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► **To cite this version:**

Robin Baudouin, A. Alali, Stéphane Hans, Marc Bernard Blumen, Frédéric Chabolle. OSAS and upper pharynx surgery: Does basilingual collapsus always rhyme with failure?. *European Annals of Otorhinolaryngology, Head and Neck Diseases*, 2021, 138 (3), pp.135-139. 10.1016/j.anorl.2020.07.004 . hal-03230880

HAL Id: hal-03230880

<https://hal.science/hal-03230880>

Submitted on 24 May 2023

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OSAS and upper pharynx surgery: does basilingual collapsus always rhyme with failure?

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ABSTRACT

Objective: Drug-induced-sedation endoscopy (DISE) has proved superior to awake clinical examination for diagnosis of upper-airway obstruction sites and surgical planning. Our question is: does multilevel obstruction on DISE systematically entail failure for surgery limited to the upper pharynx?

Material & Methods: We conducted a retrospective single-center study in patients with obstructive sleep apnea syndrome (OSAS) treated by single-level surgery of the upper pharynx (tonsillectomy with or without pharyngoplasty). Preoperative assessment included polysomnography (PSG) and DISE. Surgical efficacy was assessed on postoperative PSG. Treatment response was defined by postoperative apnea-hypopnea index (AHI) <20 events/h with 50% reduction, and cure by AHI <10 (patients with preoperative AHI ≤ 10 being excluded). Efficacy was compared between groups without (group A) and with basilingual or laryngeal collapsus on DISE (group B).

Results: We analyzed 63 patients, with mean preoperative AHI 33.8 ± 17.9 events/h. The two groups (A, $n=36$; B, $n=27$) were clinically comparable. The success rate was 66.7% in group A (mean reduction in AHI, $57.3 \pm 36.2\%$) and 59.3% in group B (mean reduction, $53.9 \pm 39.2\%$). Cure rates were respectively 48.5% and 48.1%. There was no statistically significant difference between the two groups ($p > 0.1$).

Conclusions: Oropharyngeal surgery can alleviate associated obstructive sites found on DISE in the lower pharynx, and step-by-step treatment shows efficacy equal to that of single-step multilevel surgery.

Key-words: Obstructive sleep apnea; Tonsillectomy; Pharyngoplasty; Upper-airway surgery.

INTRODUCTION

Drug-induced-sedation endoscopy (DISE) is effective and reliable in diagnosing upper-airway obstruction sites causing obstructive sleep apnea syndrome (OSAS). Superiority to awake clinical examination has been demonstrated [1].

Dynamic study of upper-airway obstruction sites has become more precise, enabling personalized surgery. However, interpretation of the endoscopic imaging remains a subject of discussion.

Two attitudes prevail: a multi-site strategy seems logical, simultaneously treating all observed obstructions, while a single-site strategy presumes that some obstruction sites are secondary to others and that single-site treatment can beneficially impact other sites. Indications follow the joint guidelines of the French Sleep Research and Medicine Society (SFRMS), French Society of ENT (SFORL) and French-Language Society of Pneumology (SPLF) [2] and the present state of knowledge.

Hsu *et al.* reported equivalent AHI decrease and response rate between 11 patients with complete basilingual obstruction on DISE and 19 without, all undergoing palatopharyngoplasty [3]. They considered certain obstructions on DISE to be secondary, improved by sequential surgery restricted to the velopharyngeal site. The same hypothesis emerges from the study by Victores *et al.*, where a nasopharyngeal tube significantly reduced lateral obstruction seen on DISE in the pharynx (by 86%), epiglottis (by 55%) and tongue-base (by 50%) [4].

The present study focused on surgery for sleep respiratory disorder in everyday practice, addressing the following question: does tongue-base obstruction on the VOTE criteria [5] on DISE (by Propofol [6]) systematically entail failure of surgery limited to the velopharyngeal level?

PATIENTS AND METHODS

A single-center retrospective study included OSAS patients undergoing oropharyngeal surgery (tonsillectomy with or without palatopharyngoplasty).

Inclusion criteria comprised: age ≥ 18 years, OSAS diagnosed on French Health Authority criteria, implementation of DISE, and oropharyngeal surgical treatment.

