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Obstructive sleep apnea in Down syndrome: Benefits of surgery and noninvasive respiratory support

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Children with Down syndrome are at increased risk of obstructive sleep apnea (OSA). The aim of the study was to describe the management of OSA in a large cohort of children with Down syndrome. A retrospective analysis of sleep studies and consequent management was performed for all consecutive Down syndrome patients evaluated between September 2013 and April 2016. The data of 57 patients were analyzed: 51/53 had an interpretable overnight polygraphy and 4 the recording of nocturnal gas exchange. Mean age at baseline sleep study was 6.2 ± 5.9 years. Eighteen patients (32%) had prior upper airway surgery. Mean apnea-hypopnea index (AHI) was 14 ± 16 events/hr with 41 of the 51 (80%) patients having OSA with an AHI >1 event/hr and 20 patients (39%) having an AHI ≥10 events/hr. Consequently, eight patients (14%) had upper airway surgery. OSA improved in all patients except two who needed noninvasive respiratory support. Nineteen (33%) patients required noninvasive respiratory support. Mean age at noninvasive respiratory support initiation was 7 ± 7 years. On 11 patients with objective adherence data available, mean compliance at 2 ± 1 years of treatment was excellent with an average use per night of 8 hr46 ± 3 hr59 and 9 patients using the noninvasive respiratory support >4 hr/night. Noninvasive respiratory support was associated with an improvement of nocturnal gas exchange. The prevalence of OSA is high in Down syndrome. Upper airway surgery is not always able to correct OSA. Noninvasive respiratory support represents then an effective treatment for OSA and good compliance may be achieved in a majority of patients.

KEYWORDS
continuous positive airway pressure, Down syndrome, noninvasive ventilation, sleep apnea, treatment adherence, upper airway surgery

1 | INTRODUCTION

Down syndrome (DS), defined by an extra copy of chromosome 21, is the commonest chromosomal disorder (Parker et al., 2010), with an estimated prevalence in the United States from 9.0 to 11.8 per 10,000 live births (Shin et al., 2009). Patients with DS are predisposed to upper airway obstruction and obstructive sleep apnea (OSA) due to altered craniofacial anatomy with midfacial and mandibular hypoplasia, glossoptosis with relative macroglossia, frequent adenotonsillar hypertrophy, muscle hypotonia with an increased prevalence of pharyngo-laryngomalacia and subglottic and/or tracheal stenosis (Lal, White, Joseph, van Bakergem, & LaRosa, 2015). These anatomical predisposing factors for OSA are aggravated by obesity, hypothyroidism, and gastroesophageal reflux disease (Lal et al., 2015). Sleep-disordered breathing is common in patients with DS with a prevalence of OSA between 30% and 66% (Alexander et al., 2016; Bassell, Phan, Leu, Kronk, & Visootsak, 2015; Lal et al., 2015). Moreover, patients with DS tend to have severe OSA (Goffinski et al., 2015) which adversely affects language, neurocognitive development, behavior, functional outcome, and quality of life (Breslin et al., 2014; Brooks et al., 2015; Churchill, Kieckhefer, Bjornson, & Herting, 2015; Edgin et al., 2015).

Adeno-tonsillectomy represents the first line surgical treatment for severe OSA (Lal et al., 2015). However, adeno-tonsillectomy is significantly less effective in children with DS as compared to non-DS children (Shete, Stocks, Sebelik, & Schoumacher, 2010). In the case of persistent OSA, noninvasive continuous positive airway pressure (CPAP) or noninvasive ventilation (NIV) in the case of associated alveolar hypoventilation, is recommended (Amaddeo, Moreau et al., 2016; Kaditis et al., 2016). However, the implementation of CPAP/NIV may be more difficult and therapeutic compliance may be reduced in patients with DS as compared to non-DS patients (Brooks et al., 2015).

The aim of the study was first, to describe the sleep respiratory parameters of a large cohort of DS patients and second, the management of OSA with a particular emphasis on upper airway surgery and CPAP/NIV.

2 | MATERIALS AND METHODS

2.1 | Patients

Clinical and sleep study data of all consecutive DS patients followed at the sleep unit of Necker Children hospital (Paris, France), between September 2013 and April 2016 were retrospectively analyzed. Follow-up data were collected for patients who underwent upper airway surgery and/or who were treated with CPAP/NIV.

