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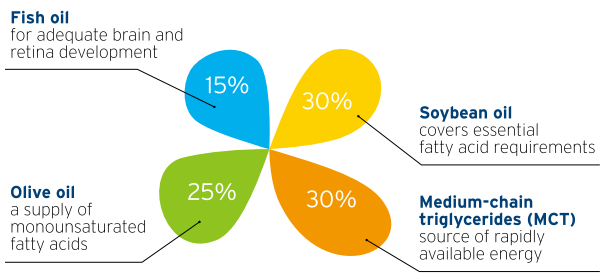

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Contents

Beginning of the End

On behalf of the Journal, I send a warm greeting to our colleagues across Asia in this month of June 2022. The COVID pandemic is entering its final phase and I hope I will be proved right that 2022 indeed spells the end of pandemic COVID. Time will tell.

This issue sees an excellent review coming from colleagues in Indonesia looking at the use of heated humidified high flow in children. This could not come more timely with the huge need for respiratory support to be given outside the ICU setting.

Diseases other than COVID continue unabated, COVID or not. OSAS is one of these. The current issue sees 2 papers addressing this disease. Our colleagues from Hong Kong presented an original study looking at the role of drug induced sleep endoscopy in teasing out the pathophysiology of OSAS and another group from Hong Kong reviewed the current evidence of training the orofacial muscles to mitigate OSAS. I believe that paediatric OSAS is under-diagnosed and under-treated globally with tremendous consequences like stroke, cardiovascular diseases. Colleagues are urged to incorporate asking symptoms of OSAS as a routine in the history taking.

On behalf of APPS, I would like to wish all readers a safe and happy summer.

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There are no conflicts of interest.

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Review Article

High-flow Nasal Cannula in Pediatric Patients

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Abstract

High-flow nasal cannula (HFNC) provides conditioned high-flow oxygen through an open system with high pressure and high velocity. HFNC has been widely used in neonatal patients with comparable benefit to CPAP; however, the use in pediatric patients has not been well evaluated. In pediatric patients, a regular nasal cannula is widely used as oxygen therapy, but the flow provided is limited because the humidity is not optimal. While HFNC as noninvasive oxygen therapy can deliver heated, humidified gas, via nasal cannula. High-velocity HFNC makes oxygen-rich gases occupy the dead space of the nasopharynx, increasing FiO_2, and improving alveolar ventilation. The use of HFNC in children begins with bronchiolitis patients, also considered effective in various respiratory disorders including cases of hypoxemic respiratory failure. HFNC has been shown to have a better patient tolerance, less nose damage, and less work for the staff than CPAP and noninvasive ventilators (NIV). HFNC can be used in the emergency department and even the patient ward, while CPAP and NIV require intensive care unit facility as it needs close monitoring. HFNC is considered safe with mild side effects such as epistaxis and skin irritation that have been reported. While serious side effects such as pneumothorax are rarely reported because open system HFNC can prevent a sudden increase in airway pressure.

Keywords: Continue positive airway pressure, high-flow nasal cannula, pediatric

Introduction

A nasal cannula is widely used for oxygen therapy in pediatric patients. The fraction of inspired oxygen (FiO_2) delivered via nasal cannula increases along with flow increment. However, the non-optimal air humidity limits the flow generated by regular nasal cannula.[1] A High-flow nasal cannula (HFNC) is a noninvasive oxygen therapy that delivers heated, humidified gas via nasal cannula. There is currently no defined flow limit to achieve high flow and high pressure. In neonates, a flow greater than 2 L/min is considered high flow, while in children a flow of 4–6 L/min is needed to generate high flow with a velocity ranging from 4–70 L/min.[1,2] Previous studies support that HFNC is more superior to low-flow nasal cannula, and is comparable or even better than Continuous Positive Airway Pressure (CPAP). There are currently not many studies on HFNC use in pediatric patients.

Types of Oxygen Therapy

Oxygen therapy can be in the form of low-flow, reservoir, and high-flow systems. The low-flow system uses a regular nasal cannula, the reservoir system uses regular masks and reservoir masks to obtain greater FiO_2, while the high-flow system uses conditioned air. Unlike the low-flow system that can only deliver FiO_2 of 24–40%, the high-flow system can deliver oxygen with flow and velocity greater than normal inspiratory flow, thus achieving FiO_2 of 21–100%.[3,4]

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Principle of High-Flow Nasal Cannula

Unlike CPAP (continuous positive airway pressure) or BiPAP (bilevel positive airway pressure), HFNC is an open system in which equipment does not cover more than 50% of the nostril. Also, in HFNC air is conditioned (heated and humidified) to enable the delivery of high flow and high velocity of oxygen exceeding the peak inspiratory flow.[1]

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The use of HFNC can reduce respiratory effort through several mechanisms, including reducing airway resistance during inspiration, reducing nasopharyngeal dead space, providing conditioned air (warm and humidified), and providing various degree of positive inspiration and expiration pressure.[1,5]

The use of HFNC with flow greater than normal allows oxygen-rich gas to bypass the area with high airway resistance (nostril up to nasal cavity), reducing breathing effort as more oxygen-rich gas reaches the lower respiratory tract. The high-velocity, oxygen-rich gas administered through HFNC also occupies the nasopharyngeal dead space, increases FiO_2 in the next cycle, and improves alveolar ventilation. This is especially important in children as the extrathoracic anatomical dead space can reach 3 ml/kg in children, and will only reach an adult rate of 0.8 ml/kg by 6 years old.[1,5]

Cold air damages respiratory mucosa and reduces lung compliance. In vitro study demonstrated even short-term exposure of air with low humidity caused dysfunction of respiratory epithelial. Humidified and warmed gas in HFNC are not only able to reduce insensible water loss and energy consumption, but also can reduce mucus production and improve mucociliary clearance.[2]

High-flow nasal cannula can apply positive pressure to the respiratory system. HFNC creates positive pressure variation on the pharynx (preventing pharyngeal collapse) and auto-positive end-expiratory pressure (auto-PEEP). Auto-PEEP reduces inspirational requirements and facilitates inspiratory flow. Positive end-expiratory pressure has a stenting effect, preventing the collapse of the small airway and extending expiration time [Figure 1].[1,2,5,6]

Milési *et al.* measured pharyngeal pressure under HFNC in 21 patients (aged under 6 months, an average body weight of 4.3 kg) with respiratory distress. He reported amount of flow is associated with pressure generated in the pharyngeal cavity. Flow ≥2 L/kg/min generates pharyngeal pressure ≥4 cmH_2O. Pharyngeal pressure >6 L/min generates positive pressure upon both inspiration and expiration.[5,6]

The flow entrained by HFNC depends on the cannula diameter. The flow starts from 0.5 L/kg/min and can be increased up to 2 L/kg/min. Flow greater than 2 L/kg/min does not confer additional benefit for pediatric patients.

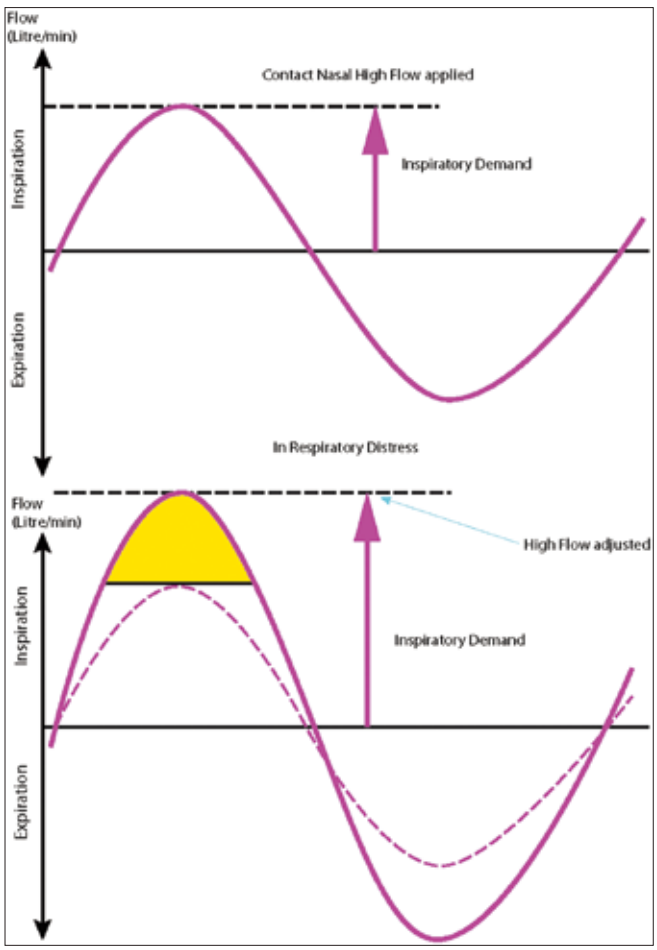

Figure 1: Physiological effects of high-flow nasal cannula (HFNC). During inspiration, HFNC reduces respiratory distress though fulfilling increased inspiratory flow demand through high flow, greater than patient's requirement. During expiration, patient feels positive airway pressure, preventing pulmonary collapse[6]

Basic Components of High-Flow Nasal Cannula System

Principally, HFNC components are made of a pressurized oxygen generator, flow meter, or blender that regulates outflow, sterile gas reservoir attached to heater and humidifier, a circuit to distribute conditioned gas, and cannula connected to the patient [Figure 2].[1]

Clinical Application

Three important variables to regulate in HFNC are temperature, FiO_2, and flow. Temperature is set 1–2°C lower than normal body temperature for comfort.[1,2] FiO_2 setting depends on the patient's clinical condition. In hypoxemia patients, FiO_2 of HFNC is set at 60% that can be adjusted to achieve a target saturation of 92–97%. Patients without hypoxemia also benefit from conditioned air without additional FiO_2. Flow is determined by the patient's size, usually starting from 0.5–1 L/kg/min, and can be increased up to 2 L/kg/min.[1,2,5]

Indications and Contraindications of High-Flow Nasal Cannula

Initially, HFNC is widely used in neonates. The use in pediatric patients started in bronchiolitis patients, due to sub-optimal symptoms reduction by medicamentosa.[1,2] In various respiratory distress and even in respiratory failure cases HFNC is deemed effective. General indications for HFNC use are dyspnea, both primer or secondary to postextubation acute respiratory insufficiency (ARI), and even respiratory failure [Table 1].

Since 2010, HFNC use has been common in the intensive care setting, emergency room, and even pediatric wards for dyspnea caused by a disturbance in oxygenation and ventilation due to pneumonia, congestive heart failure, asthma, croup, wheezing induced by a viral infection, neuromuscular diseases, stridor due to postextubation, and obstructive sleep apnea (OSA).[7,8]

Adapted from Spoletini with modifications[9]

Existing data support the use of HFNC in the oxygenation problem. A study by Oto *et al.* involved pediatric patients under 17 years old with type I respiratory failure (hypoxemia with PO_2 <55 mmHg) showed significant improvement in respiratory rate ($P = 0.032$) and heart rate ($P = 0.03$) within 30 minutes following equipment of HFNC. Improvement was also seen for PO_2 (80.36 + 34.87 mmHg, $P = 0.569$).[10] Another study conducted by Corley *et al.* involving 18 years old subjects with decreased PaO_2/FiO_2 (<300, baseline average of 160) following heart surgery showed that HFNC was able to increase PaO_2/FiO_2, mean airway pressure (MAP), and end-expiratory lung impedance (EELI) significantly.[11] The use of HFNC is contraindicated in cases such as pneumothorax, apnea, and orofacial abnormality.