Exclusion criteria comprised: acute or chronic respiratory, cardiovascular or neuromuscular pathology independent of OSAS, multilevel surgery in the upper airway (basiglossectomy, tongue-base tonsillectomy, hyoid bone suspension, 12th cranial nerve stimulator implantation) or bone foundations (bimaxillary advancement, apophysis geni advancement), or untreated nasal respiratory disorder. Patients failing to undergo postoperative polysomnography (PSG) were considered lost to follow-up.

Preoperative work-up included awake clinical examination by an ENT sleep specialist, with flexible endoscopy, recording symptoms and body-mass index (BMI), and the Epworth self-administered questionnaire. Type 2 or 3 PSG was required for OSAS diagnosis, and was repeated in case of excessive interval since last PSG, significant weight-change or other event found on interview liable to affect sleep respiration. Apnea and hypopnea episodes were recorded on the 2012 American Academy of Sleep Medicine criteria. Systematic DISE was

performed in theater following the department's protocol, with incremental continuous Propofol perfusion. Interpretation used the VOTE classification (Velum, Oropharynx (i.e., palatine tonsils and lateral pharyngeal walls), Tongue base, Epiglottis). Retrobasilingual obstruction was diagnosed if the glottic plane was masked by more than 50%, and considered moderate for 50-75% and complete for >75% masking. Velar obstruction was considered complete for $\geq 75\%$ and partial for <75% stenosis. Endoscopy results were recorded at end of examination: i.e., ahead of and blind to surgery.

Surgery was indicated on DISE by the ENT sleep specialist, after refusal or failure of continuous positive airway pressure (CPAP) ventilation and/or mandibular advancement orthosis for severe OSAS (AHI ≥ 30), or as first-line alternative for mild-to-moderate OSAS (AHI 5-30). Tonsillectomy was proposed whatever the severity of OSAS in case of severe tonsillar hypertrophy (Friedman grade III or IV). Indications for palatopharyngoplasty were at the surgeon's discretion.

All surgeries were oropharyngeal. Tonsillectomy was by extra-capsular cold-instrument dissection conserving the posterior and anterior pillars; no closure of the fossa was performed. No simple velectomy was associated. Any associated palatopharyngoplasty was according to our department's habits. After tonsillectomy, full-thickness sectioning of the palatopharyngeal muscle was performed in the superior third, sparing the mucosa; the inferior part was isolated from the mucosa for ≥ 1 cm and sutured laterally and superiorly to the palatoglossal muscle to allow lateral and anteroposterior enlargement of the pharynx. Any nasal respiration surgery (septoplasty, turbinoplasty, adenoidectomy) was performed in the same step.

Surgical efficacy was assessed on PSG at >3 months. One patient was classified as responder, with AHI <20 for $\geq 50\%$ reduction. One was classified as cured, with AHI <10, patients with preoperative AHI ≤ 10 being excluded. Efficacy against OSAS was compared between groups without (group A) and with basilingual or laryngeal collapsus (group B) on DISE.

The Mann-Whitney was used to compare physical and PSG characteristics, and the Fisher exact test for response and cure rates. The significance threshold was set at $p \leq 0.05$.

RESULTS

Between November 2007 and July 2017, 63 patients were included, with mean AHI 33.8 ± 179 events/h. Thirty-two (50.8%) had severe, 24 (38.1%) moderate and 7 (11.1%) mild OSAS.

Palatine tonsillectomy was performed in 61 patients (96.8%), including 40 (63.5%) with associated palatopharyngoplasty, and 21 (33.3%) with isolated tonsillectomy; 2 patients (32%) had isolated palatopharyngoplasty. Nasal surgery was associated in 8 cases, with 2 septoplasties, 7 inferior turbinoplasties, and 2 adenoidectomies.

Thirty-six patients (57.1%) showed no associated retrobasilingual obstruction (group A). Twenty-seven (42.9%) showed low-airway obstruction (group B): 4 with total (14.8%) and 15 with partial (55.6%) basilingual obstruction and 8 (29.6%) with epiglottic tilt. Low-airway obstacles were isolated in 21 patients (87.8%), and comprised associated basilingual collapsus and epiglottic tilt in 6 (22.2%).

