The Laryngoscope

The Effect of Aging on Drug-Induced Sleep Endoscopy Findings

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Objectives/Hypothesis: To evaluate the correlation of aging and upper airway collapse characteristics observed by drug-induced sleep endoscopy (DISE), and report the observed differences on obstructive sleep apnea (OSA) subjects, older and younger than 60 years.

Study Design: Case series.

Methods: This study analyzed the data of 200 OSA patients who underwent DISE between January 1, 2013 and June 30, 2017. The variables sex, body mass index (BMI), Epworth Sleepiness Scale score, tonsil size, modified Mallampati (MM) classification, apnea-hypopnea index (AHI), oxygen desaturation index (ODI), lowest oxygen saturation, and VOTE (velum, oropharynx, tongue base, epiglottis) classification were compared between two groups: <60 and ≥60 years old.

Results: Older age had significant correlation with higher AHI, ODI, lower O_2 nadir, multisite obstruction, combined upper (palatopharyngeal) + lower (hypopharyngeal) level obstructions, and complete anterior-posterior (AP) velum collapse pattern. Lateral oropharyngeal wall collapse was significantly lower in the older group. Findings remained statistically significant when adjusted for sex, BMI, tonsil size, and MM.

Conclusions: Aging was an independent factor that directly correlated with increased AHI and hypoxemia, multisites, combined levels of obstruction, and complete AP velum collapse pattern. Being older than 60 years had higher of complete AP velum collapse and lower incidence of lateral oropharyngeal wall collapse, regardless of OSA severity and tonsil size.

Key Words: Age, drug-induced sedation endoscopy, sleep endoscopy, obstructive sleep apnea, upper airway.

Level of Evidence: 4

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INTRODUCTION

Obstructive sleep apnea (OSA) is the most common sleep-related breathing disorder in the general population, and its prevalence has been suggested to be a mean of 22% in men and 17% in women based on review of epidemiological studies.[1] Considering the aspect of a global aging population, the impact of OSA in older adults has become relevant.[2] Increased OSA prevalence has been reported in subjects over 60 years old,[3,4] and increased prevalence of 2.2 × per 10 years of age has been described in subjects from 30 to 70 years old.[5] Studies have shown that the prevalence in community-dwelling population subgroups aged 39 to 49, 50 to 59, and 60 to 70 years old increased by 30%, 40%, and 51%, respectively.[4] Increased severity of OSA was also correlated with aging in the over 65-years-old group.[6] Among hospitalized older patients, the prevalence increased from 1.47% in 2006 to 5.01% in 2012 in United States.[7] Older patients are more likely to have comorbid chronic conditions,[8] such as cardiovascular disease[9,10] and chronic obstructive pulmonary disease,[11] which can potentially worsen OSA and heighten overall mortality. OSA has been also described as an independent risk factor for chronic kidney disease,[12] stroke,[13] and is associated with impaired cognitive function[14] and higher risk of dementia[15] in older adults.

Previous studies demonstrated that older subjects were predisposed to severe OSA due to an increasing collapsibility of the upper airway, based on indirect assessment: continuous positive airway pressure (CPAP),[16] nasal mask pressure measurements,[17] acoustic reflection,[18] electroneuromyography,[19] and magnetic resonance imaging (MRI).[20]

To our knowledge, a detailed description about age-related changes in collapse pattern and/or degrees of obstruction in drug-induced sleep endoscopy (DISE) is lacking. DISE is a direct, dynamic, and low cost evaluation,[21] which is useful for identifying obstruction sites and patterns in patients with OSA, and may be useful in directing a surgical plan.[22,23] It has increased in popularity and been utilized worldwide.[24] The objective of

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TABLE I.
Baseline Characteristics Between Groups

