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Role of submental ultrasound in diagnosing severe obstructive sleep apnea: A prospective diagnostic accuracy study

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ABSTRACT

Background: Recent research has explored the role of submental ultrasound (US) in assessing dynamic changes in upper airway soft tissues, particularly the tongue in obstructive sleep apnea syndrome (OSAS).

Aim: To investigate diagnostic potential of submental ultrasonographic parameters in diagnosing severe OSAS.

Patients and methods: A prospective diagnostic study including 60 adult patients with obstructive sleep apnea confirmed by polysomnography. Submental US was used to evaluate multiple parameters at rest and during Müller's maneuver, which were then analyzed in relation to the apnea-hypopnea index (AHI) to identify markers of severe OSAS.

Results: Two equal groups of 60 patients based on AHI (< 30 vs. ≥ 30) were created. Ultrasonographic measurements showed significant increases in resting tongue base thickness (65.9 vs. 58.6 mm), and during Müller's maneuver (64.9 vs. 58.6 mm), and a large distance between lingual arteries (32.6 vs. 28.0 mm) in the severe OSAS group (all $p < 0.001$). We didn't find a significant difference in retropalatal space diameter during Müller's maneuver ($p = 0.135$). The Epworth sleepiness scale scores were slightly higher, but not statistically significant in the severe group ($p = 0.679$).

Conclusion: The submental US is a practical, effective, and noninvasive bedside modality to diagnose severe OSAS.

Keywords: obstructive sleep apnea, submental ultrasound, upper airway, tongue base, sleep-disordered breathing

INTRODUCTION

Obstructive sleep apnea syndrome (OSAS) is a common sleep-related breathing disorder characterized by recurrent episodes of partial or complete upper airway (UA) obstruction during sleep, resulting in fragmented sleep and intermittent hypoxia [1]. Classic clinical features include prolonged loud snoring, witnessed apneas, and excessive daytime sleepiness [2]. OSAS has increasingly become a major public-health concern due to its rising prevalence and its strong associations with multiple metabolic, cardiovascular, and neurocognitive complications [3].

Untreated or undiagnosed obstructive sleep apnea (OSA) carries substantial clinical and societal consequences. Persistent intermittent hypoxia and sleep fragmentation contribute to systemic hypertension (HTN), coronary artery disease, arrhythmia, stroke, insulin resistance, mood disturbances, and impaired cognitive performance [4]. OSA also significantly increases the risk of motor-vehicle and occupational accidents, representing a serious public-safety issue [5]. Recent global estimates indicate that nearly 1 billion adults aged 30-69 years have some degree of OSA, of whom approximately 425 million have moderate-to-severe disease requiring treatment [6]. Alarmingly, up to 80% of clinically significant cases remain undiagnosed [7]. In Egypt, persistent underdiagnosis attributable to limited availability of sleep laboratories and low public and clinical awareness [8]. These epidemiological patterns highlight the urgent need for simple, accessible diagnostic approaches to support early identification, particularly in resource-limited settings.

Although overnight polysomnography (PSG) is still the gold standard for diagnosing OSA, it is costly, time-consuming, resource-intensive, and often inaccessible in many clinical

settings [9]. OSAS severity is commonly assessed by the apnea-hypopnea index (AHI) of 30 events per hour or greater, that quantifies frequency of apneas and hypopneas that occurring each hour during sleep. Alternatively, the respiratory effort-related arousals are included in the respiratory disturbance index (RDI) bedside apneas and hypopneas. OSAS is diagnosed when the AHI exceeds 5 events per hour in symptomatic individuals or when the RDI is ≥ 15, regardless of symptoms [10]. During sleep, reduced muscle tone leads to increased UA collapsibility, this results in increased mobility and vibration of the pharyngeal tissues, particularly during snoring episodes in OSAS patients [11]. Histopathological changes, such as muscle fiber atrophy and neurogenic lesions in palatopharyngeal muscles, have been reported in apneic individuals, likely as a consequence of chronic vibratory trauma [12].

To explore possible histopathological characteristics of pharyngeal tissues linked to OSA, transverse sections from the uvula distal and soft palate were examined under electron and light microscopy qualitatively from four severe apneic (over 50 apnea/hour), four severe snorers (under 20 apnea/hour), and four non-snorers. Light microscopy findings in both apneic and snorers demonstrated hypertrophy of mucous glands, dilation of glandular ducts, areas of squamous metaplasia, muscle bundles displacement by glandular infiltration, focal muscle fiber atrophy, and marked lamina propria edema accompanied by vascular dilation [13].