2.2 | Sleep data

All sleep studies were performed in the sleep laboratory of Necker hospital. All patients were accompanied by one parent throughout the night. Neither sedation nor sleep deprivation were used on any patient.

The following standardized measurements were simultaneously recorded during every polygraphy: nasal flow through a nasal pressure transducer, pulse oximetry by a pulse oximeter (SpO_2), thoracic and abdominal respiratory inductance plethysmography, synchronized infrared video monitoring (Cidelec, St. Gemme sur Loire, France or Alice 6, Philips Respironics, St. Priest, France), and transcutaneous carbon dioxide pressure ($PtcCO_2$, SenTec, Thurnwill, Switzerland).

Scoring of respiratory events was performed according to the 2012 scoring rules of the American Academy of Sleep Medicine (Berry et al., 2012). The following definitions for respiratory events were used for scoring purposes (Berry et al., 2012). Obstructive apnea (OA) was defined as the absence of nasal airflow with continued chest wall and abdominal movements for at least two breaths. Central apnea (CA) was defined as the absence of airflow with the cessation of respiratory effort, lasting more than 20 s or of shorter duration and associated with an arousal and/or a 3% oxygen desaturation. CA occurring after gross body movements or after sighs were not included in the analysis. Mixed apnea was defined as an apnea that usually begins as central and ends as obstructive according to changes in the chest, abdominal, and flow traces. Hypopnea was defined as a decrease in nasal airflow of at least 30% with a corresponding decrease in SpO_2 of at least 3% and/or an arousal. The apnea-hypopnea index (AHI) was calculated as the sum of apneas and hypopneas per hour of time on bed. The obstructive AHI was defined as the number of obstructive apneas-hypopneas per hour of time in bed with an obstructive AHI (OAHI) < 2 events/hr being considered as normal (Marcus et al., 1992; Montgomery-Downs, O'Brien, Gulliver, & Gozal, 2006; Uliel, Tauman, Greenfeld, & Sivan, 2004). Central apnea index (CAI) was defined as the number of central apneas per hour of time in bed, with a CAI < 5 events/hr being considered as normal (Kritzinger, Al-Saleh, & Narang, 2011).

Mean and minimum SpO_2 values were calculated. The oxygen desaturation index (ODI) was defined as the number of SpO_2 drops of at least 3% per hour of total time in bed. Mean and maximal values of $PtcCO_2$ were gathered and the percentage of total time in bed spent with a $PtcCO_2$ > 50 mmHg were calculated. All the SpO_2/$PtcCO_2$ data that were not interpretable (probe detachment, outlier data, artifacts) were discarded from the analysis.

2.3 | Upper airway surgery

All patients were evaluated by a pediatric ear, nose, and throat (ENT) surgeon. Upper airway surgery with adenoidectomy ± tonsillectomy ± turbinectomy were variably performed according to the clinical ENT examination in case of an AHI > 5 events/hr (Kaditis et al., 2016).

2.4 | CPAP/NIV

Continuous positive airway pressure was initiated in case of an AHI > 10 events/hr, despite upper airway surgery or when upper airway surgery was not indicated, by a pediatrician and a nurse with expertise in CPAP/NIV and therapeutic education (Amaddeo, Frapin, & Fauroux, 2016; Amaddeo, Moreau et al., 2016). CPAP/NIV was started in an out-patient setting in selected patients, or during a short hospitalization of two to three nights in patients with severe behavioral problems or neurocognitive impairment. CPAP titration was performed during a daytime nap study in the outpatient setting and during the night in the inpatient setting (Kushida et al., 2008). CPAP was changed for NIV in case of persistent desaturations and/or hypercapnia despite the highest tolerated CPAP pressure (Kushida et al., 2008). Continuous positive airway pressure/NIV initiation was performed within a specific therapeutic education program adjusted on mental age, cognition, and cooperation. The therapeutic education tools integrated booklets, a teddy bear breathing with NIV, and playful evaluation tools (see http://vnietsommeil.aphp.fr and Online Supplement). Patients were discharged after a therapeutic education session. Home visits with overnight gas exchange recording were performed every 2 weeks during the first 2 months and then every 1–3 months by technicians trained in pediatric CPAP/NIV. Patient adherence data were downloaded from the in-built software of the device during the routine hospital and home care provider visits (Ramirez et al., 2013). The mean daily adherence, the mean number of nights with CPAP/NIV use, and the number of nights the patient used CPAP/NIV for more than 4 hr were analyzed. The duration of home CPAP/NIV use also was reported.