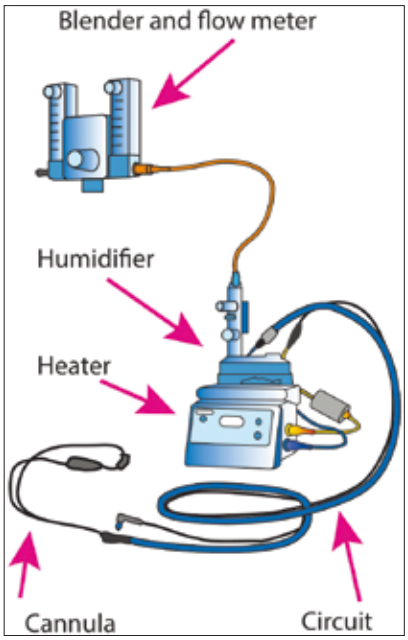

Figure 2: High-flow nasal cannula components made of equipment from intensive care room[1]

Table 1: Indication of HFNC[9]

The use of HNFC	Benefits of HFNC
Procedures	Maintains oxygenation during procedure
Hypoxemic respiratory failure	Mild and acute
Acute respiratory distress syndrome (ARDS)	Increases oxygenation
Pneumonia	Increases oxygenation
Pulmonary edema due to cardiac etiology	Increases thoracoabdominal and alleviates respiratory distress
Postoperative	
Cardiac, cardiothoracic, and vascular surgery	Increases thoracoabdominal synchronization, Increases end-expiratory lung volume (EELV)
Postextubation	Increases oxygenation and ventilation, more comfortable for the patient, decreases the need for re-intubation
Do-not-intubate (DNI)	Improves oxygenation and respiratory mechanics

Benefits of High-Flow Nasal Cannula

The pressure generated from HFNC is affected by flow, the ratio between the nasal cannula and nostril diameter, and leakage from an open mouth. Therefore there is a high variation between individuals with HFNC.[7] As measuring pressure reaching the distal airway is challenging, the clinical response should be observed with HFNC use. Objective parameters include heart rate, respiratory rate,

oxygen saturation level, and respiratory distress symptoms such as nasal flaring, and chest retraction.

In pediatric patients, several studies have demonstrated the benefit of high flow measured as pressure rate product (PRP). PRP is a product of delta pleural pressure (ΔPes) multiplied by respiratory rate. In a study by Rubin *et al.* on children age <18-year-old, the average body weight of 6.4 kg in pediatric intensive care room recorded pleural pressure and respiratory rate using HFNC at flows of 2, 5, 8 L/min. The flow of 8 L/min demonstrated significantly lower PRP, ΔPes, and respiratory rate compared to 2 L/min and 5 L/min.[12] Similarly, a study by Weiler *et al.* in subjects ≤ 3-year-old obtained improved PRP among patients with HFNC flow of 2 L/kg/min compared to 0.5L/kg/min and 1.5 L/kg/min.[13] Therefore, higher flow and higher velocity oxygen therapy generally confers a benefit.

Respiratory disorders pose a high risk of aspiration, hence the patient is usually incapable of oral feeding. Agitation due to oxygen therapy can delay nutritional feeding. A report from a previous study mentioned that oral feeding is well-tolerated in adults receiving a flow of 40 L/min.[1] Another study by Slain *et al.* on patients aged <1-year-old equipped with HFNC also reported that 90% were able to tolerate enteral nutrition within 24 hours, with similar incidences of emesis and respiratory distress between oral and enteral feeding methods.[14]

Comparison Between High-Flow Nasal Cannula With Other Noninvasive Respiratory Support

Noninvasive respiratory supports for instance are high-flow nasal cannula, continuous positive airway pressure (CPAP), and noninvasive ventilator (Bi-level positive airway pressure (BiPAP)). There were several studies done to compare various noninvasive respiratory supports, most of them were done in bronchiolitis patients. Comfort was one of the issues regarding the use of noninvasive respiratory support, while the need for close monitoring during device installation is the other.

CPAP works by generating a certain degree of positive end-expiratory pressure (PEEP), distending airway pressure, and maintaining the patency of the airway. While BiPAP provides two levels of positive pressure, hence it can improve the functional residual capacity and decrease ventilation-perfusion (V-Q) mismatch. Both devices use a closed system, require special staff skills, close monitoring, and can be stressful to the child.[15,16] In contrast, HFNC has been shown to have a better patient tolerance, less nose damage, and less work for the staff than CPAP and noninvasive ventilator.[17,18] Vahlkvist *et al.* conducted an open randomized trial of HFNC and CPAP to explore the effects of treatment on respiratory variables in infants and young children with bronchiolitis. This study found similar effects on respiratory rate, Modified Woods Clinical Asthma Score (M-WCAS), and pCO_2 compared to CPAP. Pain scores were significantly lower in the HFNC group indicating better patient acceptance. This study suggests that HFNC can be a good alternative to CPAP and an effective tool for respiratory support in young children with moderate-severe bronchiolitis.[19] Metge *et al.* also found no differences between HFNC and CPAP in terms of length of stay, respiratory rate, $PaCO_2$, or FiO_2 requirements.[15] Sarkar *et al.* found less nose damage with HFNC.[16]

A randomized control trial was also conducted by Chandra *et al.* in children aged 1–18 years who presented with or developed ARDS during their course of hospitalization.[17] This study compared oxygen therapy by HFNC and CPAP in pediatric ARDS patients (mean PaO_2/FiO_2 237.7). There was a higher incidence of hemodynamic instability, subsequent requirement of invasive ventilation, and longer total duration of respiratory support in the CPAP compared to the HFNC group. Hence this study concluded that HFNC has a higher efficacy in the management of PARDS. Subsequent requirement invasive ventilation and hemodynamic deterioration were significantly low with HFNC compared with CPAP.[17]

The installation of CPAP and NIV requires intensive care unit facility as it needs close monitoring, while HFNC can be used in the emergency department and even the patient ward. A previous study in bronchiolitis, pneumonia, and asthma patients in community pediatric wards showed a good result using HFNC installed in the emergency room and continued in the pediatric ward. The study described treatment failure with HFNC as defined by the presence of worsening breath requiring transfer to the ICU and only 18% of patients needed to be transferred to the intensive care unit with 6% of them needed intubation. Interestingly, this study found that younger age, prematurity, medical comorbidity, or a diagnosis of bronchiolitis, were not found to be risk factors for deterioration, in contrast to the hypothesis at the start of the study.[20] The findings of this study are in line with the study by Betters *et al.* which found that FiO_2 requirement greater than 50% was the largest factor associated with HFNC failure outside of the ICU, despite a prior history of intubation and cardiac co-morbidity.[21]

Limitations of the Use of High-Flow Nasal Cannula

Generally, HFNC is safe to use. Adverse events associated with its use are mild, such as epistaxis and skin irritation due to nasal cannula use and aerophagia. Serious adverse events like pneumothorax are very rare due to an open system of HFNC that prevent a sudden increase in airway pressure. An observational study by Baudin *et al.* on 177 patients in the pediatric intensive care unit showed 1% pneumothorax and 0.6% epistaxis incidence associated with HFNC use.[18] Although HFNC is relatively

contraindicated in pneumothorax, a study on patients with pre-existing pneumothorax before heart surgery, showed no worsening of pneumothorax associated with HFNC use. Compared to CPAP, previous studies in neonates found similar pneumothorax incidence, with a higher rate of mucosal irritation associated with CPAP. However, in terms of noise created, HFNC creates more noise, reaching 80 dB and increasing according to its flow.[5]

The failure rate of HFNC in children varies from 6–20%.[5,18,21] In the emergency room, the HFNC failure rate in patients presenting with dyspnea that require intubation is 8–11%.[8,21,22] In 2013, Betters *et al.* conducted a retrospective study on 231 pediatric patients with a median age of 6.9 months and body weight of 7.3 kg. The majority (83%) presented with primary diagnoses of respiratory problems, that is, bronchiolitis (64%), pneumonia, asthma, and croup. This study reported a rate of HFNC failure of 6% and failure was associated with existing heart abnormalities ($P < 0.001$), history of intubation ($P < 0.001$), and FiO_2 requirement of 60–100% ($P < 0.001$).[21] Kelly *et al.* reported an 8% failure rate of HFNC. In this report, failure was associated with risk factors such as respiratory rate (>p90 (OR 2.11)), pCO_2 level (>50 mmHg (OR 2.5)), and venous pH (7.30 (OR 2.53)) on arrival.[23] Similarly, an observational study by Long *et al.* on children with persistent respiratory distress and hypoxemia obtained HFNC failure of 11% in which patients eventually required intubation.[8]

Summary

This review briefly summarizes the use of high-flow nasal cannula as a noninvasive oxygen therapy in pediatric patients. High-flow nasal cannula delivers high flow and high velocity of oxygen that may confer respiratory benefit in many clinical conditions. Its use is generally safe and thus can potentially be widely used for pediatric patients who need respiratory assistance.

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Review Article

Paediatric Obstructive Sleep Apnoea: Pathophysiology and the Role of Myofunctional Therapy

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Abstract

The pathophysiology of obstructive sleep apnoea (OSA) is well studied in the adult population, but not in the paediatric population, although it can be generally classified into anatomical, functional, and pathological factors, with the most common aetiology being adenotonsillar hypertrophy and a reduced neuromuscular tone of the upper airway (UA) muscles. It is vital to understand the pathophysiology behind paediatric OSA, so that treatment can be optimized. Although the first-line treatment remains to be adenotonsillectomy (AT), this is not always effective, as indicated by the complex pathophysiology of OSA, leading to residual OSA post-AT. Myofunctional therapy (MFT), a newer non-invasive method focusing on re-educating, strengthening, and stimulating UA muscles, improves neuromuscular tone and prevents airway collapse, as supported by multiple randomized controlled trials (RCTs). Outcomes after 2 months to 2 years of therapy have also been positive, with children experiencing improved sleep quality, reduced emotional distress and mood swings, and reduced daytime problems, whereas polysomnogram (PSG) results revealed a clinically significant reduced apnoea–hypopnoea index post-therapy. Major limitations include poor compliance for active MFT and the short duration of the studies with small sample sizes. Given the high prevalence rates of childhood OSA, it is essential that more high-quality studies and RCTs are performed to assess the effectiveness of this treatment method, with a specific emphasis on its long-term impacts, risks, and optimal treatment duration.

