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## Evaluation of nasal obstruction in children by acoustic rhinometry: a prospective study

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1 Evaluation of nasal obstruction in children by acoustic rhinometry: a prospective study

2

### 3 **1. Introduction**

4 Evaluation of nasal obstruction can be especially challenging in children. History-  
5 taking with the parents is very subjective. Self-completed questionnaires, like NOSE (nasal  
6 obstruction symptom evaluation) scale, can be used only from 6 years old [1], and with  
7 children without mental retardation. Physical examination with nasal endoscopy is the gold  
8 standard, but it is invasive, difficult to perform in children [2], and results are subjective.

9 Radiography and computed tomography (CT) scans are limited in children because of  
10 radiation, and magnetic resonance imaging (MRI) is difficult to achieve requiring a compliant  
11 child. Moreover, both CT and MRI only provide static, non-physiological information.

12 Acoustic Rhinometry (AR) is a non-invasive method, painless and easy to perform. It exists  
13 since 1980 [3] and the first use in children's upper airways has been reported in 1994 [4,5].

14 AR gives objective and repeatable measures of nasal cavity volume (NV) and minimal cross-  
15 sectional area (MCA), as shown in a preliminary study in healthy pre-school children in 2017  
16 [6]. AR should be a good method to assess child nasal obstruction, but too few studies on  
17 pediatric patients have been published. To our knowledge, no study has yet been performed  
18 using AR in children with facial malformations.

19 Children with Down syndrome and children with achondroplasia are prone to  
20 obstructive sleep apnea syndrome (OSAS) due to hypotonia and to their cranio-facial  
21 anatomy including a narrowed mid-face [7,8]. OSAS in children with facial malformations is  
22 usually caused by multilevel obstruction, involving the nose at two levels: the nasal cavity  
23 (turbinate hypertrophy, nasal valve collapse, pyriform aperture stenosis) and the  
24 nasopharynx (adenoid hypertrophy) [9]. Assessment of the exact level and importance of

25 nasal obstruction can be particularly challenging. Diagnosis of OSAS in children requires a  
26 sleep study with an obstructive apnea-hypopnea index (OAHl) over 1.5 e.h-1 [10]. The OAHl  
27 is also the standard criterion for grading severity of the OSAS. The first-line treatment is  
28 usually adenotonsillectomy [11], which may not be sufficient in severe cases [12]. For severe  
29 OSAS, medical treatment with nasal corticosteroid is indicated [13], and other procedures  
30 can be performed to treat upper airway obstruction at different levels. Nasal obstruction is  
31 known to be involved in children's OSAS [14,15] and turbinoplasty in addition to  
32 adenotonsillectomy may be recommended in cases with turbinal hypertrophy [16].

33 The primary aim of this study was to measure and compare NV and MCA between 3  
34 groups of children: "achondroplasia", "Down syndrome", and "control". The control group  
35 corresponded to children with suspicion of sleep disorder without cranio-facial  
36 malformation. The secondary aim was to look for a correlation between the AR  
37 measurements and the OAHl.

## 38 **2. Materials and methods**

39 This prospective study was conducted from February to July 2017 in a tertiary  
40 pediatric care center. Children aged between 6 months and 18 years were selected from the  
41 sleep study department where patients are routinely screened for various types of sleep  
42 disorders. Included children stayed overnight for a sleep polygraphy or an external gas  
43 exchange test, and an AR measurement was performed the same day. The following data  
44 were collected: demographic characteristics, medical and surgical history, NV, MCA, and  
45 OAHl. We used Dr. Warehouse® to collect medical and surgical history data [17]. Three  
46 groups of children were created: "achondroplasia", "Down syndrome" and "control".  
47 Achondroplasia and Down syndrome children underwent a sleep study for routine  
48 management. Control group children had a clinical suspicion of sleep disorder, but no

49 underlying disease with cranio-facial malformation (Chiari malformation, myasthenia,  
50 obesity, laryngeal paralysis, other diseases). Exclusion criteria were concomitant acute  
51 rhinitis, major behavioral issues, other facial malformations than achondroplasia and Down  
52 syndrome, AR nasal leak and lack of data (Fig. 1). Written informed consent was obtained  
53 from the parents. This study was approved by our Institutional Review Board (N°ID-RCB:  
54 2016-A02036-45).