Groups were comparable on preoperative data (Table 1). Six patients in each group showed concentric velar palate collapsus. Surgeries in Group A comprised palatine tonsillectomy (n=15, 41.7%), tonsillectomy+palatopharyngoplasty (n=20, 55.6%) and isolated velopharyngoplasty (n=1, 2.8%), and in Group B palatine tonsillectomy (n=5, 18.5%), tonsillectomy+palatopharyngoplasty (n=21, 77.8%) and isolated palatopharyngoplasty (n=1, 3.7%).

Pre- and post-operative data are compared between groups in Table 2.

The postoperative sleep examination took place at a mean 8.5 ± 11.5 months.

Response rate was 66.7% in Group A, with mean drop in AHI of $57.3 \pm 36.2\%$, and 59.3% in Group B, with $53.9 \pm 39.2\%$. Cure rates were respectively 48.5% and 48.1%. There were no significant intergroup differences ($p > 0.1$) (Table 3). Results were similar according to severity (Table 3). Two of the 4 patients with complete basilingual obstruction were cured and 3 responded, with mean drop in AHI of $65.2 \pm 27.6\%$.

Twelve patients (6 in each group) showed concentric velar palate obstruction, with poorer results for uvulopalatopharyngoplasty (UPPP). Five of these were responders in Group A, and 2 in Group B.

Twelve patients in group B showed complete velar obstruction, with 5 cures (41.7%) and 7 responses (58.3%) with AHI drop of $52.2 \pm 36.3\%$. Five patients showed partial velar obstruction, with no cures and 1 response (20.0%) with AHI drop of $21.0 \pm 48.0\%$. There were no significant intergroup differences.

DISCUSSION

DISE findings of multilevel obstruction are not infallibly predictive of failure of surgery restricted to the oropharynx or velar palate.

Even so, multiple and especially retrobasilingual obstruction is frequent, and appears logically to be a risk factor for failure of limited surgery [7]. The literature is largely retrospective, but lower obstructions are reported in most cases after failure of velar or oropharyngeal surgery [8]. Preoperative findings of multilevel obstruction may lead to over-treatment by multisite surgery, incurring greater iatrogenic risk for only slight efficacy at tongue-base level [9], or, in contrast, to mistaken abstention from any surgery.

Surgery is one of the three classical attitudes in OSAS, alongside CPAP and mandibular advancement, but is the only one that is not dependent on patient compliance. Efficacy is poorer than for CPAP, but improvement and cure are possible in selected cases [10]. The issue is thus to refine phenotypic diagnosis of obstructive sleep disorder so as to be able to predict the outcome of the chosen surgical option.

DISE is the gold-standard for analysis of airway obstruction. It consists in reproducing sleep disorder within a medical environment, enabling precise diagnosis of obstruction levels. It takes account of sedation impact on muscle tonus and the impact of decubitus on OSAS episode onset [11]. It has been shown to be superior to wake clinical examination, significantly affecting indications for surgery [12]; notably, it is more effective in diagnosing velar and especially retrobasilingual obstruction [1] [13]. However, do findings of low

pharyngeal obstruction on DISE in a patient in whom velum or pharynx surgery is indicated preclude implementing velotonsillar surgery?

Although DISE is an effective and reliable diagnostic tool, certain limitations have to be borne in mind. There is no consensus on practical implementation. Sedation can use Midazolam or Propofol, and these differ in their action, notably on muscle tonus, and in their perfusion concentrations, which moreover are not consensually defined. Secondly, there are no guidelines for examination time, despite this being a crucial parameter for the detection of obstruction sites: too short an examination risks overlooking some site, while too long an examination risks false-positives due to cumulative sedative concentration [14]. Thus, no particular sedation level has been set as limit or as target, although it would seem that the deeper the sedation the lower the tonus and the more likely DISE is to reveal multiple severe obstacles at different retrobasilingual levels, which are in fact false-positives biasing treatment planning [15]. Thirdly, numerous read-out and interpretation grids are available, for none of which is there consensus.

A mistaken indication for tongue-base surgery or mistaken abstention from limited surgery on an obvious obstacle are the scylla and charybdis to be avoided in managing multiple obstruction. The present failure rates of 33.3% in Group A and 40.7% in Group B (non-significant difference) may not be due simply to retrobasilingual obstruction seen on preoperative DISE. Concentric velar collapsus is also a risk factor for failure of velotonsillar surgery [16], which was, however, neutralized in the present series by identical incidence (n=6) in either group. Other factors for success/failure need to be screened for.