2.5 | Statistical analysis

Data are expressed as mean ± standard deviation, median (range). The comparison of the characteristics of the patients was performed using the Student's *t*-test in case of normal distribution or Mann–Whitney rank sum test otherwise. Comparisons between qualitative variables were done using the χ^2 test. The comparison of the nocturnal gas exchanges before and after the initiation of the CPAP/NIV was done using the paired *t*-test in case of normal distribution or the Wilcoxon signed rank test otherwise. A *p*-value ≤ 0.05 was considered as statistically significant.

3 | RESULTS

3.1 | Patients and sleep data

Fifty-seven patients were included in the study (Table 1). Mean age at baseline sleep study was 6.2 ± 5.9 years. Associated disorders were common with 58% of the patients having an associated cardiopathy, 30% being treated for hypothyroidism and/or asthma, and 23% being treated for gastro-oesophageal reflux. Eighteen (32%) patients had prior upper airway surgery at a mean age of 5.1 ± 3.4 years before the baseline sleep study, with a majority of patients having adenoidectomy and/or tonsillectomy.

The results of the baseline sleep study are shown in Table 2. Fifty-three patients had a polygraphy with recording of nocturnal gas exchange and four had only a recording of nocturnal gas exchange. Two polygraphies were not interpretable. Mean AHI was 14 ± 16 events/hr, with 20 of the 51 patients (39%) having severe OSA defined by an AHI ≥ 10 events/hr (Table 2 and Figure 1). OSA was observed at any age (Figure 1). Of the 26 patients younger than the age of 4 years, 22 (85%) had an AHI > 1 event/hr, 16 (62%) had an AHI > 5 events/hr, and 11 (42%) had an AHI ≥ 10 events/hr.

Of the 18 patients who had upper airway surgery before the baseline sleep study, 6 had an AHI between 1 and 5 events/hr, 2 an AHI between 5 and 10 events/hr, and 4 an AHI ≥ 10 events/hr (Supplementary Online Table S1). The mean age of the patients who had prior upper airway surgery was higher than the age of patients who did not have prior upper airway surgery (Supplementary Online Table S1). There was a trend for mean AHI to be higher in patients without prior surgery (16 ± 18 events/hr) as compared to those with

TABLE 1 Characteristics of the patients

	Total population, *n* = 57
Age at first study (years), mean ± SD, median [min;max]	6.2 ± 5.9, 4.0 [0.2;24.7]
Male/female (number)	31/26
Body mass index, mean ± SD (Kg/m^2)	19.0 ± 4.9
Body mass index *z*-score, mean ± SD	1.7 ± 4.0
Associated disorders	
Cardiopathy (*n*, %)	33 (58)
Ventricular septal defect (*n*)	8
Atrial septal defect (*n*)	9
Ventricular atrial communication (*n*)	8
Other (*n*)	14
Arterial pulmonary hypertension (*n*, %)	11 (19)
Hypothyroidism (*n*, %)	17 (30)
Asthma (*n*, %)	17 (30)
Gastro-oesophageal reflux (*n*, %)	13 (23)
Prior upper airway surgery (*n*, %)	18 (32)
Adenoidectomy (*n*)	15
Tonsillectomy (*n*)	17
Turbinoplasty (*n*)	2
Other (*n*)	2

