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ORIGINAL RESEARCH

Clinical Significance of Upper Airway Dynamic Magnetic Resonance in the Assessment of Obstructive Sleep Apnea Hypopnea Syndrome

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Purpose: This study aimed to clarify the value of upper airway dynamic magnetic resonance (UADMR) in assessing the level and degree of obstruction in the upper airway during sleep in patients with obstructive sleep apnea hypopnea syndrome (OSAHS).

Patients and Methods: Patients with OSAHS diagnosed by polysomnography (PSG) from February 2025 to March 2025 were included in this study, and UADMR was performed to detect the obstructive levels (palatopharyngeal level, root of tongue level, and epiglottic level) and assess the degree of obstruction at the root of the tongue and epiglottic levels. Subgroup analyses were performed according to different obstructive characteristics and the results of UADMR were assessed for correlation analysis with the results of PSG or manual titration of positive airway pressure. This study used Müller maneuver to simulate the airway collapse during sleep.

Results: A total of 34 OSAHS patients were included in this study. It was observed that the hypopnea index, apnea hypopnea index, and tongue axial change ratio were significantly higher in OSAHS patients with multiple layers of airway obstruction than in those with palatopharyngeal obstruction only. The anteroposterior diameter change ratio at the level of the root of the tongue and the area change ratio at the level of the epiglottis in patients with OSAHS were positively correlated with the results of the PSG, and the tongue axial change ratio was positively associated with the results of the manual titration of positive airway pressure.

Conclusion: UADMR is an effective method for assessing the level and degree of upper airway obstruction during sleep in patients with OSAHS.

Keywords: obstructive sleep apnea hypopnea syndrome, upper airway dynamic magnetic resonance, Müller maneuver

Introduction

Obstructive sleep apnea hypopnea syndrome (OSAHS) is characterized by the recurrent partial or complete obstruction of the upper airway during sleep, resulting in hypopnea or apnea.[1] The prevalence of OSAHS is approximately 3–7% in adult males and 2–5% in females.[2] Also, OSAHS is associated with an increased incidence of hypertension, type 2 diabetes, atrial fibrillation, heart failure and stroke.[1] Currently, the treatment options for OSAHS patients include continuous positive airway pressure, oral appliances, surgical treatment, etc,[1,3] which depends on the results of polysomnography (PSG).[4]

PSG is the main tool to diagnose OSAHS, but it cannot accurately assess the degree and location of upper airway obstruction, which are crucial to the prognosis of OSAHS patients.[5] For patients with different levels of obstruction, different surgical approaches should be selected. For example, a hypoglossal nerve stimulator was used for a patient who had isolated collapse, the treatment could be less effective than a for a patient with combined collapse.[6] Currently, many imaging modalities have been used to quantify the degree of upper airway obstruction.[7] However, X-rays and CT expose

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patients to radiation and does not provide good differentiation of soft tissue.[7] Due to apnoea and the respiratory cycle are dynamic progress, the conventional MR cannot reflect the dynamic situations of airway obstruction.[8] Laryngoscope also fails to detect the obstruction below the palatopharyngeal layer.[6,9] Thus, there is an urgent need for a novel examination to accurately evaluate the obstructive characteristics of OSAHS patients.

In this regard, we used 3.0T upper airway dynamic magnetic resonance (UADMR), which has no risk of radiation exposure, better soft tissue resolution, and more imaging layers than the above-mentioned examinations.[6] UADMR is a non-invasive procedure that allows dynamic observation of upper airway movements during breathing. However, the MR during sleep has the problems such as difficulty falling asleep and the long time required for the procedure.[7] Thus our study innovatively introduced the Müller maneuver to UADMR, which was recognized by the general public as a tool for assessing the location of airway obstruction during sleep,[10] aiming to confirm the value of the prediction of disease prognosis and provide evidence-based evidence for guiding the further management in OSAHS.

Materials and Methods

Inclusion Criteria

Patients with snoring as the main symptom from February 2025 to March 2025 were screened for this study, and those who were diagnosed as OSAHS by polysomnography (PSG) were finally included in the study. Ethical consideration was sought from the Ethic Committee of the Fifth Affiliated Hospital of the Sun Yat-sen University (2025-K30-1). Informed consent was sought from the study subjects by signing the informed consent form. The research was also conducted per the guidelines outlined in the Declaration of Helsinki. Collected data including gender, age, height, weight, neck circumference, and body mass index (BMI) were recorded. Informed consent was obtained from each subject before the study. The study was approved by the Institutional Review Board. All subjects were required to be free of any related treatment in the last three months, no history of radiotherapy, no serious systemic diseases or other diseases causing airway obstruction.

Polysomnography

All subjects underwent all-night PSG using the Philips Alice 6 system (Philips Respironics, PA, RRID: SCR_025500) for ≥ 7h in bed, and monitoring leads included electroencephalogram, mandibular electromyography, electrooculogram, snoring, nasal and oral airflow, pressure airflow, oxygen saturation, heart rate and electrocardiogram. The monitoring results were recorded by the Sleepware G3 software (Philips Respironics, PA, RRID: SCR_025509) and manually analyzed by two sleep specialists. Sleep event determination was performed according to the American Academy of Sleep Medicine Manual for the Scoring of Sleep and Associated Events (Version 2.6).[11] The monitoring indexes included: apnea index, hypopnea index, apnea hypopnea index (AHI) during rapid eye movement (REM) sleep, AHI during non-rapid eye movement (NREM) sleep, and total AHI. The definitions of the indexes were listed in Table 1 in detail.