Characteristics	OSA <60 Years Old, n = 148	OSA ≥60 Years Old, n = 52	*P* Value
Sex, no. (%)			
Male	122 (82.4%)	41 (78.8%)	
Female	26 (17.6%)	11 (21.2%)	.567*
Age, mean ± SD (no.)	41.2 ± 11.1 (148)	67.7 ± 5.5 (52)	<.0001†
BMI, kg/m^2, mean ± SD (no.)	28 ± 4.8 (148)	27.6 ± 3.6 (52)	.657†
ESS, mean ± SD (no.)	9.8 ± 5.2 (140)	9.5 ± 4.9 (51)	.676‡
Tonsil size, no. (%)			
0	15 (10.1%)	23 (44.2%)	
1	72 (48.6%)	29 (55.8%)	
2	46 (31.1%)	0	
3	13 (8.8%)	0	
4	2 (1.4%)	0	<.0001§
Modified Mallampati, no. (%)			
1	21 (14.2%)	2 (3.8%)	
2	29 (19.6%)	16 (30.8%)	
3	65 (43.9%)	28 (53.8%)	
4	33 (22.3%)	6 (11.5%)	.028§
AHI, events/hr, mean ± SD (no.)	34 ± 20.9 (148)	44.9 ± 20 (52)	.001‡
ODI, events/hr, mean ± SD (no.)	22 ± 22.4 (99)	36.2 ± 15.7 (24)	<.0001‡
LSAT, %, mean ± SD (no.)	84.5 ± 8.1 (147)	80.4 ± 8 (49)	<.0001‡

Values are statistically significant at $P < .05$.
*Pearson χ^2 test.
†Student *t* test.
‡Wilcoxon rank sum test.
§Fisher exact test.
AHI = apnea-hypopnea index; BMI = body mass index; ESS = Epworth Sleepiness Scale; ODI = oxygen desaturation index; OSA = obstructive sleep apnea; LSAT = lowest oxygen saturation; SD = standard deviation.

this study was to evaluate the association between age and upper airway collapse characteristics during sedated endoscopy in patients with OSA.

MATERIALS AND METHODS

Study Design

This study was a retrospective review of 200 OSA patients who underwent DISE at Stanford Sleep Surgery Clinic between January 1, 2013 and June 30, 2017. Patients who underwent upper airway procedures for sleep-disordered breathing including uvulopalatopharyngoplasty, uvulopalatal flap, genial tubercle advancement, tongue base reduction, maxillomandibular advancement, or orthognathic surgeries were excluded. The following variables were extracted from Stanford Hospitals and Clinic REDCap[25] (Research Electronic Data Capture) and EPIC (Epic Systems Corp., Verona, WI) databases: age, sex, body mass index (BMI), Epworth Sleepiness Scale (ESS) score, tonsil size, modified Mallampati (MM), apnea-hypopnea index (AHI), oxygen desaturation index (ODI), lowest oxygen saturation (LSAT), and DISE findings described by VOTE (velum, oropharynx, tongue base, epiglottis) classification.[26] Patients were divided into two groups, younger than 60 years old and 60 years old or older, and baseline characteristics and DISE findings were compared. Meanwhile, the associations between age and the above-mentioned variables were analyzed in all subjects. This project was approved by the institutional review board and hospital research ethics committee of Stanford Hospital and Clinics (protocol 35054).

Sleep Studies

Only patients who underwent an overnight in-laboratory polysomnography or a home sleep test that reported all assessed respiratory and oximetry variables were included. Respiratory variables were scored in accordance to the 2012 guidelines of the American Academy of Sleep Medicine.[27] Apnea was identified when the amplitude of the airflow was decreased by at least 90% for longer than 10 seconds. Hypopnea was identified when there was a 30% reduction in the airflow amplitude for at least 10 seconds, associated with oxygen desaturation ≥3% or an arousal. OSA was classified based on the AHI as follows: mild (≥5 and <15 events/hour), moderate (≥15 and <30 events/hour), or severe (≥30 events/hour). The ODI represented the number of events of oxygen desaturation ≥3% per hour.

DISE Protocol

DISE was performed in the operating room in the supine position. Topical nasal decongestion with the use of oxymetazoline and topical lidocaine gel was applied to the nasal valve area to decrease any discomfort caused by endoscope introduction. Dexmedetomidine was the sedative agent, administered with an intravenous bolus at 1.5 μg/kg over 10 minutes, followed by a maintenance infusion rate of 1.5 μg/kg/hr. An Olympus ear,