### 55 2.1. *Acoustic Rhinometry*

56 The first step was to gain the child's trust by playing for a few minutes (testing the AR  
57 device with a toy), or by watching a cartoon if they were too young to understand the game.  
58 The AR measurements were made in a second step. They were performed by the same  
59 investigator, measuring the MCA and the NV in both sides of the nasal cavity (Fig. 2). AR  
60 device used in this study has been previously described as the two microphones method  
61 [18]. This device was used with a nose adaptor, as in the preliminary study [13]. The third  
62 and last step was the calculation of NV and MCA. The investigator had to enter the nasal  
63 cavity length into the computer to calculate NV and MCA. In order to take facial growth into  
64 account, we decided to set the length according to the child's age. The nasal cavity distances  
65 that we established were: 3 centimeters before 2 years, 4 centimeters between 2 years and  
66 6 years, and 5 centimeters after 6 years. Those lengths correspond only to nasal cavity  
67 anatomy anterior to the nasopharynx, because AR cannot measure nasopharyngeal  
68 obstruction. For each patient, 1 to 3 AR measures were made (some children were not  
69 compliant enough to accept 3 consecutive measures). In order to minimize any artifact due  
70 to nasal cycle, the mean of both sides AR results was calculated.

### 71 2.2. *Sleep study*

72 All patients underwent a sleep study: polygraphy in 77 cases (93%), or an external gas  
73 exchange test in 6 cases (7%). Results were interpreted by experienced sleep physiologists.  
74 Sleep apnea diagnosis and the OAHl (only for polygraphy cases) was collected. We excluded  
75 cases with associate central apnea.

### 76 2.3. *Statistics*

77 A paired t-test was used to compare mean value of NV and MCA in all 3 groups after  
78 matching patients on age and sex. A Wilcoxon signed-rank test was used after matching  
79 patients on age and sex when data did not have normal distribution. The Kendall rank  
80 correlation coefficient was used to compare NV and MCA values with OAHl. This test was  
81 used only for patients who underwent a polygraphy. The p-value was considered significant  
82 if  $p < 0.05$ .

## 83 3. Results

### 84 3.1. *Feasibility of AR in children*

85 Fifteen out of 164 patients were excluded because of behavioral issues rendering AR  
86 measurements impossible. The median age of these patients was 3.8 years, of which 46%  
87 had Down syndrome. Ten patients were excluded because of acute rhinitis. AR  
88 measurements were possible even for extreme ages (from 6 months to 18 years).

### 89 3.2. *AR learning process*

90 The learning curve of AR use was calculated. The main difficulty was to detect nasal leaks  
91 that induce false results. The investigator was able to correctly detect nasal leaks after 30 RA  
92 measurements.

### 93 3.3. *Medical and surgical history*

94 None of the children had treatment with topical nasal spray. Several children had had  
95 upper airway surgery before inclusion in the study. Surgeries were palatine tonsillectomy,

96 adenoidectomy, lingual tonsillectomy and turbinoplasty. Turbinoplasty had been performed  
97 in 7 children of the achondroplasia group, and in 1 child of the Down syndrome and control  
98 groups.

#### 99 3.4. *MCA and NV*

100 Table 1 shows the AR results in all 3 groups: achondroplasia, Down syndrome and  
101 control. MCA mean and range were respectively: 0.53 cm<sup>2</sup> [0.14;0.68], 0.50 cm<sup>2</sup> [0.35;0.66]  
102 and 0.50 cm<sup>2</sup> [0.43;0.80]. NV mean and range were respectively: 2.75 cm<sup>3</sup> [0.61;5.08], 3.06  
103 cm<sup>3</sup> [1.41;4.97] and 3.60 cm<sup>3</sup> [1.82;6.35]. After matching patients for age and sex, NV was  
104 significantly lower in the achondroplasia group compared to the control group (p= 0.02).  
105 Likewise, MCA was significantly lower in the Down syndrome group compare to control  
106 group (p= 0.02). Results can be found in Table 2.

#### 107 3.5. *Sleep study*

108 In the achondroplasia group, 19 patients underwent a respiratory polygraphy and 5 a  
109 nocturnal gas exchange test. All patients of the Down syndrome group underwent a  
110 respiratory polygraphy. In the control group, 26 patients underwent a respiratory  
111 polygraphy and one a nocturnal gas exchange test. The OSAS was confirmed by respiratory  
112 polygraphy when the OAHl was over 1.5 e.h-1. We excluded cases with associate central  
113 apnea. The OSAS was confirmed in 41.7%, 56.3% and 30% cases, in achondroplasia, Down  
114 syndrome and control group, respectively. OAHl mean and range were respectively 4 e.h-1  
115 [0;49.3], 2 e.h-1 [0;43] and 1.1 e.h-1 [0;19] in achondroplasia, Down syndrome and control  
116 group.

