Comparing upper airway awake exploration, drug-induced sleep endoscopy and natural sleep—a systematic review

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Background: The optimal exploration of a patient suffering from obstructive sleep apnea (OSA) should be performed during natural sleep. Nevertheless, this is not feasible in everyday clinical practice, therefore, OSA patients are explored awake and during drug-induced sleep endoscopy (DISE). Maneuvers performed in the awake exploration cannot represent what occurs during natural sleep due to the reduced pharyngeal muscle tone, regardless, there are doubts regarding the validity of DISE. The goal of this paper is to compare natural sleep and DISE and to find out whether DISE provides additional information to awake exploration.

Methods: A systematic review of the literature comparing DISE, natural sleep, and awake exploration. Thirty-six studies were finally included.

Results: According to the literature review, DISE is comparable to natural sleep when midazolam or propofol with a target-controlled infusion pump is administrated. Articles comparing propofol and dexmedetomidine sedation in the same group of patients at the same level of sedation found that the effect on the upper airway (UA) was similar for both drugs. Although no articles comparing dexmedetomidine and natural sleep have been found, one would assume that it is also a suitable drug for sedation. Regarding awake UA exploration, the results are inconclusive, but the simulated snoring maneuver appears to reflect DISE findings better.

Conclusions: Evidence supports the use of DISE as a tool to explore OSA patients in a similar state to natural sleep, whereas awake exploration has limitations in predicting DISE collapse.

Keywords: Awake endoscopy; drug-induced sleep endoscopy (DISE); Müller’s maneuver; Friedman tongue position (FTP); obstructive sleep apnea (OSA)

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Introduction

Background

Traditionally, the assessment of obstructive sleep apnea (OSA) patients has relied on cervicofacial profiling and awake upper airway (UA) exploration. However, this approach merely allows the observation of static anatomical traits, failing to provide insights into the dynamic behavior of these structures when the UA muscle tone diminishes during sleep. Some authors even contend that only the evaluation of palatine tonsils is reliable in awake UA exploration (1). Many physical traits observed in OSA patients, such as retrognathia, highly arched palates, palatine tonsil hypertrophy, septal deviations, and inferior turbinate hypertrophy, are also present in otherwise healthy individuals without snoring or OSA (2). Additionally, imaging studies using computer tomography (CT) scans and magnetic resonance have revealed disparities in obstructed areas between awake and sleeping OSA patients (3).

Rationale and knowledge gap

To replicate the collapse observed during sleep, various maneuvers, such as the Müller maneuver (MM) and simulated snoring, have been proposed to transform static exploration into a dynamic one. Numerous studies have compared dynamic awake exploration with UA sleep endoscopy, yielding conflicting results (4-12). Although the ideal exploration would occur during natural sleep, it is impractical in daily practice. This limitation was addressed in 1991 when Croft and Pringle first introduced sleep nasendoscopy, now known as drug-induced sleep endoscopy (DISE) (13). DISE offers the opportunity to assess the UA in a pharmacologically induced state simulating natural sleep. The key question is whether this pharmacologically induced sleep state can replicate natural sleep and if conducting endoscopy during this induced sleep state provides additional information compared to awake exploration.

Objective

The objective of this paper is to systematically review the literature comparing DISE with natural sleep, particularly focusing on UA collapse, and to analyze which aspects of awake exploration might correlate with the UA collapse observed in DISE. We present this article in accordance with the PRISMA reporting checklist (available at https://joma.amegroups.com/article/view/10.21037/joma-23-36/rc).

Methods

Data search

Two authors (P.M.R.d.A. & S.M.Q.) independently conducted a search in PubMed/MEDLINE, Cochrane Database, Google Scholar, and Scopus/Embase in December 2023. *Table 1* outlines the search strategies for each database. Additionally, a manual search of the references in selected articles was performed.

Eligibility criteria

This review considered studies conducted in adults with OSA. Papers published in languages other than English or those without available full text were excluded. The search was restricted to studies involving human subjects, and single case reports were excluded.

Results

A total of 877 publications were identified. After removing duplicates, reviewing titles and abstracts, and applying inclusion and exclusion criteria to the full text, 22 articles were selected. An additional 14 articles were added after a manual review of references, resulting in the inclusion of 36 studies in this systematic review. *Figure 1* depicts the flowchart of the procedure, and a summary of the included studies is provided in *Table 2*.

DISE vs. natural sleep

Fifteen studies compared natural sleep with sleep under different drugs, analyzing various parameters of collapse and respiration (14-28). All studies were prospective cohort studies. *Table 3* presents the different parameters studied and their similarities or differences between natural sleep and DISE. Notably, Ordones *et al.* compared target-controlled infusion (TCI)-propofol DISE *vs.* zolpidem-induced sleep (25). Another article suggested that zolpidem, with its short half-life and minimal impact on UA collapsibility, could be comparable to natural sleep (41).