Table 1 The Definition of the Indexes in Polysomnography

Item	Index	Definition
1	Apnea	≥ 90% decrease in oro-nasal respiratory airflow from baseline levels during sleep, lasting ≥ 10 seconds
2	Hypopnea	≥ 30% decrease in the intensity of oro-nasal airflow from baseline levels during sleep accompanied by a ≥ 4% decrease in arterial oxygen saturation for ≥ 10 seconds; or a ≥ 50% decrease in the intensity of oro-nasal airflow from baseline levels accompanied by a ≥ 3% decrease in arterial oxygen saturation or a microarousal for ≥ 10 seconds
3	AHI	The average total number of apnea events and hypopnea events per hour during sleep
4	Mild OSAHS	5 ≤ AHI ≤ 15
5	Moderate OSAHS	15 < AHI ≤ 30
6	Severe OSAHS	AHI > 30

Abbreviations: AHI, apnea-hypopnea index; OSAHS, obstructive sleep apnea hypopnea syndrome.

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Manual Titration of Positive Airway Pressure

Manual titration of positive airway pressure was performed in patients who have been diagnosed with OSAHS. During the procedure, positive airway pressure was dynamically adjusted throughout the recording period to determine the optimal pressure to maintain upper airway patency.[12] Monitoring metrics included: post-treatment AHI, maximum and minimum therapeutic pressure (cm H_2O).

Laryngoscope

All subjects underwent laryngoscopy and completed the Müller maneuver during the examination (Supplementary Video 1). It required the patient to inhale forcefully with the nose pinched and mouth closed to mimic the collapse of the laryngopharyngeal lumen in a state of upper airway obstruction, ie, to mimic an apnoeic event during sleep.[13] This method has been used to assess upper airway obstruction in patients with OSAHS.

Upper Airway Dynamic Magnetic Resonance

All subjects underwent dynamic MR and imaging of the upper airway while awake and completed training in the relevant examination maneuvers before being tested. MR imaging was performed with a 3.0-T whole-body unit using a 19-channel head-neck coil. Midsagittal images of the pharynx were acquired using a two-dimensional single-shot fast spin echo (SSFSE) sequence with imaging parameters of 810/60 (TR/TE), a flip angle of 90°, a 5-mm slice thickness, a 512×512 matrix, and a 260×244 mm field of view. One image was acquired per second. Axial sections of the velo- and oropharynx were acquired using a 2D-SSFSE sequence with the same imaging parameters. The total in-layer resolution was 0.51×0.48mm. Each section location was imaged 30 consecutive times, with a total acquisition time of 30 seconds.

Prior to the examination, we will provide movement training to all participants to ensure that the movements meet the required standards. As it was difficult to judge the obstructive situation in the pharyngeal cavity in the axial position, we chose both the sagittal position and axial position.[14] All participants were required to close their mouths and breathe calmly firstly to obtain the sagittal and axial images. The subjects were then required to perform the Müller maneuver to obtain the sagittal images (Supplementary Video 2 and 3). The optimal imaging positions were determined by selecting the narrowest layers in the sagittal image of the palatopharyngeal region, the root of the tongue, and the epiglottis, respectively. After it, the Müller manoeuvre was performed again and the three layers were imaged axially. The imaging specialist measured the parameters of the axial and sagittal images of the three layers, including the maximum anteroposterior diameters in the sagittal position under calm breathing and under the Müller maneuver. The definition of the airway obstruction in imaging was that any horizontal layer (the palatopharynx, the root of the tongue or epiglottis) had a ratio of change in area and anteroposterior diameter greater than 50%.

The study used the ratio of axial changes in the tongue (RAC) for tongue measurement (Figure 1). We located the midpoint (point A) of the line between the upper and lower boundaries of the maxilla in the sagittal position and connected this point to the anterior-superior border of the third cervical vertebra (point C), and measured the distance between the two points (AC). The minimum (AB) and the maximum value of the axial direction of the tongue under the Müller maneuver (AD) were measured. The formula of the ratio of axial changes in the tongue (RAC, %) is RAC=(AD-AB)/AC*100%.

Data Analysis

The software SPSS 27.0 (SPSS Inc., Chicago, IL) and GraphPad Prism 10.1.2 (GraphPad, La Jolla, CA) were used for statistical analysis and graphing. Data were expressed as mean ± standard deviation. The Mann–Whitney *U*-test were used to analyze the difference between two variables without a normal distribution. Pearson correlation analysis was used when both variables were normally distributed, while Spearman correlation analysis was used if at least one of the two variables was ranked or did not satisfy normal distribution. When $P < 0.05$, a statistical difference was indicated. The correlation coefficient $r > 0.8$ was considered highly correlated; $0.5 < r \leq 0.8$ was considered moderately correlated; $0.3 < r \leq 0.5$ was considered lowly correlated; $r \leq 0.3$ was considered non-correlated.