Keywords: Apnoea–hypopnoea index, children, myofunctional therapy, obstructive sleep apnoea, paediatric, pathophysiology, treatment

Introduction

Obstructive sleep apnoea (OSA) is an increasingly prevalent form of sleep-disordered breathing (SDB), occurring in 1–5% of school-aged children.[1] A previous community-based local study involving 6447 children in Hong Kong revealed that OSA has a prevalence rate of 5.8% and 3.8% in boys and girls aged between 5 and 13, respectively,[2] which was identified upon sleep questionnaires and then further confirmed by polysomnography (PSG). This figure is towards the higher end of the global prevalence rates, indicating that it is a significant problem among the paediatric population. This may be due a higher prevalence of atopy in the Chinese population, especially allergic rhinitis, leading to the swelling of the soft tissue in the airway, compromising breathing. Another reason for this could be the use of different diagnostic cut-offs for the definition OSA based on PSG results, which differs among different laboratories, thus emphasizing the importance of standardization.[2] OSA is broadly defined as the recurrent episodes of prolonged partial or intermittent complete upper airway (UA) obstruction,[3] causing fragmented sleep with disrupted ventilation. Although OSA is highly prevalent in adults and children, its pathophysiology and treatment modalities differ vastly between the two populations. It is vital that the mechanisms behind childhood OSA are understood and the condition diagnosed and treated early to avoid morbidities and detrimental complications,

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such as delayed growth, neurobehavioural problems, and cardiovascular dysfunction.[3]

Adenotonsillectomy (AT) is often employed to treat paediatric OSA, as a large proportion of children presenting with OSA suffer from adenotonsillar hypertrophy (ATH), which occurs in 42–70% of children,[4] thus obstructing airflow. However, studies have reported that the efficacy of AT ranges from 27% to 83%,[5-7] with lower efficacies observed if children are concurrently suffering from obesity, neuromuscular disorders, and/or craniofacial anomalies, resulting in residual OSA post-AT. Intranasal corticosteroids may be recommended in mild cases, especially if the child suffers from allergic rhinitis, or if AT is contraindicated.[8] Montelukast is another medication that may be used to alleviate symptoms of paediatric OSA, working as a leukotriene receptor antagonist to dilate airways and has proven to significantly reduce apnoea, hypopnoea, and respiratory arousals during sleep in meta-analysis studies and randomized controlled trials (RCTs).[9,10] Continuous positive airway pressure (CPAP) has also proven to be an effective second-line treatment, but its uncomfortable and frequent side effects such as nasal dryness, mask pain, and skin irritations[11] have limited compliance to only 50% in children.[12] Furthermore, long-term usage may cause facial alterations.[13] Therefore, myofunctional therapy (MFT) has recently been introduced to treat paediatric OSA, as it is non-invasive, inexpensive, and easily applicable.

MFT was first used to treat orofacial myofunctional disorders in 1990,[14] such as tongue thrusting and impaired speech, mastication, and deglutition, but recent studies have shown its efficacy in treating residual paediatric OSA, with a meta-analysis study reporting a 62% reduction in the apnoea–hypopnoea index (AHI) afterwards,[15] which is the combined number of apnoea and hypopnoea episodes per hour during sleep. Through the combination of isotonic and isometric exercises, muscle strength, tone, and endurance can be increased.[16] Isotonic exercises refer to the pronunciation of an oral vowel sound intermittently, whereas isometric exercises involve pronouncing the sound continuously, with isotonic exercises also recruiting the pharyngeal muscles of the lateral wall.[17] It also increases the adherence to CPAP[18] by reducing the amount of pressure needed due to the strengthened UA muscles. Studies conducted in children with orthodontic problems have also demonstrated the role of MFT in re-establishing the normal orofacial anatomy.[19]

Given the high prevalence rates of paediatric OSA and its severe consequences on children's quality of life, academic performance, brain development, and their physical and mental wellbeing, optimizing treatment is pivotal. As studies focusing on MFT and paediatric OSA remain limited, this literature review endeavours to present up-to-date information on this area, by first exploring the pathophysiology of childhood OSA, before moving onto the role of MFT in treating OSA and its implications for future patients.

Pathophysiology of Paediatric Obstructive Sleep Apnoea

Structural and anatomic factors

As mentioned previously, the pathophysiology of paediatric and adult OSA is very different. In children, ATH is the most common predisposing factor for OSA.[3,4,20] However, an increase in the size of the soft palate, uvula, and lateral pharyngeal walls also reduces the anterior–posterior and lateral dimensions of the mouth, resulting in increased airway resistance. As younger children aged between 3 and 6 years have more prominent tonsils and adenoids,[21,22] this may explain why OSA is more prevalent in children in this age group,[23] and why children with obesity have higher OSA prevalence rates.

Table 1: Studies assessing the use of MFT in treating paediatric OSA

Study	Study design and sample size	Duration of study	P-values for AHI reductions before and after MFT
Huang *et al.*[19]	Randomized controlled trial (RCT) study involving 121 children with OSA (mean age 7.82 ± 2.84)	6 months for MFT and 1 year for passive MFT	0.015 in the active MFT group 0.003 in the passive MFT group
Guilleminault *et al.*[24]	Retrospective case series study involving 24 children with normal PSGs post-AT (mean age 11.5 ± 1.2)	2 years	0.001
Lee *et al.* 2015[31]	Retrospective case series study involving 18 children diagnosed with 'mouth breathing' via PSG, which is defined as breathing with the mouth in 44–100% of the sleep duration	1 year	Not applicable
Cheng *et al.* 2017[32]	Prospective local case series study involving seven children with OSA (mean age 12.86 ± 4.95), with five who had received AT before	2 months	Not applicable
Villa *et al.*[33]	RCT involving 27 children with residual OSA post-AT (mean age 5.88 ± 1.19)	6 months	0.0001
Villa *et al.*[34]	RCT study involving 54 children with SDB (mean age 6.75 ± 1.70)	2 months	<0.001

Other structural factors increasing the risk of developing childhood OSA include craniofacial skeletal dysmorphologies in the mandible and maxilla.[21] Cephalometric studies have discovered that children with a narrow maxilla, mandibular retrognathia, excessive vertical lower facial development, and caudal placement of the hyoid bone are more prone to suffer from OSA, with this collection of findings termed 'long face syndrome'.[21] These anomalies may lead to oral breathing, or 'mouth breathing', instead of nasal breathing, and the chronic exposure to this non-humidified and non-filtered air may elicit damage and inflammation to the UA muscles, as well as to the adenoids and tonsils, resulting in hypertrophy,[24] whereas vibratory stress, induced by prolonged oral breathing and snoring, may elicit pathological and inflammatory changes to the neuromuscular structures.[21] Additionally, continuous UA obstruction and oral breathing may induce even more craniofacial abnormalities, such as a high-arched palate and narrower maxilla,[21] leading to multiple sites of structural collapsibility.

Functional factors

The UA size is mainly determined by static pharyngeal mechanics, neuromuscular tone, and luminal pressure,[25] with multiple studies reporting children with OSA having higher positive critical closing pressures of the pharynx (Pcrit), with airways collapsing easily in mild inspiratory negative pressures,[21,26] and did not reach the Pcrit level in healthy subjects without OSA even after AT.[21] This indicates that other neuromuscular factors may play an integral role, with the passive Pcrit and mean airway closing pressure (Pclose) being −25 cm H_2O and −7.4 cm H_2O, respectively, in normal children, compared with −5 cm H_2O and −2 cm H_2O in children with OSA,[21,27] indicating problems with neuromuscular compensation. These factors may also result in a low lung and tidal volume, reducing tracheal tug and bronchodilation forces, thus further increasing airway collapsibility.[21]

Indeed, the control and tone of the pharyngeal dilators, such as the genioglossus, hyoglossus, and styloglossus muscles, may be impaired and dysregulated in children with OSA. These muscles are usually activated by hypercapnia, hypoxaemia, and a drop in the luminal pressure, allowing children to maintain normal inspiratory airflow even at subatmospheric pressures.[23] However, this cannot be said for children with OSA, with the study by Marcus *et al.* showing a significant increase in maximal inspiratory flow (V_{Imax}) during hypercapnia in normal children ($P < 0.001$), as opposed to no statistically significant differences in children with OSA.[27] Moreover, when comparing the V_{Imax} of normal children and those with OSA during negative atmospheric pressures, there were significant differences ($P < 0.01$).[27] The study by Katz and White[25] also showed more significant decreases in the genioglossus muscle activity in children with OSA during sleep onset, when compared with normal children, especially during the rapid eye movement (REM) phase. The proposed mechanisms for these findings include muscle hypotonia, low responsiveness, and impaired afferent receptors in the UA, although this is still unconfirmed.[21]

Pathological factors

Intermittent hypoxia and re-oxygenation episodes induced by OSA stimulate tissue necrosis, oxidative stress, and macrophage infiltration,[28] resulting in localized inflammation and consequent systemic inflammation due to circulating cytokines released by proinflammatory immune cells. Indeed, studies have shown that proinflammatory markers, such as tumour necrosis factor alpha (TNF-α), interleukin (IL)-17, IL-23, and C-reactive protein (CRP),[23,29] are significantly increased in children with OSA, a study by Huang *et al.*[29] revealing a significant increase in these cytokines among children with ATH. A positive correlation was also found between high-sensitivity CRP (HS-CRP), the apnoea index (r=0.498), and the percentage of awake time (r=0.528).[29] These elevated proinflammatory cytokines may also affect neurocognitive functions, as demonstrated by a decrease in executive functions and reaction times in children with increased TNF-α, IL-17, and IL-23,[29] suggesting that they have adverse effects on the neural structures, which may explain the unstable ventilatory drive and low arousal threshold in children with OSA, although more studies are warranted to confirm this.

It is vital to understand the pathophysiology of this disorder before examining potential treatments, to optimize the treatment strategy. The complex pathophysiology

Table 2: Studies assessing the use of passive MFT in treating paediatric OSA

Study	Study design and sample size	Duration of study	*P*-values for AHI reductions before and after passive MFT
Chuang *et al.*[30]	Prospective case series study involving 29 children with OSA (mean age 9.75 ± 3.54)	6 months	0.041 in the full-term birth group 0.036 in the preterm birth group during REM sleep
Levrini *et al.*[35]	Prospective case series study involving nine children with OSA between 4 and 8 years old	90 days	0.002
Chuang *et al.*[36]	Prospective case–control study involving 57 children diagnosed with OSA (mean age 7.86 ± 3.09)	1 year	0.0425

also explains why AT alone may not be able to treat OSA, especially if the child concurrently suffers from neuromuscular and other craniofacial anomalies.

The Role of Myofunctional Therapy

MFT involves using specific orofacial and pharyngeal exercises to improve and enhance labial seal and lip tone and to promote nasal breathing, while also promoting favourable positioning and coordination of the tongue.[13] By practicing these exercises consistently every day, the tongue and UA muscles can be strengthened and appropriately stimulated, while also addressing and improving their stomatognathic functions, such as breathing, mastication, phonation, swallowing, and suction.[19] Soft palate elevation exercises involve practicing various humming sequences, blowing and suctioning exercises, and pronouncing various oral vowel sounds,[19] stimulating the palatoglossus, palatopharyngeal, and tensor and levator veli palatini muscles,[14] whereas tongue exercises involve moving and positioning the tongue in different planes, with isotonic exercises being performed intermittently and isometric exercises performed continuously.[19] Facial exercises address and strengthen the orbicularis oris, buccinators, and jaw muscles,[19] so that they can efficiently elevate the mandible to reduce mouth opening.