DISE vs. awake exploration

Twenty-one articles attempted to compare awake exploration and DISE, with results being non-uniform and sometimes contradictory. Among these studies, 14 were prospective cohort studies

Table 1 Search strategy for a systematic review of the literature comparing DISE, natural sleep and awake exploration

Database	Terms
PubMed/MEDLINE	("drug induced sleep endoscopy"[Title] OR "sleep-endoscopy"[Title] OR "DISE"[Title] OR "induced sleep"[Title] OR "sedation"[Title]) AND ("awake"[Title] OR "wakefulness"[Title] OR "natural"[Title] OR "nasendoscopy"[Title] OR "clinical examination*"[Title] OR "clinical exploration*"[Title] OR "mallampati"[Title] OR "nocturnal"[Title])
	It also included ("sleep endoscopy"[Title] AND "sedation"[Title])
Cochrane Database	We searched for combinations of the following terms within the title: "Drug induced sleep endoscopy" or "induced sleep" or "sedation" AND "awake" or "wakefulness" or "clinical examination" or "nasendoscopy" or "natural sleep"
Google Scholar	Allintitle: "awake" "drug induced sleep endoscopy" OR "DISE" OR "sleep endoscopy" OR "induced sleep" OR "sedation"
	Allintitle: "wakefulness" "drug induced sleep endoscopy" OR "DISE" OR "sleep endoscopy" OR "induced sleep" OR "sedation"
	Allintitle: "clinical examination" "drug induced sleep endoscopy" OR "DISE" OR "sleep endoscopy" OR "induced sleep" OR "sedation"
	Allintitle: "clinical exploration" "drug induced sleep endoscopy" OR "DISE" OR "sleep endoscopy" OR "induced sleep" OR "sedation"
	Allintitle: "natural sleep" "drug induced sleep endoscopy" OR "DISE" OR "sleep endoscopy" OR "induced sleep" OR "sedation"
Scopus/Embase	('drug induced sleep endoscopy':ti OR 'DISE':ti OR 'sleep endoscopy':ti OR 'induced sleep':ti OR 'sedation':ti) AND ('awake':ti OR 'wakefulness':ti OR 'natural':ti OR 'nocturnal':ti OR 'nasendoscopy':ti OR 'clinical examination':ti OR 'clinical exploration':ti OR 'mallampati':ti)

DISE, drug-induced sleep endoscopy.

(4,6-9,11,12,29,30,32,34,35,38,39), five were retrospective cohort studies (31,33,36,37,40), and two were retrospective case series (5,10). *Table 4* outlines the aspects of awake exploration (both static and dynamic) positively or negatively correlated with DISE collapse.

Discussion

DISE vs. natural sleep

The studies comparing natural sleep with sedation using propofol or midazolam conclude that the UA collapse observed in those situations is similar and therefore DISE represents natural sleep (14,19,21,25,26). There were no differences in the pattern or the degree of collapse at any UA level (25,26), although one study demonstrated a slightly higher degree of obstruction with midazolam (26). This finding might be related to the longer duration of DISE compared to natural sleep (≥20 *vs.* <20 minutes respectively). Abdullah *et al.* reported that midazolam did not cause deeper muscle relaxation compared to natural sleep (14). Propofol administered with a TCI pump also conferred muscle relaxation similar to natural sleep (21). Nevertheless, propofol has a central inhibitory effect on the respiratory muscles and, if administered in higher doses, produces a relaxation of the genioglossus muscle that increases the UA collapsibility (19,42,43). Therefore, it is of the utmost importance to monitor the depth of the sedation and try to avoid propofol in bolus.

Some studies used the critical closing pressure (Pcrit) in order to compare natural sleep and DISE. For instance, Genta *et al.* concluded that the Pcrit during natural sleep was equal to the one during DISE (19). However, Maddison *et al.* observed a higher Pcrit with propofol, although both were linearly correlated (24). This increased collapsibility was likely induced by the depth of sedation. The authors reported reaching bispectral index (BIS) levels lower than 50, whereas the recommended sedation depth in the European position paper for DISE ranges from 80 to 60 (44). It is noted that deeper sedation leads to increased UA collapsibility (45,46).

Civelek *et al.* did not find differences in the titration pressure of continuous positive airway pressure (CPAP)