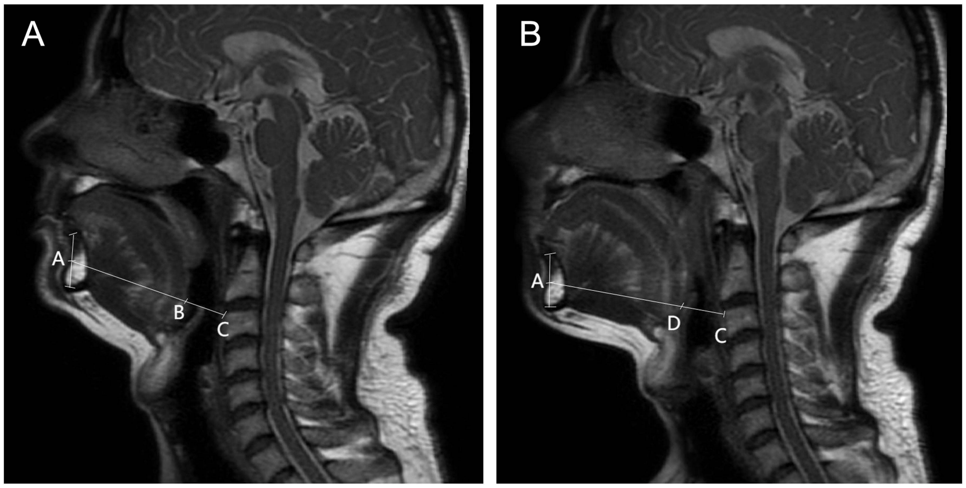

Figure 1 Sagittal image of the patient with obstructive sleep apnea hypopnea syndrome under (**A**) nasal breathing and (**B**) after performing the Müller test. Point A indicates the midpoint of the line joining the upper and lower boundaries of the maxilla. Point B indicates the intersection of the AC line under nasal breathing with the tongue root backup. Point C indicates the anterior superior margin of the third cervical vertebra. Point D indicates the intersection of the AC line after performing the Müller test with the tongue root backup. The formula of the ratio of axial changes in the tongue (RAC, %) is (AD-AB)/AC*100%.

Results

A total of 34 subjects were included in this study, with 8 patients with moderate OSAHS and 26 patients with severe OSAHS. Two of these patients had missing data in PSG. One patient did not complete a subsequent manual titration of positive airway pressure after PSG. The remaining 31 subjects completed all the examinations.

Airway collapse was clearly observed on UADMR images during breathing in all participants. The ratio of anteroposterior diameter change or area change in the palatopharyngeal layer was greater than 90% in almost all but two subjects with the Müller maneuver. Correspondingly, subjects performing the Müller maneuver under laryngoscopy all demonstrated a greater degree of palatopharyngeal layer occlusion, but it could not observe whether there was concomitant airway collapse at other layers due to the restricted field of view (Figure 2). In addition to the palatopharyngeal layer, most of the subjects had varying degrees of obstruction at the root of the tongue and epiglottic levels during the Müller maneuver compared to nasal breathing in UADMR (Figure 3), which might be relevant to the heterogeneity of OSAHS disease and prognosis. Therefore, the subjects were divided into the single-obstruction group (n = 14, 41.2%) and the multiple-obstruction group (n = 20, 58.8%). There was airway obstruction only in palatopharynx (from the tip of soft palate to the free edge of uvula) in the single-obstruction group, while there was concomitant airway collapse at the root of the tongue and/or epiglottic layers with a ratio of change in area and diameter greater than 50% in the multiple-obstruction group.

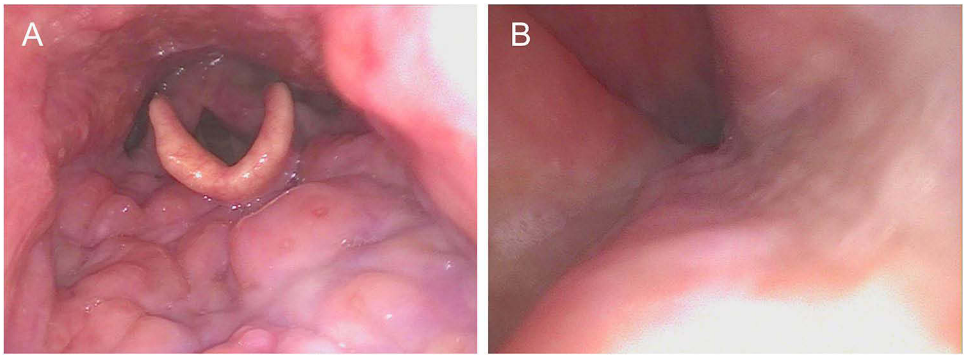

Figure 2 Fibreoptic laryngoscopic images of the upper airway. (**A**) Image of a subject under nasal breathing. (**B**) Image of a subject after performing the Müller test.