#### 117 3.6. *MCA and NV compared to OAHl*

118 Figure 3 shows the Kendall's tau coefficient between the AR results (MCA and NV) and  
119 the OAHl, for each group. This analysis was only performed in patients with respiratory

120 polygraphy recording, excluding cases of nocturnal gas exchange test. We found a negative  
121 correlation between the NV and the OAHl in achondroplasia group ( $T=-0.37$ ;  $p=0.02$ ). No  
122 other correlation was found.

## 123 **4. Discussion**

### 124 *4.1. Acoustic rhinometry in children*

125 This study confirmed the high feasibility rate of AR in children, AR measurements were  
126 impossible in less than 10% of children. Indeed, this technique is painless, harmless and  
127 requires only a few minutes to be performed. There are too few publications about AR in  
128 healthy children. In 1999 Ho et al. calculated from a database of 183 children a mean MCA at  
129  $0.32 \text{ cm}^2$  [19], and 10 years later Paiva et al. calculated a mean MCA at  $0.24 \text{ cm}^2$  and a  
130 mean NV at  $6.41 \text{ cm}^3$  based on 29 children [20]. Results were different, but those studies  
131 were not comparable because performed in children at different ages, respectively 1 to 11  
132 and 6 to 8 years of age. Furthermore, they chose a different nasal cavity length to us and did  
133 not consider nasal growth. Indeed, the main issue in our study was to take into account  
134 nasal growth by adapting the nasal cavity distance to the age of the child. A previous study  
135 conducted in our department showed a mean MCA between  $0.46$  and  $0.58 \text{ cm}^2$  and a mean  
136 NV between  $2.14$  to  $2.86 \text{ cm}^3$  for pre-school children (age 2 to 5 years) [13], based on a 4 cm  
137 nasal cavity distance (as in the present study) with similar results. Acoustic rhinometry  
138 should be standardized in future pediatric applications. For example, CT scans of healthy  
139 children could be useful to precisely determine nasal cavity growth and distance to help  
140 choose the best age-specific values in AR.

141 Usually in adult AR, topical nasal decongestants are used to avoid the nasal cycle. We  
142 chose not to use these as most of the drugs do not have the marketing authorization for  
143 children. Moreover, the purpose of this study was to report the nasal obstruction's

144 functional role in OSAS. Also, patients underwent sleep study after AR, which was not  
145 compatible with topical nasal decongestant use.

#### 146 4.2. *Acoustic rhinometry and OSAS in achondroplasia*

147 Prevalence of OSAS in the achondroplasia group was 41.7%. The study was conducted in  
148 the achondroplasia national reference center, in which a sleep recording is systematic at  
149 diagnosis, therefore, this percentage is close to the OSAS prevalence in the pediatric  
150 achondroplasia population. In achondroplasia, because of the midface hypoplasia, OSAS is  
151 very common and recurs after adenotonsillectomy in up to 67% of cases [21]. In these cases,  
152 noninvasive ventilation by CPAP is the main treatment but requires patent nasal cavities  
153 [22]. In our study, there was a high proportion of history of turbinoplasty in the  
154 achondroplasia group (29%) compared to other groups. Indeed, turbinoplasty can be  
155 performed to improve nasal patency and therefore treat OSAS and improve CPAP efficacy.

156 In 2016, a study showed that adult patients with OSAS have lower MCA and NV  
157 compared to a healthy control group [23]. Our study demonstrated a significantly smaller NV  
158 in achondroplasia group compared to the control group and a negative correlation between  
159 NV and OAHl in the achondroplasia group: the lower the NV, the higher the OAHl. These  
160 results support the major role of nasal obstruction in the physiopathology of OSAS in  
161 achondroplasia. One patient with achondroplasia underwent turbinectomy during the study  
162 and AR was recorded before and after surgery. The difference was not significant concerning  
163 MCA or NV, but the AR recording was very early after surgery, at 2 months, and nasal  
164 endoscopy revealed persistent nasal scabs. We plan to perform in the near future a  
165 prospective study recording AR before and 6 months after turbinectomy in children with  
166 achondroplasia.