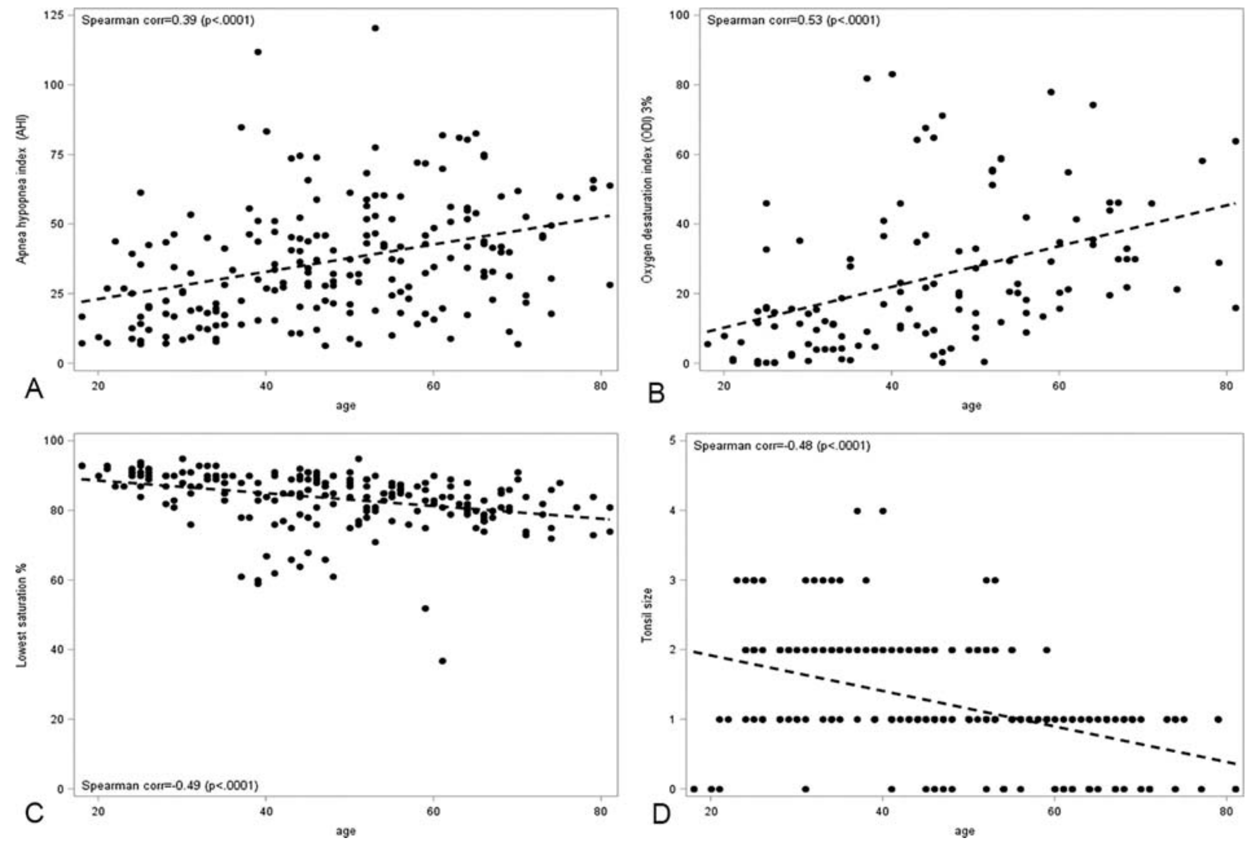

Fig. 1. Correlation between age and AHI, ODI, LSAT, and tonsil size. Age had a significant positive correlation with AHI (A) (corr = 0.39, $P < .001$) and ODI (B) (corr = 0.53, $P < .001$), and a negative correlation with lowest saturation (C) (corr = −0.49, $P < .001$) and tonsil size (D) (corr = −0.48, $P < .001$). Statistically significant at $P < .05$. AHI = apnea-hypopnea index; LSAT = lowest oxygen saturation; ODI = oxygen desaturation index

nose, and throat flexible endoscope, with a 3.2-mm diameter, was inserted into the nose, starting from the nasopharynx to the hypopharynx and larynx. The assessment of the upper airway obstruction during DISE was performed after the first cycle of snoring and obstruction had been completed. The cycle is here defined as a complete and stable sequence of snoring–obstructed breathing, or desaturations. At least two cycles of obstructed breathing were observed for each subsite, as recommended by the European position paper on DISE.[24] Patients were evaluated in the drug-induced sleep state for approximately 15 to 20 minutes. The grade and patterns of upper airway collapse were recorded with the VOTE classification.[26] All evaluations were performed and classified exclusively by a senior and experienced surgeon (R.C).

