCHN 2022ETH01082, THROAT study- Tertiary Hospital Retrospective Observational Audit of Tonsillectomy	-	19 October 2022
LNR HREC Submission checklist - Jaensch - 2022ETH01082 THROAT study- Tertiary Hospital Retrospective Observational Audit of Tonsillectomy	1	7 June 2022

Document	Version	Date
ETH01082, THROAT study- Tertiary Hospital Retrospective Observational Audit of Tonsillectomy *(waiver of consent)*	1	7 June 2022
069194_Project Registration	-	Received 27 September 2022

Should you have any queries about the HREC's consideration of your project please contact the Research Ethics Support Officer on (02) 9845 1253 or SCHN-Ethics@health.nsw.gov.au.

You are reminded that this letter constitutes ethical approval only. You must not commence this research project at a site until separate authorisation from the Chief Executive or delegate of that site has been obtained. A copy of this letter must be forwarded to all site investigators for submission to the relevant Research Governance Officer.

The SCHN HREC wishes you every success in your research.

Yours faithfully,

Associate Professor Sarah Garnett
Chair, Sydney Children's Hospitals Network Human Research Ethics Committee
Sydney Children's Hospitals Network Human Research Ethics Committee

NB: All clinical trials must now be registered on a publicly accessible registry such as the Australian New Zealand Clinical Trials Registry. For further information please go to www.anzctr.org.au. Please provide this office with a copy of your registration number for our records if you have not already done so.

CC: Dr Samantha Jaensch

SITE SPECIFIC ETHICS APPROVAL LETTER: 2022/STE03348

Contact for this correspondence:
Name: Priya Kumar
Phone: (02) 9845 3011
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Governance inbox: SCHN-Governance@health.nsw.gov.au

09 January 2023

Dr Samantha Jaensch
Department of Ear, Nose and Throat
The Children's Hospital at Westmead

Site Authorisation Letter

Dear Dr Jaensch,

PID number (from REGIS):	2022/PID01225
ETH number:	2022/ETH01082
STE number:	2022/STE03348
Study Title:	THROAT study: Tertiary Hospital Retrospective Observational Audit of Tonsillectomy
Study Site:	The Children's Hospital at Westmead

Thank you for submitting an application for authorisation of this project. I am pleased to inform you that authorisation is granted for this study to take place at the above site.

The following documents are authorised at this site and include HREC/Ethics documents approved on submission:

- LNR HREC Project protocol - Jaensch - 2022ETH01082, THROAT study- Tertiary Hospital Retrospective Observational Audit of Tonsillectomy, version 2.0 dated October 2022
- ETH01082, THROAT study- Tertiary Hospital Retrospective Observational Audit of Tonsillectomy *(waiver of consent)*, version 1.0 dated 07 June 2022

The following conditions apply to this research project. These are additional to those conditions imposed by the Human Research Ethics Committee that granted ethical approval. ***Site authorisation may be withdrawn if these conditions are not met.***

1. Please advise us, via email SCHN-Governance@health.nsw.gov.au the **date when the project starts** at this site.

2. Proposed **amendments** to the research protocol or conduct of the research which may affect the **ethical acceptability** of the project, and which is submitted to the lead HREC for review, are submitted to Research Governance office via REGIS

3. Proposed **amendments** to the research protocol or conduct of the research which may affect the ongoing **site acceptability** of the project are to be submitted to Research Governance office via REGIS.

4. A copy of the **annual report** submitted to the lead HREC must be provided to Research Governance office **after receipt of HREC acknowledgement** via REGIS.

All site post-authorisation reports and amendment applications should be submitted on REGIS. Please visit Research Governance website for more information:
https://www.schn.health.nsw.gov.au/research/ethics-governance/ethics-governance/research-governance

Yours sincerely,

Priya Kumar
Research Governance Officer

ETHICS APPROVAL LETTER: 2024/ETH00819

Contact for this correspondence
Research Ethics Office
Research Ethics Support Officer
Phone: (02) 7825 1253
Email: SCHN-ethics@health.nsw.gov.au

4 July 2024

Professor Alan Cheng
ENT Surgery
The Children's Hospital at Westmead

Dear Professor Alan Cheng,

HREC Reference: **2024/ETH00819**

Project title: **THROAT study: Tertiary Hospital Retrospective Observational Audit of Tonsillectomy 2015-2023**

Sites: **The Children's hospital at Westmead**

Thank you for submitting the above project for single ethical and scientific review. This project was first considered by the Executive of Sydney Children's Hospitals Network (SCHN) Human Research Ethics Committee (HREC) ("the Committee") at its meeting on **11 June 2024** and subsequently on **1 July 2024**.

The HREC has been accredited by the NSW Department of Health as a lead HREC under the model for single ethical and scientific review, and by the National Health and Medical Research Council as a certified committee in the review of multi-centre clinical research projects.

This HREC is constituted and operates in accordance with the National Health and Medical Research Council's National Statement on Ethical Conduct in Human Research and CPMP/ICH Note for Guidance on Good Clinical Practice.

I am pleased to advise that the Committee has granted ethical approval of this research project. Your approval is valid for five (5) years, effective the date of this letter.

This application has been assessed in accordance with, and meets the requirements of the National Statement on Ethical Conduct in Human Research (2023) (including all updates).

Please note the following conditions of approval:

1. The Coordinating Investigator will immediately report anything which may warrant review of ethical approval of the project in accordance with the NSW Health's monitoring and safety reporting requirements https://www.medicalresearch.nsw.gov.au/clinical-trial-safety-monitoring/ .