#### 167 4.3. *Acoustic rhinometry and OSAS in Down syndrome*

168 The prevalence of OSAS in the Down syndrome group was 56.3%, and this prevalence in  
169 the literature varies from 31% to 73% [8,24]. MCA were significantly lower in the Down  
170 syndrome group compare to control group. No correlation was found between OAHl and  
171 MCA. Those results demonstrated that nasal cavity anatomy of children with Down  
172 syndrome is different to control children without cranio-facial malformation. Nevertheless,  
173 nasal obstruction seems to play a less important role in Down syndrome OSAS than in  
174 achondroplasia OSAS. Those results are consistent with the known etiopathogenesis of OSAS  
175 in children with Down syndrome, with multiple obstructive sites.

#### 176 4.4. *Critical analysis*

177 Firstly, an experimental acoustic rhinometry device was used in this study; for future  
178 prospective and multi-center studies we would prefer a commercial device to obtain  
179 standardized results. Secondly, all AR measures were recorded in children sitting down and  
180 positional obstruction was not detected. In 2010, Okun et al. recorded children AR in upright  
181 and supine positions, but this method required a high level of compliance (25). Thirdly, our  
182 study's subjects were included while undergoing sleep examination in a tertiary referral  
183 hospital, inducing a selection bias which may have affected our findings. Fourthly, history of  
184 surgery within the groups was heterogenous, and OSAS had multiple causes being only  
185 partially explained by nasal obstruction. Moreover, in the achondroplasia group some  
186 children had turbinoplasty and others did not, leading to a bias. Finally, the study period was  
187 short, and a longer prospective study with more patients of different ages could better  
188 define the correlation between AR, subsequent condition, polygraphy results and benefit of  
189 various therapies.

#### 190 5. **Conclusion**

191 AR is a suitable exam to assess nasal obstruction in children as it can be performed  
192 quickly and without pain. It is a reproducible and easy to learn method. In the future, the  
193 recording technique in children should be standardized. Our findings confirmed the  
194 significance of nasal obstruction in achondroplasia OSAS physiopathology and we found a  
195 correlation between AR measurements and OAH in this group. AR is an interesting tool in  
196 OSAS assessment of children with nasal obstruction, such as children with achondroplasia  
197 when OSAS recurs after adenotonsillectomy.