Statistical Analysis

Continuous variables were summarized with mean ± standard deviation as well as median (interquartile range) due to lack of normality in distribution in some variables (AHI, ODI, LSAT, ESS). Categorical variables were summarized with frequencies and percentages. Continuous variables were compared using the Student *t* test if normally distributed or Wilcoxon rank sum test otherwise. Categorical variables were compared using the Fisher exact test or χ^2 test unless the categories were ordered, in which case a Wilcoxon rank sum test was used. Spearman correlation was analyzed between age and the outcome variables due to lack of normality in distribution. A linear regression model was used to analyze the association between age and AHI, ODI, LSAT, ESS. Various transformations of continuous outcome variables including log transformation were explored through the Box-Cox transformation method. A logistical regression model was used to analyze the association between age and single/multiple obstructive sites, isolated/combined obstructive levels, and non (0) and partial (1)/complete (2) collapse pattern in differential obstructive sites. All the models were presented with no adjustment and with adjustment for gender, BMI, tonsil size, and MM. All the analyses were performed by SAS 9.4 (SAS Institute Inc., Cary, NC). $P < .05$ was considered statistically significant.

RESULTS

The average age was 48.1 years (±15.3; range, 18–81 years). Furthermore, there were 29 subjects in the <30-years-old subgroup, 33 in the 30- to 39-years-old subgroup, 42 in 40- to 49-years old subgroup, 44 in 50- to 59-years old subgroup, and 52 in ≥60-years-old subgroup. BMI, AHI, ODI, and LSAT were, 27.9 kg/m^2 (±4.6), 36.8 events/hr (±21.2), 24.8 events/hr (±21.9), and 83.4% (±8.2), respectively. There were significant differences between the <60-years-old and ≥60-years-old groups in baseline AHI, ODI, LSAT, tonsil size score, and MM score (Table I). No significant differences were found in subjects with severe OSA (AHI ≥ 30) and small tonsils (size = 0, 1, and 2).

Age had a significant positive correlation with AHI and ODI, a negative correlation with LSAT and tonsil

TABLE II.
Association Between Age (Per Year Increase) and Sleep Study Outcomes and Obstruction Levels

Dependent Variables	Unadjusted % Change	*P* Value	Adjusted % Change	*P* Value
AHI	1.7% (1.1%, 2.2%)	<.0001	1.7% (1.1%, 2.3%)	<.0001
ODI	4.6% (3.2%, 6.1%)	<.0001	4.1% (2.6%, 5.6%)	<.0001
LSAT	−0.2% (−0.3%, −0.1%)	<.0001	−0.2% (−0.3%, −0.1%)	<.0001
ESS	−0.2% (−1.1%, 0.8%)	.723	0% (−1.1%, 1.1%)	.988
	Unadjusted OR		Adjusted OR	
Multiple sites	1.08 (1.03, 1.13)	.002	1.07(1.01, 1.12)	.013
Combined levels	1.04 (1.02, 1.07)	.001	1.03 (1.00, 1.06)	.025

Multiple sites, sum of obstructive sites ≥2; combined levels, obstruction occurred in upper level (velum and/or oropharynx), and lower level (tongue base and/or epiglottis). OR adjusted for sex, body mass index, tonsil size, and modified Mallampati. Statistically significant at $P < .05$.

AHI = apnea hypopnea index; ESS = Epworth Sleepiness Scale; LSAT = lowest oxygen saturation; ODI = oxygen desaturation index; OR = odds ratio.

size (Fig. 1), and no correlation with BMI, ESS, or MM ($P > .05$). Increase in age had significant association with observed collapse in multiple sites and combined obstruction levels in unadjusted and adjusted linear regression model and logistic regression models, respectively (Table II). No significant association was found between age and ESS.

Only 6.5% of the patients presented a single site of obstruction, and the remaining presented obstruction in multiple sites: two sites (29%), three sites (48.5%), and four sites (15.5%). Figure 2 shows that there was no significant difference in number of obstruction sites between the ≥60-years-old and <60-years-old groups; however, combined upper and lower levels obstruction in the ≥60-years-old group was significantly higher than <60-years-old group.