The available treatment options include mandibular advancement devices, continuous positive airway pressure (CPAP), and UA surgery, the accurate and time diagnosis remains a critical step in managing OSA. Recently, submental ultrasound (US) has become non-invasive, bedside imaging examination to assess anatomical structures implicated in UA obstruction [14]. The study in [15] pioneered the use of tongue base ultrasonography to evaluate tongue width in OSA patients. Subsequent studies [16, 17] investigated retropharyngeal diameter and tongue base thickness (TBT), respectively, proposing ultrasonographic markers as potential predictors of OSA severity. These findings support the growing interest in submental US as a practical and accessible tool for evaluating UA anatomy and potentially identifying patients with severe OSA [17].

Despite these promising preliminary findings, submental US remains underutilized and insufficiently validated as a diagnostic tool in routine clinical assessment of OSA severity. There is a need for further research to define reliable ultrasonographic parameters that correlate with established diagnostic indices such as AHI. Identifying non-invasive, accurate predictors of severe OSA may help streamline diagnosis, particularly in settings where PSG is limited or unavailable. Therefore, the current study aimed to evaluate the diagnostic utility of submental ultrasonographic measurements in predicting severe OSA.

PATIENTS AND METHODS

Study Design and Setting

A prospective observational diagnostic accuracy study was conducted over a 12-month period, from June 2023 to June 2024, at the departments of otorhinolaryngology, chest, and radiology, as well as the respiratory intensive care unit, Al-Hussein University Hospital, Cairo, Egypt.

Study Participants

A total of 60 patients diagnosed with OSA were consecutively recruited from those referred to the participating departments. Participants were divided into two equal groups (n = 30 each) based on their AHI (< 30 vs. ≥ 30) to distinguish non-severe from severe OSA, as severe OSA (AHI ≥ 30) is associated with higher risk of systemic complications and may require more urgent clinical intervention. This stratification is supported by previous studies investigating anatomical and ultrasonographic differences between OSA severity groups [16, 17].

The sample size was calculated using G*Power software (version 3.1.9.7) for a two-tailed independent sample t-test, aiming to detect a clinically significant difference in submental ultrasonographic parameters between severe and non-severe OSA groups. We assumed a medium-to-large effect size (Cohen's d = 0.75) based on previously reported differences in TBT between severe and non-severe OSA patients [16, 17], with $\alpha = 0.05$ and power = 0.80. This calculation indicated a required sample size of 30 per group.

Participants had to be at least 18 years old. All patients underwent a complete otorhinolaryngological examination to identify the anatomic level(s) of obstruction, followed by overnight (PSG), have an AHI of at least 5 occurrences per hour, be willing to participate, and give written informed consent. Exclusion criteria included patients with central or mixed sleep apnea (to include only obstructive mechanisms), history of prior UA surgery or craniofacial anomalies (which could alter airway anatomy and confound ultrasonographic measurements), neuromuscular disorders affecting respiration (to avoid independent effects on airway collapsibility), significant comorbidities that may interfere with sleep assessment (e.g., uncontrolled heart failure and severe chronic obstructive pulmonary disease) (to ensure PSG data reliability), incomplete or poor-quality PSG or US data (to maintain measurement accuracy), and pregnancy (due to physiological changes affecting airway anatomy and respiratory patterns).

Ethics Approval

The Institutional Review Board of Al-Azhar Faculty of Medicine in Cairo, Egypt granted ethical approval for this study (IRB #1208, dated 17/04/2023). After a comprehensive explanation of the study's goals and methods, each participant provided written informed consent. Participants also gave explicit consent for inclusion of their photographs in the study, with all images anonymized by masking the eyes to ensure privacy. All patient data were kept confidential throughout the study in compliance with ethical research standards, and participation was completely voluntary.

Clinical and Sonographic Assessment Procedures

Age, sex, height, body weight, and neck circumference were among the demographic information that was documented. Risk factors such as alcohol consumption and smoking were documented through structured interviews. Comorbidities including HTN and diabetes mellitus (DM) were also noted based on medical history and clinical evaluation. Blood groups were determined using standard serological testing. All participants underwent a comprehensive otorhinolaryngological and chest examination to identify the anatomic level(s) of UA obstruction, followed by overnight PSG, and submental ultrasonography which was performed by the radiologist co-author in the Radiology department.