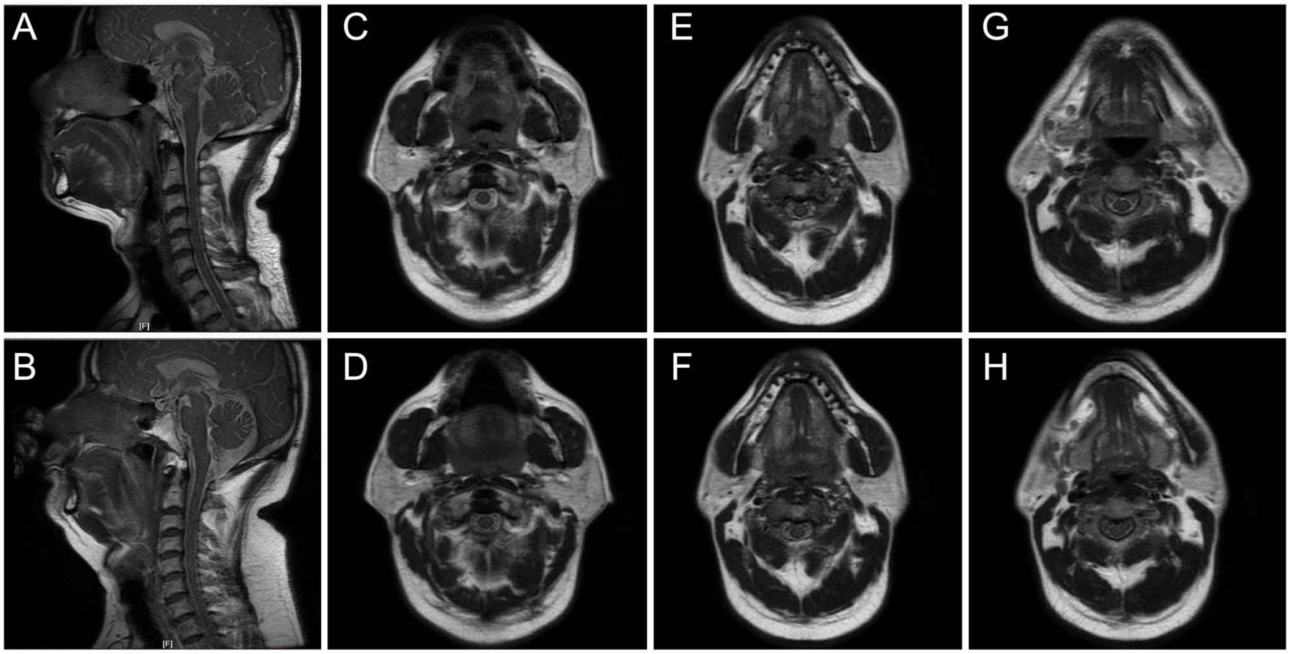

Figure 3 Upper airway dynamic magnetic resonance images of patients at different levels in sagittal and axial positions. (**A** and **B**) Subjects with partial obstruction (**A**) and complete obstruction (**B**) at the level of the root of the tongue and the epiglottis. (**C** and **D**) Images of a subject with complete obstruction at the axial palatopharyngeal level under nasal breathing (**C**) and after performing the Müller test (**D**). (**E** and **F**) Images of a subject with complete obstruction at the axial tongue root level under nasal breathing (**E**) and after performing the Müller test (**F**). (**G** and **H**) Images of a subject with complete obstruction at the axial epiglottis level under nasal breathing (**G**) and after performing the Müller test (**H**).

There was a significant difference in hypopnea index (P = 0.0481) and apnea hypopnea index (P = 0.0431) between the two groups, and both hypopnea index and AHI were higher in the multiple-obstruction group than in the single-obstruction group (Figure 4B and C), while the apnea index (P = 0.8798) (Figure 4A), post-treatment AHI (P = 0.5227) (Figure 4F), ratio of change in AHI (P=0.7510) (Figure 4G), maximum therapeutic pressure (P = 0.0738) (Figure 4H) and minimum therapeutic pressure (P = 0.2943) (Figure 4I) did not have a significant difference, as shown in Table 2. We noticed that some subjects had an apnea index as the predominant AHI, and the rest had a hypopnea index as the predominant AHI. Thus, we classified the subjects with predominant apnea index as Group A (n = 19, 59.4%) and the rest of the subjects as Group H (n = 13, 40.6%). Performing the Müller maneuver, the ratio of area change at the epiglottic level was significantly different between the two groups (P = 0.033) and was greater in Group A than in Group H (Figure 5A). The majority of subjects in Group A had a ratio of area change at this level greater than 50%. Most subjects in Group H had a ratio of change of area of less than 50%, and only in Group H were there three subjects with a ratio of change of area of less than 0%. In addition, the AHI during the NREM period (NAHI) was significantly higher in the multiple-obstruction group than in the single-obstruction group (P=0.33) (Figure 4D), whereas the AHI during the REM period (RAHI) was not significantly different (P=0.472) (Figure 4E). Some subjects' sleep events occurred mostly during NREM (Group N), while the rest of the subjects were mostly during REM (Group R). We found the anteroposterior diameter change ratio at the level of the root of the tongue and the area change ratio at the level of the epiglottis of the subjects in Group N were significantly greater than that of the subjects in Group R (P = 0.004 and P = 0.010, respectively) (Figure 5B and C), and the area change ratio at the level of the epiglottis of the subjects was less than 0% only in Group R.