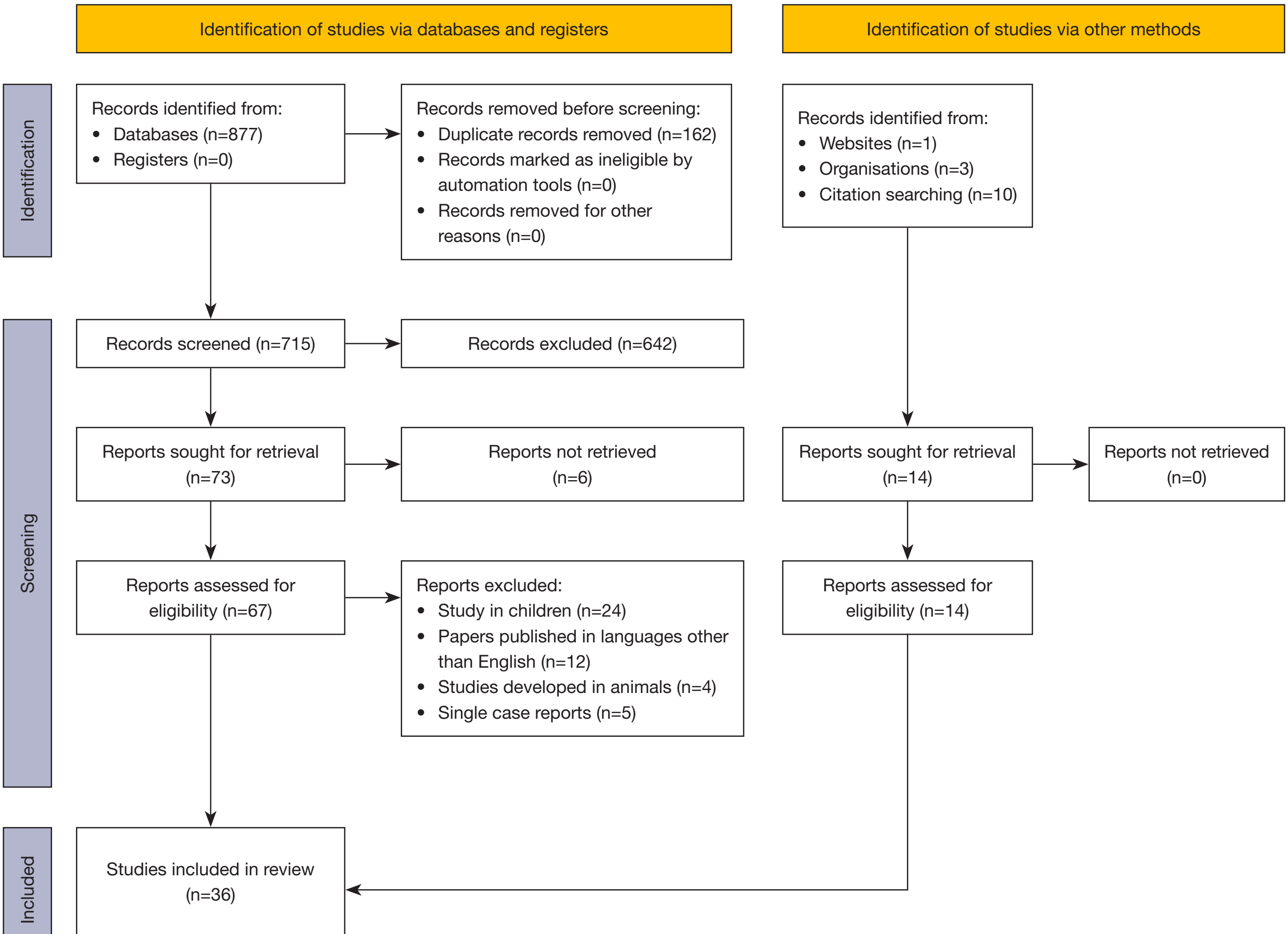

Figure 1 Selection of articles included in the systematic review comparing drug-induced sleep endoscopy with natural sleep and awake exploration.

obtained during conventional polysomnography (PSG) or DISE, reinforcing that both explorations show similar results regarding UA collapse (18).

It is also crucial to determine whether snoring under sedation is comparable to snoring occurring during natural sleep. Despite the administration of high doses of propofol using a TCI pump, Berry *et al.* demonstrated that snoring in control subjects could not be induced. However, it could be triggered in habitual snorers and patients with OSA (17,27). Koo *et al.* did not observe differences in the frequency or intensity of snoring (23). Agrawal *et al.* found a correlation between snoring during DISE and natural sleep, but noted it to be more frequent during DISE (15). Jones *et al.* reported that the intensity of snoring was higher with propofol compared to natural sleep (22).

These differences might be caused by the different tools used to explore snoring (intensity, frequencies, different microphones between the different studies), more studies are needed in this regard.

No studies comparing dexmedetomidine with natural sleep were found in our review of the literature. Nevertheless, it has shown minimal effect in the UA collapse (42). Moreover, the studies that compare propofol and dexmedetomidine UA collapse in the same patients showed similar patterns and degree of collapse with both (47,48).

Concerning respiratory parameters, the majority of the studies did not find differences between natural sleep and sleep induced with different drugs. No distinction was found in minimum (min) O_2 saturation (sat) values with propofol compared to natural sleep (16,20). Similarly, there