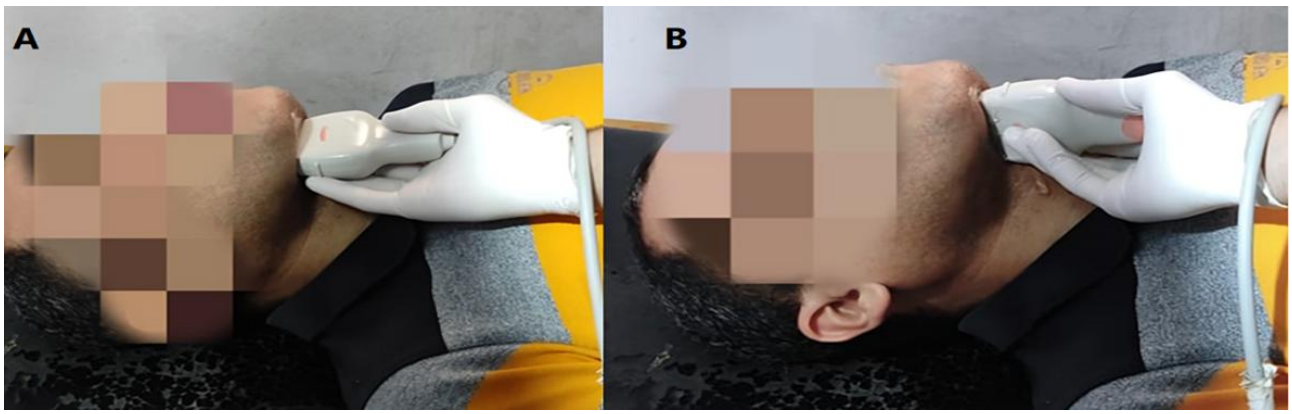

Figure 1. Submental US positions: (A) axial/transverse position & (B) sagittal position (Source: Field study)

US Imaging Protocol

The submental US examination was carried out using Toshiba, Xario 200 Platinum system with a high-frequency linear US probe. Patients were positioned supine, and the probe was placed along the midline in between the mandibular symphysis and hyoid bone (as illustrated in **Figure 1**). The US operator was blinded to PSG outcomes to reduce bias.

Measured Sonographic Parameters

The following sonographic findings were evaluated and addressed during both resting breathing and the Müller's maneuver (forced inspiration against a closed nose and mouth).

TBT

Measurements were obtained from sagittal planes to assess dynamic airway changes. The maximal TBT was calculated as the perpendicular distance between the tongue's dorsal surface and the submental skin.

Distance between lingual arteries

Measurements were obtained from the transverse plane using Power Doppler Doller study to identify the lingual arteries. The distance between lingual arteries (DLA) was calculated as the distance between both arteries.

Retropalatal space diameter

Measurements were obtained from the transverse plane by identifying the retropalatal space and ensuring the airway lumen is visible between the soft palate and posterior pharyngeal wall. Measurements were taken at rest and during the Müller's maneuver.

Statistical Analysis

IBM SPSS statistics software (version 26.0, SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. The normality of continuous data was evaluated using the Shapiro-Wilk test. For continuous variables, descriptive statistics were displayed as mean (M) ± standard deviation (SD) and as frequencies with corresponding percentages for categorical variables. Group comparisons involving categorical data were carried out through the Fisher's exact test or Chi-square test as appropriate. For normally distributed continuous variables, independent t-tests were employed to assess differences between groups. Pearson's correlation coefficient was applied to identify factors correlated with the AHI. Using receiver operating characteristic (ROC) curve analysis, the area under the curve (AUC) was computed to evaluate the diagnostic performance of US parameters in predicting severe OSA. Optimal cut-off values were identified based on the highest sensitivity and specificity. Univariate logistic regression was initially applied to identify variables linked to severe OSA, followed by multivariate logistic regression for variables that showed significance in univariate analysis, to identify independent predictors. Results were displayed as an odds ratio (OR), an adjusted odds ratio (AOR), and confidence intervals 95% (CI). There was no missing data for any of the analyzed variables, and thus no imputation methods were required. Values below 0.001 were regarded as high statistically significant, while a two-tailed p of less than 0.05 was regarded as statistically significant.

RESULTS

Two equal groups of 60 patients based on AHI (in = 30 each) were created. Patients with AHI ≥ 30 had significantly higher M age (44.3 ± 4.1 vs. 38.8 ± 4.0 years; $p < 0.001$), body weight (84.9 ± 3.5 vs. 70.6 ± 4.2 kg; $p < 0.001$), body mass index (BMI) (31.9 ± 2.8 vs. 26.3 ± 2.2 kg/m^2; $p < 0.001$), and neck circumference (41.6 ± 4.3 vs. 36.9 ± 3.6 cm; $p = 0.001$), compared to patients with AHI < 30. There were no statistically significant differences between the groups regarding sex distribution, alcohol consumption, cigarette smoking, blood group, or comorbid conditions such as HTN and DM ($p > 0.05$ for all).