Almost all subjects, the axial changes in the tongue lengthen significantly after the Müller manoeuvre. In addition, there was only one subject in whom the axial distance of the root of the tongue became shorter during the Müller maneuver. The RAC was significantly higher in the multiple-obstruction group than in the single-obstruction group (P < 0.001) (Figure 4J). The value of the RAC had a positive correlation with the maximum therapeutic pressure (r = 0.373, P = 0.0494) (Figure 6A). Meanwhile, the value of RAC had the same positive correlation with the minimum therapeutic pressure (r = 0.3448, P = 0.0332) (Figure 6B).

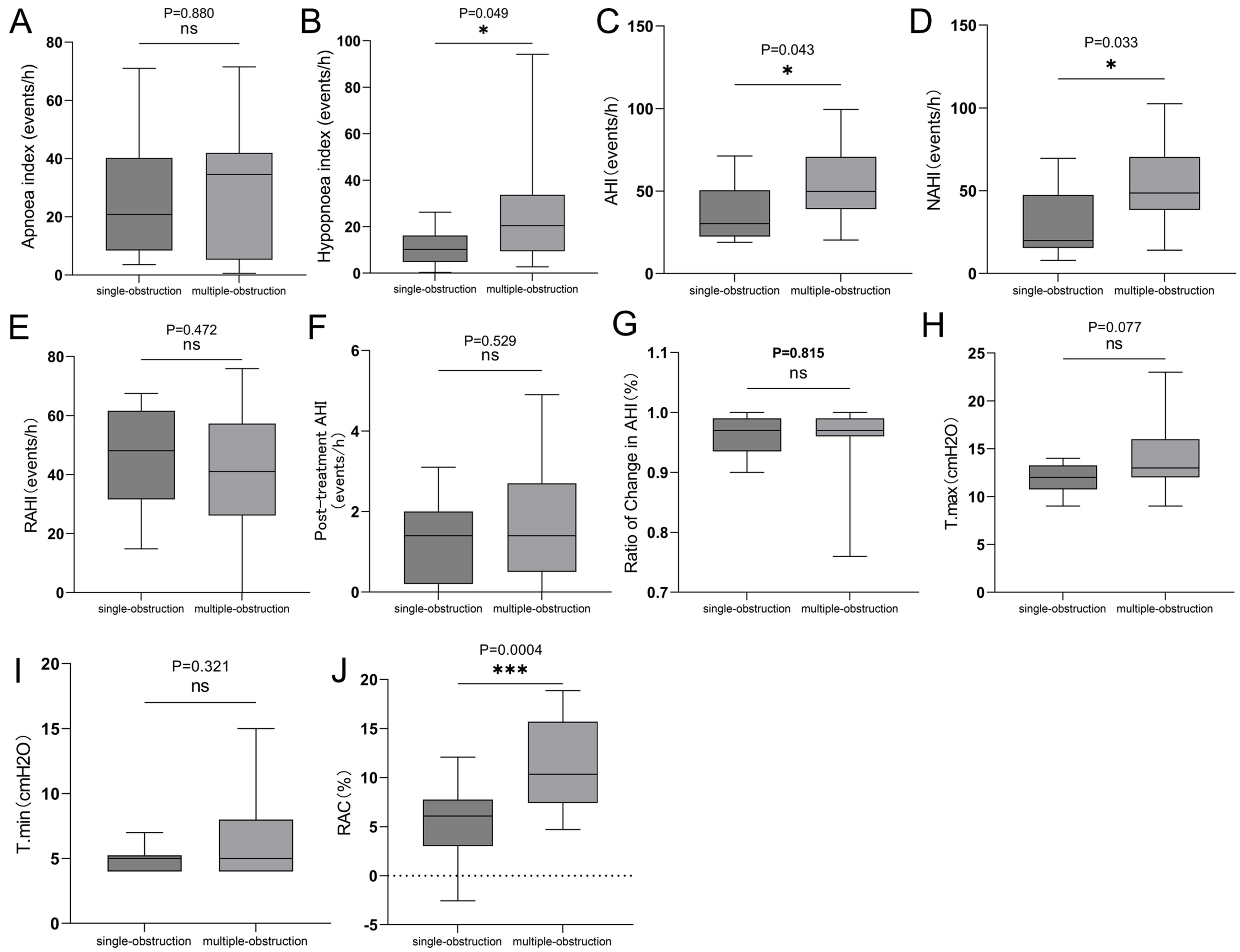

Figure 4 The differences in outcomes of polysomnography and upper airway dynamic magnetic resonance between single-obstruction and multiple-obstruction groups. (**A**) a comparison of apnea index in single-obstruction and multiple-obstruction groups. (**B**) a comparison of hypopnea index in single-obstruction and multiple-obstruction groups. (**C**) a comparison of apnea hypopnea index (AHI) in single-obstruction and multiple-obstruction groups. (**D**) a comparison of apnea hypopnea index during non-REM sleep (NAHI) in single-obstruction and multiple-obstruction groups. (**E**) a comparison of apnea hypopnea index during REM sleep (RAHI) in single-obstruction and multiple-obstruction groups. (**F**) a comparison of post-treatment AHI in single-obstruction and multiple-obstruction groups. (**G**) a comparison of the ratio of change in AHI in single-obstruction and multiple-obstruction groups. (**H**) a comparison of maximum therapeutic pressure (T.max) in single-obstruction and multiple-obstruction groups. (**I**) a comparison of minimum therapeutic pressure (T.min) in single-obstruction and multiple-obstruction groups. (**J**) a comparison of the ratio of axial changes in the tongue (RAC) in single-obstruction and multiple-obstruction groups. Bars show the ranges of maximum to minimum. * indicates $P < 0.05$. *** indicates $P < 0.001$. ns indicates $P \geq 0.05$.

Then, we investigated the correlation between UADMR and results of manual titration of positive airway pressure/PSG. It was observed that at the palatopharyngeal level, the ratio of change in area under the Müller maneuver correlated with AHI (r = 0.353, P = 0.041) (Figure 6C). At the root of the tongue level, the ratio of change in anteroposterior diameter under the Müller maneuver correlated with AHI (r = 0.359, P = 0.037) (Figure 6D). Similarly, the ratio of change in the area at the epiglottic level under the Müller maneuver also correlated with the AHI (r=0.464, P=0.006) (Figure 6E). The NAHI also correlated with the ratio of area change at the epiglottic level as well (r = 0.411, P = 0.019) (Figure 6F), while the RAHI did not show a significant difference. When we focused on the results of the manual titration of positive airway pressure, we found that the minimum treatment pressure correlated with the ratio of area change at the epiglottic level under the Müller maneuver (r = 0.393, P = 0.024) (Figure 6G). Correspondingly, the maximum therapeutic pressure correlated with the ratio of change in anteroposterior diameter at the root of the tongue level under the Müller maneuver (r = 0.522, P = 0.002) (Figure 6H).

