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Henrik Sjöblom

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To Sarianne, Sulo, and Oula

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ABSTRACT

Obstructive sleep apnoea (OSA) affects a substantial portion of the population in Finland and worldwide, with prevalence rising. Untreated OSA carries wide-ranging consequences, including cardiovascular, metabolic, cognitive, and mental health issues. The palatine tonsils, located in the oropharynx, consist of lymphatic tissue and contribute to immune defence. In children, sleep-disordered breathing is often caused by enlarged tonsils, and tonsillectomy resolves symptoms. Recently, the procedure has been replaced by the less invasive tonsillotomy, which offers comparable efficacy in paediatric sleep-disordered breathing. Tonsil hypertrophy may persist into adulthood, and traditional tonsillectomy remains a relevant, though understudied, treatment option for adults with OSA.

The aim of this thesis was to study the prevalence of adult tonsil hypertrophy, assess complications related to tonsil surgery, and evaluate the long-term effectiveness of tonsillectomy in treating OSA. A further objective was to examine whether adults, as shown in children, could benefit from partial tonsil surgery. We analysed tonsil surgeries in our hospital district from 2004 to 2018, identifying adults operated on for hypertrophic indications and assessing long-term outcomes in those treated for sleep apnoea. Severe complications were examined using Patient Insurance Centre data. Finally, we conducted a prospective multicentre study to evaluate the efficacy of intracapsular tonsillectomy (ICTE) in adults with large tonsils and OSA.

We found that adult tonsil hypertrophy is rare and appears to become rarer with age. Serious complications from tonsil surgery were uncommon and related mainly to routine operations. Although our results with tonsillectomy in OSA are in line with earlier studies, long-term outcomes remain uncertain. Finally, ICTE emerged as a promising alternative to tonsillectomy in adults with OSA.

This thesis suggests that many adults with enlarged tonsils, who might benefit from surgery, may remain unidentified within current care pathways. It also highlights the need for further research on long-term outcomes of tonsillectomy. In addition, the findings indicate that ICTE may offer an effective alternative to tonsillectomy in adult OSA.

KEYWORDS: obstructive sleep apnoea; tonsil hypertrophy; tonsillectomy; intracapsular tonsillectomy; tonsillotomy; long-term outcomes; complications

TURUN YLIOPISTO
Lääketieteellinen tiedekunta
Korva-, nenä- ja kurkkutautioppi
HENRIK SJÖBLOM: Aikuisten obstruktiivisen uniapnean hoito nielurisaleikkauksella
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TIIVISTELMÄ

Obstruktiivinen uniapnea (uniapnea) on merkittävä kansanterveydellinen haaste, joka koskettaa suurta osaa sekä Suomen että muun maailman väestöstä. Uniapnean esiintyvyys on kasvussa. Hoitamaton uniapnea altistaa muun muassa sydän- ja verisuonitaudeille, aineenvaihdutahäiriöille sekä mielenterveysongelmille.

Nielurisat sijaitsevat suunielussa, koostuvat imukudoksesta ja osallistuvat immuunipuolustukseen. Lapsilla unenaikaiset hengityshäiriöt johtuvat usein suurentuneista nielurisoista, ja nielurisaleikkaus on tehokas hoito. Tavallisimmin nielurisat pienenevät murrosiän jälkeen. Nielurisaleikkaus on varteenotettava uniapnean hoitomuoto myös aikuisilla, joiden nielurisat ovat suuret, joskin leikkauksen pitkäaikaistehoa on tutkittu niukasti. Viime vuosina lapsilla on siirrytty lähes kokonaan säästävämpään nielurisojen osapoistoon, jonka on todettu vähentävän leikkauksen haittoja säilyttäen kuitenkin sen tehon.

Tämän väitöskirjan tavoitteena oli tutkia aikuisten nielurisojen liikakasvun esiintyvyyttä, arvioida nielurisaleikkauksiin liittyviä vakavia komplikaatioita ja tarkastella nielurisaleikkauksen pitkäaikaistehoa uniapnean hoidossa. Lisäksi tavoitteena oli selvittää, voisivatko aikuiset hyötyä lasten tapaan osittaisesta nielurisakirurgiasta. Analysoimme sairaanhoitopiirissämme vuosina 2004–2018 tehdyt nielurisaleikkaukset, tunnistimme aineistosta suurien nielurisojen vuoksi leikatut aikuispotilaat ja arvioimme uniapnean vuoksi leikattujen pitkäaikaistuloksia. Vakavia komplikaatioita tutkittiin Potilasvakuutuskeskuksen aineiston perusteella. Lisäksi toteutimme prospektiivisen monikeskustutkimuksen, jossa arvioitiin intrakapsulaarisen nielurisaleikkauksen tehoa aikuisten uniapnean hoidossa.

Aikuisten nielurisojen liikakasvu oli harvinaista, ja sen esiintyvyys väheni iän myötä. Aikuisten nielurisojen liikakasvu saattaa jäädä huomaamatta, jolloin potilaat, jotka voisivat hyötyä kirurgisesta hoidosta, jäävät tunnistamatta. Nielurisakirurgian vakavat komplikaatiot ovat hyvin harvinaisia. Vaikka nielurisaleikkauksen tulokset uniapnean hoidossa olivat aineistossamme aiempien julkaisujen kaltaisia, tulokset korostavat tarvetta uniapnean kirurgisen hoidon pitkäaikaistulosten seurannalle. Myös aikuisilla osittaisen nielurisaleikkauksen tulokset saattavat vastata perinteistä nielurisat kokonaan poistavaa leikkausta.

AVAINSANAT: obstruktiivinen uniapnea; nielurisojen liikakasvu; nielurisaleikkaus; intrakapsulaarinen nielurisaleikkaus; tonsillotomia; pitkäaikaistulokset; komplikaatiot

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Abbreviations

AHI	apnoea–hypopnoea index
BMI	body mass index
BNSQ	Basic Nordic Sleep Questionnaire
BPI	Brief Pain Inventory
BSP	barbed suture pharyngoplasty
CPAP	continuous positive airway pressure
DISE	drug-induced sleep endoscopy
ECTE	extracapsular tonsillectomy
ESP	expansion sphincter pharyngoplasty
ESS	Epworth Sleepiness Scale
FTP	Friedman tongue position
GAS	group A β-haemolytic streptococci
GBI	Glasgow Benefit Inventory
ICTE	intracapsular tonsillectomy
Ig	immunoglobulin
ISI	Insomnia Severity Index
NCSP	Nordic Medico-Statistical Committee Classification of Surgical Procedures
NTSR	Nordic Tonsil Surgery Register
OSA	obstructive sleep apnoea
PFAPA	periodic fever, aphthous stomatitis, pharyngitis, adenitis
PIC	Finnish Patient Insurance Centre
PTH	post-tonsillectomy haemorrhage
REI	respiratory event index
SD	standard deviation
SDB	sleep-disordered breathing
UPPP	uvulopalatopharyngoplasty
VAS	visual analogue scale
VPI	velopharyngeal insufficiency

List of Original Publications

This dissertation is based on the following original publications, which are referred to in the text by their Roman numerals:

I Sjöblom HM, Timgren JM, Piitulainen JM, Jero J. Patient injuries from tonsil and adenoid surgery in Finland. *Laryngoscope Investigative Otolaryngology*, 2022;7(6):1773–1779.

II Sjöblom HM, Nahkuri M, Suomela M, Jero J, Piitulainen JM. Treatment of sleep apnoea with tonsillectomy: a retrospective analysis using long-term follow-up data. *European Archives of Otorhinolaryngology*, 2022;279(7):3727–3732.

III Sjöblom HM, Knubb JC, Kauko T, Pulkkinen J, Piitulainen JM. Incidence of adult tonsillectomy for hypertrophic indications in Southwest Finland. *Acta Otolaryngologica,* 2025;145(2):176–180.

IV Sjöblom HM, Knubb JC, Suomela M, Lustig-Tammi L, Piitulainen JM. Intracapsular tonsillectomy in adults with obstructive sleep apnoea and large tonsils. *Manuscript*.

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1 Introduction

Obstructive sleep apnoea (OSA) has become an important public health issue in Finland and in the world. It is estimated that 17% of middle-aged men and 9% of women have the disease, and with rising obesity rates the prevalence of sleep apnoea is also rising (Heinzer et al., 2015; Peppard et al., 2013). Comparable with adult OSA, sleep-disordered breathing (SDB) in children is an abnormal breathing pattern during sleep that can range from simple snoring to pauses in breathing, apnoea.

OSA is caused by repetitive partial or complete collapse of the upper airway during sleep. These collapses result in reductions or cessations of respiration during sleep. Some symptoms of OSA are unrefreshing sleep, excessive sleepiness, fatigue, tiredness, lack of energy, and insomnia (Gottlieb & Punjabi, 2020). OSA increases inflammation, causes metabolic dysfunction, and activates the sympathetic nervous system, all of which negatively impact the cardiovascular system and contribute to morbidity and mortality (Hirani & Smiley, 2023).

Tonsils are comprised of lymphatic tissue. They form the initial immunological response to pathogens, because of their location near the entrance of the respiratory and digestive tract. Located in the oropharynx, this ring of tonsillar tissue includes the palatine tonsils, adenoid, lingual tonsil, and tubal tonsils (Masters et al., 2023). The ring is known as the Waldeyer's ring after the German anatomist who first described this group of tissue in 1884 (Waldeyer, 1884).

The most common cause for paediatric SDB is adenoid and (palatine) tonsil hypertrophy, and the first-line treatment has, for many years, been adenotonsillectomy. It resolves SDB in most children (Mitchell et al., 2019). In recent years operative treatment for paediatric SDB has almost completely changed from tonsillectomy to a less invasive treatment where only part of the enlarged tonsil is removed, tonsillotomy. Multiple studies have shown equal efficacy between these methods with reduced peri- and postoperative risks in children (Blackshaw et al., 2020; Sakki et al., 2019; L.-Y. Zhang et al., 2017).

Although the palatine tonsils usually reach their maximum size by puberty and involute by adulthood (Arambula et al., 2021), tonsillar hypertrophy is still an issue with some adults. In the adult population, even in those with enlarged tonsils, traditional tonsillectomy has, unfortunately, been somewhat forgotten as a treatment for adult OSA in an era of multiple more novel surgical approaches. According to recent studies, tonsillectomy seems to still be an effective treatment also for adults with OSA, but data are somewhat limited (Camacho et al., 2016; Reckley et al., 2018).

This thesis aimed to increase the knowledge, firstly, in the risks associated with both tonsillectomy and tonsillotomy, the prevalence of adult tonsil hypertrophy, the long-term efficacy of adult tonsillectomy in the treatment of OSA, and lastly to study if the more s could also be used in the treatment of adult OSA.

Artificial intelligence disclosure statement: Editing assistance was provided by the Microsoft 365 Copilot provided by the University of Turku (GPT-5 chat model). I have carefully reviewed, edited, and taken full responsibility for all artificial intelligence assisted text.

2 Review of the Literature

2.1 Palatine tonsils

2.1.1 Anatomy

The palatine tonsils (tonsils) are a pair of lymphoid tissue aggregates located in the tonsillar fossae in the oropharynx, at the back of the mouth. The oropharyngeal surface of the tonsil is covered by stratified squamous non-keratinized epithelium (Jović et al., 2015). The tonsillar fossae are shaped by the palatine arches, the palatoglossal arch anteriorly and the palatopharyngeal arch posteriorly. These arches which are formed by muscle fibres are also known as the anterior and posterior tonsillar pillars. Laterally the tonsils are bordered by the superior constrictor muscle. (Arambula et al., 2021; Masters et al., 2023)

The capsule of the tonsil rises from the deep layers of the lamina propria, when the post-natally enlarging lymphoid component of the tonsil pushes the deepest layers to condense in a thin, compact membrane (Ohtsuka et al., 2002). The tonsillar capsule surrounds the tonsil on all but the medial surface (Isaacson & Parikh, 2008). The capsule extends into the tonsil, usually dividing it into lobes, which means there is no natural surgical plane between the tonsillar parenchyma and the capsule (Da Conceição Passos et al., 2004). Even though sometimes there is only loose connective tissue separating the tonsil from pharyngeal musculature, most often the tonsil capsule can be identified in histopathological samples (K. D. Lee et al., 2008; Ohtsuka et al., 2002).

The tonsils receive a rich blood flow from several branches of the external carotid artery through the pharyngeal constrictor muscle. The inferior pole of the tonsil is primarily supplied by a branch of the facial artery, the tonsillar artery. The superior pole is primarily supplied by tonsillar branches of the ascending pharyngeal artery and by the descending palatine artery, which branches off the internal maxillary artery. The external palatine or paratonsillar vein provides the venous drainage, eventually joining the common facial vein through the pharyngeal venous plexus. There is a dramatic difference between the diameter of vessels internal and external to the tonsillar capsule. For arteries, the intracapsular diameter of 73 µm increases to 139.5 µm just 1 mm into the extracapsular plane (K. D. Lee et al., 2008). (Arambula et al., 2021; Shah & Garritano, 2015)

Sensory information is carried by the lesser palatine nerve (part of the second division of the trigeminal nerve) and by tonsillar branches of the glossopharyngeal nerve (Chan, 2010). Patients with tonsillar disease often complain of otalgia because the glossopharyngeal nerve also provides sensation to the middle ear. Important to clinical practice is the course of the lingual branch of the glossopharyngeal nerve, which supplies taste sensation to the posterior third of the tongue. The lingual branch can pass as close as 5.5 mm to the posteroinferior border of the tonsillar fossa and may sometimes be tightly adhered to the tonsillar capsule (Ford & Cruz, 2004; Ohtsuka et al., 2002). Because of the anatomical relationship to the tonsils, this nerve is susceptible to injury during tonsillectomy. (Goins & Pitovski, 2004; Heiser et al., 2012)

2.1.2 Function

The function of the tonsils is immunologic. In contrast to lymph nodes, the tonsils do not have an afferent lymphatic network. When antigens enter the oropharynx the reticulated crypt epithelium of the tonsils is first challenged. The epithelial layer can be very thin and lymphocytes and dendritic cells are located just under the epithelial surface, allowing for rapid transport and presentation of antigens from the oropharynx to lymphoid cells. The invaginated structure of the tonsillar crypts increases the surface area for this process significantly. (Arambula et al., 2021; Nave et al., 2001)

Once antigens cross the epithelium they are processed by antigen-presenting cells (dendritic cells, macrophages), after which they are presented to T and B cells. In the case of a previously encountered antigen a secondary immune response is stimulated. With novel antigens, helper T cell recognition leads to activation, proliferation, and differentiation into an antigen specific T-cell population, being that co-stimulatory signals are available. These T cells stimulate naïve B cells which differentiate into antigen-specific plasma cells and memory B cells in nearby follicles, eventually forming a germinal centre. These cells can then travel to other mucosal sites where they terminally differentiate into specific immunoglobulin-producing cells. Immunoglobulins (Ig) extravasate between tonsil epithelial cells to reach the surface for immune surveillance, preventing antigen attachment to tissues and stimulating destruction. Also important to the immunologic response is apoptosis, which helps maintain homeostasis in the tonsils as they continue to encounter new antigens. Apoptosis also eliminates autoreactive or non-specific immune cells. (Arambula et al., 2021; Brandtzaeg, 2003)

The possible downside of a tonsillectomy to a patient's immune function is a question of continuing research. An early report by Ogra showed that adenotonsillectomy in children delayed their local immune response to live oral poliovaccine (Ogra, 1971). Another study found that tonsillectomy reduced serum Ig and salivary IgA levels in children for up to three years (Jeschke & Stroeder, 1980). A subsequent study however found elevated salivary Ig levels three years after tonsillectomy in children (Lenander-Lumikari et al., 1992). A cohort study of more than one million children reported increased risk of allergies, respiratory diseases and infectious diseases later in life after adenotonsillectomy (Byars et al., 2018). The alteration of immunity after tonsillectomy is difficult to address because of the many factors in play (Arambula et al., 2021). Especially in small children a conservative attitude towards adenotonsillectomy may be immunologically wise, but there is a need for more immunological studies focusing on the tonsils (Brandtzaeg, 2003). Nevertheless, a 2015 meta-analysis of 35 published studies (1,997 patients in total, 1971–2014) concluded that only four reported a negative immunological effect of tonsillectomy, suggesting that the weight of evidence does not support the presence of lasting immunological sequelae (Bitar et al., 2015).

2.1.3 Disease

2.1.3.1 Acute and recurrent tonsillitis

A complete discussion of acute or recurrent tonsillitis is beyond the scope of this thesis. Tonsillitis occurs if the activity of pathogens in the tonsillar tissue exceeds the protective capabilities of activated lymphoid and Ig-producing cells (Nave et al., 2001). The peak incidence is in school age, but it occurs in all ages (J. P. Windfuhr et al., 2016a). Acute tonsillitis is most often caused by viruses, such as adenoviruses, rhinoviruses, corona viruses, respiratory syncytial virus, cytomegalovirus, or Epstein Barr Virus, among hundreds of others (Bathala & Eccles, 2013). The most important bacterial causes of tonsillitis are group A β-haemolytic streptococci (GAS) i.e. *Streptococcus pyogenes*, which is responsible for 5–15% of sore throat visits in adults (Chan, 2010; Ebell et al., 2000). The disease is generally transmitted from other acute GAS tonsillitis patients, but even autoinfection via the normal oral flora is possible (J. P. Windfuhr et al., 2016a). Many other bacteria can also cause bacterial tonsillitis e.g. Streptococci of group C and G, *Haemophilus influenzae*, *Corynebacterium diphteriae*, and *Neisseria gonorrhoeae* (Chan, 2010). *Fusobacterium necrophorum* is particularly important among anaerobes (Righini et al., 2014).

Diagnosis of acute tonsillitis is clinical. It can be very difficult, impossible even, to distinguish viral and bacterial infection with clinical examination. For example, adenoviruses can cause tonsillitis with purulent exudation (Esposito et al., 2004). In addition, the mere presence of GAS in the patient's throat does not mean it is the cause of current sore throat. To predict the possibility of GAS infection, different scoring systems have been developed, with McIsaac and Centor being the most used (Centor et al., 1981; McIsaac et al., 2000). Antimicrobial therapy is of no proven benefit for acute pharyngitis/tonsillitis caused by organisms other than GAS (Guntinas-Lichius et al., 2023). Even the significance of other groups of β-haemolytic streptococci is not fully established (Naik et al., 2016). First-line therapy of β-haemolytic streptococci consists of oral penicillin. Untreated, GAS tonsillitis symptoms typically resolve within 3–5 days (Shulman et al., 2012). Antibiotic treatment decreases the severity of symptoms and reduces their duration by approximately 1 day and reduces suppurative complications (Denny, 1985). These complications include but are not limited to peritonsillar abscess, suppurative lymphadenitis, bacteraemia, and the exceptionally rare rheumatic fever (Dajani et al., 1995; Shulman et al., 2012). The more severe complications are so rare that aggressive antibiotic use cannot be justified (Georgalas et al., 2014). Antibiotic treatment of GAS additionally reduces transmissions and prevents wider outbreaks (Hedin et al., 2023).