In terms of ultrasonographic findings, the severe OSAS group (AHI ≥ 30) demonstrated significantly higher M retropalatal space diameter (RPD) (60.7 ± 4.2 vs. 55.7 ± 3.3 mm; $p < 0.001$), M resting TBT (65.9 ± 4.0 vs. 58.6 ± 3.1 mm; $p < 0.001$), M Müller's maneuver TBT (64.9 ± 4.0 vs. 58.6 ± 3.3 mm; $p < 0.001$), and M dynamic lateral airway width (32.6 ± 3.7 vs. 28.0 ± 3.2 mm; $p < 0.001$). However, Müller's maneuver RPD did not differ significantly between the two groups ($p = 0.135$).

The Epworth sleepiness scale (ESS) scores were slightly higher, but not statistically significant in the severe group ($p = 0.679$) (**Table 1**). The following variables showed a statistically significant positive correlation with AHI: older age, increased body weight, higher BMI, greater neck circumference, RPD, resting TBT, Muller's TBT, and DLA.

Table 1. Demographic, risk factors, comorbidities, and ultrasonographic features of enrolled patients

Variables		AHI < 30		AHI ≥ 30		p
		n=17	%	n=23	%	
Age (years)	M ± SD	38.8 ± 4.0		44.3 ± 4.1		< 0.001*
	Min-max	31-45		35-50		
Sex	Male	13	76.5	21	91.3	0.373
	Female	4	23.5	2	8.7	
Body weight (kg)	M ± SD	70.6 ± 4.2		84.9 ± 3.5		< 0.001*
	Min-max	63-78		80-93		
BMI (kg/m^2)	M ± SD	26.3 ± 2.2		31.9 ± 2.8		< 0.001*
	Min-max	22.5-29.8		26.4-36.5		
Neck circumference (cm)	M ± SD	36.9 ± 3.6		41.6 ± 4.3		0.001*
	Min-max	30-43		33-50		
Alcohol drinking	Yes	2	11.8	4	17.4	1.000
Cigarette smoking	Yes	4	23.5	8	34.8	0.505
Blood group	A	7	41.2	6	26.1	0.406
	B	2	11.8	8	34.8	
	AB	1	5.9	1	4.3	
	O	7	41.2	8	34.8	
HTN	Yes	2	11.8	9	39.1	0.079
DM	Yes	1	5.9	4	17.4	0.373
RPD (mm)	M ± SD	55.7 ± 3.3		60.7 ± 4.2		< 0.001*
	Min-max	50-61		52-68		
Muller's RPD (mm)	M ± SD	49.4 ± 3.6		51.3 ± 3.9		0.135
	Min-max	42-55		43-58		
Resting TBT (mm)	M ± SD	58.6 ± 3.1		65.9 ± 4.0		< 0.001*
	Min-max	53.8-63.8		55.9-73.1		
Muller's TBT (mm)	M ± SD	58.6 ± 3.3		64.9 ± 4.0		< 0.001*
	Min-max	53.8-64.9		54.9-72.1		
DLA (mm)	M ± SD	28.0 ± 3.2		32.6 ± 3.7		< 0.001*
	Min-max	22.3-32.7		25.2-39.9		
ESS	M ± SD	7.9 ± 3.2		8.4 ± 3.5		0.679
	Min-max	3-14		2-16		
AHI	M ± SD	17.1 ± 5.9		38.8 ± 4.2		<0.001*
	Min-max	8-28		31-45		

Note. Values displayed as numbers and percentages were analyzed by Chi-square or Fisher exact tests; values displayed as M ± SD were analyzed by independent samples t-test; & *Significant

Among these correlated factors, body weight had the strongest correlation (r = 0.74, p < 0.001), followed by BMI (r =0.70, p < 0.001), resting TBT (r = 0.64, p < 0.001), Muller's TBT (r = 0.59, p < 0.001), RPD (r = 0.53, p < 0.001), age (r = 0.51, p = 0.001), DLA (r = 0.50, p < 0.001), and neck circumference (r = 0.46, p = 0.003) (**Table 2**).

Variables that were statistically significant in **Table 1** demonstrated varying predictive abilities for severe OSA, as shown by the ROC curve analysis. Among the demographic and anthropometric measures, age with a cutoff > 42.5 years showed 74% sensitivity and 82% specificity (AUC: 0.84; 95% CI: 0.71-0.96; p < 0.001). Body weight > 80.5 kg yielded 87% sensitivity and 88% specificity (AUC: 0.97; 95% CI: 0.93-1.00; p < 0.001), while BMI > 29 kg/m^2 had the same sensitivity and specificity values (AUC: 0.95; 95% CI: 0.89-1.00; p < 0.001). Neck circumference > 39.5 cm showed 70% sensitivity and 77% specificity (AUC: 0.80; 95% CI: 0.66-0.93; p = 0.001). Regarding ultrasonographic features, RPD > 58.5 mm demonstrated 70% sensitivity and 83% specificity (AUC: 0.83, 95% CI: 0.71-0.96; p < 0.001). TBT > 63.3 mm had 83% sensitivity and 94% specificity (AUC: 0.93, 95% CI: 0.84-1.00; p < 0.001), while Muller's TBT > 61.7 mm yielded 83% sensitivity and 82% specificity (AUC: 0. 89, 95% CI: 0.79-0.98; p < 0.001). The DLA > 31.2 mm showed 65% sensitivity and 83% specificity (AUC: 0.83, 95% CI: 0.71-0.95; p < 0.001). Accordingly, the resting TBT (AUC 0.93; p<0.001) demonstrated the highest predictive accuracy for severe OSA, followed by Muller's TBT (AUC 0.89; p < 0.001) when compared to both RPD and DLA (**Table 3** and **Figure 2**).