Table 2 Characteristics of the studies

Author, year	Type of study	Patients (n)	Study design
Natural sleep *vs.* DISE			
Abdullah *et al.*, 2013 (14)	Prospective cohort study	43	43 OSA patients. BIS & chin EMG during DISE with midazolam bolus was compared with PSG natural sleep
Agrawal *et al.*, 2002 (15)	Prospective cohort study	16	16 snoring patients. Frequency (in Hz) of snoring sounds during DISE with midazolam or propofol *vs.* natural sleep and correlation of the site of snoring in DISE with its sound frequency
Babar-Craig *et al.*, 2012 (16)	Prospective cohort study	30	30 snoring patients undergoing DISE with midazolam and propofol evaluating depth of sedation with BIS monitoring
Berry *et al.*, 2005 (17)	Prospective cohort study	107	53 suspected OSA patients compared with 54 non-snoring patients, evaluating snoring and obstruction in DISE with propofol-TCI pump
Civelek *et al.*, 2012 (18)	Prospective, double-blinded, cohort study	16	16 OSA patients. Conventional CPAP titration compared with CPAP titration with DISE
Genta *et al.*, 2011 (19)	Prospective cohort study	15	15 OSA patients. PSG and Pcrit under midazolam sedation compared with natural sleep
Ghorbani *et al.*, 2020 (20)	Prospective cohort study	38	38 OSA patients. Stage and duration of obstructive events in DISE with propofol *vs.* in PSG
Hoshino *et al.*, 2009 (21)	Prospective cohort study	9	9 non-OSA patients. Respiratory timing and upper airway responses to decreases in nasal pressure under decreased (passive) and increased (active) neuromuscular activity in DISE with propofol
Jones *et al.*, 2006 (22)	Prospective cohort study	20	20 snorers, non-OSA patients. Prediction of surgical outcome with questionnaires, snoring parameters and endoscopic findings during DISE with propofol
Koo *et al.*, 2018 (23)	Prospective cohort study	30	30 OSA patients. Snoring parameters during natural sleep *vs.* DISE and between sites of obstruction in DISE
Maddison *et al.*, 2020 (24)	Prospective cohort study	10	10 non-OSA and OSA patients. Comparison of Pcrit in DISE with propofol *vs.* in normal sleep
Ordones *et al.*, 2020 (25)	Prospective cohort study	21	21 OSA patients. UA collapse compared during nocturnal zolpidem-induced sleep and DISE with propofol
Park *et al.*, 2019 (26)	Prospective cohort study	26	26 OSA or snoring patients. Comparison of obstruction patterns in DISE with midazolam *vs.* natural sleep
Rabelo *et al.*, 2013 (27)	Prospective cohort study	30	24 OSA patients and 6 controls. EEG and respiratory parameters compared in PSG under natural sleep *vs.* DISE with propofol-TCI pump
Sadaoka *et al.*, 1996 (28)	Prospective cohort study	50	50 OSA or snoring patients. Comparison of characteristics of apnea and stages of sleep in nocturnal PSG *vs.* DISE after diazepam
Awake static and/or dynamic exploration *vs.* DISE			
Aktas *et al.*, 2015 (29)	Prospective cohort study	20	20 OSA patients. Correlation of surgical success with awake exploration using MMS, MM and sites of collapse in DISE with propofol
Askar *et al.*, 2020 (8)	Prospective cohort study	81	81 OSA patients. Awake endoscopy with MM during sitting and supine positions, *vs.* DISE findings
Bachar *et al.*, 2008 (30)	Prospective cohort study	55	55 OSA patients. Patterns and sites of the UA collapse in awake exploration with MM *vs.* DISE with midazolam
Bindi *et al.*, 2022 (11)	Prospective cohort study	43	43 OSA patients. Comparison between DISE findings and awake examination using MM

Table 2 (*continued*)

Table 2 (*continued*)

Author, year	Type of study	Patients (n)	Study design
Campanini *et al.*, 2010 (31)	Retrospective cohort study	250	250 OSA patients. Awake exploration using MM *vs.* DISE findings
Cavaliere *et al.*, 2013 (7)	Prospective cohort study	66	66 OSA patients. Awake exploration using MM *vs.* DISE findings
den Herder *et al.*, 2005 (32)	Prospective cohort study	127	127 OSA or snoring patients. Correlation of MMS with obstruction at the tongue base in DISE with midazolam
Eggerstedt *et al.*, 2020 (33)	Retrospective cohort study	99	99 OSA patients. Correlation between awake airway assessments and DISE with propofol
Fernández-Julián *et al.*, 2014 (4)	Blinded prospective cohort study	162	162 OSA patients. Correlation between awake clinical examination, lateral and cephalometry and MM with DISE (propofol TCI pump)
Ibrahim *et al.*, 2014 (34)	Prospective cohort study	50	50 OSA patients. Awake exploration using MM *vs.* DISE findings
Joy *et al.*, 2021 (35)	Prospective cohort study	41	41 OSA patients. Correlation between awake endoscopy and propofol induced DISE per VOTE and Fujita classifications
Kastoer *et al.*, 2018 (36)	Retrospective cohort study	860	860 patients including positional OSA (PP), NPP and non OSA. Comparison of awake characteristics, UA collapse and treatment outcome (MAD and surgery)
Lin *et al.*, 2020 (37)	Retrospective cohort study	55	55 OSA patients. Comparison of awake characteristics (Brodsky classification, MMS, modified Friedman's staging system MM) *vs.* DISE with propofol per VOTE classification
Lovato *et al.*, 2015 (6)	Prospective cohort study	20	20 OSA and snoring patients. Awake exploration using MM, nasal snoring and oral snoring *vs.* DISE findings
Pérez-Martín *et al.*, 2022 (12)	Prospective cohort study	100	100 OSA patients. Correlation of retropalatal and retrolingual obstruction in DISE and awake endoscopy evaluation of MM, Friedman staging and Friedman lingual tonsil hypertrophy grading
Rabelo *et al.*, 2013 (38)	Multicentric prospective cohort study	34	34 OSA patients. Awake exploration using MM *vs.* DISE findings
Soares *et al.*, 2013 (5)	Retrospective case series chart review	53	53 OSA patients. Comparison of clinical examination (MMS) and awake endoscopy MM with DISE findings
Van de Perck *et al.*, 2021 (9)	Prospective cohort study	73	73 OSA patients. Awake endoscopy with tidal breathing and MM *vs.* DISE findings
Wang *et al.*, 2018 (39)	Prospective cohort study	142	142 OSA patients. Correlation between clinical explorations, including MMS and MM, with DISE regarding retrolingual obstruction
Zerpa Zerpa *et al.*, 2015 (10)	Retrospective chart review	138	138 OSA patients. Comparison between awake findings (including MM, MMS, and Friedman staging system) and DISE
Zhao *et al.*, 2020 (40)	Retrospective cohort study	205	205 OSA patients. Assessment of association between FTP on awake exploration and DISE findings