As shown in Table III, increase in age had a significant association with velum complete anterior-posterior (AP) collapse and complete tongue collapse. After adjusting for sex, BMI, tonsil size, and MM, complete tongue collapse lost significance.

The collapse pattern and degree according to the VOTE classification in both groups is shown in Table IV. The proportion of velum complete AP collapse was higher (69.2%), and oropharynx complete lateral collapse was lower (23.1%) in the ≥ 60-years-old group (39.2% and 41.2%, respectively) (Table V), despite significant difference in baseline characteristics between the two groups. Nevertheless, there was still significance (65.9% vs. 39.7%, $P = .01$ and 24.4% vs. 51.5%, $P = .009$, respectively) when analysis was limited to subjects with severe OSA and small or absent tonsils (0, 1, and 2) and without significance in baseline between groups.

DISCUSSION

To our knowledge, this study was the first to use DISE to evaluate the association between age and upper airway collapse characteristics in patients with OSA. The main findings were that aging increases the probability of multiple obstruction sites, combined upper and lower obstruction levels, and velum complete AP collapse. All these factors are likely secondary to increased upper airway collapsibility and likely are at least partially responsible for a more severe OSA. In addition, more AP velum complete collapse and less lateral oropharynx complete collapse were the distinct characteristics in older (age ≥ 60 years) patients with OSA.

In general, most patients (93.47%) presented multiple sites of obstruction (two or more sites). These results were higher than others already reported: 68.2%,[28] 73%,[29] and 84.06%.[30] The subdivision on levels of

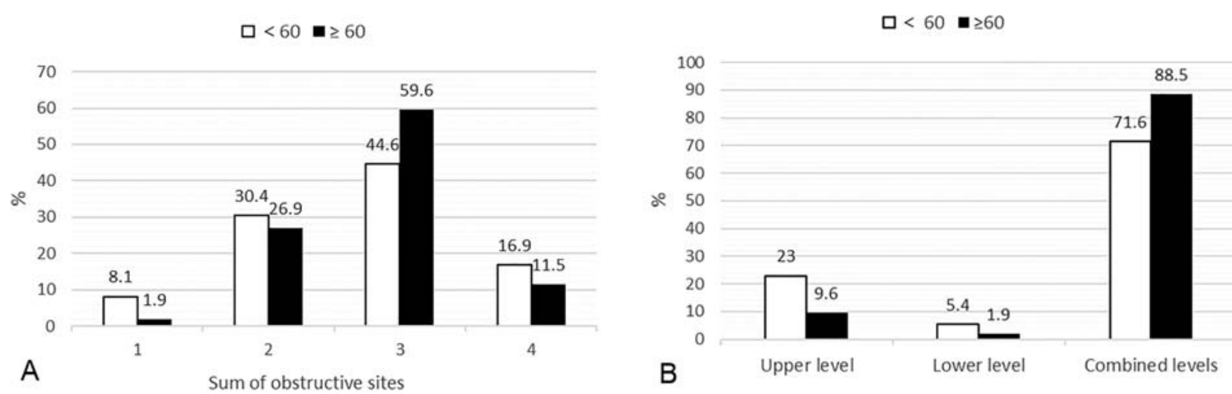

Fig. 2. Obstructive sites and levels in groups. (A) There was no significant difference in single or multiple sites obstruction between groups ($P = .468$). (B) Combined upper and lower levels obstruction in the ≥60-years-old group were significantly higher than <60-years-old group ($P = .046$). Upper level: obstruction in velum and/or oropharynx. Lower level: obstruction in tongue base and/or epiglottis. Combined levels: obstruction in both upper and lower levels. Statistically significant at $P < .05$.