Table 2. Correlations between current variables (demographic, risk factors, comorbidities, and ultrasonographic) and AHI among enrolled patients

Variables	Correlation with AHI (r)	p
Age (years)	0.51	0.001*
Sex	- 0.21	0.203
Body weight (kg)	0.74	< 0.001*
BMI (kg/m^2)	0.70	< 0.001*
Neck circumference (cm)	0.46	0.003*
Alcohol drinking	- 0.06	0.705
Cigarette smoking	- 0.07	0.654
Blood group	- 0.04	0.813
HTN	- 0.32	0.062
DM	- 0.12	0.454
RPD (mm)	0.53	< 0.001*
Muller's RPD (mm)	0.19	0.250
Resting TBT (mm)	0.64	< 0.001*
Muller's TBT (mm)	0.59	< 0.001*
DLA (mm)	0.50	< 0.001*
ESS	0.18	0.270

Note. r: Pearson correlation coefficient & *Significant

Based on univariate logistic regression analysis, significant predictors of severe OSA included age (OR: 1.39; 95% CI: 1.12-1.71), body weight (OR: 2.74; 95% CI: 1.21-6.17), BMI (OR: 2.73; 95% CI: 1.39-5.38), neck circumference (OR: 1.37; 95% CI: 1.10-1.70), RPD (OR: 1.42; 95% CI: 1.13-1.78), resting TBT (OR: 1.64; 95% CI: 1.23-2.19), Muller's TBT (OR: 1.52; 95% CI: 1.19-1.94), and DLA (OR: 1.49; 95% CI: 1.15-1.93). In multivariate logistic regression analysis adjusting for age, body weight, BMI, and neck circumference, Muller's TBT > 61.7 mm remained the only independent ultrasonographic predictor of severe OSA (OR: 1.16; 95% CI: 0.41-1.89; p = 0.040) (**Table 4**).

Table 3. ROC curve analysis for predictors of severe OSAS among the study patients

Variables	Cutoff value	Sensitivity (%)	Specificity (%)	ROC: AUC [95% CI]	p
Age (years)	> 42.5	74	82	0.84 [0.71-0.96]	< 0.001*
Body weight (kg)	> 80.5	87	88	0.97 [0.93-1.00]	< 0.001*
BMI (kg/m^2)	> 29.0	87	88	0.95 [0.89-1.00]	< 0.001*
Neck circumference (cm)	> 39.5	70	77	0.80 [0.66-0.93]	0.001*
RPD (mm)	> 58.5	70	83	0.83 [0.71-0.96]	< 0.001*
Resting TBT (mm)	> 63.3	83	94	0.93 [0.84-1.00]	< 0.001*
Muller's TBT (mm)	> 61.7	83	82	0.89 [0.79-0.98]	< 0.001*
DLA (mm)	> 31.2	65	83	0.83 [0.71-0.95]	< 0.001*

Note. *Significant

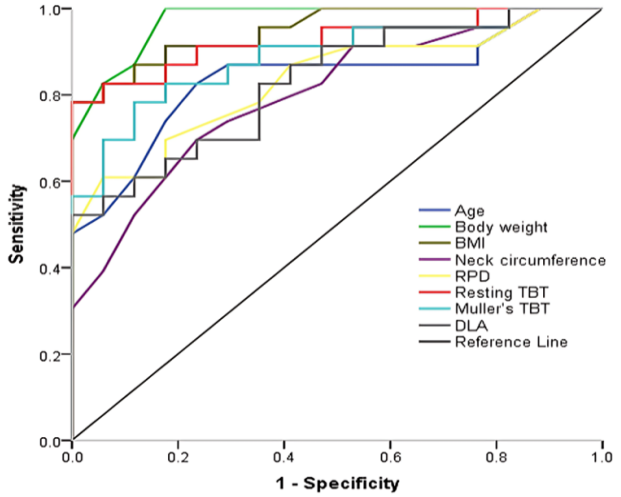

Figure 2. ROC curve analysis of different predictors of severe OSAS (Source: Authors' own elaboration)