In point of fact, retrobasilingual pharyngeal obstruction during sleep, if associated with velar or oropharyngeal obstruction accessible to surgery, can be alleviated by surgery limited to the upper pharynx. Hsu *et al.* reported equal efficacy of palatopharyngoplasty in reducing AHI between one group of patients with associated retrobasilingual obstruction and another without [3]. Kwon *et al.* reported no significant difference in efficacy (44.4% vs 40.7%) between patients with (n=27) and without (n=27) epiglottic obstruction undergoing multilevel upper-airway surgery without laryngeal procedure [17]. Victores *et al.*, in a prospective study, found alleviation of retrobasilingual obstruction in 50% of 41 patients using a nasopharyngeal tube that eliminated upper pharyngeal obstruction. Results were especially clear in case of complete velar collapsus, while the tube did not significantly improve lower sites in case of partial velar collapsus, where the retrobasilingual obstruction seemed independent of higher-level obstruction and to be unaffected by velopharyngeal surgery [4]. The present study confirmed this to the extent of a statistical trend, but was not able to demonstrate significant effects: in Group B (with retrobasilingual obstruction), rates of cure, response and AHI reduction were non-significantly lower in partial versus complete velar obstruction.

Physically, it is understandable that treating a higher level site might improve retrobasilingual obstruction. The physiology of OSAS can be seen in terms of a Sterling resistance model associating a fluid (air) flowing under negative pressure (inspiration) in a collapsible tube (upper-airway collapsibility varying with neuromuscular tonus, varying in turn with depth of sleep, the specific elastic properties of each part of the airway, decubitus, and fatty or aqueous tissue infiltration) with weak zones (tongue base, epiglottis, lateral pharyngeal walls) and anatomic stenoses (palatine or lingual tonsillar hypertrophy, macroglossia) (<tel-00012061> Institut National Polytechnique de Grenoble - INPG, 2005). Airway freedom is ensured by a balance between inspiration pressure and anti-collapsus factors [18]. The narrower the

upstream airway (nose, oropharynx), the greater the negative pressure of inspiration (Venturi effect) and the risk of it inducing downstream (tongue-base) collapsus. Upstream widening by velar or oropharyngeal surgery lowers the negative pressure on the airway and can resolve a retrobasilingual obstruction revealed only at high negative pressure. It is thus a mistake to systematically rule out surgery limited to an obvious velar or oropharyngeal obstacle on the grounds that some lower obstruction would compromise efficacy.

CPAP and mandibular advancement are effective treatments for OSAS, but presuppose constant compliance by the patient [19], whence the advantage of surgery [20]. The issue in phenotypic diagnosis is to determine optimal individual medical or surgical treatment according to morphology [21]. DISE improves OSAS diagnosis and treatment by refining the indications for surgery, but its limitations have to be borne in mind, and prediction of surgical efficacy from endoscopic data must be made with caution [22].

CONCLUSION

Surgery restricted to the velum or oropharynx can alleviate collapsus in retrobasilingual obstruction sites. Surgical improvement of upper pharyngeal ventilation reduces the inspirational negative pressure underlying retrobasilingual collapsus. Retrobasilingual obstruction on DISE is not an infallible predictor of failure of surgery limited to the upper pharynx. Interpretation should take into account all the obstruction sites observed and the patient's morphology. The aim is to achieve reliable prediction of which medical or surgical treatment will be most effective for the individual patient. Retrobasilingual obstruction on DISE should not rule out surgery on easily accessible upper pharyngeal sites nor, on the contrary, indicate excessive multisite surgery involving the tongue base and larynx.

Disclosure of interest: the authors have no conflicts of interest to disclose.

