

# World Journal of *Clinical Cases*

*World J Clin Cases* 2024 February 16; 12(5): 872-1038



## EDITORIAL

- 872 Is it possible to anchor a tooth with photobiomodulation?  
*Dominguez A*
- 875 Strengthening pharmacotherapy research for COVID-19-induced pulmonary fibrosis  
*Liu YM, Zhang J, Wu JJ, Guo WW, Tang FS*

## ORIGINAL ARTICLE

## Clinical and Translational Research

- 880 Causal associations between gastroesophageal reflux disease and essential hypertension: A bidirectional Mendelian randomization study  
*Wei N, Liu MH, Song YH*
- 891 Serum urate is associated with an increased risk of inflammatory bowel disease: A bidirectional Mendelian randomization study  
*Zhang S, Fang X, Kang L, Sui XY, Liu M, Luo YJ, Fu S, Li ZS, Zhao SB, Bai Y*

## Retrospective Cohort Study

- 903 Effect of health education based on information-motivation-behavioral skills model on patients with unilateral vestibular dysfunction  
*Shi Q, Wu RJ, Liu J*

## Retrospective Study

- 913 Removal of intrahepatic bile duct stone could reduce the risk of cholangiocarcinoma: A single-center retrospective study in South Korea  
*Kim TI, Han SY, Lee J, Kim DU*
- 922 Effect of nursing on postoperative respiratory function and mental health of lung cancer patients  
*Yang X, Yin D, Chen SQ*
- 931 Value of glucose transport protein 1 expression in detecting lymph node metastasis in patients with colorectal cancer  
*Kim H, Choi SY, Heo TY, Kim KR, Lee J, Yoo MY, Lee TG, Han JH*

## Observational Study

- 942 Clinical efficacy and mechanism study of mid-frequency anti-snoring device in treating moderate obstructive sleep apnea-hypopnea syndrome  
*Qian B, Chen ZJ, Wang YS, Hu XY, Hu XB, Zheng YH*
- 951 Urinary metabolic profiles during *Helicobacter pylori* eradication in chronic gastritis  
*An WT, Hao YX, Li HX, Wu XK*

- 966 Clinical significance of platelet mononuclear cell aggregates in patients with sepsis and acute respiratory distress syndrome

*Huang CM, Li JJ, Wei WK*

### CASE REPORT

- 973 Left ventricular thrombosis caused cerebral embolism during venoarterial extracorporeal membrane oxygenation support: A case report

*Bai YB, Zhao F, Wu ZH, Shi GN, Jiang N*

- 980 Abnormal uterine bleeding successfully treated *via* ultrasound-guided microwave ablation of uterine myoma lesions: Three case reports

*Kakinuma T, Kakinuma K, Okamoto R, Yanagida K, Ohwada M, Takeshima N*

- 988 Omental fibroma combined with right indirect inguinal hernia masquerades as a scrotal tumor: A case report

*Zhou P, Jin CH, Shi Y, Ma GQ, Wu WH, Wang Y, Cai K, Fan WF, Wang TB*

- 995 Imaging, pathology, and diagnosis of solitary fibrous tumor of the pancreas: A case report and review of literature

*Wang WW, Zhou SP, Wu X, Wang LL, Ruan Y, Lu J, Li HL, Ni XL, Qiu LL, Zhou XH*

- 1004 Neuroimaging features in a patient with non-ketotic hyperglycaemic seizures: A case report

*Wu J, Feng H, Zhao Y, Li J, Li T, Li K*

- 1010 Novel approach of ultrasound-guided lateral recess block for a patient with lateral recess stenosis: A case report

*Yang J, Li XL, Li QB*

- 1018 Ankylosing spondylitis coexisting with *Clonorchis sinensis* infection: A case report

*Yi TX, Liu W, Leng WF, Wang XC, Luo L*

- 1025 Hematuria after nocturnal exercise of a man: A case report

*Bai MJ, Yang ST, Liu XK*

### LETTER TO THE EDITOR

- 1029 Response letter to "Acute cholangitis: Does malignant biliary obstruction *vs* choledocholithiasis etiology change the outcomes?" with imaging aspects

*Aydin S, Irgul B*

- 1033 Exploring multifaceted factors in chronic kidney disease risk: A comprehensive analysis of biochemistry, lifestyle, and inflammation in elderly Chinese individuals