Recurrent acute tonsillitis means the occurrence of repeated episodes of sore throat with intervals without or with little complaints (J. P. Windfuhr et al., 2016a). The term is sometimes used synonymously with chronic tonsillitis, which is not a scientifically defined term. A large twin study of 9479 Norwegian participants reported a recurrent tonsillitis prevalence of approximately 12% among those with a history of tonsillitis, with a notable female predominance (Kvestad et al., 2005). The tonsils may be a more common site for infection compared to the surrounding tissues because of their cryptic structure. It has been suggested that tonsils may be the most commonly infected site of the upper airway (Bathala & Eccles, 2013). Chronically inflamed tonsils often secrete and cling to caseous crypt material, which calcifies into tonsilloliths (Ferguson et al., 2014). GAS infection is the only known hard risk factor for recurrent acute tonsillitis (Roberts et al., 2012). Some studies suggest that tonsillar tissues are a potential reserve of *Helicobacter pylori*, and this colonization is suspected to be relevant to recurrent tonsillitis (Wu et al., 2022). Recurrent tonsillitis could also be a genetic immunosusceptibility disease (Dan et al., 2019). The previously mentioned Norwegian study also provided evidence of a substantial genetic predisposition to recurrent tonsillitis (Kvestad et al., 2005). Recurrent tonsillitis appears to speed up the involution of the tonsils, reducing B-cell differentiation to plasma cells (Brandtzaeg, 2003). Recurrent tonsillitis may also lead to fibrosis and fixation of the tonsils (J. P. Windfuhr et al., 2016a).

The debate on the optimal treatment for recurrent acute tonsillitis is still ongoing. The surgical standard, worldwide, is tonsillectomy, but the amount of sore throat episodes and the requirement of GAS positive episodes before tonsillectomy is indicated varies greatly between countries (Crowson et al., 2017; Guntinas-Lichius et al., 2023). Multiple large studies have reported a high degree of patient-reported symptom relief after tonsillectomy for recurrent tonsillitis (Stalfors et al., 2012; Wilson et al., 2023). Patients with recurrent pharyngitis are on average satisfied after tonsillectomy regardless of the aetiology of the episodes (Koskenkorva et al., 2014). The surgical removal of the adenoid and palatine tonsils still leaves lymphoid tissue in other areas of the upper airway. Severe sore throat episodes also occur after tonsillectomy, as other tissues than the tonsils also cause throat pain (Bathala & Eccles, 2013).

2.1.3.2 Hypertrophy

The immunologic function of the tonsils gives rise to their rapid growth in early childhood (Arambula et al., 2021). The peak of tonsil size is reached at 4–8 years old and hypertrophy is slightly associated with male sex (Akcay et al., 2006; Mattila et al., 2001). This coincides with the peak of immune activity in this tissue during the initial exposure to common pathogens, although the volume of tonsils alone is not relevant when diagnosing tonsillitis (J. P. Windfuhr et al., 2016a). In a random sample of 1211 Turkish school children between 6 and 13 years of age the prevalence of tonsillar hypertrophy was 11%, and it is likely higher in younger children (Kara et al., 2002). (Adeno)tonsillar hypertrophy causes obstructive symptoms, such as SDB, mouth breathing, and swallowing difficulties, some of which can even lead to poor school performance in children (Mitchell et al., 2019; Redline et al., 2023).

Usually somewhere during the second decade of life the B-cell component of the tonsils begins to involute (Siegel et al., 1982). Germinal centres become smaller, and the fibrous tissue of the trabeculae and capsule proliferates, while the tonsil mass decreases and disappears behind the anterior tonsillar pillar (Isaacson & Parikh, 2008). Fatty degeneration usually begins somewhere around the age of 25 and it progresses with age (Harada, 1989). The fibrotic evolution of the tonsils with age is depicted in Figure 1.

Very little has been published on the prevalence of adult tonsillar hypertrophy on a population-based level, but the incidence of tonsil hypertrophy with adult snorers has been estimated at 6% (Dahlqvist et al., 2007).

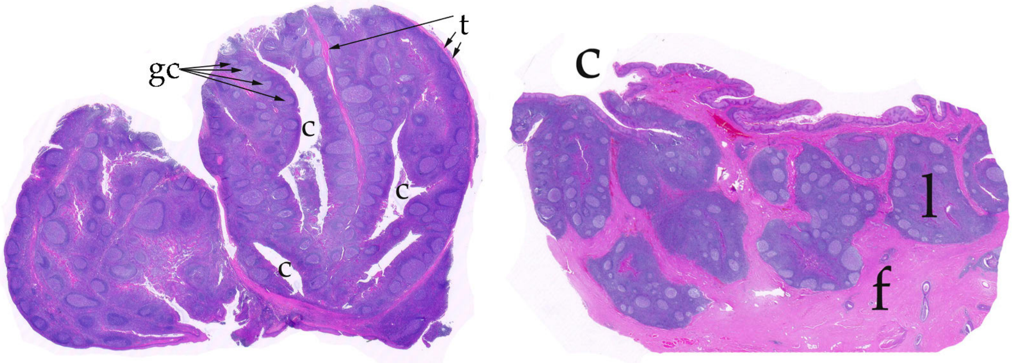

Figure 1. The hyperplastic tonsil of a 3-year-old (left) and the tonsil of a 67-year-old at autopsy (right). C, Tonsillar crypt; gc, germinal centers; t, trabeculae; l, lymphoid element; f, fibrosis. *Reprinted from Int J Pediatr Otorhinolaryngol. 2008 Jan, Volume 72, Issue 1. Isaacson G, Parikh T. Developmental anatomy of the tonsil and its implications for intracapsular tonsillectomy. Pages No. 89–96, Copyright 2024, with permission from Elsevier.*

The mechanisms behind the hyperplasia of tonsils are not fully understood. Significantly enlarged germinal centres and less inflammation are found in tonsillar hypertrophy compared to tonsillitis (P. C. Zhang et al., 2003). Increased B cell, helper T cell and suppressor T cell counts have been reported (Brodsky et al., 1988). It has been suggested that apoptosis, which balances lymphocyte proliferation in tonsil tissue, plays a role in tonsillar hypertrophy (and atrophy) (Önal et al., 2015). Increased cellular senescence, a status of cell arrest, in the germinal centres has been associated with tonsillar hypertrophy (S. Chen et al., 2020). Some have reported of increased numbers of T follicular helper cells in hypertrophic tonsils, a subset of helper T cells (Yamashita et al., 2016).

Tonsillar grading scales allow clinicians to record and communicate palatine tonsil size. Different grading systems for tonsil size have been developed, but two are most widely adopted, the Brodsky and Friedman grading scales (Brodsky, 1989; M. Friedman et al., 1999; Kumar et al., 2014). The Brodsky grading scale assigns a grade from 0 to 4 depending on the percentage of oropharyngeal airway occupied by the tonsils and has the highest mean interobserver reliability (Brodsky, 1989; Kumar et al., 2014). The Friedman grading scale has the advantage of recognizing post-TE patients as grade 0 (M. Friedman et al., 1999). A combined Friedman-Brodsky scale, which has the ease of the percentual grading of the Brodsky system but also includes Friedman's grade 0 for missing tonsils has been proposed and is depicted in Figure 2 below (Fernandez-Salvador et al., 2016). Subjectively assessed tonsil grade reliably predicts objective tonsil volume (Cahali et al., 2011; Lai et al., 2014; J. H. Wang et al., 2009). Every increase in tonsil grade seems to be associated with an average increase of ~2 ml in volume (Jara & Weaver, 2018).

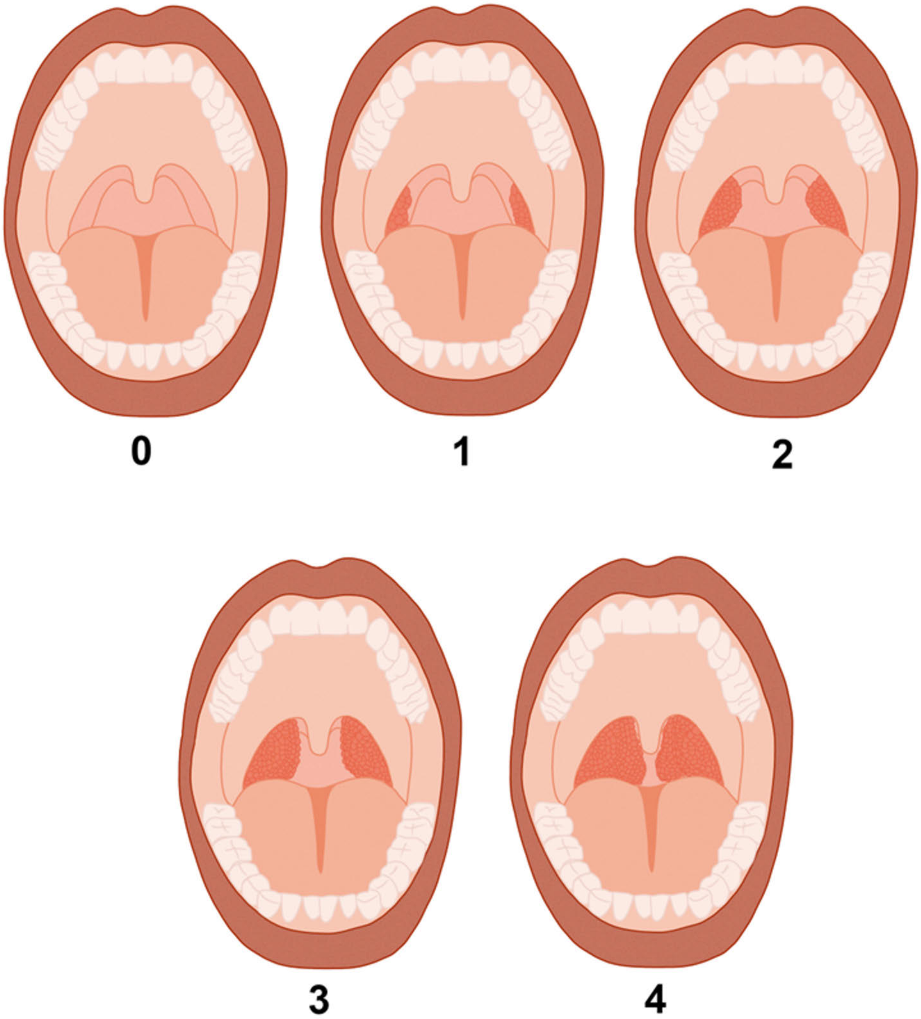

Figure 2. The combined Friedman-Brodsky palatine tonsil grading system. 0, tonsils removed; 1, tonsils occupy up to 25% of airway; 2, tonsils occupy 25-50%; 3, tonsils occupy 50–75%; 4, tonsils occupy more than 75%. Illustration by Pihla Ranta.

2.1.4 Tonsillectomy

In the first century AD, the Roman encyclopaedist Cornelius Celsus described a procedure using the surgeon's index finger or a blunt hook to separate the tonsillar tissue from oropharynx; haemostasis was achieved with a vinegar-milk mixture. The first operations described in textbooks excised only the exophytic portion of the palatine tonsils (Cohen, 1872; Thomson, 1912). To reduce operative time, a variety of tonsillotomes were developed during the nineteenth and twentieth centuries. In 1828, Philip Syng Physick described such an instrument for the excision of the tonsils (Physick, 1828). In the early 1900s guillotines, snares and sutures also made extracapsular tonsillectomy (ECTE) possible (Sluder, 1916). Due to surgical technique, tonsillar remnants were almost always left behind.

There is debate to who was the first person safely remove the entire tonsil and its capsule as several physicians separately described their techniques in the early twentieth century (Karatzanis et al., 2011). Soon, several tonsil hospitals were established to offer therapy for sore throats in the pre-antibiotic era. In part, tonsillectomy became extremely widespread because of the focal infection theory, the belief that various diseases resulted from the dissemination of pathogens through blood from a local focus, namely the tonsils. (J. P. Windfuhr et al., 2016b; Younis & Lazar, 2002)

2.1.4.1 Indications

The indications for tonsillectomy are varied and have been in constant change throughout history. Treatment of recurrent episodes of tonsillitis by tonsil surgery was already suggested in the Atharvaveda as early as 700 BC (J. P. Windfuhr et al., 2016b).

Nowadays, tonsil surgery is performed for several indications, most frequently for tonsillitis, be it recurrent, chronic, or acute, and obstructive symptoms of the upper airway related to tonsil hypertrophy. For recurrent tonsillitis that meets the United Kingdom guidelines, tonsillectomy has been proved clinically effective and cost-effective even after 24 months of follow-up compared with conservative management (Wilson et al., 2023). In Finland, the criteria for tonsillectomy were published in 2010 and have remained unchanged since (Sosiaali- ja terveysministeriö, 2019). The United Kingdom guidelines and the Finnish criteria are depicted below. Indications for tonsillectomy in adult OSA or paediatric SDB are discussed in more detail later in this thesis in chapter 2.3.

Tonsillar focal infection is also a factor in a variety of diseases, such as palmoplantar pustulosis or IgA nephropathy. tonsillectomy has been suggested to be effective for the treatment of these diseases, but the mechanistic details of these diseases are unclear (Yamashita et al., 2016). The periodic fever in children first described in 1987 and later termed PFAPA syndrome – periodic fever, aphthous stomatitis, pharyngitis, and adenitis – is also resolved, in most patients, with tonsillectomy (A. Wang et al., 2021).

Finnish criteria for tonsillectomy (Sosiaali- ja terveysministeriö, 2019)
Recurrent pharyngitis with fever:
1) 3–4 yearly infections: fever, throat pain, generalized symptoms, tonsillar exudates, or inflammation
2) GAS in bacterial culture
3) patients without GAS if disabling symptoms

Chronic pharyngitis:
1) Halitosis, tonsilloliths, throat pain
2) infected tonsils with pus of mucous plugs extruding from crypts with compression of tonsil

PFAPA
1) recurrent fever episodes of a couple of days
2) suspected pharyngitis with no other apparent infection sites

Obstruction of the nasopharynx and oropharynx because of adenoid and/or palatine tonsil hypertrophy
1) SDB in children, nasal obstruction, difficulties swallowing or bite defect
2) diagnosed enlarged tonsils or open bite caused by mouth breathing

The United Kingdom (SIGN) criteria (National Health Service in Scotland, 2010)
Pathway for tonsillitis:
1) sore throats are due to acute tonsillitis
2) the episodes of sore throat are disabling and prevent normal functioning
3) seven or more well documented, clinically significant, adequately treated sore throats in the preceding year or
4) five or more such episodes in each of the preceding two years or
5) three or more such episodes in each of the preceding three years.

Pathway for children with SDB:
1) if there is clear obstructive sleep apnoea then discuss surgery
2) children with simple snoring are unlikely to benefit from adeno-tonsillectomy
3) for children with mild to moderate signs and symptoms consider active monitoring

Although there are situations in which tonsillectomy may be appropriate outwith these criteria, note that e.g. tonsillectomy for halitosis is not recommended.

2.1.4.2 Surgical Techniques

Modern instruments and modifications have evolved tonsillectomy, but the basic approach has not changed. The most frequent and traditional method is cold steel tonsillectomy with metal instruments (Guntinas-Lichius et al., 2023). The tonsil is grasped with forceps and medialized, the peritonsillar space is dissected with metal instruments, and bleeding is preferably controlled by compression or sutures. Cold metal instruments used for tonsillectomy can include knives, scissors, elevators or microdebriders (J. P. Windfuhr et al., 2015). Total ECTE leaves the pharyngeal musculature bare (Pynnonen et al., 2017). No matter the technique it is also important to understand that the palatine tonsil is almost always contiguous with the lingual tonsillar tissue and in the surgeon decides where the boundary is.

A hot dissection or a hot tonsillectomy, in comparison, means that an instrument which delivers thermal energy is used to dissect the peritonsillar space. Most often this means using electrosurgery, in which radiofrequency energy is applied via means of an instrument, to cut, coagulate, or fulgurate tissue (Cordero, 2015). In bipolar electrosurgery both the active and return electrode functions are performed at the site of surgery, i.e. the tips of electrical forceps or scissors perform the active and return electrode functions. In monopolar electrosurgery the return electrode is placed on the patient's body and the current passes through the patient. Coblation can also be used for hot tonsillectomy, but it is discussed more thoroughly in the next chapter as it is one of the more popular techniques used for intracapsular tonsillectomy (ICTE). Laser and ultrasound instruments have also been used (Mixson et al., 2007; Tsikopoulos et al., 2023).

Multiple studies conclude that cold dissection might be beneficial in reducing post-operative bleeding after tonsillectomy, especially when compared to bipolar diathermy or coblation (Lowe et al., 2007; Lundström et al., 2020; Morris et al., 2018; Sarny et al., 2011; Söderman et al., 2015; Tomkinson et al., 2011). It is important to note that these studies do not compare cold tonsillectomy with monopolar instrumentation and there is some recent evidence that monopolar diathermy might equal cold tonsillectomy in post-TE haemorrhage rates (Knubb et al., 2023). Cold tonsillectomy is evidently more ecological as it produces less waste (Meiklejohn & Chavarri, 2021). Still, modern surgeons have evolved towards hot techniques due to superior control of intraoperative bleeding and thus operation time (Pinder et al., 2011; Setabutr et al., 2011). In terms of post-operative pain or surgical success there is no technique that is accepted as superior (Pynnonen et al., 2017).

2.1.4.2.1 Intracapsular techniques

The alternative for tonsillectomy is most often called TT. Many different intracapsular techniques have been described and named, and the different terms are often confused with one another. Common synonyms used in literature include tonsillotomy, partial tonsillectomy, tonsil ablation, ICTE, and subtotal tonsillectomy (J. P. Windfuhr & Savva, 2017). While the first tonsillectomies centuries ago were partial removals due to suboptimal surgical techniques, intentional tonsillotomy was re-introduced in the 1990s and has since become a regular intervention around the world (Wong Chung et al., 2018). It has gained notable popularity especially in paediatric patients, as it has been proven that it has equal effects to tonsillectomy in child sleep disordered breathing symptoms while having fewer post-operative complications (Blackshaw et al., 2020; Hultcrantz et al., 1999, 2013; Koltai et al., 2003; Sakki et al., 2019; S. Smith, 2016; L.-Y. Zhang et al., 2017).