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Table 2 Differences in Polysomnography and Manual Titration of Positive Airway Pressure Results Between Single-Obstruction Group and Multiple-Obstruction Group

Item	Single-Obstruction Group	Multiple-Obstruction Group	P value
Apnea index, event/h	27.96±22.21	30.14±23.07	0.880
Hypopnea index, event/h	10.95±7.46	23.47±20.72	0.049 *
AHI, event/h	38.21±17.86	53.74±20.77	0.043 *
NAHI, event/h	32.81±21.07	51.93±21.95	0.033 *
RAHI, event/h	46.67±16.50	38.87±23.73	0.472
Post-treatment AHI, event/h	1.271±1.01	1.63±1.29	0.529
Ratio of change in AHI,%	96.12±0.03	96.12±0.05	0.815
T.max, cmH_2O	11.93±1.54	13.95±3.39	0.077
T.min, cmH_2O	5.07±1.00	6.11±2.62	0.321
Sleep stage N1,%	24.41±12.94	27.50±12.85	0.362
Sleep stage N2,%	52.77±9.07	50.56±10.05	0.910
Sleep stage N3,%	6.62±5.12	7.42±5.52	0.705
Sleep stage REM,%	16.19±6.01	14.51±9.02	0.570

Notes: Data are shown as mean ± SD. * are considered significant differences (P<0.05).
Abbreviations: AHI, apnea-hypopnea index; NAHI, apnea-hypopnea index during non-rapid eye movement sleep; RAHI, apnea-hypopnea index during rapid eye movement sleep; T.max, maximum therapeutic pressure; T.min, minimum therapeutic pressure; Sleep stage N1 to 3, NREM stage 1 to 3.

Discussion

OSAHS has a high prevalence and is of great concern because of its multiple complications and impact on daily life. Previous studies have shown that hypoxia caused by tissue collapse in the upper airways plays a pivotal role in OSAHS.[15] multiple-obstruction and collapse of the upper airway are important factors influencing the severity of OSAHS.[16] Clinically, uvulopalatopharyngoplasty is less effective in patients with multiple-obstruction in upper airway than in patients with simple palatopharyngeal collapse.[17] Therefore, the detection of multiple-obstruction of the upper airway is essential for the management of OSAHS.

Many imaging methods, eg CT, X-ray and conventional MR, have a limited role in showing the movement of the upper airway.[14] The PSG can provide various physiological data during sleep, but it cannot reflect the locations and the degree of obstruction in the upper airway.[5] UADMR can monitor the airway collapse of the subjects in real time.[18] In this study, UADMR was used to monitor airway collapse in real-time, and the soft tissue movement of the upper airway during the Müller maneuver was recorded in detail to simulate airway collapse during sleep.