Efficacy

As the UA neuromotor tone is vital in maintaining airway patency and preventing collapsibility, strengthening and stimulating these muscles may be beneficial in treating OSA. This section will review the efficacy of active MFT and passive MFT in treating paediatric OSA.

Traditional active myofunctional therapy

There were six studies assessing the role of active MFT in treating OSA or reducing the risk factors for OSA, such as oral breathing and low tongue strength and endurance, although the study by Huang *et al.*[19] in 2019 evaluated both active and passive MFT in treating OSA. Passive MFT involves using an oral device during sleep to reshape the mandible and strengthen the tongue muscles through rolling the tongue bead provided in the device.[19] Active MFT requires at least one parent and child practicing the exercises at least once per day, but preferably both in the morning and evening, with exercises such as tongue sweeping, where the tongue is moved around in an anteroposterior direction against the hard palate, along with other exercises such as pronouncing various vowel sounds and alternating bilateral chewing.[30] Passive MFT, on the contrary, involves using an oral device with a bead placed on the tip of the tongue during sleep, stimulating tongue activity during the light stages of sleep, while also placing the tongue in a forward position to open the airway.[30] This would theoretically increase compliance, as there would be no additional need to perform the oropharyngeal exercises during the day and would not require the aid of parents or caregivers. The treatment durations were also different in this study by Huang *et al.*[19] for the MFT and passive MFT groups, as none of the children in the MFT group attended the 1-year follow-up, but those who attended the 6-month follow-up had their PSG results recorded. Unfortunately, not all studies listed evaluated the AHI scores pre- and post-treatment, such as in the study by Lee *et al.*[31] in 2015, which only examined the AHI scores between the MFT and the control groups, whereas Cheng *et al.*[32] in 2017 focused more on assessing changes in tongue strength and reductions in oral breathing post-treatment and did not use PSG to evaluate the outcomes. The results and descriptions of the studies are summarized in Table 1. The mean ages of the participants are included for studies that provided information on age.

Passive myofunctional therapy

There were three studies assessing the role of passive MFT in treating paediatric OSA, as summarized in Table 2. Excluding the study by Huang *et al.*, which is included in the active MFT table. The study by Chuang *et al.*[30] in 2017 also evaluated passive MFT in children with full-term births and premature births, with significant AHI improvements only noted during REM sleep in children with preterm births. Home sleep tests (HSTs) were also utilized to detect for OSA in the study by Levrini *et al.*,[35] if hospital PSG was not available or easily scheduled, which may have affected the precision of assessment. However, if HST was used to assess the pre-treatment values, then it would also be used post-treatment, so that the results would still be valid.

MFT and PSG Results

All studies evaluating MFT and AHI values pre- and post-treatment showed statistically significant results, ranging from *P*-values of 0.0001 to 0.0425,[19,24,30-36] whereas no statistically significant changes were observed in the control groups who did not undergo active MFT or passive MFT. However, the study by Lee *et al.*[31] only compared AHI differences between the MFT and control groups, although this also yielded a significant *P*-value of 0.015, which is supported by the study from Huang *et al.*,[19] yielding a *P*-value of 0.037 when comparing the AHI values between the MFT group post-treatment and the control group. Other important sleep breathing variables that were assessed with PSG include respiratory disturbance index (RDI), hypopnoea index (HI), mean oxygen saturation (SaO_2), flow limitation, sleep latency, and arousal index (AI), such as in the study by Huang *et al.*,[19] noting statistically significant reductions in the RDI and AI and increased sleep latency, with *P*-values of 0.032, 0.048, and 0.036, respectively, among the 10 children who remained compliant and attended the 6-month

follow-up PSG in the MFT group. Moreover, children with normal full-term births, as reported in the study by Chuang *et al.*,[30] had statistically significant decreases in the HI and AI (P = 0.029 and 0.021, respectively) after completing passive MFT for 6 months. The study by Guilleminault *et al.*[24] also assessed the lowest SaO_2 (%) and flow limitation in children post-AT before and after MFT, with P-values of 0.01 and 0.0001, respectively, and all participants maintained normal PSG results, whereas the control group who did not undergo MFT had a recurrence of OSA, with AHI values increasing from 4.3 ± 1.6 to 5.3 ± 1.5, compared with the reduction to 0.5 ± 0.4 in the MFT group, and lowest SaO_2 (%) of 91 ± 1.8, compared with 96 ± 1 in the MFT group.[24] However, the study by Levrini *et al.* did not reveal statistically significant improvements in the mean SaO_2 (%) after 90 days of passive MFT, although this could have been influenced by the short duration of the study.

MFT, Quality of Life (QOL), and Daytime Symptoms

Only one study, which was by Chuang *et al.*[36] in 2019, evaluated the impact of passive MFT on QOL and daytime symptoms before and after treatment, using the OSA-18 survey, revealing statistically significant improvements in symptoms such as mood swings (P = 0.000), aggression/hyperactivity (P = 0.008), difficulty awakening (P = 0.034), and QOL (P = 0.005).[36] The total score for sleep disturbance, physical symptoms, emotional distress, and daytime problems also improved before and after treatment, with P-values of 0.001, 0.003, 0.003, and 0.048, respectively, whereas there were no statistically significant outcomes in the control group.[36] Caregiver frustration was also decreased, with a P-value of 0.024.[36]

More studies should be performed to assess the effectiveness of MFT in improving the QOL and daytime symptoms experienced.

MFT and Morphological and Functional Evaluations

Several studies assessed the role of MFT in improving airway morphology and function. The study by Villa *et al.*[33] in 2015 reported a statistically significant reduction in oral breathing (P = 0.002) and an increased labial seal ($P < 0.001$) and lip tone ($P < 0.05$) after treatment, which would coalesce to promote nasal breathing, the preferred respiratory route. This is supported by another study performed by Villa *et al.*[34] in 2017 assessing children with SDB, revealing significant decreases in oral breathing (P = 0.0002), increased lip tone (P = 0.003), reduced abnormal tongue resting position (P = 0.03), and increased tongue endurance ($P < 0.01$), strength ($P < 0.000$), and peak pressure ($P < 0.000$) in the MFT group after 2 months of treatment.

Similarly, the study by Cheng *et al.*[32] in 2017 showed statistically significant increases in the mean tongue strength (P = 0.018), from 6% to 76% after MFT, as well as improvements in stomatognathic functions such as breathing, deglutition, and mastication (P = 0.026), as assessed through Nordic Orofacial Tests.[30]

MFT and Cephalometric Analysis

Several studies also examined the impact of MFT on cephalometric measurements, as shown in the study by Huang *et al.*[19] in 2019, identifying significant improvements in the passive MFT group, such as in the width of the airway at the level of the nasopharynx (P = 0.001) before and after treatment, with no significant changes observed in cephalometric analyses of the active MFT group. Similarly, the passive MFT studies by Chuang *et al.*[36] in 2019 reported statistically significant improvements in measurements such as the increased distance between the posterior nasal spine and adenoid tissues (P = 0.03) and increased width of the oropharynx (P = 0.007) in the passive MFT group after treatment. No side effects were reported, although long-term complications remain unknown, due to the limited follow-up studies performed. From the literature reviewed, the minimum length of duration to perform MFT is 2 months to see significant results, although most studies have demonstrated a duration of 6 months having more long-lasting results, and performing the exercises for around 30 min every day, with the youngest age group reported in the literature being 4–8 years old.

Limitations

Unfortunately, the major limitation of MFT is the lack of compliance to therapy, due to the requirement to perform these exercises daily, along with regular meetings with myofunctional therapists.[30] Therefore, parental involvement is crucial to ensure proper completion of this training, which is a major problem in the current society, with both parents often working full-time jobs with long working hours. Furthermore, the use of MFT as a stand-alone therapy, along with its long-term effects, optimal overall treatment duration and exercise duration for each session, and whether its effects remain after cessation of therapy or whether it requires consistent practice in the long run, warrants further investigation, as this remains unknown. Younger children may also find it difficult to practice these exercises and may even perform it incorrectly, which is why parental and therapist guidance and involvement are essential.

However, the major limitation of these studies is the small sample size, large age ranges among the children assessed, absence of long-term follow-up, and the short duration of the studies, with passive MFT studies ranging from 90 days to 1 year and regular MFT studies ranging from 2 months to 2 years. There are also possible biases

elicited in these studies, such as performance bias, due to the lack of blinding in the participants. However, attrition bias may be the most significant, due to the vast number of loss of follow-ups, resulting in incomplete outcome data. Heterogeneity on the duration and type of exercises performed was also presented across the studies, with some studies requiring a minimum of 20 min daily[19] and others requiring up to 45 min.[32]

Future implications

Adopting passive MFT may be helpful in increasing compliance, as it requires little involvement from parents, and children often rapidly adapt to it.[19,30] However, potentially unfavourable impacts of passive MFT on the mandibular development remain unknown, although clinical and imaging evaluations did not detect any alterations when the device was used for 6 months.[19]

Poor compliance can also be resolved by providing adequate education and support to patients and caregivers, such as through visual coaching, smartphone health apps, and support programmes. For instance, patients participating in a 12-week MFT support programme consisting of in-person education seminars and interactions, and frequent phone calls and messages offering support, coaching, and guidance from therapists, saw significant increases in self-efficacy and decreases in AHI and daytime sleepiness (P = 0.02, 0.039, and 0.028, respectively) when compared with the control group who did not receive support and accountability and had an 82.06 ± 23.70% MFT adherence rate, compared with 72.52 ± 30.09% in the control group.[37] This is supported by an RCT conducted by O'Connor-Reina *et al.*,[38] in which the MFT adherence rate was 90% in patients interacting with a smartphone app for 90 sessions, compared with 50% in the control group, with the app enabling constant communication with health professionals and feedback on patient performance. As MFT is non-invasive, inexpensive, and does not carry major risks, what most patients require is simply education, motivation, and support.

Conclusion

The pathophysiology of OSA in children remains complex, with multiple anatomical, functional, and pathological factors interacting with each other. It is pivotal that treatment options are optimized, due to its high prevalence rates in Hong Kong. Due to the multifactorial nature of this disorder, AT alone may not be able to resolve the issue, requiring other forms of treatment or conjunct therapy. Due to MFT and passive MFT's proven beneficial effects on the UA muscular framework, as reported in the literature reviewed, it should be used as a treatment modality for OSA in children. However, more high-quality studies are required to clarify the adequate protocols, long-term effects, and risks of active MFT and passive MFT, and whether or not it can be used as a stand-alone therapy, as this is a relatively new treatment option, which warrants further research and understanding among physicians and patients.