To reduce the volume of the tonsils, different methods exist. They all share the goal of preserving the tonsillar capsule and removing only part of the palatine tonsils. A rim of tonsillar tissue is left in place with the capsule as not to expose the pharyngeal musculature. Since extracapsular vessels and nerve endings are not injured the postoperative recovery period is much gentler (J. Windfuhr & Werner, 2013). In 1994, CO2 laser -assisted “serial TE” was described, in which a partial tonsillectomy was achieved without significant morbidity experienced compared to traditional methods (Krespi & Ling, 1994). The first large retrospective study on pediatric tonsillotomy in 2003 used a microdebrider to remove excess tonsil tissue (Koltai et al., 2003). In 2015, a microdebrider was the most used instrument for tonsillotomy, with coblation being the second most popular instrument of choice (J. P. Windfuhr et al., 2015). Coblation (cold ablation) is a technique first developed for orthopaedic surgery, and it is a form of high frequency electrosurgery. Used for ECTE at least since 2001, the coblation wand, a bipolar probe, passes energy through isotonic sodium chloride used as a conductive medium to produce a plasma field (Temple & Timms, 2001). The resulting ions have enough energy to break molecular bonds, resulting in a relatively low-temperature (40–70ºC) disintegration of tissue (Pynnonen et al., 2017).

In 2013, to clarify future literature, a distinction between removing only the protruding parts of the tonsil versus aiming to remove most (~90%) of the tonsil was made (J. Windfuhr & Werner, 2013). The authors described a class I intracapsular procedure or a tonsillotomy as an operation where only the protruding parts medial to the tonsillar pillars are removed, stopping the reduction at Brodsky size 1. A class II operation or a subtotal/intracapsular/partial tonsillectomy, which the authors abbreviated as SIPT, would remove ~90% of the tonsil leaving only a small rim of tonsillar tissue as a protective layer along the surface of the tonsil capsule. In subsequent studies the abbreviation ICTE for intracapsular (~90%) tonsillectomy has also been used, while comparing it to ECTE (Bender, 2015; Piitulainen et al., 2022).

It has been speculated that the remaining tonsillar tissue may become a subject of recurrent tonsillitis or regrowth, requiring revision surgery in the form of a later tonsillectomy (Hultcrantz et al., 1999). Regrowth in children occurs in rates of under 6% on average and revision surgery seems to become necessary in a third of these patients (J. P. Windfuhr et al., 2015). Other studies report the risk of reoperation after tonsillotomy as 3.9% (Odhagen et al., 2016). In a six-year follow-up study there were no significant differences between tonsillectomy and tonsillotomy regarding throat infections (Wireklint & Ericsson, 2012). Still, the risk of reoperation has been reported to be seven times higher after tonsillotomy compared to tonsillectomy, but the risk is significantly and strongly associated with younger age (Odhagen et al., 2016). The most common indication for reoperation seems to be recurrent upper airway obstruction, not infections (Odhagen et al., 2016). With eight years of follow-up, the risk of second surgery is highest in patients less than three years of age at the time of first surgery and the risk decreases by 41% for each additional year of age (Sunnergren et al., 2017). Although the longest follow-up times published from large Swedish register studies, of tonsillotomy in small children, may seem long (6–8 years), they are not yet long enough to cover the teenage incidence of tonsil surgery caused by tonsillitis (Odhagen et al., 2016). There is no data published on the risk of reoperation after partial tonsillectomy in adults.

2.1.4.3 Complications

Complications are an inevitable consequence of any surgery, including tonsillectomy. In a large Swedish register study 13.9% of 54 696 patients reported an unplanned visit to a doctor within 2 weeks of surgery (Stalfors et al., 2012). It is questionable if significant postoperative pain can be classified as a complication of tonsillectomy as it is an expected, although unwanted, outcome of the procedure. It is to be noted, though, that tonsillectomy as a surgical procedure is one with an extremely high pain intensity, more painful than several major abdominal surgeries (Gerbershagen et al., 2013). The average recovery from surgery lasts for 12 days (Homer et al., 2002; Salonen et al., 2002). The natural course of postoperative tonsillectomy pain follows a gradual increase, reaching its maximum intensity at approximately one week after surgery, followed by a rapid decline throughout the second postoperative week (M. S. Kim et al., 2018; Tolska et al., 2017). Even though no technique is widely accepted as superior, there is some evidence that post-operative pain might be greater after monopolar dissection (Pinder et al., 2011; Pynnonen et al., 2017).

Post-tonsillectomy haemorrhage is a potentially fatal complication. The reported bleeding rates in studies range from 0.3 to 15% (Harju & Numminen, 2017; Tolska et al., 2013; J. P. Windfuhr, 2013). The bleeding is often categorized as primary bleeding, within 24 hours of the operation, and secondary bleeding any time later (Randall & Hoffer, 1998). As already discussed earlier, cold techniques appear to be somewhat beneficial in reducing post-operative bleeding. Post-tonsillectomy haemorrhage rates vary considerably across studies due to differences in patient populations and study designs. Some prospective studies may classify blood-tinged sputum as a bleeding event while other retrospective studies may only include haemorrhages requiring general anaesthesia for control (Tolska et al., 2013; J. P. Windfuhr, 2013). Thus, the definition of post-tonsillectomy haemorrhage also varies from study to study (J. H. Liu et al., 2001). Apart from operative technique, other known risk factors for post-tonsillectomy haemorrhage include the male sex, higher age, infectious mononucleosis, bipolar diathermy, and a history of recurrent tonsillitis (Tomkinson et al., 2011; J. P. Windfuhr et al., 2005). A retrospective study reported that patients older than 14 years were 4.5 times more likely to experience secondary haemorrhage (Harju & Numminen, 2017).

Contrary to what might be expected, death after tonsillectomy is not always preceded by visible bleeding or coughing; instead, it may occur quietly and unexpectedly (Goldman et al., 2013). Mortality associated with tonsillectomy is very rare and appears comparable to that of general anaesthesia. Reported mortality rates after tonsillectomy range from 1/1000 to 0/170000 (Goldman et al., 2013; Østvoll et al., 2015; Ow & Parikh, 2008; Randall & Hoffer, 1998; J. Windfuhr et al., 2009; J. P. Windfuhr, 2003). Traditionally it has been thought that the most common cause of death after tonsillectomy would be postoperative haemorrhage. This notion was challenged by a survey-based study, from the United States, where only 16% of 51 lethal events were related to haemorrhage, and most involved either suspected overdose of medication or were unexplained (Goldman et al., 2013). Then again, a malpractice claims study from the same country published one year earlier found postoperative bleeding to be the most common cause of death at 54% (Stevenson et al., 2012). Most published studies are only case series, and perhaps liability concerns or negative publicity contribute to the poor quality of data on this important topic (Østvoll et al., 2015).

As patients are usually well informed that postoperative haemorrhage is common and not a result of malpractice, the most common complications to warrant malpractice claims are burn injuries (Simonsen et al., 2010). Burns are caused by cautery or, rarely, a hot mouth gag. Despite up to 60.4% of otolaryngologists reporting having a patient develop a burn, they are rarely cited in literature. One study reported the incidence of perioral burns as 0.16%. Burns can be caused by e.g. defective equipment, operator error, or conduction. (Nuara et al., 2008)

Of primary complications, teeth injuries, temporomandibular joint dislocation, accidental extubation, and kinking of the intubation tube are results of mouth gag use (Johnson et al., 2009). Dental injury is rare in patients with healthy teeth (Randall & Hoffer, 1998). Atlantoaxial subluxation, associated with excessive neck extension, is extremely rare but possible in high risk-groups, such as Down syndrome patients (Johnson et al., 2009; Sipilä et al., 1981).

Taste disorders, velopharyngeal insufficiency (VPI), and nasopharyngeal stenosis are some of the long-term complications described in literature (Johnson et al., 2009; J. P. Windfuhr et al., 2016b). In a large study of over 50,000 patients, 6.9% of patients reported one or more problems 6 months after surgery and the prevalence was 4.0% after excluding for complications without a plausible causal relationship to the surgery. Each specific complication is so rare that no reported complication reached a prevalence of even 0.6%. (Odhagen et al., 2023).

Taste disorders are the result of lingual nerve injury, as discussed earlier. Hot surgical technique seems to be an independent risk factor for taste disturbances and dysphagia after tonsillectomy (Odhagen et al., 2019). VPI is most likely to occur in patients with undiagnosed palatal problems and usually resolves spontaneously within weeks or months (Obiako, 1988). Hypernasal speech and nasal regurgitation are the main symptoms of VPI (Randall & Hoffer, 1998). Nasopharyngeal stenosis is caused by the improper approximation of raw surfaces during the healing process, but it is associated mainly with combined adenotonsillectomy because of the larger potential for scarring (Johnson et al., 2009; Randall & Hoffer, 1998).

2.2 Adult obstructive sleep apnoea

2.2.1 Definitions, symptoms and diagnosis

OSA is a disease with recurrent episodes of partial or complete closure of the upper airway occur during sleep. In contrast, central sleep apnoea is a heterogeneous group of conditions where ventilatory drive changes without airway obstruction and it is not discussed further in this thesis (Donovan & Kapur, 2016). The airway closures in OSA lead to periods of absent (apnoea) or reduced (hypopnea) airflow lasting more than 10 seconds in length and associated with a fall in blood oxygen saturation or cortical arousal (Gottlieb & Punjabi, 2020). OSA syndrome is defined by the combination of OSA and the resulting symptoms (Patel, 2019).

The most common symptoms associated with OSA include bothersome snoring, witnessed episodes of apnoea, nocturnal awakening (with or without nocturia), unrefreshing sleep, daytime sleepiness, sleep-maintenance insomnia (prolonged wake after sleep onset), morning headaches, and problems with concentration, mood, and libido (Patel, 2019). The most common presenting symptom of OSA, especially in men, is excessive sleepiness (Gottlieb & Punjabi, 2020). Snoring has the highest sensitivity for OSA but is nonspecific and therefore not useful for establishing diagnosis (Myers et al., 2013). The most useful observation for identifying patients is nocturnal chocking or gasping (Myers et al., 2013).

OSA can sometimes present with insomnia and fatigue as the main symptoms, especially in women. Sleep-maintenance insomnia, where it is difficult to fall back asleep after waking up nocturnally, is more likely to be related to OSA than sleep-onset insomnia (Björnsdóttir et al., 2013).

A diagnosis of OSA requires testing of obstructive events during sleep. Historically testing was performed in sleep laboratories, but several trials have found home-based ambulatory sleep studies to lead to equivalent outcomes in patients with uncomplicated OSA (Rosen et al., 2012; Skomro et al., 2010). Commonly used terms to quantify and classify OSA and its severity obtained from sleep studies are presented in Table 2. The key metric used to evaluate OSA is the apnoea-hypopnoea index (AHI). OSA severity is classified as mild (AHI < 15 events/h), moderate (15–30 events/h), and severe (≥ 30 events/h). With home tests, in contrast to laboratory tests, respiratory event index (REI) should be used, where the number of events is divided by the total recording time (Pitkänen et al., 2024). Varying definitions of hypopnoea also exist (e.g. 4% instead of 3% desaturation), which can lead to different calculations between laboratories (Punjabi et al., 2012).

While AHI and REI are standard metrics, they do not capture the full picture of how OSA affects a person. Studies have found inconsistencies between patient-reported symptoms, like daytime sleepiness, and their AHI and REI scores (Malhotra et al., 2021; Pitkänen et al., 2024). AHI is the best-studied metric, and thus most often used. Alternative measures, suggested to provide a more complete picture of OSA, include the time spent with low oxygen levels and arousal intensity (Malhotra et al., 2021).

Because of these inconsistencies, the severity of OSA is often recommended to be classified based on three components: sleepiness, AHI, and blood oxygen saturation, with severity determined by the most severe of these. Sleepiness is assessed by how much it impairs the patient's daily life rather than by questionnaire scores or test results. While a low AHI may suggest mild OSA, the condition can still be clinically significant if the patient experiences excessive fatigue and sleepiness. (Sleep apnoea (OSA in adults): Current Care Guidelines, 2026)

Table 1. Obstructive sleep apnoea terminology and definitions.

Terminology	Definitions
Apnoea: Breathing cessation for 10 seconds	Mild OSA: AHI or REI ≥5 but <15/h
Hypopnoea: Breathing flow reduction for ≥10 seconds, accompanied by a ≥3% blood oxygen desaturation or arousal	Moderate OSA: AHI or REI ≥15 but <30/h
AHI: Apnoea-hypopnoea index, the number of episodes per hour of sleep	Severe OSA: AHI or REI ≥30/h
REI: Respiratory event index, the number of episodes per hour of recording	
ODI: Oxygen desaturation index, the number of desaturation events per hour of sleep	
Time below SpO_2 90%: Sleep or recording time spent with oxygen saturation <90%	

2.2.2 Screening and symptom questionnaires

Excessive daytime sleepiness is most often measured with the Epworth Sleepiness Scale (ESS, Table 1), correlation with OSA severity is poor but it can help standardize the patient's subjective perception and it is also used to follow response to therapy (Johns, 1991; Patel, 2019). The scale has been adopted by many institutions and is commonly used in studies, a score of >10 is abnormal and should prompt further evaluation (Scharf, 2022).

The STOP-BANG questionnaire is a widely used screening tool for OSA (Pivetta et al., 2021). The name is an acronym for its eight components: snoring, tiredness, observed apnoea, high blood pressure, body mass index (BMI), age, neck circumference, and gender. It was designed to be a simple and effective way for clinicians to identify patients at high risk for OSA (F. Chung et al., 2008). Many studies, including large-scale meta-analyses, have validated the questionnaire's effectiveness as a screening tool across different global regions and clinical settings (L. Chen et al., 2021; Pivetta et al., 2021).

The Basic Nordic Sleep Questionnaire (BNSQ) was published in 1995, developed to standardize the collection of data on sleep-related issues (Partinen & Gislason, 1995). While it is often used for sleep apnoea, its scope is more comprehensive in gathering subjective sleep quality and disturbance data (Partinen & Gislason, 1995). As an illustration, the BNSQ item "feeling sleepy" has demonstrated greater sensitivity as an indicator of reduced quality of life compared to a high ESS score (Thorarinsdottir et al., 2019).

Insomnia, a common comorbidity in OSA, can be measured with the Insomnia Severity Index (ISI) published in 1993 originally as the Sleep Impairment Index (Bastien et al., 2001). ISI is a brief questionnaire used to assess the nature, severity, and impact of insomnia (Bastien et al., 2001). ISI is widely employed in studies to examine examining the bidirectional relationship between sleep apnoea and insomnia (Ong et al., 2020; Wallace & Wohlgemuth, 2019). A score of 0–7 points indicates no clinically significant insomnia (Bastien et al., 2001).

Table 2. Epworth Sleepiness Scale.

How likely are you to doze off or fall asleep in the following situations?
0 = no, 1 = slight, 2 = moderate, 3 = high chance of dozing

Sitting and reading	
Watching tv	
Sitting inactive in a public place (e.g., a theater or a meeting)	
As a passenger in a car for an hour without a break	
Lying down to rest in the afternoon when circumstances permit	
Sitting and talking to someone	
Sitting quietly after a lunch without alcohol	
In a car, while stopped for a few minutes in traffic	
Add above for total score	

2.2.3 Epidemiology

The prevalence of OSA, already common, is increasing with the increased prevalence of obesity. In the general North American adult population OSA syndrome occurs in 14% of men and 5% of women (Peppard et al., 2013). The 5-year incidence is 7–11% in middle-aged adults (Tishler et al., 2003). A 10% increase in body weight is associated with an 32% increase in AHI and a 6-fold increase in developing OSA (Peppard et al., 2000). The prevalence of OSA in Finnish adult population is 3.7–4.2% and the one-year incidence is 0.6% (Palomäki et al., 2022; Strausz et al., 2018). At the time of diagnosis 63% of patients were presenting with comorbidities (Palomäki et al., 2022). Mild asymptomatic OSA seems to be very common, occurring in up to 34.1% of men and 37.4% of women between the ages of 35–75 in one study (Heinzer et al., 2015). In a general population sample of 415 middle-aged Icelanders, the prevalence of mild, moderate, and severe OSA was 24%, 13%, and 3%, respectively (Arnardottir et al., 2016). OSA becomes more common and severe with age, but older adults tend to report fewer symptoms of poor sleep (Ernst et al., 2019; Ghavami et al., 2023).

2.2.4 Pathophysiology and comorbidity

OSA is defined by repeated collapse of the upper airway in sleep, resulting in hypopnoea or apnoea despite respiratory effort (Gottlieb & Punjabi, 2020). The immediate effects of OSA include intermittent hypoxia, fragmented sleep, exaggerated fluctuations in heart rhythm and blood pressure (Somers et al., 2008). These disruptions may evolve into hypertension and cardiovascular morbidity, decreases in cognitive function, lowered mood and quality of life, and premature death (Baldwin et al., 2001; Kim et al., 1997; Marshall et al., 2008; Peppard, Young, Palta, & Skatrud, 2000; Peppard et al., 2006; Shamsuzzaman et al., 2003; Somers et al., 2008; Yaffe et al., 2011; Young et al., 2008). Intermittent hypoxemia activates the sympathetic nervous system and is the major contributor to elevated blood pressure (Somers et al., 2008).

The hazard of mortality is 3-6 times greater in untreated severe OSA, especially of cardiovascular causes and especially in men under 50 (J. He et al., 1988; Lavie et al., 2005; Marti et al., 2002). Untreated OSA can increase risk for motor vehicle and occupational accidents (Terán-Santos et al., 1999). OSA is associated with increased risk for type 2 diabetes and Alzheimer’s disease, but whether treatment can prevent or reverse these is unclear (Patel, 2019). It should be noted that even when untreated, mild to moderate OSA (AHI <30/h) does not increase the risk of all-cause mortality or cardiovascular mortality (Young et al., 2008). As mentioned, mild asymptomatic OSA is very common and does not warrant treatment, but when the patients are symptomatic it seems to be beneficial to treat even mild OSA to improve the patients' quality of life (Engleman et al., 2012; Wimms et al., 2020).