TABLE 2 Baseline sleep data of the 57 patients

Respiratory events (*n* = 51)	
Mean AHI (events/hours), mean ± SD, median [min;max]	14 ± 16, 7 [0;62]
AHI ≤ 1 events/hr, *n* (%)	10 (19)
AHI > 1 and ≤5 events/hr, *n* (%)	12 (24)
AHI > 5 and <10 events/hr, *n* (%)	9 (18)
AHI ≥ 10 events/hr, *n* (%)	20 (39)
Mean central AI (events/hours), mean ± SD, median [min;max]	1 ± 2, 0 [0;10]
Central AI > 5 events/hr, *n* (%)	4 (8)
Mean obstructive AI (events/hours), mean ± SD, median [min;max]	8 ± 11, 3 [0;45]
Obstructive AI > 5 events/hr, *n* (%)	16 (31)
Obstructive AI > 10 events/hr, *n* (%)	10 (19)
Nocturnal gas exchange (*n* = 57)[a]	
Mean SpO_2 (%), mean ± SD, median [min;max]	95 ± 3, 96 [82;99]
Minimal SpO_2 (%), mean ± SD, median [min;max]	83 ± 14, 86 [61;98]
% of time with SpO_2 < 90% (%)	13 ± 29, 0 [0; 100]
Patients with >10% of time with a SpO_2 < 90%, *n* (%)	9 (18)
Mean 3% ODI (events/hours), mean ± SD, median [min;max]	17 ± 21, 10 [2;86]
ODI > 10 events/hr, *n* (%)	24 (47)
Mean $PtcCO_2$ (mmHg), mean ± SD, median [min; max]	43 ± 5, 43 [34;53]
Maximal $PtcCO_2$ (mmHg), mean ± SD, median [min;max]	48 ± 6, 47 [36;68]
% of time with $PtcCO_2$ > 50 mmHg (%), mean ± SD, median [min;max]	4 ± 17, 0 [0;95]
Patients with >10% of time with a $PtcCO_2$ > 50 mmHg, *n* (%)	3 (6)

AHI, apnea-hypopnea index; AI, apnea index; ODI, oxygen desaturation index; SpO_2, pulse oximetry; $PtcCO_2$, transcutaneous carbon dioxide.
[a]Four patients had only nocturnal gas exchange without a polygraphy, the nocturnal gas exchange data of these patients are included in the gas exchange data.

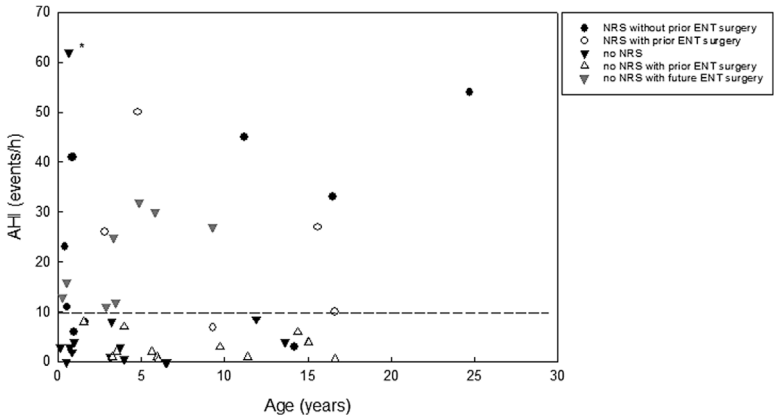

FIGURE 1 Apnea-hypopnea index (AHI) according to the age of the patient and his medical history. NRS, noninvasive respiratory support (including continuous positive airway pressure or noninvasive ventilation); ENT, ear, nose, and throat

prior surgery (9 ± 13 events/hr) but this was not statically significant ($p = 0.054$) (Supplementary Online Table S1). Similar results were observed for the mean obstructive AI. Only the ODI and the minimal SpO_2 differed between the two groups. Indeed, the ODI was higher and minimal SpO_2 was lower in patients without prior upper airway surgery as compared to those with prior surgery (20 ± 22/hr vs. 11 ± 18/hr, $p = 0.033$ for the ODI and 82 ± 8% vs. 89 ± 6%, $p = 0.003$ for minimal SpO_2).

Four patients had severe symptoms of sleep disordered breathing with witnessed apneas and arousals, snoring, and sweating which justified prompt overnight gas exchange assessment. The abnormalities of gas exchange in room air required immediate CPAP, which was initiated in the intensive care unit for two patients (Figure 2). These patients did not have a polygraphy but their baseline nocturnal gas exchange data are included in Table 2.

3.2 | Therapeutic management of OSA

Eight patients with severe OSA (AHI ≥ 10 events/hr) had upper airway surgery after the baseline sleep study with seven children having adenoidectomy and tonsillectomy and one adenoidectomy only (Table 3 and Figure 2). Patients treated with ENT surgery had a higher AHI than those not treated with ENT surgery (mean AHI 26 ± 11 vs. 13 ± 19 events/hr, $p = 0.045$). In the five patients who had a control sleep study after surgery, mean AHI decreased from 26 ± 11 events/hr before surgery to 13 ± 19 events/hr after surgery. A control sleep study is planned in the three remaining patients. Two patients subsequently required CPAP (Figure 2) because of persistent OSA (AHI of 47 and 11 events/hr) despite ENT surgery (Figure 2).