TABLE III.
Association Between Age and Complete Collapse Pattern in Different Sites

Site	Pattern	OR Unadjusted	*P* Value	OR adjusted	*P* Value
Velum	AP	1.05 (1.03-1.07)	.000	1.04 (1.02-1.07)	.001
	L	0.95 (0.90-1.01)	.108	0.90 (0.80-1.01)	.061
	C	1.00 (0.98-1.02)	.999	1.01 (0.98-1.03)	.634
Oropharynx	L	0.99 (0.97-1.01)	.265	0.99 (0.97-1.02)	.581
Tongue base	AP	1.02 (1.00-1.04)	.037	1.01 (0.99-1.03)	.352
Epiglottis	AP	1.01 (0.98-1.03)	.630	1.01 (0.98-1.03)	.682
	L	1.01 (0.99-1.03)	.789	1.00 (0.99-1.02)	.999

OR adjusted for sex, body mass index, tonsil size, and modified Mallampati. Statistically significant at $P < .05$.
AP = anterior-posterior; C = concentric; L = lateral; OR = odds ratio.

obstruction (upper and lower) allowed an analysis from the VOTE classification system adds some elements described in the traditional Fairbanks et al.'s[31] and the more recent nose, oropharynx, hypopharynx, and larynx classifications.[32] The proportion (76.38%) of combined upper and lower level obstruction was also higher than previous studies: 52.17%[33] and 31.9%.[34] There were many other differences among studies: demography, airway anatomy, baseline sleep study outcomes, and sedative medicine used during DISE. Therefore, multivariable regression analysis was used to assess the association between OSA severity, hypoxia, airway collapse characteristics, and age by adjustments for some widely accepted confounders such as sex, BMI, tonsil size, and MM.

Our main finding was that age was an independent predictor of multiple sites and combined levels of obstruction. Each additional year was associated with increased multiple sites of obstruction by 6.6%, combined levels obstruction by 3%, AHI by 1.7%, ODI by 4.1%, and decreased LSAT by 0.2%. These results provided evidence on how aging affects upper airway collapsibility leading to increased OSA severity. Carlisle et al. pointed out that MRI studies of older adults had greater retropalatal and retroglossal airway length.[18] By means of electromyography, studies found that age-related weakening in genioglossus muscle function induced susceptible tongue collapse in both the human[19] and mouse model.[35] Our study confirmed through DISE, which is a dynamic direct visual observation, that age predisposed older subjects to an increasing upper way multisites and multilevels collapse.

The other main finding was that age affected the pattern and the degree of collapse. In our study, a 1-year rise in age was associated with 8.0% increase in the odds ratio of complete AP velum collapse and 2% of complete tongue base collapse. This can be due to upper airway anatomic changing and dysfunction of dilator muscles. Studies demonstrate that older adults have a longer soft palate, more parapharyngeal fat deposit,[36] a longer hypopharyngeal airway, greater hypopharyngeal soft tissue volume,[37] as well as obvious recruitment of genioglossus (GG) activity and higher upper airway resistance during sleep onset stage.[38] The mechanism for tongue base collapse is complex. There is evidence that BMI was an independent predictor of tongue collapse,[28] and that older patients with OSA showed lower BMI than young and middle-aged adults with an equivalent AHI.[39] The exact cause for increased upper airway collapsibility is likely multifactorial. Sex hormones have been described to have an association with OSA. Decline

TABLE IV.
Collapse Pattern and Obstruction Degree Between Groups

Site/Pattern/Degree		OSA, No. (%) <60 Years Old, n = 148	OSA, No. (%) ≥60 Years Old, n = 52	*P* Value
Velum				
AP	0	9 (6.1%)	1 (1.9%)	
	1	16 (10.8%)	0 (0%)	
	2	58 (39.2%)	36 (69.2%)	
L	0	0 (0%)	0 (0%)	
	1	2 (1.4%)	0 (0%)	
	2	6 (4.1%)	0 (0%)	
C	0	1 (0.7%)	0 (0%)	
	1	9 (6.1%)	0 (0%)	
	2	47 (31.8%)	15 (28.8%)	.002*
Oropharynx				
L	0	40 (27%)	17 (32.7%)	
	1	47 (31.8%)	23 (44.2%)	
	2	61 (41.2%)	12 (23.1%)	.058†
Tongue base				
AP	0	42 (28.4%)	10 (19.2%)	
	1	63 (42.6%)	20 (38.5%)	
	2	43 (29%)	22 (42.3%)	.066†
Epiglottis				
AP	0	98 (66.2%)	34 (65.4%)	
	1	14 (9.5%)	4 (7.7%)	
	2	32 (21.6%)	13 (25%)	
L	0	0 (0%)	0 (0%)	
	1	2 (1.4%)	0 (0%)	
	2	2(1.4%)	1 (1.9%)	.962*

Statistically significant at $P < .05$.
*Statistical analysis by Fisher exact test.
†Wilcoxon rank sum test.
AP = anterior-posterior; C = concentric; L = lateral; OSA = obstructive sleep apnea.