DISE, drug-induced sleep endoscopy; OSA, obstructive sleep apnea; BIS, bispectral index score; EMG, electromyogram; PSG, polysomnography; TCI, target controlled infusion; CPAP, continuous positive airway pressure; Pcrit, passive critical closing pressure; UA, upper airway; EEG, electroencephalogram; MMS, modified Mallampati score; MM, Müller maneuver; VOTE, velum, oropharynx, tongue base and epiglottis; PP, positional; NPP, non-positional; MAD, mandibular advancement device; FTP, Friedman tongue position.

were no variations in min O_2 sat or apnea/hypopnea index (AHI) between midazolam-induced sleep and natural sleep (16,19).

Sadaoka *et al.* compared diazepam to natural sleep, and found no differences in AHI, oxygen desaturation index (ODI), min O_2 sat or mean O_2 sat (28). Only Rabelo *et*

Table 3 Studies supporting differences and similarities between induced sleep and natural sleep

Correlated elements	No differences	Differences
UA collapse	Ordones *et al.*, 2020 (propofol) (25)	Maddison *et al.*, 2020 (propofol)* (24)
	Park *et al.*, 2019 (midazolam) (26)	
	Genta *et al.*, 2011 (midazolam) (19)	
Genioglossus EMG	Abdullah *et al.*, 2013 (midazolam) (14)	–
	Hoshino *et al.*, 2009 (propofol) (21)	
Induced snoring	Rabelo *et al.*, 2013 (propofol) (27)	Jones *et al.*, 2006 (propofol) (22)
	Berry *et al.*, 2005 (propofol) (17)	
Snoring sounds	Koo *et al.*, 2018 (23)	Agrawal *et al.*, 2002 (propofol & midazolam) (15)
SaO_2, AHI, ODI	Babar-Craig *et al.*, 2012 (propofol & midazolam) (16)	Rabelo *et al.*, 2013 (propofol)** (27)
	Genta *et al.*, 2011 (midazolam) (19)	
	Ghorbani *et al.*, 2020 (propofol) (20)	
	Sadaoka *et al.*, 1996 (diazepam) (28)	
CPAP titration	Civelek *et al.*, 2012 (midazolam & propofol) (18)	–

*, sedation levels higher than DISE recommended levels (BIS <50, propofol target controlled infusion pump TCI 3–5.5 µg/mL). **, minimum SaO_2 was statistically significantly lower with propofol, however clinically irrelevant (85.04% *vs.* 88.64%, P<0.01), there were no statistical differences between mean SaO_2 and AHI. UA, upper airway; EMG, electromyography; SaO_2, arterial oxygen saturation; AHI, apnea/hypopnea index; ODI, oxygen desaturation index; CPAP, continuous positive airway pressure; DISE, drug-induced sleep endoscopy; BIS, bispectral index score; TCI, target-controlled infusion.

al. found a statistically lower min O_2 sat with propofol, however this was not clinically relevant (85.04% *vs.* 88.64%, P<0.01). Moreover, the mean O_2 sat and the AHI were not statistically different (27).

UA exploration with no fiberscope vs. DISE

Several authors have discovered that the Friedman tongue position (FTP) is associated with retrolingual collapse in DISE (5,39), while others have reported a correlation between a higher FTP and velum collapse rather than retrolingual collapse (33). However, these findings were not corroborated by den Herder *et al.*, Zerpa Zerpa *et al.*, or Aktas *et al.*, who did not identify any relationship between retrolingual collapse and FTP grade, or as it was originally referred to, the modified Mallampati index (MMI) (10,29,32).

FTP and MMI are suggested to assess the space between the soft palate and the tongue base (49,50). The higher the grade, the smaller the retrolingual or retropalatal space. However, these classifications exhibit significant inter-rater variability, making them unreliable (51).

Harvey *et al.* demonstrated that patients with a higher FTP were found to have less space in the entire UA, not just in the retrolingual area (52). A high FTP grade was associated with multilevel collapse by several authors (4,36,37). Additionally, Zhao *et al.* suggested that a high FTP grade may be linked to concentric palatal collapse (40). Patients with a grade IV FTP had an odds ratio (OR) of 4.4 for experiencing a complete circumferential collapse (CCC) after adjusting for age, sex, body mass index (BMI), and tonsil grade. The author explained this phenomenon by the increase in the magnitude of tongue drop, resulting in pharyngeal occupation, antero-posterior central compression, and posterior movement of the lateral margins of the soft palate, constituting a circumferential constriction (40).