Directions for future research

- An increase in randomized multi-institutional studies, with double blinding and allocation concealment, investigating the effectiveness of MFT in treating paediatric OSA as a stand-alone therapy should be performed. It is also necessary to evaluate the optimal overall treatment duration and exercise session duration for MFT and risks it could elicit in the long run or if the exercises are not performed correctly.
- MFT educational and support groups/programmes should be further evaluated upon, as well as other interventional studies to improve adherence to MFT, focusing on patient-centred outcomes.

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Conflicts of interest

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Original Article

Review Findings of Drug-induced Sleep Endoscopy (DISE) in Children with Obstructive Sleep Apnea (OSA)

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Abstract

Background: Drug-induced sleep endoscopy (DISE) is an objective assessment and diagnostic procedure of the upper airway obstruction (UAO) under sedation. Findings of DISE in Hong Kong pediatric group patients with obstructive sleep apnea (OSA) are limited. **Materials and Methods:** This is a single-center retrospective chart review study on DISE findings in pediatric patients with OSA documented by polysomnography (PSG). We used the DISE scoring system proposed by Chan 2014, Fishman 2013 together as our internal practice. A standard sedation protocol was conducted. Endoscopic findings were recorded and evaluated the level of obstruction, severity, and correlation with PSG parameters. **Results:** A total of 124 patients who underwent DISE were reviewed in our study. Multiple levels of obstruction had been observed in all patients. Forty-five (36.6%) patients suffered from severe obstruction in more than one level. Tongue base was the most common level being severely obstructed. DISE total score is positively correlated with obstructive apnea-hypopnea index (oAHI, $r = 0.35$, $P = <0.001$), negatively correlated with oxygen nadir (SpO2 nadir, $r = –0.32$, $P = <0.001$), and positively correlated with desaturation index (DI, $r = 0.34$, $P < 0.001$). In the subgroup analysis of the post-adenotonsillectomy (AT) group, scores in nostrils, tongue base, and supraglottic showed significantly increased. None of the subjects had complications from sedation or the endoscopy procedure. **Conclusion:** In our study, DISE was shown to be a safe, feasible, and informative assessment tool for pediatric OSA patients. In particular, multiple levels of obstruction were common in children and we observed a significant correlation between the severity of UAO measured by DISE in children with OSA and PSG parameters. Changes in UAO sites were observed when preoperative patients underwent surgical treatment.

Keywords: DISE, drug-induced sleep endoscopy, obstructive sleep apnea, pediatric

Introduction

Obstructive sleep apnea (OSA) affects up to 6% of children worldwide.[1,2] This is a sleep-related breathing disorder caused by upper airway obstruction (UAO) characterized by snoring and/or increased respiratory effort. Evidence has demonstrated that left untreated cases are associated with long-term comorbidities including neurocognitive, behavioral disturbances, and cardiovascular dysfunction.[3] The American Academy of Pediatrics (AAP) suggested adenotonsillectomy (AT) as the first-line treatment for OSA children with adenotonsillar hypertrophy.[4] However, persistent OSA after AT was common. Data on OSA improvement following AT remain inconclusive, with a variable success rate between 12% and 83% observed depending on the characteristics of the study population.[5]

Drug-induced sleep endoscopy (DISE) provides a direct evaluation of the dynamics of upper airway using flexible endoscopy while patients are put under sedation.[6] It can be used as a first-line assessment tool to guide subsequent management to optimize outcomes and minimize unnecessary operations like AT, and for children with persistent OSA after AT. It is also a recommended investigation for those children with significant symptoms of sleep-disordered breathing

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(SDB) with relatively small tonsils and adenoids, and for occult or sleep state-dependent laryngomalacia. DISE has the potential to guide the surgical decision and improve the outcome. In recent studies based on UAO findings during DISE, a non-surgical treatment was proposed for 11% of children. A 91% success rate was obtained in those treated with AT.[7]

'Sleep naso-endoscopy' was first described by Croft and Pringle *et al*. for use with adults and children in early 1990.[8,9] Further study by Myatt and Beckenham in children with complex UAO disorders in 2000.[10] The name was changed to 'drug-induced sleep endoscopy' (DISE) by Kezirian and Hohenhorst in 2005 to better reflect the key elements of the procedure.[11] However, there is no universally accepted consensus on the DISE scoring system. Six different scoring systems (VOTE, SERS, Chan, Bachar, Fishman, Boudewyns) have been used to report pediatric DISE findings. VOTE is the most frequent and well published one both for adults and children but lacks scoring in the nasopharyngeal and supraglottic region.[6]

The choice of anesthetic agents for DISE remains controversial. The challenge is to find an agent that can provide analgesia to simulate a natural sleep state without causing respiratory depression, cardiovascular effects, or airway collapse beyond those seen during natural sleep.[12] The combination of anesthetic agents using dexmedetomidine (DEX) and ketamine is commonly used, because it carries lower risk of respiratory depression and UAO in children as compared with other agents like inhalational agents.

Data on DISE findings in Hong Kong children with OSA are limited. A better understanding of multiple-level airway obstructions in OSA children is crucial to directing a precise and effective treatment plan.

Materials and Methods

We conducted a retrospective chart review study in the Department of Pediatrics, Kwong Wah Hospital. Patients aged from 2 years old to less than 18 years old, confirmed with OSA by polysomnography (PSG) undergoing DISE between December 1, 2016 and December 31, 2019 were included. Significant medical illnesses, such as cardiac, respiratory, or renal insufficiency, or dysmorphic syndrome, would be excluded. The primary outcome includes the DISE score in different levels of UAO (nasal obstruction, adenoids, velum, lateral pharyngeal wall (LPW), tongue base, and supraglottis); whereas the secondary outcome includes a correlation between DISE findings with PSG parameters, and the safety of our DISE protocol.

The obstructive apnea–hypopnea index (oAHI) was defined as the number of obstructive apneas and hypopneas per hour of sleep. OSAS was defined as an oAHI ≥ 1/h. OSAS was classified as mild (oAHI between 1 and 5/h), moderate (oAHI 5–10/h), or severe (oAHI ≥ 10/h).

Pediatric sleep questionnaire (PSQ) is one of the most popular parent-report scales for screening sleep problems in children with good validity and reliability.[13] Selected 22 question-items scale (PSQ: SRBD, Pediatric Sleep Questionnaire: Sleep-Related Breathing Disorder Scale) contains 22 symptom items that ask about snoring frequency, loud snoring, observed apneas, difficulty breathing during sleep, daytime sleepiness, inattentive or hyperactive behavior, and other pediatric OSA features. Score 8 or more positive answers to the 22 question-items were considered abnormal with a sensitivity of 0.85 and a specificity of 0.87. We obtained PSQ results in most of our study populations (n = 114).

We developed a standardized DISE sedation protocol with a combination of midazolam (dose range from 0.05 mg/kg/dose to 0.1 mg/kg/dose) and fentanyl (0.5 µg/kg/dose to 2 µg/kg/dose). Lignocaine (2%) was used to topically anesthetize the nasal mucosa. The level of sedation was assessed by UMSS (The University of Michigan Sedation Scale [Figure 1]),[14] which provided the level of alertness on a 5-point scale ranging from 1 to 5. It is a simple, valid, and reliable tool for rapid and frequent assessment on the depth of sedation in children

Digital records of all endoscopies were maintained sequentially and were available for review. In our unit, we combined the Chan and Fishman[15,16] scores to better assess UAO. It included nasal, adenoids, velum, LPW, tongue base, and supraglottis, a total of 6 levels (see

UMSS Score	Description
0	Awake and alert
1	Minimally sedated: tired/sleepy, appropriate response to verbal conversation and/or sound
2	Moderately sedated: somnolent/sleeping, easily aroused with light tactile stimulation or a simple verbal command
3	Deeply sedated: deep sleep, arousable only with significant physical stimulation
4	Unarousable

Figure 1: Level of sedation during endoscopy (University of Michigan sedation scale, UMSS)

Level	Structure	Score
1	Nasal obstruction:	0 = No obstruction 1 = Mild obstruction 2 = Moderate obstruction 3 = Severe obstruction
2	Adenoids: posterior view from nasal cavity	0 = Absent adenoids 1 = 0-50% obstruction of choana 2 = 50-99% obstruction of choana 3 = Complete obstruction of choana
3	Velum: inferior view from nasopharynx, assessing anterior-posterior (AP) obstruction	0 = No obstruction (complete view of tongue base and/or larynx) 1 = 0-50% AP closure (some view of tongue base/ larynx) 2 = 50-99% AP closure (no view of tongue base/ larynx, but not against posterior pharyngeal wall) 3 = Complete closure against posterior pharyngeal wall
4	Lateral pharyngeal walls (LPW): inferior view from velum, assessing LPW/ tonsillar obstruction	0 = No obstruction 1 = 0-50% lateral obstruction 2 = 50-99% lateral obstruction 3 = Complete obstruction
5	Tongue Base: inferior view form oropharynx, assessing AP obstruction	0 = No obstruction (complete view of vallecula) 1 = 0-50% obstruction (vallecula not visible) 2 = 50-99% obstruction (epiglottis not contacting posterior pharyngeal wall) 3 = Complete obstruction (epiglottis against posterior wall)
6	Supraglottis: inferior view with tongue base (if obstructing) out of the way, wwithout jaw thrust	0 = No obstruction 1 = 0-50% obstruction (vocal cords partially obstructed but >50% visible) 2 = 50-99% obstruction (>50% of vocal cord obstructed) 3 = Complete obstruction (glott ic opening not seen)

Figure 2: Drug-induced sleep endoscopy (DISE) scoring system

Figure 2 for detailed information on the scoring system). Multiple level obstruction was defined as the presence of obstruction on more than one level.

The study was approved by the Research Ethics Committee of the Kowloon Central/Kowloon East Clusters of the Hospital Authority in Hong Kong.

Statistical analysis

The normality of data was assessed by the Shapiro–Wilk test. Continuous variables were presented as the mean ± standard deviation (SD). Non-normal variables were reported as median (interquartile range [IQR]). Categorical variables are summarized as frequencies and percentages. Pearson's correlation coefficient analysis was used for assessing the association between DISE findings and PSG parameters. Parametric and non-parametric data were compared using Student's *t* test or Mann–Whitney *U* test, respectively. The chi-square or Fisher's exact tests were used to compare proportions. Paired *t* test or Wilcoxon signed ranks test was used for comparing continuous variables such as DISE findings, PSG parameters, mESS score, OSA-18 score, and PSQ: SRBD score before and after operation. McNecmar test was used for paired nominal data. A p-value <0.05 was considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 22.0 (IBM, Armonk, New York).

Result

A total of 161 DISE were conducted during the study period. Thirty-seven were excluded (30 were syndromal cases and 7 were missing prior PSG reports). Finally, 124 sleep endoscopies met the inclusion criteria and were eligible for analysis. Ninety-seven of them were surgical

naïve patients, whereas 27 were post-adenotonsillectomy (post-AT) cases [Figure 3]. Demographic data are shown in Table 1.