TABLE V.
Collapse Pattern With Complete Obstruction Between Groups

Site	Pattern/ Degree	OSA, No. (%)		
		<60 Years Old, n = 148	≥60 Years Old, n = 52	*P* Value*
Velum	Anterior-posterior			
	0 + 1	90 (60.8%)	16 (30.8%)	
	2	58 (39.2%)	36 (69.2%)	<.0001
	Lateral			
	0 + 1	142 (95.9%)	52 (100%)	
	2	6 (4.1%)	0 (0%)	.342
	Concentric			
	0 + 1	101 (68.2%)	37 (71.2%)	
	2	47 (31.8%)	15 (28.8%)	.731
Oropharynx	Lateral			
	0 + 1	87 (58.8%)	40 (76.9%)	
	2	61 (41.2%)	12 (23.1%)	.02

Statistically significant at $P < .05$
*Statistical analysis by Fisher exact test.
0 + 1 = none (0) and partial (1) collapse; 2 = complete collapse; OSA = obstructive sleep apnea.

in testosterone levels has been associated with decrease in ventilator response[40] and increased nocturnal hypoxemia in older men with OSA.[41] In women, postmenopause progesterone decline contributed to decreased activity of GG.[42] Although tonsil size and MM classification are well known factors that correlate with upper airway obstruction.[31,43] In our study, once we adjusted for sex, BMI, tonsil size and MM, it was found that age was not an independent predictor to tongue base collapse. No significantly increased tongue base collapse was found in subjects with age ≥60 years old.

In this study, the increase in age had an inverse correlation with complete lateral oropharynx collapse. Schwartz et al.[44] found that severe lateral pharyngeal wall collapse by Muller maneuver indicated increasing severity of OSA. Complete lateral pharyngeal wall collapse on preoperative DISE was reported to have an association with failure rate after surgery.[45] Through sleep MRI, it was obviously observed that dynamic lateral wall collapse was attributed to lateral pharyngeal muscle median-direction movement[46]; therefore, the atrophy of pharyngeal muscle may be associated with age-related general muscle atrophy, thus contributing to lateral wall collapse reduction. Also, aging was associated with increase in ratio of transverse/AP diameter of mandibular contour that provided a wider pharyngeal cavity,[36] and with expansion in expiratory end lung volume that induced a decreasing inspiratory negative pressure to pharyngeal lateral wall.[47,48] Clinically, it can be judged that older patients with OSA who are CPAP intolerant may have upper airway stimulation considered early in a possible treatment strategy.

Although AHI and hypoxia increased with aging, ESS showed no significant changes. Other studies demonstrated that older people with OSA had a lower ESS score than young and middle-aged subjects.[39,49] Lower daytime activity intensity and more napping opportunity may be the reason for less subjective sleepiness symptoms in older people. Meanwhile, aging and decreased cognitive status also contributed to lower self-reporting of ESS scores in older adults as compared with scores provided by their close relatives.[50]

Despite the novelty of the concepts present in our study, there are limitations that need to be acknowledged. First, subjects in this study were not from a general population sample, but from CPAP intolerant subjects referred to a tertiary center for possible surgical management of OSA. However, the research was carried out in a group of subjects with uniform age distribution and adequate age range. The patient percentage ≥ 60 years old was 26%, which fully met the needs of the study.

CONCLUSION

Age was an independent variable directly correlated with increased AHI and hypoxia in subjects with OSA. Aging has also contributed to increase in multiple sites, combined levels of collapse, and complete AP velum collapse. Complete tongue base collapse was positively associated with age, but dependent on sex, BMI, tonsil size, and MM. The older group of patients with OSA (≥60 years old) was associated with greater incidence of the complete collapse of velum AP and less oropharynx lateral, regardless of the OSA severity and tonsil size. Future studies will contribute to clarifing the usefulness of these findings in defining treatments in older patients with OSA.

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