Nineteen (33%) patients required CPAP ($n = 15$) or NIV ($n = 4$) after the baseline sleep study (Table 4). The four patients treated with NIV had persistent alveolar hypoventilation despite CPAP. Patients who required CPAP/NIV did not differ from those who did not require CPAP/NIV with regard to age (5.9 ± 4.9 years vs. 6.9 ± 7.7, $p = 0.839$) and to mean BMI z-score (p = NS) (Supplementary Online Table S2) but they had a higher mean AHI (26 ± 18/hr) than those not requiring this treatment (9 ± 13/hr, $p < 0.001$) (Supplementary Online Table S3). Similarly, mean OAI and ODI were also higher in the patients requiring CPAP/NIV than those who did not (Supplementary Online Table S3).

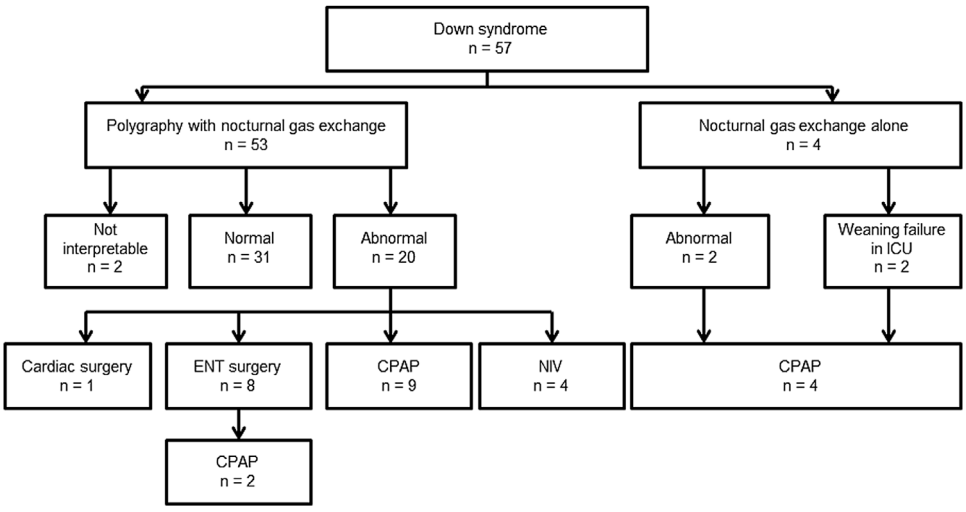

FIGURE 2 Flow chart of the patients. ICU, intensive care unit; CPAP, continuous positive airway pressure; NIV, noninvasive ventilation; ENT, ear, nose, and throat

TABLE 3 Efficacy of upper airway surgery and CPAP/NIV on nocturnal gas exchange

	Upper airway surgery			CPAP/NIV		
	Before surgery (n = 8)	After surgery (n = 5)[a]	p-value	Before CPAP/NIV (n = 19)	With CPAP/NIV (n = 16)	p-value
Mean delay (years)	Not applicable	0.5 ± 0.1,		Not applicable	0.8 ± 0.7,	
		0.5 [0.4;0.7]			0.6 [0;1.9]	
Mean SpO_2 (%)	94 ± 3,	96 ± 1,	0.269	94 ± 4,	96 ± 2,	0.142
	94 [89;97]	97 [94;97]		94 [86;99]	96 [92;99]	
Minimal SpO_2 (%)	77 ± 9,	84 ± 7,	0.063	82 ± 7,	88 ± 6,	0.02
	81 [61;85]	88 [73;88]		82 [71;93]	90 [73;95]	
% of time with SpO_2 < 90% (%)	8 ± 17,	0 ± 0,	0.205	21 ± 34,	1 ± 3,	0.01
	1 [0;49]	0 [0;0]		1 [0;100]	0 [0;11]	
ODI (events/hr)	26 ± 14,	18 ± 22,	0.267	30 ± 26,	5 ± 5,	0.003
	25 [11;48]	[8;57]		23 [2;76]	3 [92;99]	
Mean $PtcCO_2$ (mmHg)	44 ± 5,	45 ± 3,	0.624	43 ± 5,	42 ± 5,	0.131
	46 [37;49]	45 [42;48]		43 [36;53]	42 [31;48]	
Maximal $PtcCO_2$ (mmHg)	52 ± 5,	49 ± 4,	0.501	50 ± 7,	47 ± 3,	0.137
	52 [46;58]	49 [47;54]		48 [40;68]	48 [42;52]	
% of time with $PtcCO_2$ > 50 mmHg (%)	6 ± 13,	6 ± 13,	0.500	0 ± 1,	0 ± 0,	1
	0 [0;30]	0 [0;25]		0 [0;2]	0 [0;0]	