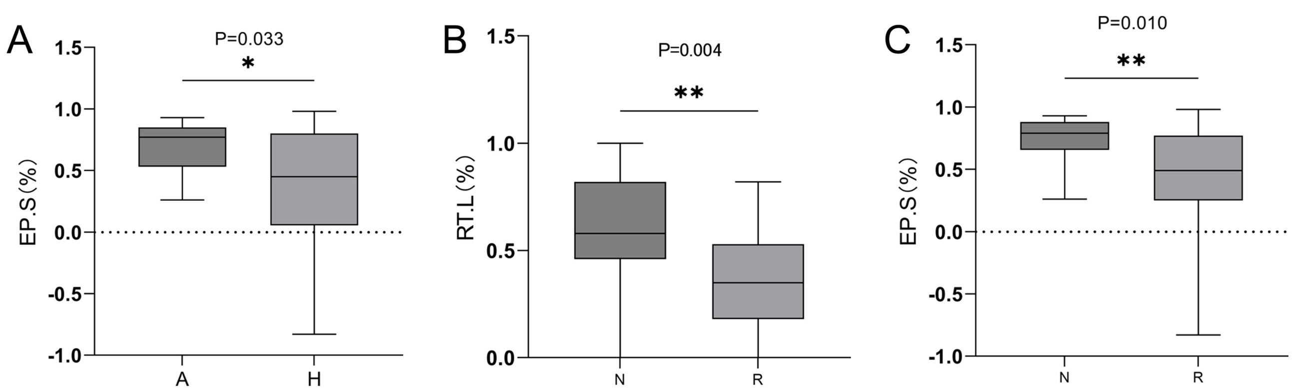

Figure 5 Differences in outcomes of the upper airway magnetic resonance in patients with different sleep characteristics. (**A**): a comparison of the ratio of change in area at the epiglottic level under the Müller test between subjects who had an apnea index as the predominant AHI (Group A) with the rest of the subjects who had a hypopnea index as the predominant AHI (Group H); (**B**): a comparison of the ratio of change in anteroposterior diameter at the root of the tongue level under the Müller test between subjects whose sleep events occurred mostly during non-rapid eye movement sleep (Group N) with the rest of the subjects whose sleep events occurred mostly during rapid eye movement sleep (Group R); (**C**): a comparison of the ratio of change in area at the epiglottic level under the Müller test between subjects whose sleep events occurred mostly during non-rapid eye movement sleep (Group N) with the rest of the subjects whose sleep events occurred mostly during rapid eye movement sleep (Group R). Bars show the ranges of maximum to minimum. * indicates P < 0.05. ** indicates P < 0.01. ns indicates P ≥ 0.05.

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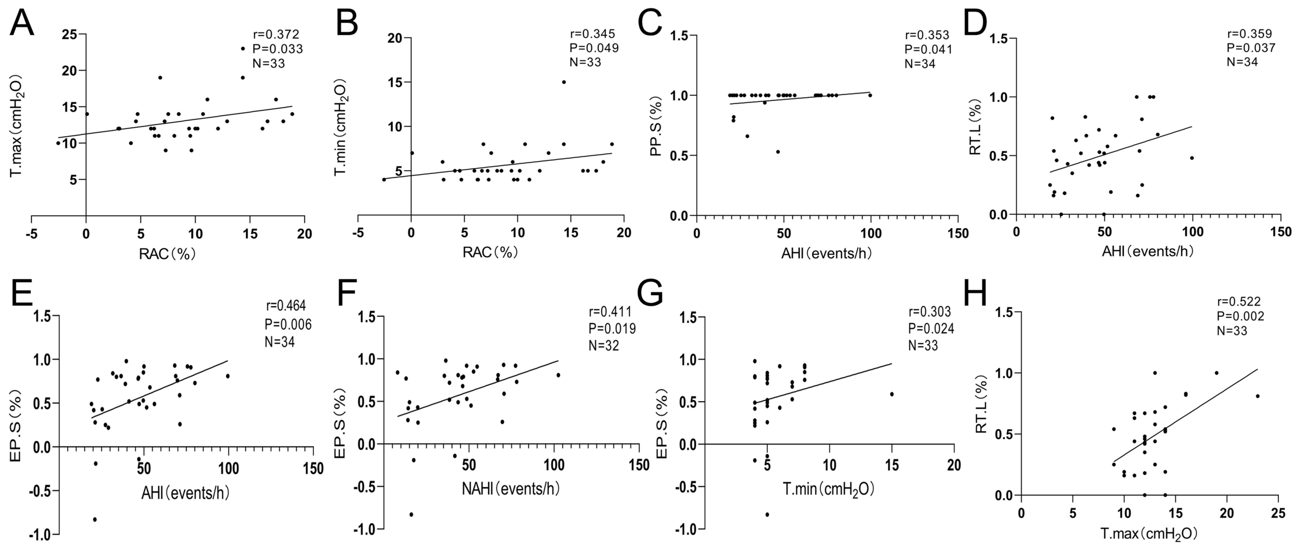

Figure 6 Correlation of upper airway dynamic magnetic resonance data with sleep-related data. (**A** and **B**): Relationship between the ratio of axial changes in the tongue (RAC) with (**A**) maximum therapeutic pressure (T.max) and (**B**) minimum therapeutic pressure (T.min); (**C-E**) Relationship between the apnea hypopnea index (AHI) with (**C**) the ratio of change in area at the palatopharyngeal level (PP.S), (**D**) the ratio of change in anteroposterior diameter at the root of the tongue level (RT.L) and (**E**) the ratio of change in area at the epiglottic level under the Müller test (EP.S); (**F**) Relationship between the apnea hypopnea index during non-REM sleep (NAHI) with the ratio of change in area at the epiglottic level under the Müller test (EP.S); (**G**) Relationship between minimum therapeutic pressure (T.min) with the ratio of change in area at the epiglottic level under the Müller test (EP.S); (**H**): Relationship between maximum therapeutic pressure (T.max) with the ratio of change in anteroposterior diameter at the root of the tongue level under the Müller test (RT.L).