In OSA patients with hypertension, successful treatment leads to reductions in blood pressure (Dediu et al., 2007). With hypertension refractory to medication, the effect is larger (Navarro-Soriano et al., 2019). OSA treatment seems to be additive to other hypertension therapies (Chirinos et al., 2014). Especially in men, treatment of severe OSA reduces the risk of both fatal and non-fatal cardiovascular events (Marin et al., 2005). There is a negative association between OSA and psychiatric morbidity, and OSA treatment seems to reduce depression symptoms and incidence (Hrubos-Strøm et al., 2012; Zheng et al., 2019).

2.2.5 Anatomical Considerations

In 1964, the first study of the oropharynx characteristics of snoring adults was published, with findings of narrow pharynx, elongated soft palate and uvula (Ikematsu, 1964). Upper airway obstruction is prevalent in humans because the hyoid bone is not rigidly attached to skeletal structures, as in other mammals (Dempsey et al., 2010). The human pharynx has rigid support only in its upper and lower ends (Dempsey et al., 2010).

The most common site of airway collapse is the retropalatal region, but it often includes the retroglossal and hypopharyngeal areas (Hudgel, 1986). Contraction of upper airway dilator muscles is necessary to airway maintenance during inspiration (Gottlieb & Punjabi, 2020). The most important dilator is the genioglossus muscle which prevents posterior collapse of the tongue, followed by the levator and tensor palatini muscles which advance and elevate the soft palate, and the geniohyoid and stylopharyngeus muscles that oppose medial collapse of the pharyngeal walls (Dempsey et al., 2010).

Most people with OSA have upper airway narrowing caused by fat deposition in pharyngeal muscles and parapharyngeal fat pads (Schwab et al., 2003). Fat seems to also deposit in the tongue, which could impair genioglossus function (Chi et al., 2011). While OSA is strongly associated with being overweight, it's not exclusive to it. Craniofacial abnormalities that can cause OSA include micrognathia and retrognathia, inferior positioning of the hyoid bone, and shorter mandibular and maxillary length (Cistulli, 1996). The contribution of soft and bony abnormalities to OSA differs among individuals and populations (Lee et al., 2010). Men seem to have longer airways than women which could explain the increased susceptibility for OSA in men (Malhotra et al., 2002).

It is well established in children that tonsillar hypertrophy is the most common source of obstruction in SDB (Baugh et al., 2011; Bitners & Arens, 2020; Blackshaw et al., 2020). A similar relation in adults is assumed, although evidence is not as plentiful (Jara & Weaver, 2018). Some studies show a positive correlation between palatine tonsil volume and AHI (Cahali et al., 2011; Lai et al., 2014). A more recent study on adults suggested that subjective Brodsky palatine tonsil grade was more strongly associated with an increase in AHI than the objective volume of the removed tonsils measured intraoperatively by water displacement (Jara & Weaver, 2018). This may be explained by the fact that, for example, grade I tonsils can extend deep into the tonsillar fossa, whereas a very superficial grade III tonsil of comparable total volume can cause greater oropharyngeal obstruction. The removal of extremely large grade IV "kissing" tonsils is well accepted and indicated in the management of adult OSA (Cahali et al., 2011; Camacho et al., 2016). In adult OSA, the impact of PTs smaller than grade IV but still large enough to extend beyond the tonsillar pillars remains somewhat controversial. However, evidence exists as to the effectiveness of tonsillectomy even in these patients (Baudouin et al., 2019; Cahali et al., 2011; Holmlund et al., 2016). The role of tonsillectomy in the treatment of OSA is discussed in depth in chapter 2.3.2.1

The Mallampati score was developed in 1983 by Seshagiri Mallampati, an anaesthesiologist, to predict difficult intubation (Mallampati, 1983). The patient opens their mouth and maximally protrudes their tongue without phonation and patients were divided into three classes based on visible structures: Class I – fully visualise the uvula, Class II – fully visualise the soft palate and the faucial pillars and Class III – only some of the soft palate is visible. Some years later another team added Class IV – only the hard palate is visible, and in 1998 Class 0 was added – part of the epiglottis is visible (Ezri et al., 1998; Samsoon & Young, 1987). Later a high Mallampati score was proved to be a risk factor of OSA, with each subsequent class increasing the odds ratio of having OSA to 2.5 and increasing AHI by 5.2 (Nuckton et al., 2006). These results were independent of over 30 other variables and measuring Mallampati score of patients thus has become a routine of many sleep apnoea clinics (Nuckton et al., 2006).

Later Michael Friedman, an otolaryngologist, published a series of studies with the intent of standardizing the description of the upper airways of patients when OSA is suspected (M. Friedman et al., 1999, 2002, 2004). The Mallampati index was modified, removing tongue protrusion, believing that it would provide a more physiological tongue position, creating the modified Mallampati index. The index was later renamed the Friedman tongue position (FTP) (M. Friedman, 2008). Later FTP further subdivided class II to IIa and IIb, making the current 5-class assessment tool, consisting of the following: class I, visualization of tonsils and entire uvula; class IIa, visualization of the entire uvula but not tonsils; class IIb, visualization of the soft palate and base of the uvula but not tonsils; class III, visualization of some of the soft palate but not base of the uvula; and class IV, visualization of only the hard palate (Figure 3) (M. Friedman, 2008; M. Friedman et al., 2002, 2004).

Mueller's manoeuvre was described by Borowiecki and Sassin for the preoperative assessment of SDB (Borowiecki & Sassin, 1983). It consists of having the patient perform a forced inspiratory effort against an obstructed airway with endoscopic visualisation of the upper airway. The test is somewhat widely used and simple to perform, but controversial, as no studies have been able to associate it as a beneficial tool for patient selection (M. Friedman, 2008; Mattos Soares et al., 2009).

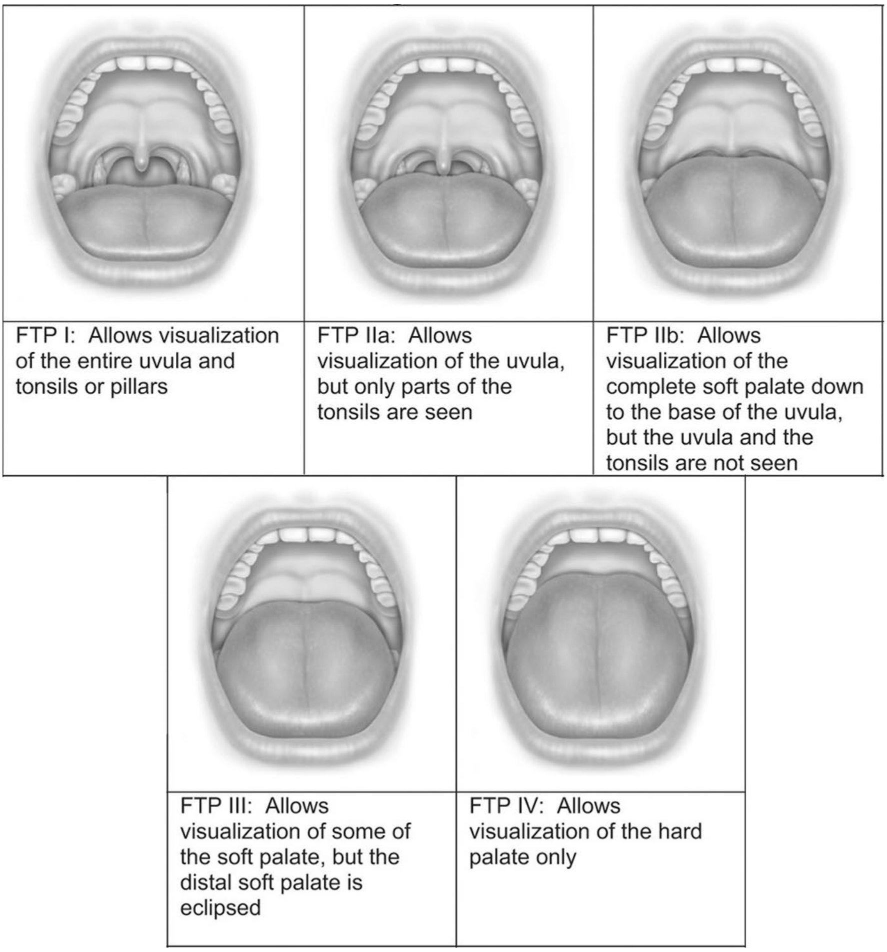

Figure 3. Friedman tongue position. *Reprinted from Otolaryngology–Head and Neck Surgery. 2013 April, Volume 148, Issue 4. Friedman et al. Diagnostic Value of the Friedman Tongue Position and Mallampati Classification for Obstructive Sleep Apnea: A Meta-analysis. Pages No. 540-547. With permission from the publisher.*

2.2.6 Treatment options

Evidence strongly indicates that patients with daytime sleepiness should be offered therapy without regard to the severity of OSA (Patil et al., 2019). Effective treatments include weight loss, positive airway pressure, oral appliances to hold the jaw forward and surgical modifications of the pharyngeal soft tissues or the facial skeleton (Gottlieb & Punjabi, 2020).

The gold standard treatment is continuous positive airway pressure (CPAP), which provides continuous pressure to the airway keeping it from narrowing during the relaxation in sleep (Srijithesh et al., 2019). CPAP should be considered the first-line treatment in moderate to severe OSA syndrome (Patel, 2019). Traditionally, CPAP settings have been determined in sleep laboratories, but modern autotitrating devices detect flow limitation and adjust pressure to remain therapeutic (Patil et al., 2019). Studies show a linear relationship between hours of CPAP use and improvements in symptoms (Weaver et al., 2007). Adequate adherence is usually defined as 4 hours or more per night on 70% of nights (Cistulli et al., 2019). 50–75% of patients achieve adequate adherence (Anttalainen et al., 2007; Cistulli et al., 2019). Poor mask fit, nasal congestion, airway drying, denial, lack of improvement, lack of social support, and claustrophobia are some of the reasons that limit adherence to CPAP (Patel, 2019).

All patients should pursue supportive options, such as weight control and avoidance of alcohol or sedatives before sleep (Patel, 2019). Many trials show that weight loss reduces OSA severity and symptoms (Hudgel et al., 2018). Starting CPAP together with weight loss interventions does not reduce adherence to either and benefits are additive (Chirinos et al., 2014). In patients with mild OSA nearly 90% who lost an estimated 15% of weight achieved remission (Tuomilehto et al., 2009). Bariatric surgery is a notable option for morbidly obese patients (Patel, 2019). Recently, a glucose-dependent insulinotropic polypeptide receptor and glucagon-like peptide-1 receptor agonist, a so-called weight-loss drug, was found to reduce AHI, body weight, hypoxic burden, and improve sleep-related patient-reported outcomes in patients with moderate to severe OSA and obesity (Malhotra et al., 2024).

Position-dependant OSA is found in up to one third of patients with mild to moderate OSA (Patel, 2019). Positional treatment involves wearing or using a variety of devices to minimize the time spent sleeping supine. Data suggests that positional treatments can reduce OSA severity and symptoms (Srijithesh et al., 2019).

Mandibular advancement devices are oral appliances that hold the mandible forward, enlarging the upper airway and decreasing airway collapse (Ramar et al., 2015). Evidence suggests that adherence is greater than with CPAP, but these devices are less effective than CPAP and therefore not recommended as initial therapy, especially for severe OSA (Ramar et al., 2015). With mild to moderate OSA, oral appliances have similar real-world effectiveness to CPAP in symptom improvement (Phillips et al., 2013). Use of these devices requires adequate dentition and patients should be referred to a dentist with expertise in OSA (Patel, 2019).

Because the dilator muscles of the upper airway maintain an open airway during sleep, it has been suggested that so called myofunctional therapy exercises could be used to treat OSA (singing, instrument playing) (Camacho, Certal, et al., 2015). Myofunctional therapy exercises involve the soft palate, tongue and facial muscles. Patients are instructed to pronounce vowel sounds continuously or intermittently or move the tongue in specific ways (Guimarães et al., 2009). Compared to sham therapy, myofunctional therapy probably reduces daytime sleepiness in the short term, but a systematic review found little to no difference in AHI reduction or sleep quality (Rueda et al., 2020).

Surgical interventions, suitable for selected patients, can be considered for patients with difficulties tolerating CPAP or mandibular advancement devices or to whom the treatment options other than CPAP, even when tolerated, do not bring adequate control of symptoms (Gottlieb & Punjabi, 2020). Surgical treatment options are discussed in chapter 2.3.

2.3 Surgical treatment of obstructive sleep apnoea

Surgery of the upper airway for the treatment of OSA has been performed for decades (Fujita et al., 1981; Ikematsu, 1964). Still, the role of surgery in the treatment of OSA remains controversial (Caples et al., 2010). There is certainly a lack of high-level, controlled studies in the surgical literature (Camacho et al., 2013; Caples et al., 2010; Elshaug et al., 2007). The classic success criteria for surgical treatment were first described by Sher as both 50% reduction of AHI and a postoperative AHI of less than 20/hour and has been adopted in many sleep surgery studies since (Sher et al., 1996).

Some critics argue that AHI should be reduced to near or below 5/hour to improve health outcomes (Elshaug et al., 2007). When assessing efficacy of surgical treatment of sleep apnoea, it should be noted that CPAP treatment is widely considered successful with 4 hours of use on 5 nights a week (Cistulli et al., 2019; Patil et al., 2019). Let us imagine a patient that sleeps for an average of 7 hours a night and meets the minimum criteria. They use CPAP for 20 hours out of 49 total sleep hours, or 40.8 percent of sleep hours and thus sleep 59.2 of the time completely untreated and, still, are counted as a successfully CPAP treated patient.

Patients who fail other treatment options often seek surgical treatment options. It was discovered early that the anatomic causes of OSA are heterogeneous (Rojewski et al., 1984). Consequently, over 30 different surgical procedures been described in literature (Camacho et al., 2013). Proper patient selection is paramount to surgical success in OSA patients (Camacho et al., 2013). Multiple surgeries might be required to maximize success and the variability in outcomes for different surgeries is large (Camacho et al., 2013; Caples et al., 2010). Contraindications to surgery include, but are not limited to, morbid obesity, active drug abuse, unstable psychological problems or unrealistic expectations from surgery (Holty & Guilleminault, 2010b). Preoperative CPAP is indicated in patients with severe OSA (Holty & Guilleminault, 2010b).

2.3.1 Drug-induced sleep endoscopy

Drug-induced sleep endoscopy (DISE), first introduced in 1991, provides a method to study the upper airway under pharmacologically induced sedation, usually with propofol (Croft & Pringle, 1991; Di Bari et al., 2024). Several refinements have been made over the years, leading to a consensus statement in 2014, further refined in 2017 (De Vito et al., 2018). Natural sleep endoscopy is the alternative gold standard, but extremely time-consuming and thus not feasible in routine practice (Van den Bossche et al., 2021). The objective of DISE is to replicate the pathological airway collapse in natural sleep to more accurately target surgical treatment (Lisan et al., 2023). DISE is resource intensive and is often reserved for patients who have failed non-surgical treatment (Lisan et al., 2023). Several scoring systems have been developed to evaluate obstruction in both adults and children (Amos et al., 2018).

The most common reporting system for DISE is the VOTE classification (velum, oropharynx, tongue base, and epiglottis) (Amos et al., 2018; Kezirian et al., 2011). The VOTE system records the degree (partial or complete) and direction (anterior-posterior, lateral, or concentric) of obstruction at the four subsites (Kezirian et al., 2011). The European consensus statement recommends the use of propofol with an infusion pump with target-controlled infusion technology (De Vito et al., 2018).

In systematic reviews, it seems that DISE may be useful in identifying sites of upper airway obstruction not detected by other tests (Viana et al., 2015). Evidence is mixed on whether it actually improves surgical outcomes (Di Bari et al., 2024). When looking at soft tissue surgery only, a meta-analysis concluded that DISE was not associated with a higher success rate nor a significant change in AHI (Lisan et al., 2023).

2.3.2 Oropharyngeal surgery

In 1952, Ikematsu began removing excessive oropharyngeal tissue to alleviate snoring (Ikematsu, 1964). In the late 1970s, Fujita et al. adapted this procedure and introduced uvulopalatopharyngoplasty (UPPP) to treat OSA (Fujita et al., 1981). The procedure was described as follows: First tonsillectomy is performed, then an incision is made over the soft palate in a curvilinear fashion from the inferior pole of the tonsillar fossa to the root of the uvula. The incision is extended on the pharyngeal side of the uvula and again down toward the inferior pole following the posterior pillar. The mucosa of the incised area is then removed, and the rim of the posterior pillar mucosa is lifted upward and laterally and approximated with absorbable suture. Finally, the uvula is truncated or amputated. Caples et al. pooled data from fifteen UPPP studies and found an overall reduction in AHI of 33% and postoperative AHI averaging 29.8/hour (Caples et al., 2010). The follow-up periods in Caples et al.'s meta-analysis ranged from three months to one year. A meta-analysis by Elshaug et al. reported a success rate of 51.5% (Elshaug et al., 2007).

Obesity seems to be one of the main limiting factors for the success of different pharyngeal surgeries (Sher et al., 1996). Friedman et al. developed a staging system to help predict patients likely to have success with UPPP versus those destined to fail (M. Friedman et al., 2002, 2004, 2017). They divided 134 patients to four stages using Friedman tongue position, tonsil grades, and BMI. The staging system and the reported success rates of UPPP are depicted below in Table 1. This staging system for patients has since been widely adopted in sleep surgery studies (Zhao et al., 2020).

Table 3. Friedman staging system. FTP, Friedman tongue position; BMI, Body mass index; Success, Success rate of uvulopalatopharyngoplasty (percent). *Success rates from Otolaryngology–Head and Neck Surgery. 2002 July, Volume 127, Issue 1. Friedman et al. Clinical staging for sleep-disordered breathing* with permission from the copyright holders.

Stage	FTP	Tonsil Size	BMI	Success
Stage I	I, IIa, IIb	3, 4	<40	80.6 %
Stage II	I, IIa,, IIb	0, 1, 2	<40	37.9 %
	III or IV	3, 4	<40	
Stage III	III or IV	0, 1, 2	Any	8.1 %
	Any	Any	>40	

The complications of UPPP include foreign body sensation, dry throat, speech frequency changes, problems with phlegm, VPI, and nasopharyngeal stenosis (Camacho et al., 2013). After a 20-year follow-up Värendh et al. reported that 47% of patients were dissatisfied with the results, 32% were using CPAP and 38% of patients were still suffering from complications of the surgery (including problems with nasal regurgitation, swallowing and oral cavity pain) (Värendh et al., 2012).