#### 198 **Conflict of interest**

199 To our knowledge, there is no conflict of interest.

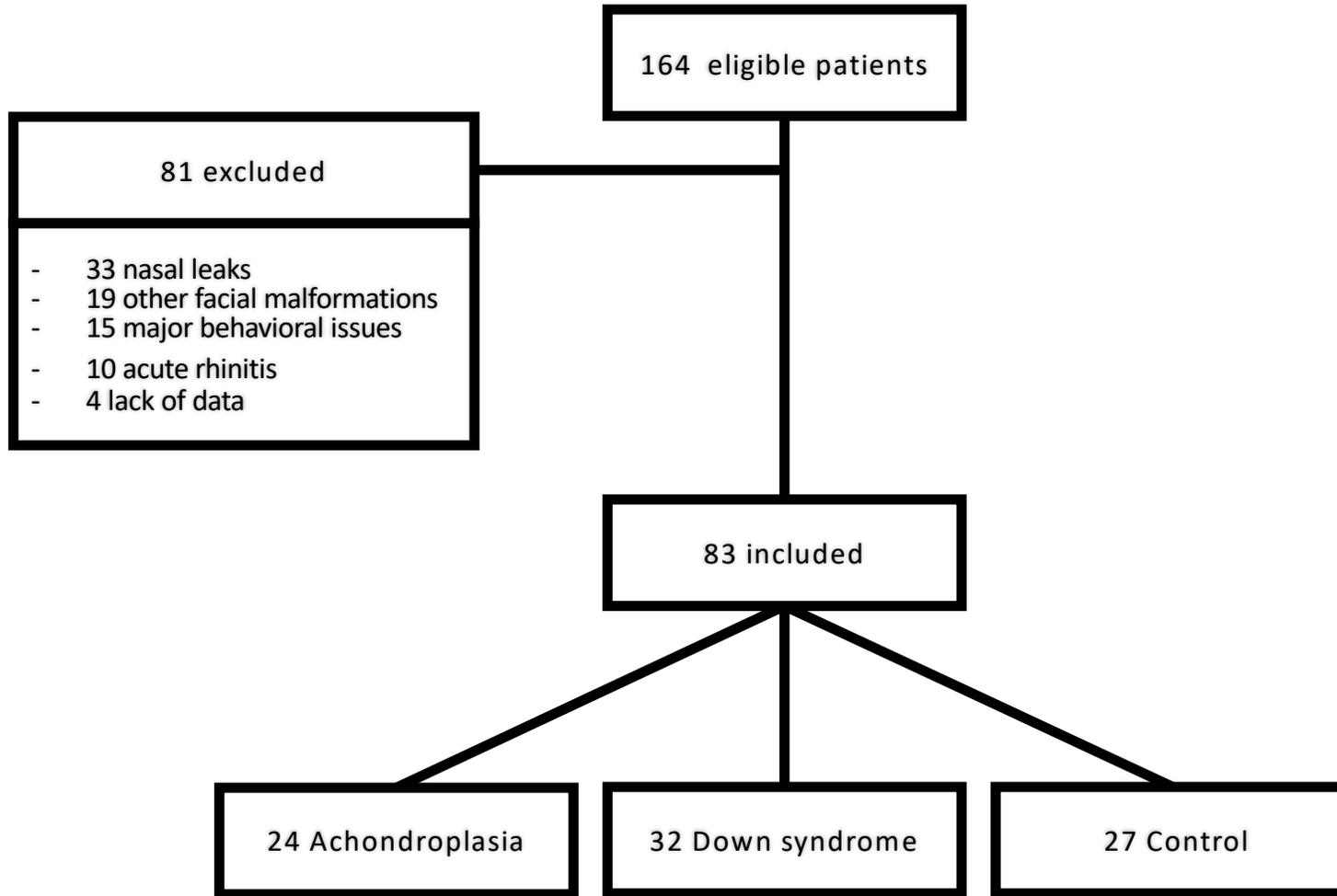
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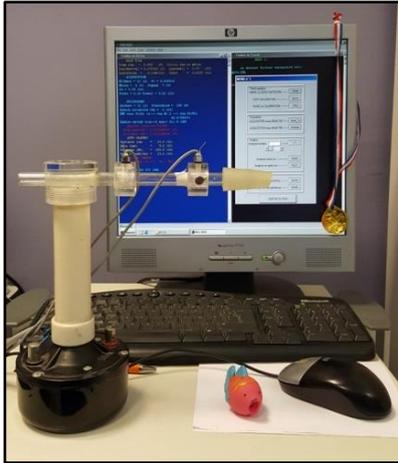
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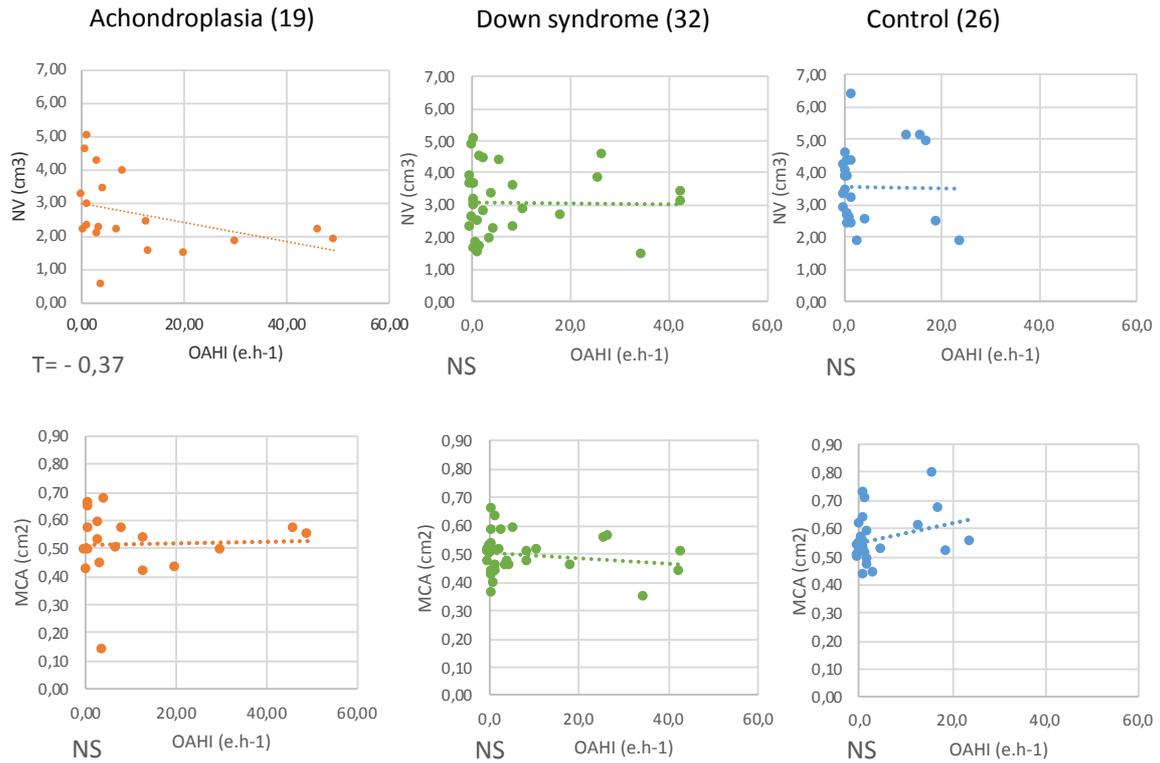
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A: Acoustic rhinometry device. B: Acoustic rhinometry measurement on a child with achondroplasia.