Table 4. OR by univariate and multivariate logistic regression analyses for severe OSAS

Variables	Univariate		Multivariate	
	OR [95% CI]	p	AOR [95% CI]	p
Age (years)	1.39 [1.12-1.71]	0.002*	0.64 [0.34-2.82]	0.154
Body weight (kg)	2.74 [1.21-6.17]	0.015*	1.03 [0.76-4.85]	0.188
BMI (kg/m^2)	2.73 [1.39-5.38]	0.004*	1.60 [0.52-5.26]	0.393
Neck circumference (cm)	1.37 [1.10-1.70]	0.004*	0.26 [0.06-1.48]	0.406
RPD (> 58.5 mm)	1.42 [1.13-1.78]	0.002*	0.51 [0.25-1.05]	0.069
Resting TBT (> 63.3 mm)	1.64 [1.23-2.19]	0.001*	1.07 [0.14-0.98]	0.064
Muller's TBT (> 61.7 mm)	1.52 [1.19-1.94]	0.001*	1.16 [0.41-1.89]	0.040*
DLA (> 31.2 mm)	1.49 [1.15-1.93]	0.003*	0.56 [0.17-2.55]	0.232

Note. *Significant

Figure 3 and **Figure 4** shows the submental U.

DISCUSSION

The present study examined the role of submental ultrasonography as a non-invasive imaging tool for assessing UA anatomy in patients with OSA. The aim was to determine whether ultrasonographic parameters, particularly TBT and dynamic airway measurements, could reliably differentiate between severe and non-severe OSA, potentially serving as an adjunct or alternative screening method to PSG, especially in resource-limited settings.

Among the 60 enrolled patients, those with severe OSA (AHI ≥ 30) were older and had significantly higher body weight, BMI, and neck circumference compared to patients with non-severe OSA. These findings are consistent with the well-established contribution of obesity-related soft tissue enlargement to airway narrowing. Prior studies similarly demonstrate that OSA prevalence rises sharply with increasing BMI, as reported by Alabaf et al., where OSA affected approximately 30% of individuals with BMI > 30 and up to 50% of those with BMI > 40 [18]. In contrast, other demographic factors–including sex, smoking status, alcohol intake, blood group, and comorbidities–did not significantly differ between the two groups, echoing the findings of [19].