CPAP, continuous positive airway pressure; NIV, noninvasive ventilation; SpO_2, pulse oximetry; ODI, oxygen desturation index, $PtcCO_2$, transcutaneous carbon dioxide pressure.
Data are presented as mean ± SD and median [range].
[a]n = 5 because three patients are scheduled for a sleep study.

Upper airway surgery and CPAP/NIV were associated with an improvement of nocturnal gas exchange (Table 3). All the parameters improved but this was significant only for minimal SpO_2, the percentage of time with SpO_2 < 90%, and the ODI.

The data concerning CPAP/NIV are shown in Table 4. The mean age at CPAP/NIV initiation was 7 ± 7 years with a wide range (0.4–23 years). Mean duration of treatment at the time of the study was 2 ± 1 years. CPAP/NIV adherence was available only in 11 patients, mainly because of a too young age in 4 patients which did not allow an accurate interpretation of actual ventilator use (Caldarelli et al., 2013). Compliance was good with an average use per night of 8 hr46 ± 3 hr59 and 9/11 patients using CPAP/NIV > 4 hr/night. Three patients could be successfully weaned from CPAP/NIV. Finally, no complications were observed with surgery or CPAP/NIV.

4 | DISCUSSION

This study confirms the high prevalence and severity of OSAS in children with DS and the limited efficacy of upper airway surgery to prevent or cure OSA. CPAP/NIV was necessary in 33% of the patients and highly efficient on nocturnal gas exchange. Importantly, a good compliance could be obtained in the majority of patients.

The high prevalence and increased severity of OSA in patients with DS has been observed in all age groups. Sleep apnea was increased three- to fourfold in children and adults in a large epidemiological study performed in Australia which compared the prevalence of acquired cardiovascular diseases in 4,081 patients with DS and 16,324 controls over a period of 17 years (Sobey et al., 2015). Another large epidemiological study analyzed the global morbidity associated with DS in a cohort of 6,430 patients with DS and 19,176 controls in the United Kingdom over a period of 9 years (Alexander et al., 2016). The global incidence rate ratio for OSA in the patients with DS versus controls was 5.3. The risk of OSA has been shown to be even more important in young children. Indeed, in a group of 59 infants <6 months of age, referred to a DS clinic at a tertiary hospital because of symptoms of sleep-disordered breathing, 95% had an AHI ≥ 2/hr and 71% met the criteria for severe OSA with an AHI ≥ 10/hr (Goffinski et al., 2015). The diagnosis and effective treatment of OSA in infants and children with DS is of paramount importance as poor sleep quality and OSAS have been shown to be associated with poor cognitive function, and in particular verbal intelligence quotient and cognitive flexibility (Breslin et al., 2014; Brooks et al., 2015), language development (Edgin et al., 2015), and functional outcomes in daily life (Churchill et al., 2015). The present study confirms the high prevalence and severity of OSA in children with DS with 29 patients (57%) having an abnormal AHI and 20 (39%) severe OSA with an AHI ≥ 10/hr.

Adeno-tonsillectomy has a limited efficacy on OSA in DS. In a small study that evaluated 11 children with DS, mean AHI decreased from 15.3 ± 12.6 events/hr before adeno-tonsillectomy to 9.1 ± 10.5 after surgery with 6 of the 11 patients requiring CPAP or NIV for persistent OSA (Shete et al., 2010). Our study confirms the limited

TABLE 4 Continuous positive airway pressure (CPAP) and noninvasive ventilation (NIV) and adherence (n = 19)