Correlation between acoustic rhinometry results and apnea-hypopnea index, using Kendall's tau coefficient. MCA= minimal cross-sectional area. NV= nasal volume. OAH= obstructive apnea-hypopnea index. T= Kendall's tau coefficient. NS= non-significant result. Those results only concern patients who have undergone a polygraphy.

	<b>Achondroplasia (n=24)</b>	<b>Down syndrome (n=32)</b>	<b>Control (n=27)</b>
<b>Sex</b>			
<b>Male</b>	15 (62.5%)	17 (53.1%)	17 (63%)
<b>Female</b>	9 (37.5%)	15 (46.9%)	10 (37%)
<b>Mean age (years)</b>	3.4 [0.5;18.6]	5.9 [0.6;15.1]	7.3 [0.8;16.6]
<b>Surgical history</b>			
<b>No surgery on upper airway</b>	13 (54.2%)	20 (62.5%)	14 (51.8%)
<b>Palatine tonsillectomy</b>	6 (25 %)	5 (15.6%)	3 (11.1%)
<b>Adenoidectomy</b>	10 (41.7%)	11 (34.4%)	11 (40.7%)
<b>Turbinoplasty</b>	7 (29.2%)	1 (3.1%)	1 (3.7%)
<b>Lingual tonsillectomy</b>	0	0	1 (3.7%)
<b>Mean MCA (cm<sup>2</sup>)</b>	0.53 [0.14;0.68]	0.50 [0.35;0.66]	0.50 [0.43;0.80]
<b>Mean NV (cm<sup>3</sup>)</b>	2.75 [0.61;5.08]	3.06 [1.41;4.97]	3.60 [1.82;6.35]
<b>Mean OSAS<sup>*</sup></b>	10 (41.7%)	18 (56.3%)	8 (30%)
<b>Mean OAHl (events per hour)<sup>*</sup></b>	4 [0;49.3]	2 [0;43]	1.1 [0;19]

MCA= minimal cross-sectional area. NV= nasal volume. OSAS= obstructive sleep apnea syndrome. AHI= apnea-hypopnea index. [ ; ]= ranges.

<sup>\*</sup>Only for patients with a respiratory polygraphy recording.

	Control - Achondroplasia	Control - Down syndrome	Achondroplasia - Down syndrome
<b>MCA</b>			
Test	Paired t-test	Wilcoxon signed-rank test'	Paired t-test
Mean	0.0275		0.0381
CI	[-0.0128;0.0678]		[-0.0901; 0.0138]
p-value	0.17	0.02*	0.14
<b>NV</b>			
Test	Paired t-test	Paired t-test	Paired t-test
Mean	0.4075	0.2226	0.1369
CI	[0.0694 ; 0.7456]	[-0.0913 ; 0.5365]	[-0.471 ; 0.1973]
p-value	0.02*	0.15	0.40

MCA= minimal cross-sectional area. NV= nasal volume. 'We used the Wilcoxon signed-rank test because after matching patients on age and sex, the data distribution was not normal. \*p< 0.05.