The median age at the time of endoscopy was 12.7 years old (IQR 9.4–15.3), with a slight male preponderance (95, 76.6%). Obesity, defined as body mass index (BMI) with z score >1.645 (i.e., 95th percentile), was noted in 35 patients (28.2%). The median of sleep efficiency (SE) was 90.3% (IQR 84.7–94.1%), whereas the median of total sleep time (TST) was 432.8 min (IQR 385.6–476.8 min). Over half of the patients (65, 52.4%) in the study population had mild OSAS. 17.7% and 29.8% of them had moderate and severe OSAS, respectively. The median oxygen saturation nadir was 90% (SpO2 nadir, IQR 86–92%). The median desaturation index (DI) was 1.8/h (IQR 0.3–6.8/h). One-third of them have obstructive hypoventilation defined as 25% of total sleeping time with PaCO2 >= 50 mm Hg. PSQ:SRBD score was obtained in 114 patients with a median score of 7.5 (IQR 5.0–11.0). The number of patients with obesity was more in the surgical naive group compared to the post-AT group (n = 32 vs n = 3, P = 0.025). Lower PSQ: SRBD score was found in post-AT groups (n = 88, 8.5 vs n = 26, 6.5, P = 0.043).

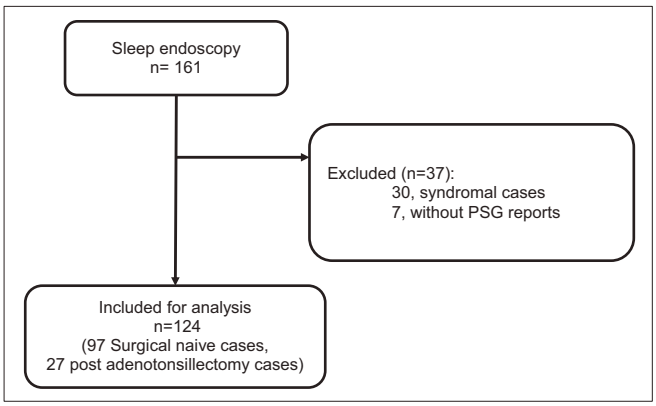

Figure 3: Flow chart of study population

Based on the grade of obstruction sites observed during DISE, their prevalence could be determined. All study populations (N = 124) had multiple levels of obstruction, defined as mild obstruction or obstruction score >=1 in more than one level. Forty-five patients (36.3%) had severe obstructions or obstruction score=3 in more than one level. For severe obstruction or obstruction score =3, tongue base was the most common level of obstruction

Table 1: Demographic, anthropometric, and PSG parameters

Variables	Overall (n = 124) Median (IQR)	Surgical naïve (n = 97) Median (IQR)	Post-TA (n = 27) Median (IQR)	*P* Value
Endoscopy age, year	12.7 (9.4–15.3)	11.9 (8.6–15.0)	13.6 (11.1–16.3)	0.035
Male, *n*(%)	95 (76.6%)	73 (75.3%)	22 (81.5%)	0.499
Body weight, kg	45.1 (26.2–57.2)	45.4 (25.1–60.1)	43.9 (29.8–54.3)	0.920
Height, cm	147.5 (126.3–162.2)	146.0 (125.2–162.2)	149.8 (135.6–162.9)	0.222
BMI	19.2 (16.0–24.2)	19.9 (16.0–26.0)	18.8 (16.2–20.5)	0.173
BMI z–score	0.85 (–0.13–1.80)	0.96 (–0.07–2.16)	0.43 (–0.26–1.24)	0.064
Overweight, *n*(%) BMI *z* score >1.036 (i.e., 85th percentile)	55 (44.4%)	47 (48.5%)	8 (29.6%)	0.082
Obese, *n*(%) BMI *z* score >1.645 (i.e., 95th percentile)	35 (28.2%)	32 (33.0%)	3 (11.1%)	0.025
PSG age, year	12.7 (9.4–15.3)	10.8 (7.7–14.0)	11.7 (9.4–13.8)	0.188
Sleep efficiency, %	90.3 (84.7–94.1)	89.7 (84.5–94.1)	91.5 (86.5–94.8)	0.375
Total sleep time, min	432.8 (385.6–476.8)	433.5 (385.5–477.8)	426.0 (387.0–474.5)	0.911
Arousal/h	20.8 (15.8–29.0)	21.5 (15.6–28.8)	19.6 (15.9–30.2)	0.976
oAHI/h	4.6 (2.1–11.1)	4.0 (1.9–11.8)	5.3 (2.3–11.0)	0.797
oAHI 1 to 5, *n*(%)	65 (52.4%)	53 (54.6%)	12 (44.4%)	0.423
oAHI>5 to 10, *n*(%)	22 (17.7%)	15 (15.5%)	7 (25.9%)	
oAHI>10, *n*(%)	37 (29.8%)	29 (29.9%)	8 (29.6%)	
Oxygen saturation nadir, %	90.0 (86.0–92.0)	90.0 (86.0–92.0)	90.0 (86.0–92.0)	0.547
Desaturation index/h	1.8 (0.3–6.8)	1.8 (0.2–7.1)	1.6 (0.7–6.0)	0.889
PaCO2>50mm Hg	0.0 (0.0–44.2)	0.3 (0.0–47.2)	0.0 (0.0–67.1)	0.495
Obstructive hypoventilation (PaCO2 >= 50 mm Hg >25% TST)	37 (29.8%)	29 (29.9%)	8 (29.6%)	0.979
Habitual snoring, *n*(%)	72/114 (63.2%) (n = 114)	55/88 (62.5%) (n = 88)	17/26 (65.4%) (n = 26)	0.789
PSQ:SRBD score	7.5 (5.0–11.0) (n = 114)	8.5 (6.0–12.0) (n = 88)	6.5 (3.0–9.3) (n = 26)	0.043

TA = adenotonsillectomy, BMI = body mass index, PSG = polysomnography, oAHI = obstructive apnea–hypopnea index, PaCO2 = partial pressure of carbon dioxide, PSQ:SRBD = Pediatric Sleep Questionnaire:Sleep-Related Breathing Disorder Scale, TST = total sleeping time

P-values were calculated with Mann–Whitney *U* test or chi-square test

(n = 54, 43.5%), followed by lateral pharyngeal wall (LPW) (n = 30, 24.2%), velum (n = 18, 14.5%), nasal, adenoid and supraglottic were comparable (n = 17, 13.7%).

The median of the total obstruction score, defined as the sum of the obstruction score in all six levels, was 10 (IQR 8–11) (DISE results are shown in Table 2). There was no difference in total score between surgical naive and post-AT group.

There were significantly higher scores in the tongue base obstruction in the post-AT group (3 vs. 2, P = 0.005) than in the surgically naive group. The post-AT group had significantly lower LPW obstruction (0 vs. 2, P < 0.001). The obstruction scores at the nostril, adenoid, and supraglottis level did not differ significantly between the two groups.

Based on the correlation analysis, oAHI was significantly correlated to the total obstruction score (r = 0.352, P < 0.001). In a similar way, DI was significantly associated with total obstruction score (r = 0.342, P < 0.001). SpO2 nadir was negatively correlated with the total obstruction score (r = –0.315, P = < 0.001) [Figure 4]. Using our DISE scoring system, we have demonstrated that oAHI, DI and SpO2 nadir on pre-procedural PSG correlate with severity of UAO in pediatric patients with OSA.

The level of sedation was assessed by UMSS (University of Michigan Sedation Scale), and the median is 1 (1 = Minimally sedated: tired/sleepy, appropriate response to verbal conversation and/or sound).

Table 2: DISE findings

Variables	Overall (n = 124) Median (IQR)	Surgical naïve (n = 97) Median (IQR)	Post-TA (n = 27) Median (IQR)	P-value
UMSS score	1 (1–2)	1 (1–2)	1 (1–2)	0.126
Levels 1: Nasal obstruction	2 (1–2)	2 (1–2)	2 (1–2)	0.770
0 = No obstruction, *n*(%)	6 (4.8%)	5 (5.2%)	1 (3.7%)	0.686
1 = Mild obstruction, *n*(%)	37 (29.8%)	29 (29.9%)	8 (29.6%)	
2 = Moderate obstruction, *n*(%)	64 (51.6%)	48 (49.5%)	16 (59.3%)	
3 = Severe obstruction, *n*(%)	17 (13.7%)	15 (15.5%)	2 (7.4%)	
Levels 2: Adenoids	1 (1–2)	1 (1–2)	1 (1–2)	0.686
0 = Absent adenoids, *n*(%)	7 (5.6%)	4 (4.1%)	3 (11.1%)	0.564
1 = 0–50% obstruction of choana, *n*(%)	60 (48.4%)	48 (49.5%)	12 (44.4%)	
2 = 50–99% obstruction of choana, *n*(%)	40 (32.3%)	32 (33.0%)	8 (29.6%)	
3 = Complete obstruction of choana, *n*(%)	17 (13.7%)	13 (13.4%)	4 (14.8%)	
Levels 3: Velum	2 (1–2)	2 (1–2)	2 (1–2)	0.898
0 = No obstruction, *n*(%)	2 (1.6%)	2 (2.1%)	0 (0.0%)	0.903
1 = 0–50% AP closure, *n*(%)	49 (39.5%)	38 (39.2%)	11 (40.7%)	
2 = 50–99% AP closure, *n*(%)	55 (44.4%)	43 (44.3%)	12 (44.4%)	
3 = Complete closure against posterior pharyngeal wall, *n*(%)	18 (14.5%)	14 (14.4%)	4 (14.8%)	
Levels 4: Lateral pharyngeal wall	2 (1–2)	2 (1–3)	0 (0–1)	<0.001
0 = No obstruction, *n*(%)	25 (20.2)	7 (7.2%)	18 (66.7%)	<0.001
1 = 0–50% lateral obstruction, *n*(%)	33 (26.6%)	27 (27.8%)	6 (22.2%)	
2 = 50–99% lateral obstruction, *n*(%)	36 (29.0%)	34 (35.1%)	2 (7.4%)	
3 = Complete obstruction, *n*(%)	30 (24.2%)	29 (29.9%)	1 (3.7%)	
Levels 5: Tongue base	2 (2–3)	2 (1–3)	3 (2–3)	0.005
0 = No obstruction, *n*(%)	6 (4.8%)	6 (6.2%)	0 (0.0%)	0.033
1 = 0–50% obstruction, *n*(%)	23 (18.5%)	22 (22.7%)	1 (3.7%)	
2 = 50–99% obstruction, *n*(%)	41 (33.1%)	32 (33.0%)	9 (33.3%)	
3 = Complete obstruction, *n*(%)	54 (43.5%)	37 (38.1%)	17 (63.0%)	
Levels 6: Supraglottis	1 (0–2)	1 (0–2)	1 (0–2)	0.707
0 = No obstruction, *n*(%)	39 (31.5%)	31 (32.0%)	8 (29.6%)	0.975
1 = 0–50% obstruction, *n*(%)	48 (38.7%)	38 (39.2%)	10 (37.0%)	
2 = 50–99% obstruction, *n*(%)	20 (16.1%)	15 (15.5%)	5 (18.5%)	
3 = Complete obstruction, *n*(%)	17 (13.7%)	13 (13.4%)	4 (14.8%)	
Multiple level obstruction, *n*(%) (any 2 level, score>=1)	124 (100%)	97 (100%)	27 (100%)	1.000
Obstruction score =3 (>1 level), *n*(%)	45 (36.3%)	36 (37.1%)	9 (33.3%)	0.718
Total score obstruction score	10 (8–11)	10 (8–12)	9 (7–11)	0.090