TABLE 1. Preoperative patient data by group

	Group A Without lower airway obstruction <i>n</i> =36	Group B With lower airway obstruction <i>n</i> =27	<i>P</i>
Physical examination			
age (years)	40.4 ± 10.1	40.7 ± 10.9	
BMI (k/m ²)	27.0 ± 3.6	27.3 ± 4.1	NS
Epworth	12.0 ± 4.4	9.7 ± 4.8	
Friedman grade			
III	17 (47.2)	13 (48.1%)	
IV	12 (33.3%)	5 (18.5%)	NS
Polysomnography			
SaO ₂ min(%)	80.7 ± 8.8	81.4 ± 6.8	
AHI(h)	33.1 ± 20.1	33.1 ± 15.2	NS
Severity			
Mild	7 (19.4%)	3 (11.1%)	
Moderate	13 (36.1%)	9 (33.3%)	NS
Severe	16 (44.4%)	15 (55.6%)	

BMI: body-mass index; AHI: apnea-hypopnea index; h: hour of sleep

TABLE 2.
Pre- to post-operative comparison, by group.

Group A Without lower airway obstruction <i>n</i> =36	Preoperative	Postoperative	<i>P</i>
Physical examination			
BMI (k/m ²)	27.0 ± 3.6	26.8 ± 3.5	NS
Epworth	12.0 ± 4.4	8.8 ± 4.2	NS
Polysomnography			
SaO ₂ min (%)	80.7 ± 8.8	86.5 ± 4.8	NS
AHI (/h)	33.1 ± 20.1	12.5 ± 11.2	<0.05
Group B With lower airway obstruction <i>n</i> =27	Preoperative	Postoperative	<i>P</i>
Physical examination			
BMI (k/m ²)	27.3 ± 4.1	26.3 ± 4.1	NS
Epworth	9.7 ± 4.8	8.2 ± 5.4	NS
Polysomnography			
SaO ₂ min (%)	81.4 ± 6.8	85.9 ± 4.8	NS
AHI (/h)	33.1 ± 15.2	12.6 ± 9.4	<0.05

BMI: body-mass index; AHI: apnea-hypopnea index; h: hour of sleep

TABLE 3.

Endpoint results.

	Group A	Group B	<i>P</i>
	Without lower airway obstruction <i>n</i> =36	With lower airway obstruction <i>n</i> =27	
AHI decrease			
/h	20.6 ± 18.6	20.9 ± 18.9	NS
%	57.3 ± 36.3	53.9 ± 39.2	NS
Response rate (S20)	24 (66.7%)	16 (59.3%)	NS
Cure rate	16* (48.5%)	13 (48.1%)	NS
Non-response rate	12 (33.3%)	11 (40.7%)	NS
Mild to moderate	<i>n</i> =20	<i>n</i> =12	
AHI decrease (/h)	10.1 ± 10.5	10.1 ± 12.1	NS
AHI decrease (%)	50.9 ± 43.0	42.1 ± 41.6	NS
Response	13 (65%)	6/12 (50.0%)	
Cure	10** (58.8%)	5/12 (41.7%)	
Non-response	7 (35%)	6 (50.0%)	
Severe	<i>n</i> =16	<i>n</i> =15	
AHI decrease (/h)	33.8 ± 18.2	29.6 ± 19.1	NS
AHI decrease (%)	65.2 ± 24.2	63.4 ± 35.1	

Response	11 (68.8%)	11 (73.3%)
Cure	6 (37.5%)	7 (46.7%)
Non-response	5 (31.2%)	4 (26.7%)

* n=33 (3 patients with preoperative AHI < 10 /h).