Several modifications of UPPP have been reported with mixed results. Some of the modifications listed in literature include the extended uvulopalatal flap, expansion sphincter pharyngoplasty (ESP), lateral pharyngoplasty and barbed suture pharyngoplasty (BSP) (Caples et al., 2010; Pang & Woodson, 2007; Vicini et al., 2015). With an increasing understanding of palatal anatomy and an attempt to reduce complications, more modern modifications attempt to preserve and re-organize tissue, rather than remove it altogether (Pang & Woodson, 2007; N. Powell et al., 1996; Vicini et al., 2015).

ESP and BSP are two popular modern soft palate procedures, both inspired by lateral pharyngoplasty, described first in 2003 (Cahali, 2003; Pang & Woodson, 2007; Vicini et al., 2015). Both surgeries are designed to lateralize the palatopharyngeus muscle to address lateral pharyngeal wall collapse, and both include cutting or weakening the muscle from its inferior aspect. ESP rotates the palatopharyngeal muscle and pulls it in a superoanterolateral direction with absorbable sutures (Pang & Woodson, 2007). BSP is further evolved from ESP, using "barbed" sutures to achieve similar goals, while also suspending the posterior pillar to the pterygomandibular raphe (Vicini et al., 2015). In a systematic review, using Sher's criteria (50% reduction of AHI and a postoperative AHI of less than 20/h), ESP was found to have a success rate of 64.8% to 90% in four studies and BSP a success rate of 66% to 86.6% (Vlad et al., 2023). Both surgeries were found to be significantly more effective in reducing AHI than UPPP, but ESP had a slightly higher incidence of complications (Vlad et al., 2023). The longest follow-up time in Vlad et al.'s review was 19 months. With adaption of these novel techniques, a meta-analysis of palatal sleep surgery publications from 2001–2018 found that UPPP popularity had fallen from 25.6% of all procedures in 2001–2010 to 12.6% of all procedures in 2010–2018, with reported success rates of OSA surgery simultaneously improving (Pang et al., 2018). Improved patient selection (in part with DISE) is thought to be an important factor in the improved success rates (Pang et al., 2018).

Laser-assisted uvulo(palato)plasty and radiofrequency ablation of the soft palate were designed to stiffen the soft palate, both performed under local anaesthetic (Halme et al., 2010; Kamami, 1990; N. B. Powell et al., 1998). Initially promising, the pooled rate of AHI reduction in laser-assited uvuloplasty was found to be 32% in eight studies (Caples et al., 2010). Later, in 2017, a meta-analysis found that AHI actually worsened among 44% of laser-assisted uvulopalatoplasty patients (Camacho et al., 2017). Similarly, some studies initially reported positive results with radiofrequency ablation, but in 2009 Bäck et al. published a study where they found no significant differences to placebo surgery (Bäck et al., 2009; Elshaug et al., 2007). Both procedures are currently recommended to be performed only with extreme caution, or not performed at all (Bäck et al., 2009; Camacho et al., 2017).

2.3.2.1 Tonsillectomy

In a statistical model for multilevel OSA surgery 58% of patients who had a tonsillectomy were considered successes, in contrast to only 19% of patients without tonsillectomy (Tschopp et al., 2011). Isolated tonsillectomy has been surprisingly scarcely reported on as a treatment modality for OSA, given the prominence of tonsillectomy as a surgical treatment in general. A systematic review and meta-analysis in 2016 found 17 studies with 216 adult patients undergoing tonsillectomy alone as a treatment for OSA (Camacho et al., 2016). Three studies have been published after with between 28 to 34 patients since (Holmlund et al., 2016; Makkonen et al., 2025; M. M. Smith et al., 2017). In the American Academy of Sleep Medicine practice guidelines, isolated tonsillectomy is not even mentioned as an option when discussing surgery to treat adult OSA (Aurora et al., 2010). In the European sleep apnoea database of 19,711 patients, those with prior tonsillectomy present with less severe OSA at time of diagnosis (Riha et al., 2021).

The meta-analysis by Camacho et al. found that tonsillectomy reduced AHI from a mean of 40.5 to 14.1 and in 54 patients, whose individual data was available, the success rate (Sher's criteria) was 85.2% (46 of 54 patients). Preoperative AHI < 30/h significantly increased the chance of surgical cure (AHI < 5/h, 84.0% chance), as those with AHI ≥ 30/h had a cure rate of 34.4%. With Sher's criteria, even those with AHI ≥ 30/h had a surgical success rate of 72.4%. In multivariate analysis BMI < 30 was significant for surgical success, but not surgical cure. It must be noted, though, that most of these studies only selected patients with grade 3–4 tonsils and some of the studies also only included patients with low FTP and Friedman stages (Figure 3, Table 3). (Camacho et al., 2016)

Holmlund et al. reported on 28 patients with large tonsils (grade 3–4) and OSA (AHI ≥ 10), excluding those with a BMI > 32. The authors were denied a randomized controlled trial by the ethics committee. The mean AHI reduced from 40/h to 7/h. No significant difference in effect regarding tonsil size 3 and 4 was found. They also assessed postoperative swallowing, which improved in five patients (none deteriorated). They did not report surgical success using Sher's criteria, but the surgical cure rate was 64.3% (18/28). The follow-up time was 6 months. (Holmlund et al., 2016)

Smith et al. recruited 34 patients with OSA (AHI > 5h), tonsil grades 3 or 4 and modified Mallampati grade 1 or 2. Patients with BMI > 40 were excluded. Unfortunately, only 18 patients completed their postoperative sleep study. The follow-up time was 8 weeks. Mean AHI reduced from 31.6/h to 8.1/h. The mean BMI of patients was 35.8. No significant difference between BMI groups (group 1, 25–29.9; group 2, 30–34.9; group 3, 35–39.9) was noted. The surgical success rate (Sher's criteria) was 78% and the surgical cure rate (AHI < 5/h) was 50%. (M. M. Smith et al., 2017)

Makkonen et al. conducted the first randomized controlled trial that compared tonsillectomy (12 patients) to lifestyle and nutritional counselling (17 patients). Inclusion criteria were an AHI of 5-30 and a tonsil size of ≥1. The surgery group showed a significant reduction in AHI over a 1-year period, whereas the control group did not. Half of their patients achieved surgical success, the mean AHI in the surgery group decreasing from 15.0/h to 7.4/h. 11 of 12 patients in the surgery group had grade 1-2 tonsils, which likely effected outcomes. (Makkonen et al., 2025)

A retrospective study assessing the relevance of simultaneous soft palate surgery with palatine tonsillectomy found no benefit to tonsillectomy alone, even in patients with grade II PTs (Baudouin et al., 2019). This result was recreated in the TEAMUP randomized controlled trial of 93 patients where tonsillectomy alone was found to be more effective than tonsillectomy with simultaneous modified UPPP in treating moderate to severe OSA, even in patients with grade 2 tonsils (Sundman et al., 2022). The mean AHI score for the tonsillectomy group (45 patients) decreased by 56%, from 56.9/h to 24.7/h. A surgical success rate was not reported.

It seems that isolated tonsillectomy can be very successful as a treatment for adult OSA, but palatine tonsil hypertrophy in adult sleep apnoea patients seems to be somewhat rare, as Holmlund recruited for 3 years in Umeå and Smith for 5 years in Cincinnati to achieve the number of reported patients (28 and 34) (Holmlund et al., 2016; M. M. Smith et al., 2017). Most studies exclude obese patients, but one study focused on obese patients (average BMI 36.6) with tonsillar hypertrophy (grade III–IV) still had similarly good results with tonsillectomy reducing average AHI from 81 to 23 (Matinho et al., 2006).

A recent systematic review found tonsillotomy versus tonsillectomy in adults to be scarcely studied, but current evidence suggests efficacy may be equal in some indications. Tonsillotomy seems to be preferable in terms of pain, complications and patient satisfaction, as already proven in children. No studies on adult tonsillotomies have reported AHI values or surgical success rates. (Wong Chung et al., 2018)

2.3.3 Tracheostomy

Tracheostomy was one of the first surgeries used to treat OSA patients, reported to be used in these patients as early as 1969 (Kuhlo et al., 1969). Because it bypasses the upper airway, tracheostomy is thought in many cases to be curative for OSA (Guilleminault et al., 1981; Haapaniemi et al., 2001). However, patients may have persistent hypopneas, and even persistent obstructive apnoeas have been reported in morbidly obese patients (Haapaniemi et al., 2001; Holty & Guilleminault, 2010b; Rodman & Martin, 1987). Worsening of central apnoeas can be observed, but they generally resolve in 3 to 6 months (Jin et al., 2007). Some studies suggest a mortality benefit of tracheostomy (0% vs 11–38%) compared to no therapy in OSA patients

(J. He et al., 1988; Partinen et al., 1988). Tracheostomy has several issues including but not limited to patient dissatisfaction, perioperative complications (such as infection, bleeding) and stoma stenosis (Thatcher & Maisel, 2003). Permanent tracheostomy is currently very rarely used and only in highly select cases with severe OSA (Holty & Guilleminault, 2010b).

2.3.4 Nasal surgery

Patients with OSA are often mouth breathers during sleep (S. H. Lee et al., 2007). Nasal breathing has a more constant resistance compared with the oral cavity and stimulation of nasal receptors is also involved in activating pharyngeal dilation (W. Chen & Kushida, 2003). A transition from nasal to oral breathing results in a greater negative pressure in inspiration (W. Chen & Kushida, 2003). Experimental nasal obstruction or even inhibiting the nasopharyngeal reflex with topical anaesthetics causes nocturnal apnoeas in normal individuals (Holty & Guilleminault, 2010b; Zwillich et al., 1981). Because nasal obstruction contributes to OSA, it is logical to assume that reducing nasal resistance surgically might alleviate OSA.

Multiple meta-analyses have been conducted on the efficacy of nasal surgery in OSA treatment (septoplasty, turbinoplasty, endoscopic sinus surgery) (Correa et al., 2024; Li et al., 2011). In one of them, the pooled success rate (Sher’s criteria) of nasal surgery was reported as 16.7% and thus the authors concluded that nasal surgery may not be effective in treating OSA (Li et al., 2011). In patients with nasal obstruction, nasal surgery seems to still help with snoring and patient daytime sleepiness, improving quality of life. However, in most studies reported, as mentioned, the change in AHI after nasal surgery is not statistically significant (Correa et al., 2024; Li et al., 2011). Nasal surgery can be used to help increase CPAP adherence, and, of course, it effectively improves nasal symptoms if present (Correa et al., 2024; Nakata et al., 2005; Sugiura et al., 2006). In one systematic review 89.1% of patients who did not tolerate or refused to use CPAP became adherent after nasal surgery (Camacho, Riaz, et al., 2015). CPAP treatment itself does not induce long-term objective or subjective nasal obstruction (Värendh et al., 2019).

2.3.5 Tongue base reduction

The base of tongue is a significant site of obstruction in many OSA patients (M. Friedman et al., 2012). Multiple surgical procedures exist to reduce obstruction, which can broadly be classified into two different approaches: tongue suspension or tongue reduction (M. Friedman et al., 2012). The first tongue procedure described was midline glossectomy with laser (Fujita et al., 1991). Due to morbidity of the initial methods focus shifted towards less invasive techniques (Murphey et al., 2015).

The majority of publications feature glossectomy as part of a multilevel approach, making it difficult to analyse the results of it without concurrent procedures. A meta-analysis of from 2015 found three studies, totalling 24 patients, without concurrent surgery, and pooled analysis did not find significant reduction in AHI (Murphey et al., 2015).

Radiofrequency or coblation base-of-tongue reduction resect a portion of the base of tongue. Eleven case series of radiofrequency ablation of the tongue base reported a surgical success rate (Sher’s criteria) of 36%, and not all studies observed even a statistically significant change in subjective daytime sleepiness (Kezirian & Goldberg, 2006). Radiofrequency ablation of the tongue base is thus not recommended as primary OSA treatment (Kezirian & Goldberg, 2006).

Tongue base coblation was first described in 2005 (M. He et al., 2005). The most frequent surgical technique is to use a 70-degree rigid endoscope trans-orally to achieve adequate visualisation during surgery (Camacho et al., 2013; Maturo & Mair, 2006). Publications are limited of tongue base coblation as a single procedure, but success rates of up to 52% have been reported (Süslü et al., 2021). Surgical techniques between publications have variance, making it difficult to assess the real efficacy of a single technique (Cammaroto et al., 2017; Kezirian & Goldberg, 2006).

Transoral robotic surgery of the tongue base and lingual tonsil to treat OSA was first described in 2010, improving visualization of the surgical field (Vicini et al., 2010). Robotic surgery improves tongue base visualization, minimizing risk to vital structures, and with it, midline glossectomy has gained some popularity again (Murphey et al., 2015). Studies have shown improved results over radiofrequency or coblation procedures as part of multilevel surgeries, but the significant cost of robot surgery and the scarcity of access to robot surgery in many parts of the world hinders more widespread adoption of the method (M. Friedman et al., 2012; Vicini et al., 2012).

For tongue base surgery, the most frequent complications include haemorrhage, dental lesions, nasogastric tube dependency, dysphagia, lingual and/or hypoglossal nerve injuries, fistulas, and upper airway obstruction. Postoperative haemorrhage, in rare cases, can be severe and even fatal. (Migliorelli et al., 2025)

2.3.6 Hypoglossal nerve stimulator

Innervated by the hypoglossal nerve, contraction of the genioglossus muscle opens the upper airway (Alrubasy et al., 2024). Hypoglossal nerve stimulation was first described in 2001 (Schwartz et al., 2001). Because it is a purely motor nerve, stimulation of the hypoglossal nerve is unlikely to cause direct arousal in response to sensory stimulation (D. H. Kim et al., 2024). Multiple devices exist on the market, some stimulating the nerve unilaterally and some on both sides (Alrubasy et al., 2024).

Success rates vary among devices but up to 73–75% success rates (Sher's criteria) have been reported after 3–5 years of stimulation (Alrubasy et al., 2024; D. H. Kim et al., 2024). The criteria for patients undergoing hypoglossal nerve stimulation include AHI 15–65, BMI <32 kg/m^2, and the absence of complete concentric collapse at the soft palate level in DISE (Strohl et al., 2017). In 2021, The European Respiratory Society recommended hypoglossal nerve stimulation only as a salvage treatment because of the very strict patient selection in available studies (Randerath et al., 2021).

2.3.7 Skeletal surgery

Mandibular advancement surgery for sleep apnoea patients was first described in 1979 (Kuo et al., 1979). Mandibular advancement is effective in treating adult OSA in patients with acquired or congenital retrognathia (Noller et al., 2017).

Hyoid bone suspension to the inferior border of the mandible was described in 1984 (Riley et al., 1984). It is most often performed simultaneously with other surgeries, alone it has a 35% success rate (Kezirian & Goldberg, 2006). Genial tubercle advancement is one of the surgeries often combined with hyoid suspension. Postoperatively, AHI improvements are only significant in some studies, and success rates range from 22% to 77% in published studies (all with combined hyoid suspension) (Kezirian & Goldberg, 2006).

Already by the mid-1980s combined maxillomandibular advancement was advocated over mandibular advancement alone in the treatment of OSA patients (Holty & Guilleminault, 2010a). Maxillomandibular advancement involves the creation of LeFort 1 osteotomy to the maxilla and bilateral sagittal split osteotomies to the mandible. It creates enlargement of the nasopharyngeal, retropalatal and hypopharyngeal airways by expanding the facial skeletal framework (Gokce et al., 2014). Maxillomandibular advancement is widely accepted as highly effective for treating OSA and surgical success rates in meta-analyses range from 80.4% to 86.0% with average AHI-reductions from 47.8/h to 54.4/h (Holty & Guilleminault, 2010a; Zaghi et al., 2016). Although maxillomandibular advancement requires significant preoperative planning, orthodontic treatment and has an average recovery process of six weeks, with regards to success rates, it is one of the most defining surgeries for the treatment of adult OSA (S. Y. C. Liu et al., 2019). Long-term outcome data remain scarce even for maxillomandibular advancement. A meta-analysis of six studies identified 35 patients with a follow-up of 8 years or more. Although still reduced from a preoperative mean AHI of 53.2, the mean post-operative AHI had risen from 8.7 to 23.1 (Camacho et al., 2019).

3 Aims

This study aimed to evaluate the short- and long-term effectiveness of intra- and extracapsular tonsillectomy in the treatment of adult OSA. Additionally, it sought to analyse patient injury claims associated with both procedures and to estimate the prevalence of tonsillar hypertrophy in the adult population

The specific aims of this study were:

1. To assess patient injury claims related to tonsil and adenoid surgeries and secondarily to compare the frequency of claims between tonsillectomies and tonsillotomies in Finland. (Study I)
2. To investigate long-term outcomes after tonsillectomy in the treatment of adult OSA (Study II)
3. To estimate the prevalence of adult tonsil hypertrophy by using population data and studying the incidence of tonsillectomy for hypertrophic indications. (Study III)
4. To examine the effectiveness of intracapsular tonsillectomy in the treatment of adult OSA (Study IV)

4 Materials and Methods

4.1 Patients and outcome measures

4.1.1 Study I

To assess patient insurance claims, all the complaints related to tonsil and adenoid surgery that were received by the Finnish Patient Insurance Centre (PIC) between the years 2000–2019 were analysed. All the claims with the Nordic Medico-Statistical Committee Classification of Surgical Procedures (NCSP) codes for tonsillectomy (EMB10), tonsillotomy (EMB15), adenotonsillectomy (EMB20), and adenoidectomy (EMB30) were collected from the PIC records. 172 such cases were noted, and all were included in the analysis.

The PIC data consisted of medical records, experts' assessments, and indemnity decisions. The data was reviewed to collect compensation status, classification code, the year of operation, the operative unit, and primary and secondary injuries. The injuries were distributed into 13 categories. Post-operative haemorrhages (post-tonsillectomy haemorrhage, PTH) were recorded separately from other complications and graded according to the severity as: Grade I being minor haemorrhage that stopped without intervention, Grade II being a required compression or electrocautery with local anaesthesia, and Grade III being a required intervention under general anaesthesia.

From the operative reports, we gathered information on the surgical technique used, the surgeons' level of training, the length of the operation, and whether it took place during regular office hours. Additionally, we documented if the suspected injury resulted in extra outpatient clinic or emergency department visits, hospital admission, or reoperation.

4.1.2 Studies II&III

For studies II and III, all tonsil and adenoid surgeries performed in the hospital district of Southwest Finland between the years 2004–2018 were analysed, a total of 9675 patients. Data of the private sector tonsillectomies in Southwest Finland was not available. Auria Clinical Informatics was used to collect data from medical records. The results were first limited to include only patients aged 16 or older for Study II and 18 or older for Study III.