Lin *et al.* assessed various UA parameters and found no relationship between FTP and retrolingual collapse; instead, they reported a correlation between the oropharyngeal collapse observed in DISE and higher tonsil grades (37).

These studies present conflicting results, likely attributed to the diverse anatomical characteristics of the sampled populations and the severity of the disease. Moreover, it is crucial to recognize that the UA collapse is not solely governed by anatomical features. Other factors such as loop gain, muscle responsiveness, and arousal threshold play a significant role, as demonstrated by Eckert *et al.*,

Table 4 Studies exploring correlation of DISE outcomes in static exploration and awake dynamic exploration

Correlated elements	Positive evidence (do correlation)	Negative evidence (do not correlation)
DISE outcomes in awake static exploration		
FTP/MMS & retrolingual collapse in DISE	Wang *et al.*, 2018 (39)	den Herder *et al.*, 2005 (32)
	Soares *et al.*, 2013 (5)	Zerpa Zerpa *et al.*, 2015 (10)
	Pérez-Martín *et al.*, 2022 (12)	Aktas *et al.*, 2015 (29)
		Lin *et al.*, 2020 (37)
FTP & velopharyngeal collapse in DISE	Eggerstedt *et al.*, 2020 (33)	NF
Brodsky & oropharyngeal collapse in DISE	Lin *et al.*, 2020 (37)	NF
Lingual tonsil & retrolingual collapse in DISE	Pérez-Martín *et al.*, 2022 (12)	Van de Perck *et al.*, 2021 (9)
Classic preoperative UA assessment of anesthesiology & DISE	NF	Eggerstedt *et al.*, 2020 (33)
New awake UA classification & palatal/oropharyngeal/retrolingual collapse in DISE	Van de Perck *et al.*, 2021 (9)	NF
Adapted Cormack-Lehane & hypopharynx level in DISE	Van de Perck *et al.*, 2021 (9)	NF
Neck circumference & complete palatal collapse in DISE	Van de Perck *et al.*, 2021 (9)	NF
Retropalatal collapse awake *vs.* DISE	NF	Joy *et al.*, 2021 (35)
Hypopharynx collapse awake *vs.* DISE	NF	Joy *et al.*, 2021 (35)
FTP & multilevel collapse in DISE	Fernández-Julián *et al.*, 2014 (4)	NF
	Lin *et al.*, 2020 (37)	
	Kastoer *et al.*, 2018 (36)	
FTP & CCC velum collapse in DISE	Zhao *et al.*, 2020 (40)	NF
DISE outcomes in awake dynamic exploration		
Nose collapse FEMM & DISE	Bindi *et al.*, 2022 (11)	NF
Velopharynx collapse FEMM & DISE	Askar *et al.*, 2020 (8)	Lovato *et al.*, 2015 (6)
	Fernández-Julián *et al.*, 2014 (4)	Cavaliere *et al.*, 2013 (7)
	Soares *et al.*, 2013 (5)	Lin *et al.*, 2020 (37)
		Van de Perck *et al.*, 2021 (9)
		Bachar *et al.*, 2008 (30)
		Ibrahim *et al.*, 2014 (34)
		Rabelo *et al.*, 2013 (38)
		Zerpa Zerpa *et al.*, 2015 (10)
		Aktas *et al.*, 2015 (29)
Oropharynx collapse FEMM & DISE	Lovato *et al.*, 2015 (6)	Campanini *et al.*, 2010 (31)
	Askar *et al.*, 2020 (8)	Ibrahim *et al.*, 2014 (34)
	Bindi *et al.*, 2022 (11)	
	Cavaliere *et al.*, 2013 (7)	
	Van de Perck *et al.*, 2021 (9)	
	Fernández-Julián *et al.*, 2014 (4)	

Table 4 (*continued*)

Table 4 (*continued*)

Correlated elements	Positive evidence (do correlation)	Negative evidence (do not correlation)
Tongue collapse FEMM & DISE	NF	Cavaliere *et al.*, 2013 (7)
		Pérez-Martín *et al.*, 2022 (12)
		Wang *et al.*, 2018 (39)
		Zerpa Zerpa *et al.*, 2015 (10)
		Fernández-Julián *et al.*, 2014 (4)
		Soares *et al.*, 2013 (5)
Hypopharynx collapse FEMM & DISE	Askar *et al.*, 2020 (8)	Lovato *et al.*, 2015 (6)
		Campanini *et al.*, 2010 (31)
		Lin *et al.*, 2020 (37)
		Van de Perck *et al.*, 2021 (9)
		Bachar *et al.*, 2008 (30)
		Bindi *et al.*, 2022 (11)
		Rabelo *et al.*, 2013 (38)
		Fernández-Julián *et al.*, 2014 (4)
Larynx collapse FEMM & DISE	NF	Campanini *et al.*, 2010 (31)
		Bindi *et al.*, 2022 (11)
		Cavaliere *et al.*, 2013 (7)
		Fernández-Julián *et al.*, 2014 (4)
NSE & all levels in DISE	Lovato *et al.*, 2015 (6)	NF
OSE & oropharynx level in DISE	Lovato *et al.*, 2015 (6)	NF
OSE & velopharynx and hypopharynx in DISE	NF	Lovato *et al.*, 2015 (6)