** n=17 (3 patients with preoperative AHI < 10 /h in group A).

AHI: apnea-hypopnea index; h: hour of sleep

REFERENCES

1. Zerpa Zerpa V, Carrasco Llatas M, Agostini Porras G, Dalmau Galofre J. Drug-induced sedation endoscopy versus clinical exploration for the diagnosis of severe upper airway obstruction in OSAHS patients. *Sleep Breath* 2015;19:1367-72.
2. Recommandations pour la Pratique Clinique. *Rev Mal Respir* 2010;27:806-33.
3. Hsu Y-S, Jacobowitz O. Does Sleep Endoscopy Staging Pattern Correlate With Outcome of Advanced Palatopharyngoplasty for Moderate to Severe Obstructive Sleep Apnea? *J Clin Sleep Med* 2017;13:1137-44.
4. Victores AJ, Olson K, Takashima M. Interventional Drug-Induced Sleep Endoscopy: A Novel Technique to Guide Surgical Planning for Obstructive Sleep Apnea. *J Clin Sleep Med* 2017;13:169-74.
5. Kezirian EJ, Hohenhorst W, de Vries N. Drug-induced sleep endoscopy: the VOTE classification. *Eur Arch Oto-Rhino-Laryngol* 2011;268:1233-6.
6. Blumen M, Bequignon E, Chabolle F. Drug-induced sleep endoscopy: A new gold standard for evaluating OSAS? Part I: Technique. *Eur Ann Otorhinolaryngol Head Neck Dis* 2017;134:101-7.
7. Lin H-C, Friedman M, Chang H-W, Gurpinar B. The Efficacy of Multilevel Surgery of the Upper Airway in Adults With Obstructive Sleep Apnea/Hypopnea Syndrome. *The Laryngoscope* 2008;118:902-8.
8. Kezirian EJ. Nonresponders to pharyngeal surgery for obstructive sleep apnea: Insights from drug-induced sleep endoscopy. *The Laryngoscope* 2011;121:1320-6.
9. Blumen M, Crampette L, Fischler M, Galet de Santerre O, Jaber S, Larzul J-J, et al. Surgical treatment of obstructive sleep apnea syndrome. *Rev Mal Respir* 2010;27:157-165.
10. Verse T, Hörmann K. The surgical treatment of sleep-related upper airway obstruction. *Dtsch Arzteblatt Int* 2011;108:216-21.
11. Kotecha B, De Vito A. Drug induced sleep endoscopy: its role in evaluation of the upper airway obstruction and patient selection for surgical and non-surgical treatment. *J Thorac Dis* 2018;10:S40-7.
12. Eichler C, Sommer JU, Stuck BA, Hörmann K, Maurer JT. Does drug-induced sleep endoscopy change the treatment concept of patients with snoring and obstructive sleep apnea? *Sleep Breath* 2013;17:63-8.

13. Blumen M, Bequignon E, Chabolle F. Drug-induced sleep endoscopy: A new gold standard for evaluating OSAS? Part II: Results. *Eur Ann Otorhinolaryngol Head Neck Dis* 2017;134:109-15.
14. Heo SJ, Park CM, Kim JS. Time-dependent changes in the 2732 obstruction pattern during drug-induced sleep endoscopy. *Am J Otolaryngol* 2014;35:42–47.
15. Hong SD, Dhong H-J, Kim HY, Sohn JH, Jung YG, Chung S-K, et al. Change of obstruction level during drug-induced sleep endoscopy according to sedation depth in obstructive sleep apnea: Change of DISE According to Sedation Depth. *The Laryngoscope* 2013;123:2896-9.
16. Iwanaga K, Hasegawa K, Shibata N, Kawakatsu K, Akita Y, Suzuki K, et al. Endoscopic examination of obstructive sleep apnea syndrome patients during drug-induced sleep. *Acta Oto-Laryngol Suppl* 2003:36-40.
17. Kwon OE, Jung SY, Al-Dilajjan K, Min JY, Lee KH, Kim SW. Is epiglottis surgery necessary for obstructive sleep apnea patients with epiglottis obstruction? *The Laryngoscope* 2019.
18. Isono S, Feroah TR, Hajduk EA, Brant R, Whitelaw WA, Remmers JE. Interaction of cross-sectional area, driving pressure, and airflow of passive velopharynx. *J Appl Physiol* (1985) 1997;83:851-9.
19. Bizieux-Thaminy A, Gagnadoux F, Binquet C, Meslier N, Person C, Racineux JL. Long term use of nCPAP therapy in sleep apnoea patients. *Rev Mal Respir.* 2005;22:951-7.
20. Rotenberg BW, Vicini C, Pang EB, Pang KP. Reconsidering first-line treatment for obstructive sleep apnea: a systematic review of the literature. *J Otolaryngol - Head Neck Surg* 2016;45.
21. Eckert DJ. Phenotypic approaches to obstructive sleep apnoea - New pathways for targeted therapy. *Sleep Med Rev* 2018;37:45-59.
22. Blumen MB, Latournerie V, Bequignon E, Guillere L, Chabolle F. Are the obstruction sites visualized on drug-induced sleep endoscopy reliable? *Sleep Breath* 2015;19:1021-6.