Age at initiation (years)	7 ± 7, 4 [0.4;23]
Duration of CPAP/NIV treatment (years)	2 ± 1, 2 [0.2;4.8]
CPAP (n = 15)	
CPAP level (cmH_2O)	8 ± 1, 8 [6;9]
NIV (n = 4)	
Inspiratory pressure level (cmH_2O)	13 ± 2, 12 [12;17]
Expiratory pressure level (cmH_2O)	7 ± 1, 8 [5;8]
Interfaces	
Nasal mask (n)	17
Nasobuccal mask (n)	2
CPAP/NIV adherence (from the in-built software)	
Average use per night (hr:min)	8 hr46 ± 3 hr59, 10 hr33 [1 hr00;13 hr00]
Number of patient using CPAP/NIV>4 hr/night (n)[a]	9/11 (82%)[a]
Failure of long term CPAP/NIV (n)	5
Successful weaning of CPAP/NIV (n)	3

Data are presented as mean ± SD and median [range].
[a]CPAP/NIV adherence was available only in 11 patients.

benefit of upper airway surgery in children with DS. Indeed, even if adeno-tonsillectomy was associated with a significant improvement of OSA, almost half of the children had persistent OSA, which was not correlated to age, gender, or BMI z-score (Maris, Verhulst, Wojciechowski, Van de Heyning, & Boudewyns, 2017). These results may be explained by the multifactorial nature of the upper airway obstruction associating anatomical and functional factors such as midfacial and mandibular hypoplasia, glossoptosis with relative macroglossia, and muscle hypotonia (Lal et al., 2015). A systematic sleep study is thus recommended before and after each upper airway surgery in patients with DS.

Continuous positive airway pressure or NIV in case of alveolar hypoventilation, is indicated if OSA persists after upper airway surgery (Amaddeo, Moreau et al., 2016; Kaditis et al., 2016). One-third (33%) of the patients in the present study required CPAP/NIV, which underlines the severity of OSA in this population. The AHI threshold for CPAP/NIV initiation has not been validated in children but levels AHI > 5 or 10 events/hr are usual (Amaddeo, Moreau et al., 2016; Kaditis et al., 2016). However, in clinical practice, the initiation of CPAP/NIV is based on an association of clinical symptoms and sleep parameters, taking in account not only the AHI but also the SpO_2 and $PtcCO_2$ levels, as well as sleep quality (Amaddeo, Frapin et al., 2016). CPAP and NIV are very effective to treat OSA ± alveolar hypoventilation, as shown by the significant improvement of nocturnal gas exchange in the present study (Table 3). Of note, four patients had such severely abnormal gas exchange that a polygraphy was not necessary for the initiation of CPAP or NIV which was started immediately (and in the intensive care unit for two patients).

The major problem of CPAP/NIV in children with DS is compliance with treatment. Poor compliance or refusal of CPAP/NIV is significantly more common in these patients as compared to patients without DS, mainly because of behavioral disorders and neurocognitive impairment. In a recent study, the patients who did not comply with CPAP were deficient in tests of adaptive behavior, visual-motor integration, and achievement (Brooks et al., 2015). However, good compliance may be achieved, as observed in the present study, with a pediatric CPAP/NIV team, having an expertise in therapeutic education and CPAP/NIV (Amaddeo et al., 2015; Caldarelli et al., 2013). Indeed, the objective compliance in our patients was excellent with an average use of CPAP/NIV per night of 8 hr46 ± 3 hr59 and 9/11 patients using CPAP/NIV>4 hr/night (Table 4). Five patients did not tolerate CPAP/NIV treatment because of major behavioral disorders and family dysfunction.

We are aware of the limitations of our study. First, it was a single-center, retrospective study explaining that adherence data were incomplete. Second, the patients had a polygraphy and not a polysomnography which does not give information on sleep architecture and sleep quality and may underestimate the numbers of hypopneas (Tan, Gozal, Ramirez, Bandla, & Kheirandish-Gozal, 2014). Finally, poly(somno)graphy was not systematically performed before all upper airway surgery.

In conclusion, the present study confirms the high prevalence and increased severity of OSA in children with DS. Upper airway surgery represents a first line treatment but has a limited efficacy. CPAP or NIV represent a very effective therapeutic option in case of persistent OSA after upper airway surgery. The major problem of CPAP/NIV is compliance but good results may be achieved by an experienced pediatric CPAP/NIV team.

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CONFLICT OF INTEREST

All the authors have indicated they have no potential conflicts of interest to disclose.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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