DISE, drug-induced sleep endoscopy; FTP, Friedman tongue position; MMS, modified Mallampati score; NF, not found; UA, upper airway; CCC, complete concentric collapse; FEMM, fiberoptic nasopharyngoscopy with modified Müller Maneuver; NSE, nasal snoring endoscopy; OSE, oral snoring endoscopy.

underscoring the necessity of observing the UA in a state similar to natural sleep to discern the pattern and areas of collapse (53).

Cervical perimeter was found to be associated with CCC in the palate, as reported by Van de Perck *et al.* (9), supporting the correlation of BMI and CCC as identified by Ravesloot and de Vries (54).

Static fiberscopy vs. DISE

In the absence of consensus on how to evaluate the UA spaces and volumes by fiberscopy, Van de Perck *et al.* proposed a new method for awake nasopharyngoscopy. It is based on anatomical features and found compatibility with DISE collapse patterns measured by Kendall's tau correlation coefficient (τ) (9). The palate is assessed by means of three distinct shapes: (I) the "oval shape", (II) the "C-shape", and (III) the "dumbbell shape". Crowding of the oropharynx corresponds to large palatine tonsils or pronounced pharyngeal pillars relative to the UA dimensions. The tongue base position is assessed according to the visibility of the vallecula: (I) completely visible, (II) partially visible, (III) not visible, and (IV) compression of the epiglottis/contact with the posterior pharyngeal wall/posteriorly located tongue. The shape of the epiglottis is described as normal (slightly concave curvature), flat, or curved (including omega-shape). Four endoscopic features during tidal breathing were significantly correlated with

DISE: (I) the position of the soft palate with complete palatal collapse [τ=0.29, 95% confidence interval (CI): 0.07–0.49; P=0.007]; (II) crowding of the oropharynx with oropharyngeal collapse (τ=0.32, 95% CI: 0.04–0.56; P=0.026); (III) a posteriorly located tongue base with complete tongue base collapse (τ=0.32, 95% CI: 0.04–0.60; P=0.046); and (IV) the modified Cormack-Lehane scale with epiglottic collapse (τ=0.45, 95% CI: 0.30–0.58; P<0.001) (9).

The Modified Cormack-Lehane scale was recently adapted for nasopharyngoscopy approach by Torre *et al.* The aim of this adaptation was to improve the assessment of the patterns of hypopharyngeal airway visualization seen during awake flexible laryngoscopy among patients with OSA (55). Indeed, this new classification method for the retropharyngeal-epiglottic aerospace (RPEA) demonstrated correlation with hypopharyngeal collapse during DISE (9).

Other authors, Joy *et al.* for instance, used Fujita classification to compare awake static endoscopic exploration with DISE findings. These authors obtained a high sensibility but very low specificity on awake endoscopic exploration for palatal collapse, and a low sensibility (40%) for hypopharyngeal collapse (35).

Another independent element evaluated was the Friedman lingual tonsil hypertrophy (LTH) grade, but no correlation with retrolingual collapse during DISE was found (9). Similarly, neither did the shape of the epiglottis correlate with epiglottic collapse (9).

Pérez-Martín *et al.* compared retrolingual obstruction in DISE, assessed with VOTE (velum, oropharynx, tongue base and epiglottis) and NOHL (nose, oropharynx, hypopharynx and larynx) classifications, with the one observed in awake endoscopy using Friedman staging and LTH. LTH and Friedman stage on awake exploration were mild predictors of collapse at retrolingual level, showing significant correlation to sleep induced endoscopy in cases with severe retrolingual collapse (12). The lack of uniformity, both in describing anatomical features while awake and in DISE classifications makes it difficult to achieve conclusions in this topic.

Dynamic fiberscopy with maneuvers vs. DISE

MM was first introduced by Sher *et al.* in 1985 to predict surgical success of uvulopalatopharyngoplasty (UPPP) (56). The patient makes an inspiratory effort while the mouth and the nose are closed, creating a negative pharyngeal pressure that would mimic the UA collapse observed during sleep. Nevertheless, there is no clear evidence that this maneuver is able to reproduce this collapse (57,58), and it is also believed that this collapse is dependent of the inspiratory effort of the patient (59).