We observed that when performing the Müller maneuver, participants exhibited obstruction in the upper airway, particularly in the palatopharyngeal layer and the root of the tongue layer.[19] The anteroposterior diameter change ratio and area change ratio of the palatopharyngeal layer exceeded 90% in almost all subjects during the Müller maneuver, in agreement with the previous findings.[14,20] Furthermore, it has been shown that epiglottic stability is one of the determinants of airflow stability in the upper airway.[21] We found the movement of epiglottis formed the airway obstruction when performing the Müller maneuver in the sagittal images. The obstruction of the epiglottic layer was rarely mentioned in previous studies. Therefore, our study focused on the obstruction of the root of the tongue and epiglottic layers in upper airway.

Subjects in the multiple-obstruction group had a higher AHI, mainly manifested by a higher hypopnea index. We attributed it to the possibility that patients with obstruction in multiple parts of the airway are more likely to cause transient hypoxia throughout sleep. Manual titration of positive airway pressure can reflect the AHI of subjects after CPAP treatment. Although the mean post-treatment pressure in multiple-obstruction group was higher than that in single-obstruction group, there was no statistically significant difference between the two groups. Further evidence is needed to prove the relationship between UADMR results and prognosis. We also compared the change ratios of each layer of the upper airway under the Müller maneuver with the results of PSG and manual titration of positive airway pressure. There was a correlation between the anteroposterior diameter change ratio of the root of the tongue and the AHI, whereas the area change ratio was not correlated with the AHI. It might be caused by the fact that the root of the tongue mainly exhibits posterior movement rather than inward constriction when performing the Müller maneuver. In the epiglottic layer, instead, the area change ratio correlated with AHI. When observing the dynamics of the upper airway, it can be seen that the epiglottis first moved towards the root of the tongue, and then moved together due to the posterior movement of the root of the tongue (Supplementary Video 4). In fact, the epiglottis oscillates back and forth during calm nasal breathing, but generally at a distance from the root of the tongue. Therefore, the endpoint of the movement under the Müller maneuver is limited from the position under calm breathing, whereas the posterior movement of the root of the tongue causes a localized deformation of the epiglottis, which might be the main reason for the correlation between the ratio of area changes and AHI. Haba et al showed that subjects with predominantly RAHI had a lower AHI,[22] which is consistent with our results, and we found that subjects with predominantly NAHI had greater anteroposterior diameters of the root of the tongue and greater epiglottic area change ratios. Furthermore, the area change ratio of the epiglottis was correlated with the minimum therapeutic pressure, and the anteroposterior diameter change ratio of the root of the tongue was correlated with the maximum therapeutic pressure. The minimum and maximum therapeutic pressures correspond to the positive pressure that maintains an open airway and the positive pressure that does not cause adverse effects, respectively. Therefore, the degree of obstruction at the epiglottic layer, the lowermost position mentioned in this study, should be more focused when we manage patients with OSAHS.

Fukushi et al[23] connected two point (one is the coordinates of a point on the tongue root and another point that is static on the most infero-posterior portion of the third cervical vertebra) and calculated to evaluate the tongue movement. They demonstrated the pattern of movement of the tongue under the Müller maneuver was mainly axial,[23] consistent with our results. However, the tongue is in constant motion, so it is difficult to accurately localize point on the tongue root. We proposed a novel index called RAC to measure the axial changes of the tongue. The RAC was significantly higher in the multiple-obstruction group than that in the simple-obstruction group. This might be related to the movement of the root of the tongue under the Müller maneuver described above. The degree of posterior movement of the root of the tongue was usually greater in subjects with significant narrowing of the root of the tongue layer, leading to the concomitant epiglottic obstruction. The RAC also showed a positive correlation with the minimum and maximum therapeutic pressures, providing more guidance for treating OSAHS.

There are some limitations in the study. We found some participants showed lower completion of the Müller maneuver, which spent more time in performing the examination and reduced patients' experience. In addition, the subjects included in the study are mainly patients with severe OSAHS, and the sample size is small. Therefore, our conclusions might not be applicable to all OSAHS populations. Further large-sample studies would be required to explore the clinical value of UADMR in OSAHS in the future.

Conclusion

UADMR with the Müller maneuver could detect the layers and degree of upper airway obstruction during sleep in patients with OSAHS, and is a reliable method for guiding CPAP treatment for OSAHS.

Data Sharing Statement

The data will be made available on reasonable request from the first author. The Email address of the first author is as follows: Jackie1181016394@163.com.

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All authors took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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