For Study II results were limited to surgeries which only contained the NCSP codes for tonsillectomy (EMB10) along with the diagnosis codes of either sleep apnoea (G47.3) or snoring (R06.5). Data was analysed for home sleep apnoea tests. Patients' age, weight and height were recorded, and BMI was calculated from the results when possible. ESS points were recorded if available. Only patients who had undergone tonsillectomy with or without only partial uvulectomy were included in the analysis and patients without both pre- and post-surgery home sleep apnoea tests available were excluded. Surgical success was defined by Sher's criteria, i.e. a >50% decrease in the overall AHI and a decrease in the overall AHI to <20/h.

For Study III results were limited to surgeries which contained the NCSP code for tonsillectomy (EMB10), tonsillotomy (EMB15), adenotonsillectomy (EMB20) and adenoidectomy (EMB30). Patients with possible symptoms of tonsillar hypertrophy were sought using the ICD-10 diagnostic codes J35.1 (hypertrophy of tonsils), J35.3 (hypertrophy of tonsils with hypertrophy of adenoids), G47.3 (obstructive sleep apnoea), or R06.5 (mouth breathing/snoring). The medical records of these patients were then evaluated in detail. Patients' tonsil sizes, along with primary and secondary indication for surgery were collected. When the indication for tonsillectomy was asymmetry, the histological diagnosis was collected and sorted into three groups: benign tonsillar hypertrophy, lymphoma, and squamous cell carcinoma. The annual quantities of hypertrophic tonsils in adult tonsillectomy patients were compared to population data per year between 2004 and 2018 and then averaged (chapter 4.2).

4.1.3 National and population data for studies I&III

For Study I the annual rates of all tonsil and adenoid surgeries in Finland from the years 2000 to 2018 were acquired from the Finnish Institute for Health and Welfare (THL). Data included the Nordic classification codes, sex, age, and diagnosis code (World Health Organization classification of diseases [ICD-10]) of every patient along with annual operation rates of the individual health care institutes in Finland.

For Study III, annual population data for the years 2004–2018 was gathered from Statistics Finland (Tilastokeskus). The population data was divided into four age groups: 18–25 years, 26–35 years, 36–45 years and ≥ 46 years.

4.1.4 Study IV

Patients for Study IV were recruited from Turku University Hospital and Satasairaala, the central hospital of the Satakunta region, from September 2020 to January 2025. Adult patients presenting to recruiting centres were evaluated and all eligible patients were invited to participate. All evaluated patients had home sleep apnoea tests results available. Inclusion criteria included an AHI ≥ 15, hypertrophic tonsils (Brodsky grade 3–4/4), and age 16–65. Exclusion criteria included BMI ≥ 35, untreated symptomatic nasal blockage, untreated symptomatic gastric reflux, prior pharyngeal surgery, and a diagnosis of malignancy or bleeding disorders. All participants were treated with ICTE (chapter 4.1.4.1). When possible, all sleep study data were (re)interpreted by a single certified scorer.

Postoperative at home sleep apnoea tests were performed 6 months after surgery. At the 6 months clinical follow-up visit, the patients were also asked if they would still choose the same surgery. Tonsils were photographed pre- and postoperatively and at 6 months. Adverse events were recorded through patient charts and questionnaires (chapter 4.1.4.2). For analgesia, at discharge, all patients were prescribed naproxen (500mg) and a combination of tramadol-paracetamol (37.5/325 mg).

The primary outcome was surgical success as defined by Sher's criteria, i.e. a >50% decrease in the overall AHI and a decrease in the overall AHI to <20/h. The secondary outcome was surgical cure, defined by a decrease in the overall AHI to <5/h. The patients were given a note for 10 days of sick leave. Participants were informed that the standard sick-leave period is 14 days and were offered the possibility to prolong their leave by an additional 4 days via a no-questions-asked phone request.

4.1.4.1 Surgical method

Intracapsular tonsillectomy was performed with a coblator wand (Procise Max or Evac 70 Xtra, Smith & Nephew plc, London, UK). Patient was placed in a supine standard tonsillectomy position. A Davis-Boyle mouth gag was used. A suction catheter, inserted into one nostril and pulled out of the mouth, was used for velotraction. Compression with gauze balls was used for haemostasis along with the coagulation setting of the coblation wand. Adrenaline (1mg/ml) soaked gauze balls were used if needed. Standard 7W power for ablation and 3W power for coagulation were used. Tonsil tissue was reduced by approximately 90%, leaving some tonsil tissue medial to the fibrous capsule and the capsule intact. All surgeries were performed by one of three surgeons.

4.1.4.2 Questionnaires

All participants were given pre- and postoperative quality of life questionnaires, including ISI, ESS, BNSQ, and the Glasgow Benefit Inventory (GBI). ESS, ISI and BNSQ are discussed in chapter 2.2.2. GBI is an otolaryngologic health-related quality of life instrument developed to detect changes in health status following interventions (Robinson et al., 1996). GBI is collected only once, postoperatively, and scores range from -100 (maximum harm) to +100 (maximum benefit), with a score of 0 representing no change.

To track recovery, participants completed the Brief Pain Inventory (BPI) daily for 21 days postoperatively and the Nordic Tonsil Surgery Register (NTSR) 1-month questionnaire. BPI is a self-report instrument developed to assess pain in cancer and other diseases (Daut et al., 1983). The BPI short form is more frequently used and consists of pain diagrams, four measures of pain severity (worst, least, average, and current pain), two items on pain treatment or medication, and one item assessing pain-related interference across seven areas: activity, mood, walking, work, social relationships, sleep, and life enjoyment. NTSR was developed as a tonsil surgery quality register for the Nordic countries (Ruohoalho et al., 2018). The 1-month questionnaire contains nine questions, three about postoperative bleeding, three about postoperative infections, and three about postoperative pain and recovery. The post-operative ISI, ESS, BNSQ, and GBI questionnaires were administered six months after surgery.

4.2 Statistical methods

In study I, descriptive statistics were used to summarise patient characteristics, surgical variables, and injury outcomes. Categorical variables were reported as absolute frequencies and proportions, while continuous variables were summarised using means. Event counts were analysed using generalized linear models for count data. Poisson regression was used to model incidence rates, with the total number of procedures included as an offset variable to account for differences in surgical volume. Because overdispersion was expected in the count data, negative binomial regression models were also fitted. Model fit between Poisson and negative binomial models was compared using Vuong's test, and the model with superior fit was selected for inference.

In study II, statistical analysis consisted of descriptive statistics and paired pre–post comparisons. Continuous variables were reported as means with 95% confidence intervals or standard deviations, and categorical variables as frequencies and percentages. Changes in AHI and ESS scores before and after tonsillectomy were evaluated using Wilcoxon matched-pairs signed-rank tests. Subgroup analyses were descriptive without multivariable modelling.

In study III, descriptive statistics were used to summarise demographic characteristics, surgical indications, and histopathological findings. Incidence rates of tonsillectomy for adult tonsillar hypertrophy were calculated as the average annual number of surgeries per 100,000 person-years, stratified by age and sex. Trends were assessed descriptively across age groups and over time.

In Study IV, changes in clinical outcomes from pre- to postintervention were analysed using statistical tests selected according to the distribution of the data. For non-normally distributed variables (AHI, AI, and snoring measures), Wilcoxon matched-pairs signed-rank tests were applied, whereas paired-samples t-tests were used for normally distributed variables (ESS and ISI). To explore differences related to surgical outcomes, patients were grouped according to surgical success and surgical cure status, and differences in age, BMI, and baseline AHI were evaluated using two-sample Student’s t-tests. Additionally, participants were categorized based on whether their preoperative AHI was above or below 30, and Fisher’s exact test was used to examine associations between smoking status, baseline AHI category, and surgical outcomes. Finally, logistic regression analysis was performed to assess the effect of age and body weight on the likelihood of achieving surgical cure.

For statistical analyses IBM SPSS (version 29.0.0 or newer, IBM Corp), and R software (version 4.4.0, R Core Team) were used.

4.3 Ethical considerations

All studies were conducted in accordance with the Declaration of Helsinki. Retrospective, register-based studies do not require institutional review boards' approval, and for that reason, an approval from the ethics committee was not applied for studies I-III. Studies II-IV had institutional approval. The data search and the study protocol for Study I were approved by the PIC and the Finnish Institute for Health and Welfare. The study protocol for Study IV was reviewed and approved by the Medical Ethics Committee of the Hospital District of Southwest Finland, and all participants provided a written informed consent.

Study IV was a prospective, single-arm clinical study in which all participants underwent intracapsular tonsillectomy and were informed of the surgical method prior to enrolment. A control group was not included, as demonstrating non-inferiority would have required an impractically large sample size.

Surgical and postoperative management followed established clinical guidelines, including routine overnight monitoring and a standard postoperative sick leave of 10 days. Participation was voluntary and based on informed consent, with individuals aged 16 years or older considered capable of independent decision-making. Participants had the right to withdraw from Study IV at any time, and withdrawal did not affect their ongoing or future medical care. Data were handled confidentially, results were reported in anonymized form. The study aimed to identify a less invasive yet effective surgical approach, representing an ethically motivated endpoint for patient benefit.

5 Results

5.1 Epidemiology of adult tonsillectomy for hypertrophic indications (Study III)

A retrospective chart within the Hospital District of Southwest Finland identified 483 patients with tonsillar hypertrophy who underwent tonsillectomy between 2004 and 2018. 286 patients were men and 197 were women. During the 15-year observation period, the adult population of Southwest Finland showed a slight increase, amounting to 392,412 individuals in 2018. Women constituted a slight majority, with 202,363 women and 190,049 men.

The pooled incidence of tonsil surgery for adult tonsillar hypertrophy was 8.49 per 100 000 person-years. The incidence showed a consistent age-related decline, from 30 per 100,000 person-years in the 18–25-year age group to 1.85 per 100,000 person-years among individuals older than 46 years. 59.2% of these patients with hypertrophic tonsils were men and, at the time of surgery, the average age was 31.2 years (range = 18-85, median = 27.0). The incidence of tonsil surgery in different age groups and sexes is listed in Table 4 and visualized in Figure 4.

The most common indication for tonsil surgery in these patients was snoring, followed by acute or chronic tonsillitis, and sleep apnoea. The primary indications for surgery are listed in Table 5. The number of surgeries remained constant within age groups over the study period. When sorting verbal descriptions of tonsil sizes into two categories, large or very large, 64.0% of patients had large and 36.0% had very large tonsils.

We found 118 patients whose tonsils were sent to histological analysis because of some degree of asymmetry. Of these, 15 patients (12.7%) were diagnosed with malignancy. Of the malignant tonsils, 13 were diagnosed as lymphoma and 2 as squamous cell carcinoma.

Table 4. The incidence of tonsillectomy for adult tonsillar hypertrophy 2004–2018 in the Hospital District of Southwest Finland (Study III). The reported number is the average number of tonsillectomies in per 100 000 person-years, calculated over 15 years. Modified from original publication III with permission from the copyright holders.

	All	**Men**	**Women**
18–25 years old	29.99	29.52	30.45
26–35 years old	15.21	21.73	8.51
36–45 years old	8.78	12.00	5.47
46 years and older	1.85	2.04	1.69
Total	8.49	10.45	6.69

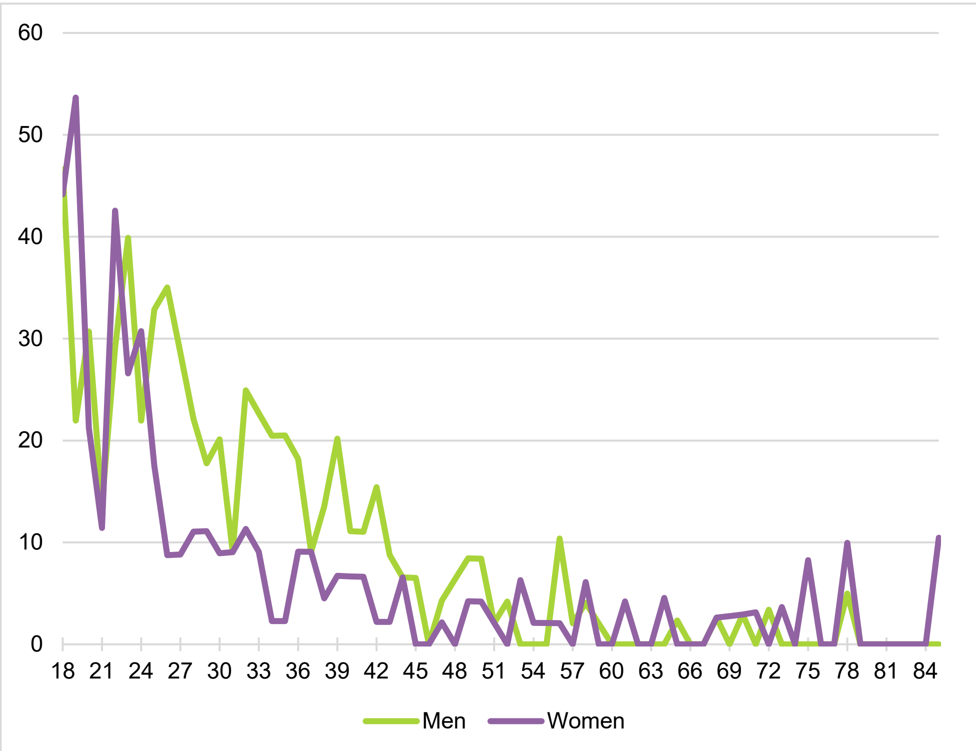

Figure 4. The incidence of tonsillectomy for tonsil hypertrophy according to age at time of surgery among men and women 2004–2018 in the Hospital District of Southwest Finland (Study III). The reported number is the average number of tonsillectomies in per 100,000 person-years calculated from the annual numbers of tonsillectomies over 15 years (n = 483) and yearly public population data. Modified from original publication III with permission from the copyright holders.

Table 5. The primary indication for tonsil surgery in 483 adults with tonsillar hypertrophy from 2004 to 2018 in the Hospital District of Southwest Finland (Study III). Modified from original publication III with permission from the copyright holders.

Primary indication	n	%
Snoring	149	30.8
Acute or chronic Tonsillitis	99	20.5
Sleep apnoea	87	18.0
Asymmetry	57	11.8
Large size only	47	9.7
Swallowing difficulties	23	4.8
Tonsil stones	13	2.7
Other	8	1.7
Total	483	

5.2 Patient injury claims from tonsil and adenoid surgery (Study I)

PIC processed a total of 156 claims regarding tonsil or adenoid surgery between the years 2000–2018. Of these claims, 34.6% were compensated for. During the same period, a total of 292 679 patients had tonsil or adenoid surgery nationwide. An average of 5.3 cases per 10 000 surgeries thus resulted in a claim and 1.8 per 10 000 resulted in compensation. Split between different surgeries, the averages were 8.7 claims for tonsillectomies, 1.3 for adenoidectomies and 4.4. for tonsillotomies, all per 10 000 surgeries. The average compensation for an accepted claim was 2358€.

Most claims in tonsil or adenoid surgery involved specialists who performed routine operations in high-volume centres during office hours. Electrocautery was used in 92.9% of compensated cases. The average number of compensations in different hospital districts ranged from 0.88 to 3.20 per 10 000 surgeries but the incidence rate ratio estimates did not differ significantly between districts in Poisson regression ($p = 0.12$). The same was true for the difference between compensations in the private and public sectors, 1.52 and 1.91 per 10 000 surgeries ($p = 0.52$).

The WHO Surgical Safety Checklist was implemented nationally around 2010. In our data, the rate of claims decreased from 6.08 to 4.25 per 10 000 operations after implementation, while the rate of compensations showed a smaller change, from 1.85 to 1.75 per 10 000 operations. In Poisson regression analyses comparing the post-implementation period to the pre-implementation period, the reduction in claims was statistically significant ($p = 0.03$), whereas the change in compensations was not ($p = 0.84$).

Surgical indications were categorized as infectious (e.g. peritonsillar abscess, tonsillitis) or hypertrophic (e.g. OSA, snoring). The rate of claims was substantially higher in infectious cases compared with hypertrophic cases (10.38 vs 3.69 per 10 000 operations; $p < 0.0001$, Poisson regression). Compensation rates were also higher in infectious cases (2.98 vs 1.76 per 10 000 operations), although this difference did not reach statistical significance ($p = 0.06$).

We divided the injuries into 13 different categories presented in Table 6. Our data search from PIC included operations from years 1996 to 2019 and for this we used all the processed 172 claims we examined, instead of limiting them to the years we had national surgical data for (2000–2018). The most often compensated injuries were burns followed by nerve injury, and the nerve most often damaged was the glossopharyngeal nerve. 55 patients who submitted claims to the PIC had PTH. Only one of these was compensated, because PTH is an expected complication. Most of PTHs (63.6%) in this data were grade III, i.e. requiring intervention under general anaesthesia.

Most of the claims, 76.7%, were for injuries that were detectable immediately after or during surgery. 28 of the 57 compensated injuries we considered to be permanent, reducing the patient's functional capacity or quality of life permanently, or were permanent cosmetic injuries, e.g. large burn marks or scars.

5.2.1 Death as a complication of tonsil or adenoid surgery

Data from the Finnish Institute for Health and Welfare shows that ten patients died within 21 days of their tonsillectomy during 2008–2018, earlier data from them is not available. No deaths during 2008–2018 occurred after adenoidectomies or tonsillotomies.

In the PIC data there were seven deaths. They were all compensated for, as even when the cause is considered unavoidable, such as PTH, death is an intolerable complication. Five of these were caused by excessive PTH and the aspiration of blood. One of seven deaths occurred within 24 hours of surgery. One death was due to inadequate monitoring after anaesthesia, and one was unexplainable even after autopsy. All deaths in the PIC data took place after routine surgery during office hours, and all surgeons were specialists in otorhinolaryngology.

Table 6. Number (and proportion) of claimed and compensated injuries sorted into 13 categories. Injuries are sorted into main and possible secondary patient reported injuries occurring after the same surgery. This table contains 172 claims from tonsil and adenoid surgery conducted between 1996 and 2019, data from PIC.