2. All proposed changes to the research protocol, including the conduct of the research, changes to site or personnel, or an extension to HREC approval, are to be provided to the HREC or its delegate for review before those changes can take effect.

3. The HREC will be notified, giving reasons, if the project is discontinued at a site before the expected date of completion.

4. The co-ordinating investigator will provide an annual report to the HREC on the anniversary of this approval letter, and a final report on completion of the study.

5. Your approval is valid for five (5) years from the date of the final approval letter. If your project extends beyond that five year period and you are still actively recruiting you will be required to submit an application for renewal for up to 5 years of ethics approval incorporating any amendments prior to the approval expiry date, and within six (6) months of the expiry date. If your project is in follow up, or analysis, please submit an application for amendment to extend the approval period. Ethics approval can be extended for a period of twelve (12) months at a time.

6. In the event of a project **not having commenced** within 12 months of its approval, the approval will lapse and reapplication to the HREC will be required.

7. This approval is restricted to research being conducted in accordance with the approved documents, and the review of the medical records you have nominated. There is to be no contact with patients, parents/guardians or other family members.

The documents reviewed and approved by the Committee are:

Document	Version	Date
HREA	2	11 Jun 2024
Response to Committee Form THROAT	-	15 Jun 2024
Project protocol THROAT	2	Jun 2024
Data collection sheet THROAT	-	Rec'd 15 Jun 2024
Waiver of consent	1	Apr 2024
Project Registration	-	Rec'd 3 Jun 2024

Should you have any queries about the HREC's consideration of your project please contact the Research Ethics Support Officer on (02) 7825 1253 or SCHN-Ethics@health.nsw.gov.au.

You are reminded that this letter constitutes ethical approval only. You must not commence this research project at a site until separate authorisation from the Chief Executive or delegate of that site has been obtained. A copy of this letter must be forwarded to all site investigators for submission to the relevant Research Governance Officer.

The SCHN HREC wishes you every success in your research.

Yours faithfully,

Caitlin Braude
Executive Officer, Sydney Children's Hospitals Network Human Research Ethics Committee

NB: All clinical trials must now be registered on a publicly accessible registry such as the Australian New Zealand Clinical Trials Registry. For further information please go to www.anzctr.org.au. Please provide this office with a copy of your registration number for our records if you have not already done so.

CC: Dr Samantha Jaensch - samantha.jaensch@health.nsw.gov.au

SITE SPECIFIC ETHICS APPROVAL LETTER:

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26/08/2024

Dr Samantha Jaensch
Paediatric ENT
The Children's hospital at Westmead

Site Authorisation Letter

Dear Dr Samantha Jaensch,

HREC reference number: 2024/ETH00819

SSA reference number: 2024/STE01988

Project title: THROAT study: Tertiary Hospital Retrospective Observational Audit of Tonsillectomy

Site/s: The Children's hospital at Westmead

Thank you for submitting an application for authorisation of this project. I am pleased to inform you that authorisation is granted for this study to take place at the above site.

The following documents are authorised at this site and to include HREC/Ethics documents approved on submission:

The site specific documents which will be implemented at our site are listed below. Additinally the documents approved by HREC/Ethics provided upon submission are included.

- Project protocol THROAT V2 Jun 2024

The following conditions apply to this research project. These are additional to those conditions imposed by the Human Research Ethics Committee that granted ethical approval. ***Site authorisation may be withdrawn if these conditions are not met.***

1. Please advise us, via email SCHN-Governance@health.nsw.gov.au the **date when the project starts** at this site.

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2. Proposed **amendments** to the research protocol or conduct of the research which may affect the **ethical acceptability** of the project, and which is submitted to the lead HREC for review, are submitted to Research Governance office via REGIS

3. Proposed **amendments** to the research protocol or conduct of the research which may affect the ongoing **site acceptability** of the project are to be submitted to Research Governance office via REGIS.

4. A copy of the **annual report** submitted to the lead HREC must be provided to Research Governance office **after receipt of HREC acknowledgement** via REGIS.

All site post-authorisation reports and amendment applications should be submitted on REGIS. Please visit Research Governance website for more information:
https://www.schn.health.nsw.gov.au/research/ethics-governance/ethics-governance/research-governance

Yours sincerely,

Lailamaryam Alkhouri
Research Governance Officer

Adenotonsillectomy for Obstructive Sleep Apnea in Children

Samantha L. Jaensch, MBBS[a,b], Alan T. Cheng, BHB, MBCHB, FRACS[c,d], Karen A. Waters, MBBS, FRACP, PhD, GCCM[c,e,*]

KEYWORDS

• Child • Sleep-disordered breathing • OSA • Tonsillectomy • Complications

KEY POINTS

- Symptoms of obstructed breathing are the commonest indication for tonsillectomy in children.
- Polysomnography remains complex, expensive, and limited in its availability to children with symptoms of airway obstruction.
- Children with obstructive sleep apnea are at higher risk of postoperative complications than those without obstructive issues, with up to 20% experiencing respiratory compromise requiring intervention.
- Age has been demonstrated to affect the rates of post-tonsillectomy complications in several ways.
- Obesity increases the risk of post-tonsillectomy complications such as bleeding, pain, and postoperative respiratory adverse events.

INTRODUCTION

Tonsillectomy is one of the most commonly performed surgical procedures in children worldwide, with estimated 530,000 tonsillectomies with or without adenoidectomies performed in children aged less than 15 years in the United States each year.[1] Techniques and tools have changed significantly over time, and the increase in childhood

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* Corresponding author. SIDS and Sleep Apnoea Research, Respiratory Support Services, The Children's Hospital at Westmead, Locked Bag 4001, Westmead, NSW 2145, Australia.
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