DISE = drug-induced sleep endoscopy, TA = adenotonsillectomy, UMSS = University of Michigan Sedation Scale, A*P* = anteroposterior
P-values were calculated with Mann–Whitney *U* test or chi-square test

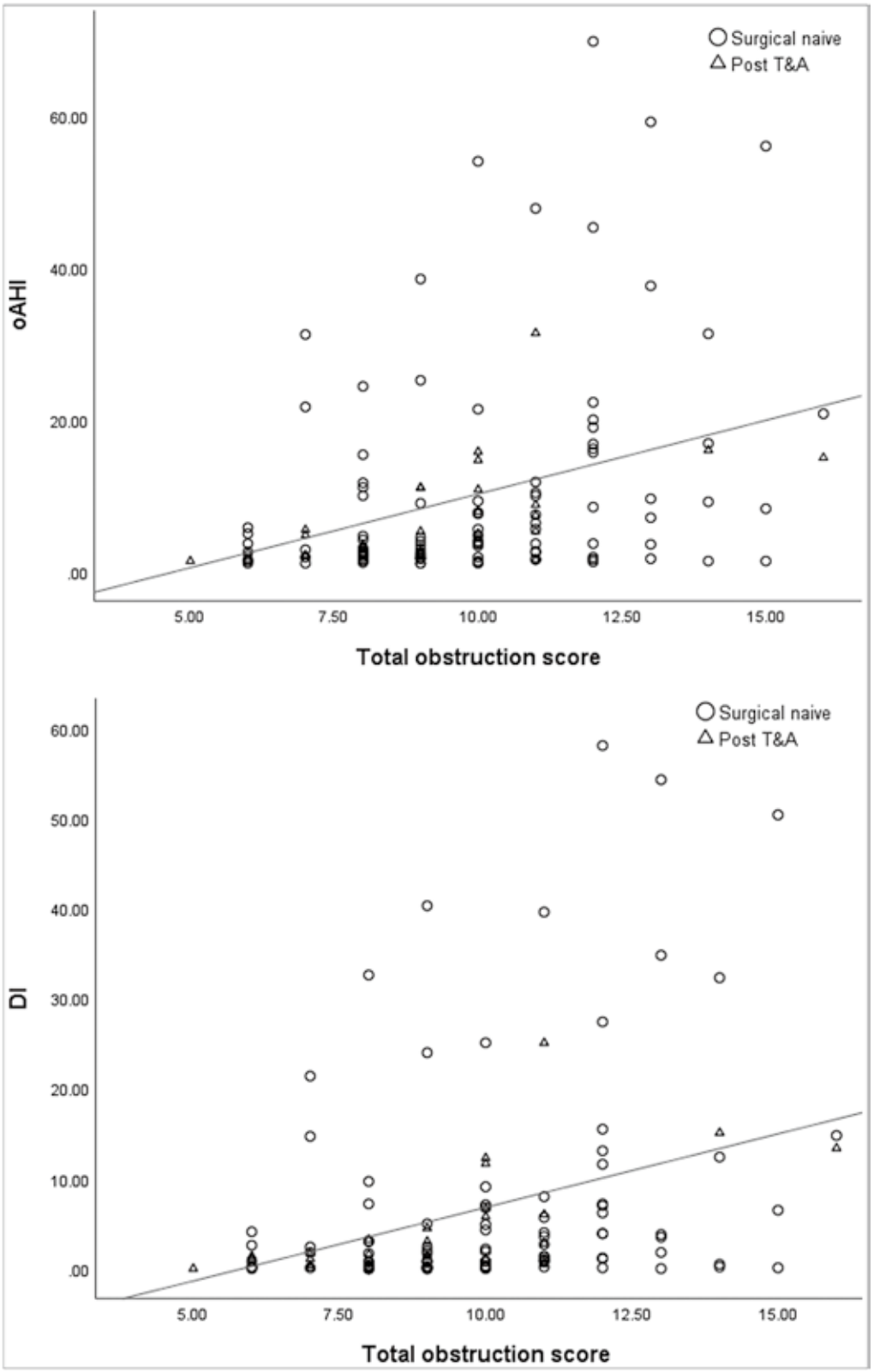

Figure 4: Correlation between total obstruction score and oAHI, DI, and SpO2 nadir

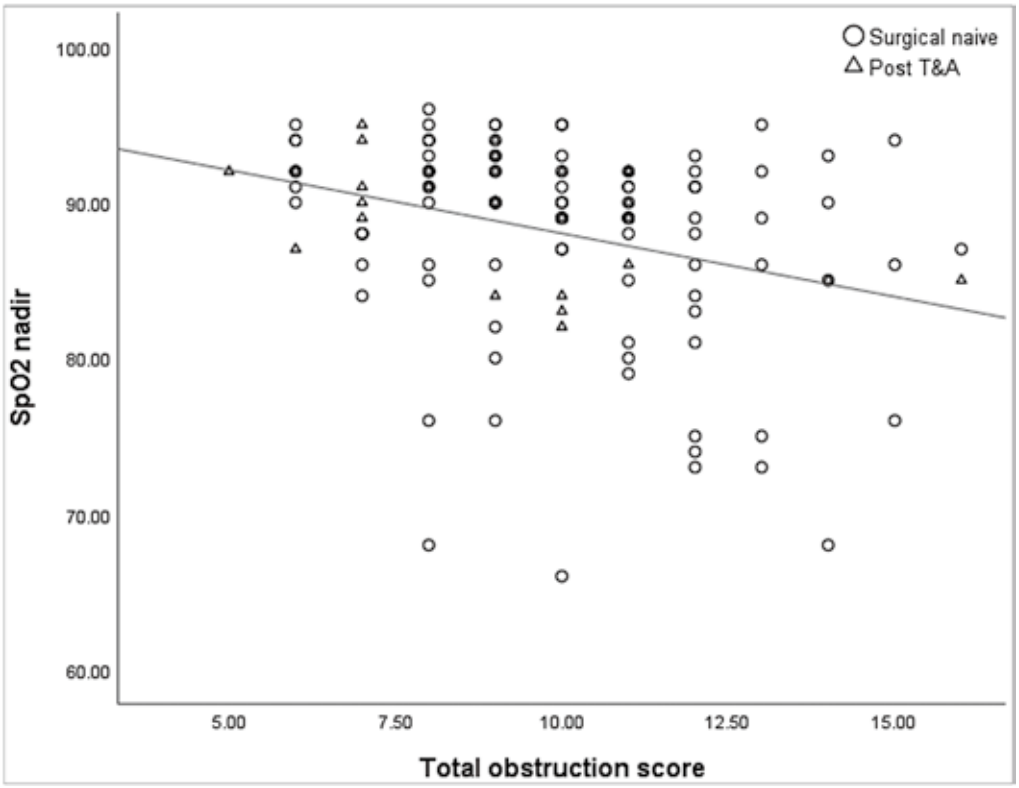

Figure 4: Continued

There were no complications nor adverse events during sedation and procedure of DISE.

For the post-AT group (n = 27), we performed a subgroup analysis to determine if ther e was a difference in their demographic and UAO status between pre and post-surgery. For comparison, 23 out of 27 patients had both pre- and post-AT PSGs. Seven of the pre-AT endoscopy records fell within our study period. We retrospectively scored 16 pre-AT endoscopy records using our updated DISE scoring system.

Regarding their demographic data, oAHI, DI and SpO2 nadir showed no difference before and after surgery. PSQ:SRBD showed lower after surgery [Table 3].

Compared to the pre-AT group, the total obstruction score was significantly lower (10 vs. 9, P = 0.034) in the post-AT group. LPW and adenoid scores were also significantly lower in the post-AT group. There was, however, a significant increase in obstruction scores in the post-AT group in the nasal, tongue base, and supraglottis scores. Velum scores showed no significant change [Table 4].

Discussion

This is the first study in Hong Kong children aged from 2 to 18 years old with OSA, without syndromic condition nor comorbidity, to report on DISE findings and to establish the correlation between severity of anatomic obstruction measured by DISE and PSG parameters. According to our data, DISE is a feasible and safe way to assess dynamic airway obstruction in children with OSA. It is worth noting that our DISE procedures and PSG were done by pediatricians specialized in respiratory and sleep medicine, whereas most of the literature about DISE is written by otolaryngologists.[6]

We found that multiple-level obstructions, defined as mild obstruction or obstruction score >= 1 in more than one level, are very common among OSA children regardless of their surgical status, and 71.8% of our study participants were not obese (n = 89). This was consistent with many previous studies. As reported by Boudewyns A *et al*.[7] and Park *et al*.,[17] 56% and 49% of their study populations were found to have multilevel obstructions. Megan *et al*.[18] investigated DISE findings in post-AT children with persistent OSA, showing multilevel obstructions contribute to persistent sleep disorder breathing after T&A. Seckin O. Ulualp *et al*.[19] found that the majority of children with OSA had obstruction at multiple sites of the airway. Combination of the oropharynx/lateral walls and velum obstruction were the most common sites of obstruction.

It is beyond our expectation that 36.3% of them had severe obstructions or obstruction score=3 in more than one level. Tongue base obstruction score was significantly higher in post-AT patients while comparing to surgical naïve group. Myatt *et al*.[10] published a series of pediatric DISE findings in 2000 demonstrating similar findings,

Table 3: Subgroup analysis of the post-AT group: demographic, anthropometric, and PSG parameters (n = 23)

Variables	Pre-AT Median (IQR)	Post-AT Median (IQR)	*P* Value
Male, *n(%)*	18 (78.3%)		
Endoscopy age, year	8.0 (7.0–10.0)	13.6 (11.1–16.3)	<0.001
Body weight, kg	24.6 (20.3–32.3)	41.5 (29.8–54.3)	<0.001
Height, cm	130.0 (119.0–135.1)	149.0 (135.6–162.9)	<0.001
BMI	15.3(13.8–17.7)	18.8 (16.2–20.5)	<0.001
BMI z–score	–0.09 (–1.12–0.99)	0.43 (–0.08–1.24)	0.023
Obese, *n(%)*	1 (4.3%)	2 (8.7%)	1.000
PSG age, year	7.6 (6.6–9.4)	11.7 (9.4–13.3)	<0.001
Sleep efficiency, %	89.4 (83.3–94.5)	91.5 (86.5–93.7)	0.935
Total sleep time, min	479.5 (441.5–516.0)	426.0 (380.0–474.0)	0.008
Arousal/h	14.5 (10.7–21.0)	19.1 (15.7–24.9)	0.072
oAHI/h	5.8 (2.6–9.5)	4.8 (2.2–10.8)	0.715
oAHI 1 to 5, *n(%)*	11 (47.8%)	12 (44.4%)	0.545
oAHI>5 to 10, *n(%)*	8 (34.8%)	7 (25.9%)	
oAHI>10, *n(%)*	4 (17.4%)	8 (29.6%)	
Oxygen saturation nadir, %	89.0 (87.0–92.0)	90.0 (87.0–92.0)	0.285
Desaturation index/h	2.1 (0.4–4.9)	1.5 (0.7–5.8)	0.987
PSQ:SRBD score	8.0 (7.0–12.0) (n = 19)	6.0 (3.0–9.3) (n = 22)	0.011

TA = adenotonsillectomy, BMI = body mass index, PSG = polysomnography, oAHI = obstructive apnea–hypopnea index, PSQ:SRBD = Pediatric Sleep Questionnaire:Sleep-Related Breathing Disorder Scale

P-values were calculated with Wilcoxon Signed Ranks Test or McNemar test

which common site of obstructions in surgical naive and complex disease (i.e., background with severe OSA, syndromal or cerebral palsy), was tongue base (30%), followed by velopharyngeal and tonsillar obstruction, both present in 20% of subjects. Park *et al*.[17] performed a similar study with one-third of them being Down Syndrome and found that the tongue base was the most common site of persistent airway obstruction. A meta-analysis by Manickam *et al*.[20] concluded the most common sites of obstruction were the tongue base, adenoids (secondary to regrowth), inferior turbinates, velum, and the lateral oropharyngeal walls.