	Patient claims		**Compensated Patients**	
Injury category	**Main complaint N (%)**	**Additional complaint N (%)**	**Compensated injury N (%)**	**Additional complaint N (%)**
Problems related to altered anatomy of pharynx	28 (16.3)	32 (40.5)	7 (12.3)	6 (24.0)
Post-tonsillectomy haemorrhage	25 (14.5)	3 (3.8)	1 (1.8)	15 (60.0)
Nerve injury	22 (12.8)	28 (35.4)	8 (14.0)	2 (8.0)
Burn injury	19 (11.0)		15 (26.3)	
Damage to adjacent anatomical structure	18 (10.5)	3 (3.8)	5 (8.8)	1 (4.0)
Infection	17 (9.9)	7 (8.9)	6 (10.5)	1 (4.0)
Tonsil remnant requiring re-operation	8 (4.7)	1 (1.3)	3 (5.3)	
Death	7 (4.1)		7 (12.3)	
Impaired taste	6 (3.5)	2 (2.5)		
Retained foreign bodies	4 (2.3)		2 (3.5)	
Anaesthesia complication	4 (2.3)	2 (2.5)	2 (3.5)	
Excessive intraoperative bleeding	4 (2.3)		1 (1.8)	
Other	10 (5.8)	1 (1.3)		
Total	172	79	57	25

5.3 Long-term outcomes of tonsillectomy in adults (Study II)

Among tonsillectomies performed between 2004 and 2018, 151 adult patients with a documented diagnosis of OSA or snoring were identified. Of these 151 patients, 81 had pre-tonsillectomy home sleep apnoea tests available, and a further 31 had post-tonsillectomy sleep tests available. Following patient chart review, ten patients were excluded. Six of them had undergone simultaneous radiofrequency ablation of the soft palate, and one had a concurrent adenotomy. Two patients received additional treatments prior to the completion of their post-tonsillectomy sleep study and were therefore excluded. One patient did not have OSA prior to surgery. Thus, in total, 21 patients were included in the study.

The average AHI was 22.3 (standard deviation [SD] ±15.1) events per hour before tonsillectomy and 11.0 (±12.3) after tonsillectomy ($p = 0.005$). During the examined period a post-tonsillectomy home sleep apnoea test was not routinely conducted at our institution and, most often, was performed because of residual symptoms. The post-tonsillectomy sleep studies in this data were performed a median of 6.2 months after surgery (average of 36.6, SD ±58.7, range 1.8–171.0), with the longest follow-up period exceeding 14 years.

We defined surgical success as AHI decreasing by >50% and a total AHI of <20 events/h post-surgery. Initially, the success rate was 61.9%, with 8 patients failing surgical treatment. After careful review of the patient charts, we found that 3 initial responders had started CPAP treatment again and the true success rate should be 47.6%. Complete surgical cure was achieved in 38.1% of patients. No patient having their follow-up sleep study a year or more after the tonsillectomy was a success. Only one of four patients with a BMI over 30 was a surgical success.

The tonsil sizes documented in patient charts were translated to English and sorted into one of four categories: one patient had small, 3 had medium, 12 had large and 5 had very large palatine tonsils. Numeric tonsil grades were not available for any patient. In the very small subgroup of small- to medium-size tonsils (n=4) the success rate was 75%, but none were cured. Averaged, patients with small to medium tonsils had an AHI change of -13.8 (-50.9%, SD ±12.7). Individual data are listed in Table 7, including tonsil size, AHI values, and weight data.

Table 7. Individual results of each patient in Study II and some notes on additional findings sorted into two groups by ascending tonsil size estimated from written descriptions. Unsuccessful outcomes are marked with bold (AHI >20 and/or <50% reduction of AHI post-operatively). N/A = not available. ID = patient identification number.

ID	Tonsil size	Pre-op AHI	Post-op AHI	AHI change	AHI change (%)	Pre-op BMI	Weight change (%)	Follow-up (mos.)
12	Small	21	9	-12.0	-57.1	27.1	N/A	3.5
8	Medium	49.3	17.6	-31.7	-64.3	26.1	+3.8	8.9
15	Medium	7.7	5.8	-1.9	**-24.7**	24.6	+9.3	87.5
19*	Medium	16.9	7.2	-9.7	-57.4	35.1	+2.8	6.2
Avg	Small–Medium	23.7	9.9	-13.83	-50.88			
1	Large	24	5.10	-18.9	-78.8	25.6	+3.5	3.3
4	Large	44.7	56	+11.3	**+25.3**	40.4	+29.7	149.5
5	Large	20	3.2	-16.8	-84.0	24.8	0.0	6.9
6	Large	11.7	3.9	-7.8	-66.7	26.3	+3.8	8.1
9	Large	9	5.1	-3.9	**-43.3**	29.1	+4.5	2.6
10†	Large	25.7	3.8	-21.9	-85.2	29.4	-3.1	3.6
11	Large	9.4	**21.2**	+11.8	**+125.5**	26.6	+10.9	171.0
14	Large	33.8	1.5	-32.3	-95.6	25.9	+0.4	6.1
16	Large	10.4	4.6	-5.8	-55.8	29.9	-2.0	2.2
17	Large	6.4	12.2	+5.8	**+90.6**	29.4	+9.9	98.7
20	Large	31.7	4.1	-27.6	-87.1	25.5	+1.2	5.9
21	Large	4.9	10	+5.1	**+104.**	31.8	+8.5	25.0
2	Very Large	54.5	17	-37.5	-68.8	N/A	N/A	1.9
3‡	Very Large	33.8	2.4	-31.4	-92.9	27.7	0.0	1.8
7	Very large	35	**23.4**	-11.6	**-33.1**	27.8	+0.4	6.6
13	Very large	8.5	16	+7.5	**+88.2**	32.8	+5.2	164.3
18	Very large	9.8	0.9	-8.9	-90.8	23.6	+22.5	6.0
Avg	Large–Very	22.0	11.2	-10.76	-26.37			

* Symptomatic four years after surgery and has re-started CPAP treatment.
† AHI 9.1 ten years after surgery and has re-started CPAP treatment.
‡ AHI 38.3 nine years after surgery and has re-started CPAP treatment.
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5.4 Intracapsular tonsillectomy for obstructive sleep apnoea (Study IV)

Twenty patients with moderate to severe OSA completed enrolment and intervention and sixteen patients completed the 6-month follow-up with a home sleep apnoea test for Study IV and were included for analysis.

The surgical success rate (Sher's criteria) was 68.8%. The mean (±SD) AHI lowered from 37.4/h (±19.8) to 11.8/h (±16.1, $p = 0.003$). The pre- and postoperative AHI of each patient is shown in Figure 5 and Table 8. The mean change in AHI was -25.5/h (95% CI -13.5 to -37.5) or -66.9% (-40.6 to -92.5). The surgical cure rate was 43.8%.

The mean AHI while supine lowered from 52.4/h (±25.7) to 25.2/h (±35.8, $p = 0.002$). The mean apnoea index lowered from 13.3/h (±13.9) to 4.1/h (±11.9, $p = 0.002$). The changes in snoring were not significant, as total snoring dropped from 22.1% (±21.8) to 19.4% (±21.2) ($p = 0.88$), and supine snoring increased from 22.8% (±23.2) to 23.2% (±21.2) ($p = 0.52$).

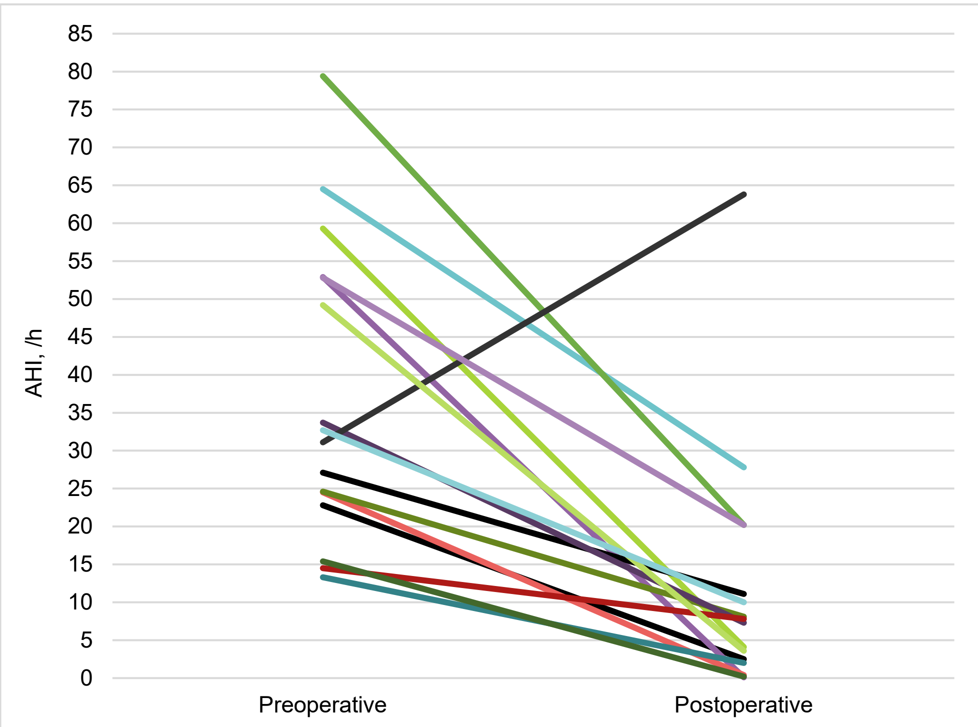

Figure 5. Apnoea-hypopnea indexes (reported number is events per hour) before and 6 months after intracapsular tonsillectomy for each patient. Modified from original publication III with permission from the copyright holders.

Table 8. Individual pre- and postoperative home sleep apnoea test data. Modified from original publication III with permission from the copyright holders.

ID	TONSIL GRADE	PRE-OP AHI (/h)	POST-OP AHI (/h)	AHI CHANGE	% CHANGE	SUCCESS
4	3	22,8	2,5	-20,3	-89,0	Yes
7	4	59,3	4,1	-55,2	-93,1	Yes
10	3	64,5	27,8	-36,7	-56,9	No
11	4	52,9	0,1	-52,8	-99,8	Yes
12	3	24,5	0,4	-24,1	-98,4	Yes
13	3	79,4	20,2	-59,2	-74,6	No
14	2	27,1	11,1	-16	-59,0	Yes
16	3	24,6	8,1	-16,5	-67,1	Yes
18	3	13,3	2	-11,3	-85,0	Yes
19	4	33,7	7,3	-26,4	-78,3	Yes
20	3	14,5	7,8	-6,7	-46,2	No
21	4	15,4	0,2	-15,2	-98,7	Yes
22	3	31,1	63,8	+32,7	+105,1	No
23	3	49,2	3,6	-45,6	-92,7	Yes
24	3	32,7	10	-22,7	-69,4	Yes
25	3	52,8	20,2	-32,6	-61,7	No
MEAN	3.2	37.4	11.8	-25.5	-66,5	

At the time of surgery, the mean age of the patients was 31.4 years (range: 17.8–47.5 years, SD ±9.2). The study group consisted of four women and 12 men, all of whom were Caucasian. Five patients (31.3%) were smokers. The mean (± SD) BMI was 29.4 (±4.5). Six months after surgery, the mean weight change was +1.1% (±7.0). No patient experienced a weight loss of ≥10% during this period, which had been predefined as an exclusion criterion.

Tonsil size was reassessed by the operating surgeon on the day of surgery. Four patients were classified as grade 4, 11 as grade 3, and one as grade 2. The patient graded as 2 at the time of surgery had been graded as 3 at recruitment and therefore met the study's inclusion criteria.

Patients were divided into two sets of two groups based on (1) surgical success and (2) surgical cure. Differences in age, BMI, smoking status, and preoperative AHI were between the groups analysed.

When comparing patients with and without surgical cure, significant differences were found in mean BMI (26.8 vs. 31.4, $p = 0.02$), mean age (24.5 vs. 36.8, $p = 0.004$), and smoking status (0% vs. 55.5%, $p = 0.03$). There was no significant difference in mean preoperative AHI between the groups. In contrast, no significant differences in mean age, BMI, smoking status, or preoperative AHI were found between patients with and without surgical success.

Patients were also divided into two groups based on whether their preoperative AHI was > 30/h or ≤ 30/h. No statistically significant differences in surgical success or surgical cure were observed between these two AHI groups.

Binary logistic regression analysis was performed to assess whether age and BMI predicted surgical success. In the univariate analysis, age was a statistically significant predictor ($p = 0.03$, OR = 0.80 [95% CI 0.651–0.975]), indicating that higher age was associated with lower odds of surgical success. BMI alone was not a significant predictor ($p = 0.06$). Age and BMI were moderately correlated (Spearman's rank correlation $r_s = 0.40$). When both variables were included in the same multivariable model, neither age ($p = 0.051$) nor BMI ($p = 0.16$) remained statistically significant.

5.5 Recovery from intracapsular surgery (Study IV)

Daily average and worst pain visual analogue scale (VAS) scores (0–10 scale), along with the impact the pain had on patients' ability to work, overall performance, and swallowing, are presented in Figure 6. Throughout the recovery period, the daily average pain never exceeded VAS 3.0 (±1.9). On postoperative day ten, in the BPI questionnaire, patients indicated that the peak pain experienced had a mean (±SD) of VAS 2.6 (±1.9) while the average pain over the same day was VAS 1.7 (±1.5).

The highest mean (±SD) consumption of tramadol-paracetamol combination (37.5/325 mg) tablets per patient occurred on day six, at 3.2 (±2.2) tablets out of a maximum of eight. By day ten, the mean intake had decreased to 1.3 (±2.0) tablets. The highest mean (±SD) consumption of naproxen was similarly on day six, at 1.7 (±0.6) tablets. By day 10 the intake was 1.3 (±0.9) tablets.

For 13 out of 16 patients (81%), a ten-day sick leave was adequate for recovery. One patient reported blood-tinged sputum which was categorized as a grade 1A PTH. No other adverse effects were recorded.

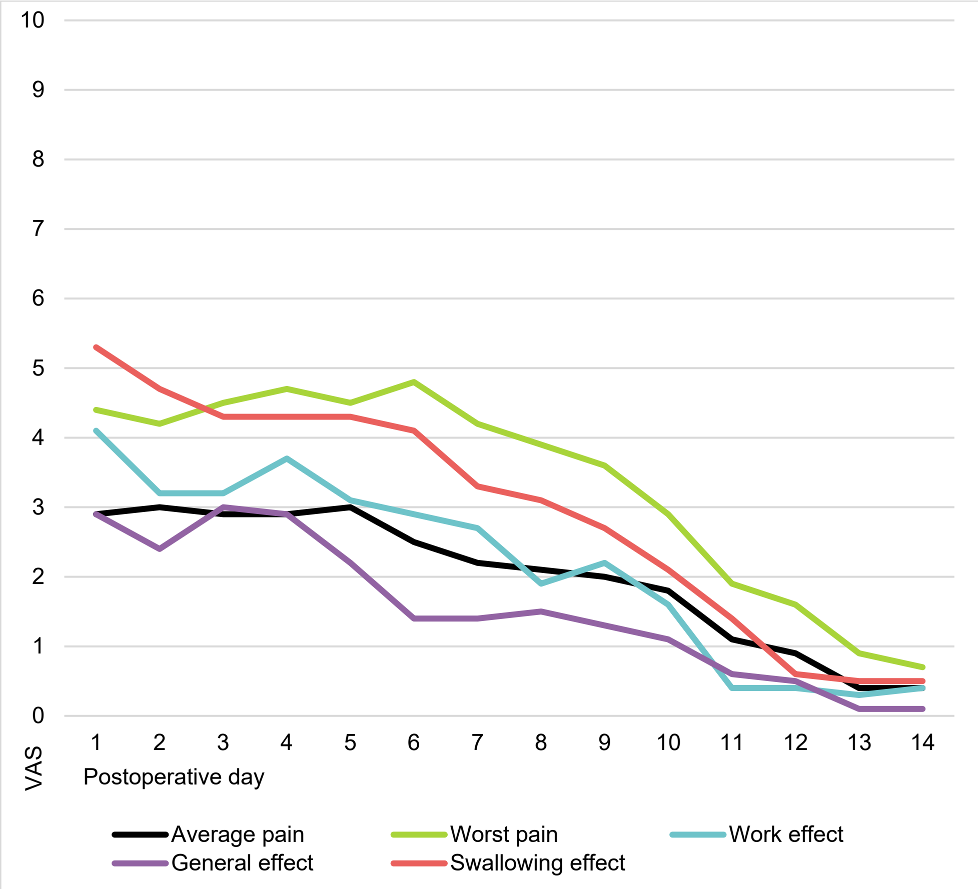

Figure 6. Mean daily average pain, daily worst pain, and pain interference on ability to work, general performance, and swallowing. On visual analogue scale 0–10, for 14 days after intracapsular tonsillectomy, from Brief Pain Inventory data (Study IV), n=16.

5.6 Patient-reported changes in quality of life (Studies II & IV)

Daytime sleepiness, assessed with ESS, showed no significant change following surgery in either study. In Study II, mean (±SD) ESS scores were recorded preoperatively and at the follow-up home sleep apnoea test for 18 and 17 patients, respectively, and remained stable (7.2 ±3.4 vs. 6.5 ±3.0, $p = 0.174$). Similarly, in Study IV, ESS mean scores did not differ significantly between the preoperative and postoperative assessments (6.1 ±3.2 vs. 5.3 ±2.8, $p = 0.32$).

The mean (±SD) ISI score, used to assess changes in daytime and nighttime insomnia in Study IV, lowered from 9.6 (±3.4) preoperatively to 6.3 (±4.0) postoperatively ($p = .001$).

GBI responses were scaled and averaged to generate a composite score ranging from -100 (poorest possible outcome) to +100 (best possible outcome). The GBI items were categorized into three established subscales (i.e., general, social support, and physical health) in accordance with the original instrument structure. In Study IV, the mean (±SD) total GBI score was +11.5 (±10.2). Subscale analysis demonstrated a mean score of +16.4 (±11.9) for the general subscale, +1.0 (±9.3) for the social support subscale, and +0.52 (±31.0) for the physical health subscale.

In study IV, at the 6-month follow-up assessment, 100% of patients reported that they would choose to undergo the same surgical intervention again.

6 Discussion

6.1 Epidemiology of adult tonsillectomy for hypertrophic indications

The incidence of adult tonsillectomy for hypertrophic indications in Study III was low (8.49 per 100,000 person-years). These findings can be related to the incidence of childhood tonsillectomy in the United Kingdom (250 per 100,000 person-years), the global incidence of appendectomy for appendicitis (100 per 100,000 person-years), and the overall incidence of tonsil surgery in Germany (80 per 100,000 person-years) (Ferris et al., 2017; Šumilo et al., 2019; J. P. Windfuhr & Chen, 2020). It should be noted that these studies also included patients from the private sector. Although we do not have information about asymptomatic tonsillar hypertrophy, Study III suggests that adult palatine tonsil hypertrophy is rare.