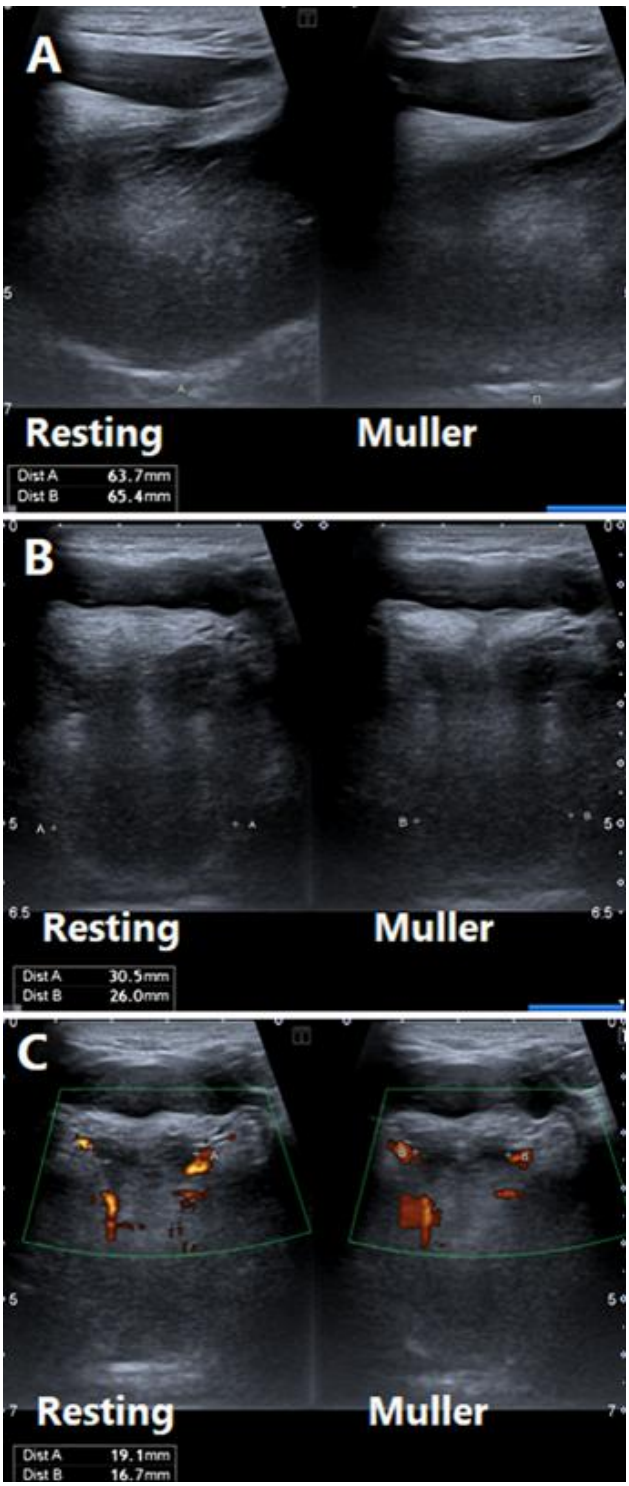

Figure 3. Submental US: (A) sagittal plane shows TBT in resting position 63.7 mm, in Müller's maneuver 65.4 mm, (B) axial plane shows RPD in resting position 30.5 mm, in Müller's maneuver 26 mm, & (C) axial plane shows DLA in resting position 19.1 mm, in Müller's maneuver 16.7 mm (Source: Feld study)

Neck circumference has been recognized as an important anthropometric marker for OSA risk. In line with the findings of [20], our results support its predictive value; they observed that a neck circumference ≥ 40 cm demonstrated a sensitivity of 61% and specificity of 93% for detecting OSA, regardless of sex.

Ultrasonographic assessments revealed that patients with severe OSAS had significantly higher resting RPD, resting and

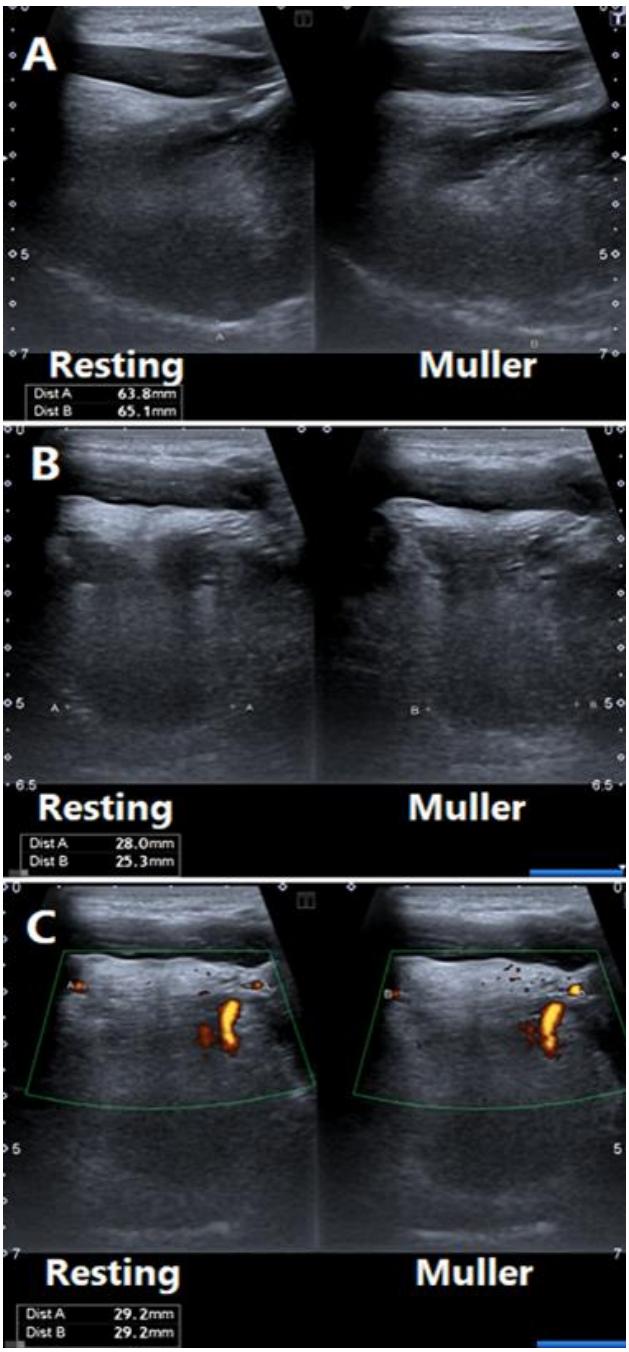

Figure 4. Submental US: (A) sagittal plane shows TBT in resting position 63.8 mm, in Müller's maneuver 65.1 mm, (B) axial plane shows RPD in resting position 28.0 mm, in Müller's maneuver 25.3 mm, & (C) axial plane shows DLA in resting position 29.2 mm, in Müller's maneuver 29.2 mm (Source: Field study)

Müller's TBT, and DLA measurements. However, Müller's RPD did not differ significantly between groups ($p = 0.135$). Interestingly, although ESS were slightly elevated in the severe OSA group, the difference was not statistically significant ($p = 0.679$). This suggests a potential mismatch between subjective symptoms and anatomical disease severity, highlighting the need for objective evaluation tools.