In the subgroup analysis focusing comparison on pre and post-AT DISE findings, we noted that obstruction scores increased in nostrils, tongue base, and supraglottis in post-AT compared to their pre-AT status. It could be postulated that these changes were primarily responsible for persistent OSA in post-AT patients. Megan *et al*.[18] reported that tongue base was the most common cause (85%), followed by adenoid regrowth and inferior turbinate hypertrophy in post-AT patients.

In our unit, we routinely use DISE for airway obstruction evaluation for all children with OSA before tailor-made subsequent management. It is known that there is no consensus on the indication of DISE in children, but at least there is no strong objection to have DISE in OSA patients before surgery. A. Boudewyns[7] suggested DISE could be a routine examination in all pediatric OSAS patients prior to surgery to improve outcome. Review article[6] proposed in an update review article that the indications include persistent OSA after AT, prior to surgery for those high-risk persistent OSA cases (obesity, Down syndrome, craniofacial abnormalities and neurological impairment), significant symptoms of SDB children with small tonsil and adenoid, occult or sleep state-dependent laryngomalacia, and prior hypoglossal nerve stimulator treatment. A retrospective cohort study[21] mentioned that DISE changed surgical decisions for 30% of children with OSA and allowed the management plan to address multiple obstruction levels, although whether it provides additional benefit on treatment outcomes remains uncertain.

It is our limitation that we did not include the DISE-guided management and their surgical outcome in data analysis. Medical treatment like nasal medications, CPAP or ventilation support, oral myofunctional therapy, multidisciplinary surgical assessment with dentist and ENT, and weight reduction programs are common treatment modalities provided in our unit. Recent systematic review suggested that outcome is better with DISE-directed surgery in a small subset of population, that is, children with underlying comorbidity or syndrome.[22] But whether DISE-guided management would provide a better outcome among non-syndromic or surgical naive patients remains doubtful and requires further research.

We developed a standardized scoring system combining Chan[15] and Fishman[16] together based on the suggestion published in the APPS paper,[3] which includes six levels for more comprehensive information on obstruction status. We take into account both structural and dynamic upper

Table 4: Subgroup analysis of the post-AT group: DISE findings ($n = 23$)

Variables	Pre-AT Median (IQR)	Post-AT Median (IQR)	*P* Value
Levels 1: Nasal obstruction	1 (1–2)	2 (1–2)	0.016
0 = No obstruction, *n*(%)	2 (8.7%)	1 (4.3%)	0.052
1 = Mild obstruction, *n*(%)	15 (65.2%)	6 (26.1%)	
2 = Moderate obstruction, *n*(%)	5 (21.7%)	15 (65.2%)	
3 = Severe obstruction, *n*(%)	1 (4.3%)	1 (4.3%)	
Levels 2: Adenoids	2 (2–3)	1 (1–2)	0.001
0 = Absent adenoids, *n*(%)	0 (0.0%)	3 (13.0%)	0.410
1 = 0–50% obstruction of choana, *n*(%)	1 (4.3%)	10 (43.5%)	
2 = 50–99% obstruction of choana, *n*(%)	13 (56.5%)	7 (30.4%)	
3 = Complete obstruction of choana, *n*(%)	9 (39.1%)	3 (13.0%)	
Levels 3: Velum	2 (1–2)	2 (1–2)	1.000
0 = No obstruction, *n*(%)	0 (0.0%)	0 (0.0%)	0.392
1 = 0–50% AP closure, *n*(%)	7 (30.4%)	9 (39.1%)	
2 = 50–99% AP closure, *n*(%)	15 (65.2%)	11 (47.8%)	
3 = Complete closure against posterior pharyngeal wall, *n*(%)	1 (4.3%)	3 (13.0%)	
Levels 4: Lateral pharyngeal wall	3 (2–3)	0 (0–1)	<0.001
0 = No obstruction, *n*(%)	0 (0.0%)	16 (69.6%)	0.103
1 = 0–50% lateral obstruction, *n*(%)	1 (4.3%)	4 (17.4%)	
2 = 50–99% lateral obstruction, *n*(%)	5 (21.7%)	2 (8.7%)	
3 = Complete obstruction, *n*(%)	17 (73.9%)	1 (4.3%)	
Levels 5: Tongue base	2 (2–3)	3 (2–3)	0.017
0 = No obstruction, *n*(%)	0 (0.0%)	0 (0.0%)	0.558
1 = 0–50% obstruction, *n*(%)	5 (21.7%)	0 (0.0%)	
2 = 50–99% obstruction, *n*(%)	10 (43.5%)	9 (39.1%)	
3 = Complete obstruction, *n*(%)	8 (34.8%)	14 (60.9%)	
Levels 6: Supraglottis	0 (0–0)	1 (0–2)	0.001
0 = No obstruction, *n*(%)	20 (87.0%)	7 (30.4%)	0.333
1 = 0–50% obstruction, *n*(%)	3 (13.0%)	9 (39.1%)	
2 = 50–99% obstruction, *n*(%)	0 (0.0%)	4 (17.4%)	
3 = Complete obstruction, *n*(%)	0 (0.0%)	3 (13.0%)	
Total score obstruction score	10 (9–11)	9 (7–12)	0.034

TA = adenotonsillectomy, DISE = drug-induced sleep endoscopy, A*P* = anteroposterior

P-values were calculated with Wilcoxon Signed Ranks Test or McNemar test

airway abnormalities in combination with a quantification of the degree of obstruction. But it's clear that there are no standardized protocols and validated grading scales in children under DISE. Inter-observer variability should be addressed providing that data from DISE is performed by up to eight different attending pediatricians. Williamson *et al*.[23] propose a standardized method of scoring and performing DISE in children with refractory OSA by adding lingual tonsil, epiglottis, aryepiglottic fold, and arytenoids into the scoring system making it a total of 10 levels to be scored. Further validation study should be followed to see if it could be applied in future clinical work.

This is the first time reported that using a combination of scoring systems, a weak to moderate correlation is obtained between total score and PSG parameters. John P. Dahl *et al*.[24] first reported that Chan 2014 DISE score correlated with PSG parameters including AHI and SpO2 nadir in children. De Corso *et al*.[25] demonstrated in an adult study that there was a good correlation between DISE obstructions severity and AHI and Epworth Sleepiness Scale scores (ESS score). Observational bias, test–retest reliability among different physicians would be generated as they were not blinded to pre-endoscopy PSG parameters.

One major controversy is about sedation, whether a drug-induced sleep state is comparable with natural sleep, especially in children whose sleep obstructive events happen frequently in rapid eye movement (REM) sleep. Updated review suggested no anesthetic agents are currently able to replicate REM sleep, and the use of DISE in children with REM obstructive disease requires cautious interpretation.[6,12] Our sedation agents were intravenous midazolam and fentanyl. Some authors[26,27] suggested that the majority of the dynamic airway obstruction occurred during N1 and N2 sleep while benzodiazepine causing no REM sleep and less N3 sleep duration making

midazolam to be a good option for sleep endoscopy. But they also mentioned the UAO was commonly seen with an increase in nasal airway resistance and decreased airway cross-sectional area. For fentanyl, opioids are known to depress both the ventilatory and pharyngeal neuromotor drive, therefore decreasing airway patency.[12] Both of the sedation agents are so far safe and effective according to our experience with no patient suffering from sedation adverse effects. But if their sedation effect worsens the upper airway condition leading more obstructions observed in study subjects remains debatable. Dexmedetomidine and ketamine are reported to be commonly used agents in previous studies. Both of them do not lead to respiratory depression with less muscular relaxation, and with a more sustained respiratory effort. Dexmedetomidine can also replicate non-rapid eye movement (non-REM) and has been preferred for its overall safer profile based upon hemodynamic stability.[28] Moreover, this is the first study using an objective score (i.e., UMSS) to document sedation level in children under DISE. This serves as an objective measurement to see if medications are given to induce a sleep-like state in patients.

The retrospective study design, as well as the fact that this represented a single-center experience, remains the major limitation of our study. We propose to use the results from the present study as a basis for a multicenter prospective study, to evaluate the association between PSG parameters and the level of obstruction on pediatric DISE, to set up a standard or validated DISE scoring and sedation system for children, and finally to improve the outcome with DISE guided management.

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Conflicts of interest

There are no conflicts of interest.

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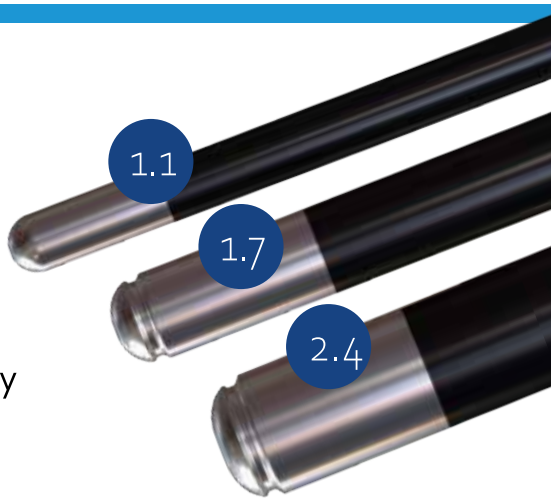

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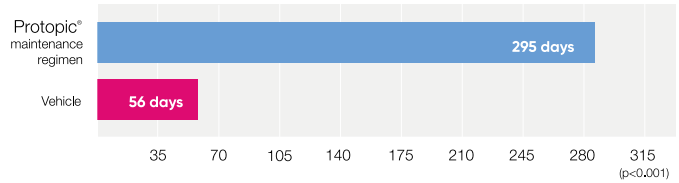

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