In Study III, the most common complaint leading to tonsillectomy was snoring. Up to 6% of adult snorers are estimated to have hypertrophic tonsils, and the annual incidence of OSA in the Finnish adult population is 600 per 100,000 (Dahlqvist et al., 2007; Palomäki et al., 2022). Taken together, these figures suggest that some patients who might benefit from surgical evaluation may remain unidentified.

Certain patterns established in childhood appear to persist into later life. Paediatric tonsil hypertrophy is known to become less common with increasing age, particularly after children reach school age (Borgström et al., 2017). Study III suggests that this trend continues into adulthood, as the incidence of tonsil surgery for hypertrophic indications decreased from 30 per 100,000 person-years among individuals aged 18–25 years to 1.85 in those aged 46 years and older. One possible explanation is that hypertrophic tonsils tend to cause clinical complications earlier in life, leading to surgical intervention before old age.

Similarly, the incidence of tonsil surgery in Study III was higher in men than in women (10.45 vs. 6.69 per 100,000 person-years). This sex difference also appears to persist from childhood, as adenotonsillectomies are known to be more common in young boys than in young girls (Borgström et al., 2017; Mattila et al., 2001).

6.2 Surgical treatment of obstructive sleep apnoea

6.2.1 Long-term results of extracapsular tonsillectomy

With follow-up durations ranging from 1.8 to 171 months, Study II includes a subset of patients with notably long follow-up periods compared to those reported in the literature for tonsillectomy performed for this indication.

The results of Study II are underscored by a selection bias more likely favouring patients with residual symptoms. The relatively modest surgical success rate of 47.6%, compared to 78−85.2% reported previously, is likely the result of several factors (Camacho et al., 2016; M. M. Smith et al., 2017). First, our patients had less severe OSA compared to previous studies with patients' AHI averaging 31.6–40.6 events/h (Camacho et al., 2016; Holmlund et al., 2016; M. M. Smith et al., 2017). Second, the patients in Study II with mild OSA before surgery had a very modest benefit from surgery.

Following the publication of Study II, a randomized controlled trial with one-year follow-up compared tonsillectomy to lifestyle counselling and demonstrated a statistically significant reduction in AHI from 15.0 to 7.4 events/h in the surgical group. A notable methodological strength of this study was the use of polysomnography rather than home sleep apnoea testing, providing more rigorous outcome assessment. The percent reduction in mean AHI was consistent with that in Study II. They did not report on the percentage of patients to achieve surgical success. (Makkonen et al., 2025)

In patients with less severe OSA the daytime sleepiness has been speculated to be multifactorial and, as such, may not respond favourably to OSA treatment alone (Gasa et al., 2013). In addition, patients with mild to moderate OSA are often analysed as a single group and it could perhaps be advantageous to see future studies comparing patients with mild and moderate OSA separately (Camacho et al., 2016).

Notably, in Study II, the six patients with the longest follow-up intervals were all non-responders, each with a follow-up time of two years or more. Additionally, three initial responders were later found to revert to CPAP treatment, experiencing a return of symptoms several years after tonsillectomy. Two non-responders also exhibited substantial weight gains of 10.9% and 29.7%. UPPP outcomes have been reported to worsen significantly 6–12 months post-surgery (Levin & Becker, 1994). Prior to this, most studies of tonsillectomy and OSA have had follow-up periods of no longer than six months (Camacho et al., 2016; Holmlund et al., 2016; M. M. Smith et al., 2017).

Even though the findings of Study II support the notion that tonsillectomy appears to be an effective intervention for OSA in adults with tonsillar hypertrophy, they also underscore the need for further research on long-term outcomes.

6.2.2 Intracapsular tonsillectomy

ICTE appears to be an effective treatment option for adults with OSA, particularly in patients presenting with grade III–IV tonsillar hypertrophy. The observed mean reduction of pre- to postoperative AHI in Study IV (-25.5/h, 70%) closely parallels published results for ECTE (-30.2/h, 65%) (Camacho et al., 2016). The minimal clinically important difference for AHI is considered to be a reduction of 15 events per hour which was reached in 81% of patients in Study IV (Patil et al., 2019).

In prior studies surgical success rates range from 78−85.2% (Camacho et al., 2016; M. M. Smith et al., 2017). Two patients disproportionately lowered our overall success rate (68.8%), because of our small sample size, regardless of outcomes that could be considered favourable. Patient 13 achieved a 74.6% reduction in AHI (-59.2/h), but the postoperative AHI of 20.2/h represented a surgical failure. In contrast, patient 20 reached a postoperative AHI of 7.8/h but demonstrated a reduction of 46.2%, which also represents surgical failure.

The only patient whose sleep apnoea worsened during Study IV, patient 22, presented with severe disease and polysomnography findings that were difficult to quantify, likely due to intermittent wake periods and consecutive hypopneas and apnoeas with poorly differentiated desaturations. Variations in these features between preoperative and successive postoperative home sleep apnoea test are the most probable explanation for the unusually variable AHI values.

Significant differences were observed between the surgical cure and no surgical cure groups with respect to mean BMI, mean age, and smoking status. In our cohort, patients in the no surgical cure group were notably older, had higher BMI values, and were more often smokers. In contrast, no comparable differences were detected between the surgical success and no surgical success groups. Previous research on the surgical treatment of OSA has demonstrated that higher BMI and age are associated with a reduced efficacy of tonsillectomy (Camacho et al., 2016; M. M. Smith et al., 2017).

While prior studies suggest that tonsillectomy is most effective in patients with preoperative AHI below 30/h, this pattern was not evident in Study IV (Camacho et al., 2016). In univariate logistic regression analysis, only age reached statistical significance, with higher age correlating with diminished surgical effectiveness. Our results indicate that BMI, age, and smoking status are potential factors affecting the likelihood of successful OSA treatment with ICTE, consistent with observations in previous sleep-surgery studies (Camacho et al., 2013).

6.2.3 Tonsil size and surgical success

Previous studies have reported good results in reducing AHI, albeit with shorter follow-up times, usually in carefully selected patients with mainly large tonsils

(Holmlund et al., 2016; M. M. Smith et al., 2017). Tonsillectomy is usually not recommended for OSA patients with grade 1−2 tonsils (Camacho et al., 2016). Two previous studies reported on very small cohorts of two and seven patients with grade 2 tonsils having surgical success with tonsillectomy (Nakata et al., 2006; Senchak et al., 2015).

In Study II, four patients had small to medium size tonsils. These were only verbal descriptions, which we speculated to translate into tonsil grade 2. Somewhat surprisingly, the patient with small tonsils and two of the three patients with medium tonsils were surgical successes with tonsillectomy. Somewhat recently, the TEAMUP trial reported on 13 patients with grade 2 tonsils in the isolated tonsillectomy group with an average AHI change of -27.9 events per hour (95% CI [-39.9 to -15.8]) (Sundman et al., 2022). In Study IV, treated with ICTE, the single patient with grade 2 tonsils on the day of surgery was a surgical success. Currently, the impact of tonsillectomy (intracapsular or extracapsular) on patients with OSA and grade 2 tonsils remains underexplored and warrants further investigation.

6.2.4 The effect of surgical treatment on quality of life

Daytime sleepiness was measured with ESS in both Studies II and IV (chapter 2.2.1, Table 1). The ESS scores of normal controls are 5.9 (SD ± 2.2) with a range of 2–10 (Johns, 1991). Prior studies of tonsillectomy in adult OSA have seen significant reductions in ESS scores after surgery (Holmlund et al., 2016; M. M. Smith et al., 2017).

The pre-operative ESS in Studies II (7.2) and IV (6.1) are significantly lower than, for example, the 11.6 reported in a systematic review previously, while the post-operative means are comparable to previously reported post-operative values of 5.0–6.1 (Camacho et al., 2016). The moderate reductions in daytime sleepiness were in line with other AHI reducing interventions and did not reach statistical significance. For example, CPAP treatment has been found to reduce ESS by an average 1.2 points in patients with mild to moderate OSA (Marshall et al., 2006).

The relationship between ESS and AHI remains controversial in the literature, with discrepancies most pronounced in younger patients with moderate AHI levels (Bausmer et al., 2010). This likely reflects the fact that ESS primarily measures subjective daytime sleepiness, which does not always correspond to objective disease severity or predict the degree of treatment response in certain patient populations.

Sleep apnoea patients frequently experience comorbid insomnia, and in Study IV, we observed a significant decrease in ISI scores following surgery, likely reflecting a reduction in nocturnal arousals and sleep fragmentation (Sweetman et al., 2021). Patients with lower baseline sleepiness, such as those in our cohort, may be particularly susceptible to developing comorbid insomnia (Chung, 2005). The coexistence of insomnia and OSA is associated with more pronounced deficits in both subjective and objective measures of sleep quality and quantity, increased daytime dysfunction, and diminished productivity and overall quality of life (Sweetman et al., 2021).

In Study IV, mean GBI scores indicated only modest improvements in quality of life. By comparison, a previous study in snoring patients reported substantially higher GBI outcomes, with a mean total score of 58 and a mean general subscale score of 39.8 (Uppal et al., 2004). Finnish cultural norms emphasize modesty and may affect how participants respond to self-report instruments, potentially limiting the cross-cultural comparability of the findings. Despite the limited changes in GBI-derived quality of life measures, all participants in Study IV indicated that they would undergo ICTE again if faced with the same decision.

6.3 Patient safety and recovery from surgery

6.3.1 Patient insurance claims

In study I, most of the self-reported patient injuries involved specialists of otorhinolaryngology operating in high-volume centres during office hours. Injury claims following surgery were significantly more frequent when the indication was infectious rather than hypertrophic. Most of the claims were related to traditional extracapsular tonsillectomy, but the difference was not statistically significant. Prior studies in children have already shown that patient injuries can be reduced by performing tonsillotomies or intracapsular tonsillectomies instead of extracapsular tonsillectomy (Odhagen et al., 2019, 2023). Current evidence suggests that the same could be true in adults (Wong Chung et al., 2018). Of the three injuries related to tonsillotomies one was a burn injury due to careless technique, and two patients had a rare infection (osteomyelitis).

No injury claims were made related to PTH after tonsillotomy in our data. Especially in children and also based on prior studies, it is crucial to consider a cold-steel dissection technique or partial tonsil surgery instead of extracapsular tonsillectomy with electrocautery as the incidence of life-threatening PTH in children is higher than in adults (Amin & Lakhani, 2019; Söderman et al., 2015; J. P. Windfuhr et al., 2008). Five of seven deaths in this study were due to excessive PTH and two of the deceased were children, both under the age of ten. Grade III PTHs were overrepresented in this study, and it may be beneficial to allocate additional time for patient counselling when controlling a PTH requires general anaesthesia, to reassure patients that no error has occurred and that PTH is a known, although unfortunate, complication.

Significantly more claims were reported after surgery in patients operated on for acute or chronic infections compared with those operated on for tonsillar or adenoid hypertrophy. This difference may be explained by adhesions and scarring following recurrent infections, as well as by surgery performed on acutely inflamed tonsils, both of which are known to increase perceived surgical difficulty.

Burn injuries are known complications of electrocautery use. Some form of electrocautery was used in most compensated claims and the most common reason for a compensation was, also, a burn injury. Presumably most surgeons are right-handed, as most burns were on the right side of the mouth.

A previous study, also from Finland, supported the role of a checklist intervention in preventing errors in otolaryngology (Helmiö et al., 2015). There was a slight statistically significant reduction in patient claims after the national implementation of the WHO Surgical Checklist in this study, but not in compensated injuries. Notably, a slight (but statistically insignificant) increase in the amount of retained surgical packing was noted after the presumed implementation of the checklist.

6.3.2 Recovery after intracapsular tonsillectomy

Partial tonsil surgery preserves the nerves and larger blood vessels located beneath the tonsillar capsule, thereby minimizing intraoperative trauma and associated complications (K. D. Lee et al., 2008). In children, ICTE has been consistently reported to offer advantages over ECTE, particularly regarding reduced postoperative pain and lower rates of PTH (Blackshaw et al., 2020; Sakki et al., 2019; L.-Y. Zhang et al., 2017). In adults, Study IV is consistent with the limited prior data, suggesting that ICTE may be a safer and less morbid option across all age groups (Amin & Lakhani, 2019).

One study defines significant postoperative pain after tonsillectomy as a VAS >3 at rest and VAS >5 at worst (during swallowing) and subsequently reports that most patients experienced significant pain during the first six days after ECTE (Salonen et al., 2002). In Study IV, with ICTE, the average and worst postoperative VAS scores never reached these thresholds for significant pain.

In Finland, after ECTE, the standard sick leave is 14 days. For most adults, our results indicate that 10 days of sick leave following ICTE is generally sufficient. One previous study in adults reported that return to work after ICTE could occur up to 7 days earlier than after extracapsular tonsillectomy (Wong Chung et al., 2022).

In Study IV, mean pain interference with work, overall performance, and swallowing remained modest during recovery. The use of mild opioids stayed well below the maximum recommended dose. A previous study has suggested that adults may even recover from ICTE without requiring any opioid medication (Wong Chung et al., 2022).

6.4 Strengths and limitations

This thesis includes both retrospective and prospective research designs, each of which introduces certain strengths and limitations. The prospective design of Study IV is a clear strength, allowing systematic assessment of postoperative symptoms, standardised follow-up, and clear documentation of recovery. However, the study included a relatively small number of patients, and its findings will need confirmation in larger cohorts. Neither FTP nor Mallampati grade were assessed in Study IV. Longer-term follow-up is also needed to determine whether ICTE offers durable improvement in OSA severity.

The retrospective studies provided access to large datasets and long follow-up periods, but they were limited by variability in documentation, missing data, and reliance on clinical codes.

Relevant to Studies II and IV, home sleep apnoea tests are known to have limitations in event detection accuracy, may underestimate or misclassify respiratory events, and night-to-night variability is large (Lechat et al., 2022). For Study IV, a polysomnography pre- and post-operatively for each patient was, unfortunately, financially unfeasible.

Study I depended on patient injury claims, which do not fully represent all complications, as many patients may never file a claim. PIC has a processing time of up to 3 years from the arrival of an application, and it is likely that some cases from recent years were missing or were still to be claimed. All the claims are reviewed by experts, and, in some borderline cases, personal opinions can affect their success rates.

Study II's long follow-up is a strength, but the lack of postoperative sleep studies for many patients introduces uncertainty about the true long-term effects of ECTE. Study II included eight patients with a partial uvulectomy, which were included because an uvulectomy has no positive long-term effect on OSA (Berger et al., 2001). Especially, the fact that post-operative home sleep apnoea tests were not routinely conducted at our institution at the time of Study II severely limits the amount of available data. It is very much possible that several patients with positive outcomes have remained symptomless and have not, as such, needed new studies.

Study III, meanwhile, lacked standardised grading of tonsil size. At our institution, during the years studied, no numeric grading systems were routinely used. Also, Study III does not have data about tonsillectomies performed in the private sector, which, from Study I, we know to amount to approximately 20% of all tonsillectomies in Finland.

In studies I-III variance in the use of classification codes is possible, especially across different hospitals. In all Studies I-IV, selection bias may be present. In some, due to their retrospective nature and in others due to their non-randomised treatment decisions. In no studies was a drug-induced sleep endoscopy performed, as it was not conducted at our institution at the time of this thesis.

Together, while each study provides valuable information, conclusions should be interpreted in light of these limitations. Future studies using larger prospective cohorts, standardised assessments, and longer follow-up will help build a more complete picture of adult tonsil surgery.

6.5 Future considerations

The findings of this thesis point towards several areas where future work could meaningfully advance the field of adult tonsil surgery. Although Study IV provides new prospective evidence supporting ICTE in adults, additional research is needed to define the long-term role of ICTE and to better understand how different patient factors influence surgical success.

First, long-term follow-up is essential after any treatment for OSA. Short-term results after tonsil surgery are encouraging, but OSA is a chronic condition, and the long-term effects of surgery in adults are still unclear. In particular, it is not well known how durable the benefits of tonsillectomy are beyond the first postoperative year. Future studies should therefore include larger prospective cohorts with standardised follow-up intervals and consistent sleep study methods. This would allow more reliable conclusions about the stability of surgical outcomes over time.

Second, comparative research between intracapsular and extracapsular surgery is needed. Currently, direct comparisons are limited. Well-designed controlled studies could help to clarify differences in effectiveness, postoperative recovery, patient-reported outcomes, and complication rates. Such trials could also explore whether particular anatomical or physiological features make some patients better suited to a certain technique.

Third, better understanding of patient-specific predictors of success would be valuable. Study IV identified age, BMI, and smoking status as factors associated with surgical cure, but further research with larger cohorts could investigate additional variables such as upper airway anatomy, positional OSA, or comorbid insomnia. Identifying reliable predictors would make it possible to improve patient selection, provide more accurate preoperative counselling, and move towards a more individualised treatment approach.

Fourth, future research on surgical safety should examine whether intracapsular techniques in adults truly contribute to significant reductions in national or institutional complication rates. Linking clinical data with patient injury registries could provide insights into whether partial tonsil surgery (ICTE or TT) reduces complications in adults on a population level and whether its adoption reduces haemorrhage-related healthcare use. Similar studies have already been conducted in children with great success (Odhagen et al., 2019).

Finally, the epidemiological findings of Study III highlight the need to improve diagnostic pathways for adult tonsillar disease. Increased awareness of tonsillar hypertrophy in adults within primary care could support earlier recognition and referral for appropriate surgical evaluation. This may be particularly important in older adults, in whom tonsillar enlargement is less common and may therefore be overlooked, despite potentially greater clinical relevance.

Overall, these suggested directions point towards a more structured and patient-centred future for adult tonsil surgery. By combining high-quality prospective research, improved identification of suitable surgical candidates, and continued monitoring of safety and long-term outcomes, clinical practice can gradually become safer, more precise, and better adapted to the needs of adults with OSA and other forms of symptomatic tonsillar disease.

7 Conclusions

The four studies presented in this thesis provide a broad view of adult tonsil surgery, combining epidemiological, safety-related, and therapeutic perspectives. Several conclusions can be drawn that help to clarify the role of tonsil surgery in modern otorhinolaryngology:

1. Tonsil and adenoid surgery is generally safe, and severe complications are rare. Most patient injuries occur during routine operations performed by specialists in high-volume centres and are related to ECTE.
2. Tonsillectomy remains an effective treatment for OSA in adults with tonsillar hypertrophy. The results may descend in the long run, highlighting the need for long-term follow-up.
3. Symptomatic tonsillar hypertrophy is rare in adults and becomes less common with increasing age. It is observed more frequently in men than in women.
4. ICTE is an effective alternative to ECTE in adults with large tonsils and OSA. The postoperative course is shorter and less painful than after ECTE.

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