Campanini *et al.* (31) showed that the collapses during the MM and DISE were not equivalent, specifically at the level of the hypopharynx, where there was 59% of disagreement regarding grade and 49% disagreement when morphology was considered. At the oropharynx, they observed a 32% disagreement in terms of the grade of collapse and a 24% of disagreement on its morphology. These findings are consistent with the ones of Bindi *et al.*, who obtained similar results on their prospective study comparing awake exploration with MM and DISE using NOHL classification. Thus, observing differences at the hypopharynx, where MM underestimates the severity of the collapse detecting less than 50% of the obstructions observed in DISE (41.8% *vs.* 88.3% hypopharyngeal collapse, P=0.000) (11). Fernández-Julián *et al.* also found fair correlation for velum/tonsil (k=0.41–0.60) and poor (k=0.01–0.20) for tongue-base, lateral pharyngeal wall, and epiglottis (4). Aktas *et al.* support these findings given that in their study 30% of patients who were identified as having only upper-airway obstruction according to Muller's maneuver had only obstruction of the lower airway involving the tongue base, epiglottis, or hypopharynx, without upper-airway obstruction (29).

Regarding retrolingual obstruction, awake exploration with MM did not exhibit a significant correlation with DISE in the studies conducted by Pérez-Martín *et al.*, Wang *et al.*, Zerpa Zerpa *et al.*, and Soares *et al.* (10,12,39). Zerpa Zerpa *et al.* also found no correlation between awake exploration with MM and DISE concerning retropalatal obstruction (10). Ibrahim *et al.* reported differences in the grade of collapse at the retropalatal, oropharyngeal, and hypopharyngeal regions, as well as the morphology of the collapse between retropalatal and oropharyngeal areas when comparing awake endoscopic exploration with MM and DISE (34).

Cavaliere *et al.* used the VOTE classification to compare awake endoscopic exploration with MM versus DISE, reporting differences mostly on the severity of the obstruction at the palate and the tongue, but not at the oropharynx. These authors did not observe differences on the morphology of the collapse for any of the areas analyzed (7). Van de Perck *et al.* who only found correlation at the oropharynx (r=0.33, P=0.003), but not at other sites of collapse (9).

Rabelo *et al.* employed Fujita classification, which the authors favored for its simplicity over VOTE or NOHL, to compare awake endoscopic exploration with MM. The study revealed no agreement in the Fujita classification assigned to patients between awake and DISE (Kappa=−0.03) (38).

Lovato *et al.* introduced the simulated snoring maneuver, placing the endoscope through the nose and the mouth. The agreement with DISE was higher when the endoscope was introduced through the nose in all the levels, hypopharynx included (6). Reproducing snore with the endoscope through the mouth was effective in observing oropharyngeal collapse but failed to reproduce the remaining UA collapses. The agreement between the MM and DISE was also reported in this paper obtaining a moderate agreement just for the oropharyngeal collapse, and no agreement for the remaining collapses. Hence, the simulated snoring maneuver involving the passage of the endoscope through the nose could serve as a viable surrogate to replicate the collapse observed in DISE. However, further evidence is required to establish its efficacy with certainty (6).

Recently, Askar *et al.* conducted a comparison between MM performed in the supine position and DISE to replicate conditions similar to natural sleep. The authors reported that supine MM accurately predicts the type of collapse in the velum or hypopharynx (lateral, anteroposterior, or concentric) (8). Unfortunately, this conclusion was based on the similar proportion of observed collapses, without employing statistical tests such as Cohen's Kappa or Kendall's Tau to assess the equivalence of collapses in both situations. It should be noted that despite the comparable proportions of collapse, the observations of collapse in DISE and MM may differ as they could have been conducted on different patients. Additionally, the authors noted a higher proportion of collapse in the hypopharynx during DISE compared to supine MM. These findings align with the argument made by other authors who assert that hypopharyngeal collapse is underestimated with supine MM, even though oropharyngeal collapse is not (9,30,47).

Concerning epiglottic collapse, it can only be observed during DISE and is not likely to be suspected during awake exploration unless there is an anatomical malformation (7,31,60).

In summary, the consensus among most studies is that dynamic awake exploration underestimates the grade of collapse in the UA. This underestimation is attributed to the physiological muscle hypotonia occurring during sleep, which is more pronounced in patients with OSA.

Limitations

The studies included that performed nasal snoring endoscopy (NSE) had relatively small sample sizes, suggesting the possibility that results might differ with larger sample sizes. A recent systematic review of NSE papers indicated that the soft palate was the most frequently reported site of UA collapse during natural sleep endoscopy, followed by the tongue base, lateral walls, and epiglottis, aligning with previous findings during DISE (61). However, further research is needed in this area. It is conceivable that new tools based on flow appearance or sound analysis could provide a reliable understanding of events during natural sleep without requiring NSE or DISE.

The impact of body position on UA collapse is crucial, particularly in positional patients. However, this review did not delve into this aspect extensively, as many centers perform DISE only in the supine position, and information on other body positions was lacking.

Additionally, there is a gap in the literature regarding publications that compare UA findings while awake with airway evaluation during natural sleep. Despite the prevailing view that DISE represents natural sleep, particularly non-rapid eye movement (REM) sleep, there is a dearth of information concerning REM sleep-related collapse.

Conclusions

The gathered evidence supports the utilization of DISE as an exploration method similar to natural sleep. Awake exploration, whether static or dynamic, lacks good agreement with the types of collapse observed in DISE for many patients. Consequently, up to the present time, no exploration method surpasses DISE in effectively observing the UA collapse in patients with OSA, particularly those in need of alternative treatments to standard positive pressure therapies.

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Footnote

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