Our findings align with previous research. For instance, the study in [17] emphasized that increased TBT is a key anatomical factor contributing to airway narrowing in patients with OSAS. They noted dynamic changes during Müller's maneuver. Similarly, in our study, the TBT greater than 63.3 mm was strongly associated with severe OSAS, demonstrating high diagnostic accuracy. While some patients showed variation, such as an increase or decrease in TBT during Müller's maneuver, logistic regression identified a resting TBT ≥ 61.7 mm as the sole reliable predictor of severe OSAS. From a clinical perspective, using a cut-off value of ≥ 60 mm for TBT could be a practical screening marker for severe OSAS [17].

Lahav et al. also found that a distance between the lateral pharyngeal wall greater than 30 mm significantly raises the likelihood of moderate-to-severe OSAS [21]. In alignment with these findings, our results indicate that a lateral pharyngeal wall over 31.2 mm offers good diagnostic potential, with 65% sensitivity and 83% specificity. This reflects both tongue base width and lateral airway space compromise.

Further supporting evidence, the study in [22] demonstrated that patients with severe OSAS had thicker TBT both at rest and during Müller's maneuver. They also observed a greater separation between the lingual arteries, suggesting a link between increased soft tissue mass and disease severity. Their results indicated that a TBT ≥ 60 mm serves as an independent indicator of severe OSAS. They reported 84.9% sensitivity and 59.3% specificity at this cutoff [22].

In our sample, Müller's TBT of ≥ 61.7 mm emerged as the only ultrasonographic variable independently associated with severe OSAS, aligning with findings of [22]. A resting TBT > 63.3 mm yielded 83% sensitivity and 94% specificity, highlighting its strong diagnostic capability [22].

Additionally, the studies [19, 23] further support the diagnostic value of ultrasonographic tongue measurements. The study in [19] found significantly larger tongue areas in OSA patients during both rest and Müller's maneuver, with reduced tongue mobility in moderate-to-severe cases. The study in [23] demonstrated that TBT measured during drug-induced sleep achieved high accuracy (AUC = 0.875), with a cutoff of 63.20 mm yielding 95% sensitivity for severe OSA. Collectively, these findings reinforce the relevance of tongue-related ultrasonographic measurements in identifying clinically significant disease.

Study Limitations

Despite the promising results, several limitations must be acknowledged.

1. Ultrasonographic measurements are highly dependent on the skill and experience of the sonographer, which may limit reproducibility across clinical settings.
2. All US assessments were performed while patients were awake. This may underestimate UA collapsibility, as reduced muscle tone during sleep contributes more prominently to obstruction, highlighting a key limitation when compared to PSG conducted during sleep.
3. Inter-observer variability may affect measurement consistency. Therefore, standardized imaging protocols and training are essential to improve reliability and comparability across institutions.
4. The relatively small size of sample (n = 60) and single center nature of the study may limit the generalizability of the findings. Multicenter studies are advised to validate these results in more diverse populations.

5. This study did not evaluate changes in US parameters over time or in response to treatment interventions such as CPAP. Therefore, its utility in monitoring disease progression or treatment response remains untested.
6. Potential selection bias as participants were recruited from hospital referrals, thus may represent a more symptomatic or clinically complex population. This could overestimate the diagnostic performance of submental US in general populations.

CONCLUSION

Submental ultrasonography represents a promising adjunctive tool for diagnosing severe OSA, particularly in settings where PSG is unavailable. It provides a non-invasive means of evaluating anatomical risk factors associated with UA obstruction and may enhance early screening and triage, especially in resource-limited environments. However, its utility may be constrained by the need for skilled operators and the differences between awake and sleep states. While submental US cannot replace PSG, it has the potential to strengthen diagnostic pathways when PSG is inaccessible. Future research should focus on validating dynamic assessment protocols and exploring methods to bridge the awake-sleep diagnostic gap.

Recommendations

Integrate submental US into multi-parameter diagnostic frameworks for OSA to enhance early identification and risk stratification. Develop standardized US protocols and provide structured training programs for clinicians to ensure consistency and accuracy across operators. Explore real-time sleep US applications to better capture airway dynamics under natural sleep conditions and improve diagnostic accuracy. This approach may transform OSAS management by balancing diagnostic rigor with clinical practicality.

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