*Cardona F*

- 1036 Transcranial direct current stimulation efficacy in trigeminal neuralgia

*Fasilis T, Gatzonis S, Patrikelis P, Korfiatis S, Alexoudi A*

**ABOUT COVER**

Peer Reviewer of *World Journal of Clinical Cases*, Abdulkarim Hasan, MD, MSc, Consultant Physician-Scientist, Doctor, Lecturer, Department of Pathology, Al-Azhar University, Faculty of Medicine, Cairo 11884, Egypt. doctorabdulkarim7@gmail.com

**AIMS AND SCOPE**

The primary aim of *World Journal of Clinical Cases* (WJCC, *World J Clin Cases*) is to provide scholars and readers from various fields of clinical medicine with a platform to publish high-quality clinical research articles and communicate their research findings online.

WJCC mainly publishes articles reporting research results and findings obtained in the field of clinical medicine and covering a wide range of topics, including case control studies, retrospective cohort studies, retrospective studies, clinical trials studies, observational studies, prospective studies, randomized controlled trials, randomized clinical trials, systematic reviews, meta-analysis, and case reports.

**INDEXING/ABSTRACTING**

The WJCC is now abstracted and indexed in Science Citation Index Expanded (SCIE, also known as SciSearch®), Journal Citation Reports/Science Edition, Current Contents®/Clinical Medicine, PubMed, PubMed Central, Reference Citation Analysis, China Science and Technology Journal Database, and Superstar Journals Database. The 2023 Edition of Journal Citation Reports® cites the 2022 impact factor (IF) for WJCC as 1.1; IF without journal self cites: 1.1; 5-year IF: 1.3; Journal Citation Indicator: 0.26; Ranking: 133 among 167 journals in medicine, general and internal; and Quartile category: Q4.

**RESPONSIBLE EDITORS FOR THIS ISSUE**

Production Editor: Hua-Ge Yin; Production Department Director: Xiang Li; Editorial Office Director: Jin-Lei Wang.

**NAME OF JOURNAL**

*World Journal of Clinical Cases*

**ISSN**

ISSN 2307-8960 (online)

**LAUNCH DATE**

April 16, 2013

**FREQUENCY**

Thrice Monthly

**EDITORS-IN-CHIEF**

Bao-Gan Peng, Salim Surani, Jerzy Tadeusz Chudek, George Kontogeorgos, Maurizio Serati

**EDITORIAL BOARD MEMBERS**

<https://www.wjgnet.com/2307-8960/editorialboard.htm>

**PUBLICATION DATE**

February 16, 2024

**COPYRIGHT**

© 2024 Baishideng Publishing Group Inc

**INSTRUCTIONS TO AUTHORS**

<https://www.wjgnet.com/bpg/gerinfo/204>

**GUIDELINES FOR ETHICS DOCUMENTS**

<https://www.wjgnet.com/bpg/GerInfo/287>

**GUIDELINES FOR NON-NATIVE SPEAKERS OF ENGLISH**

<https://www.wjgnet.com/bpg/gerinfo/240>

**PUBLICATION ETHICS**

<https://www.wjgnet.com/bpg/GerInfo/288>

**PUBLICATION MISCONDUCT**

<https://www.wjgnet.com/bpg/gerinfo/208>

**ARTICLE PROCESSING CHARGE**

<https://www.wjgnet.com/bpg/gerinfo/242>

**STEPS FOR SUBMITTING MANUSCRIPTS**

<https://www.wjgnet.com/bpg/GerInfo/239>

**ONLINE SUBMISSION**

<https://www.f6publishing.com>



Observational Study

# Clinical efficacy and mechanism study of mid-frequency anti-snoring device in treating moderate obstructive sleep apnea-hypopnea syndrome

Bao Qian, Zhan-Jun Chen, Yong-Sheng Wang, Xiao-Yan Hu, Xiao-Biao Hu, Yong-Hua Zheng

**Specialty type:** Respiratory system

**Provenance and peer review:**

Unsolicited article; Externally peer reviewed.

**Peer-review model:** Single blind

**Peer-review report's scientific quality classification**

Grade A (Excellent): 0  
Grade B (Very good): 0  
Grade C (Good): C  
Grade D (Fair): 0  
Grade E (Poor): 0

**P-Reviewer:** Nooripour R, Iran

**Received:** November 2, 2023

**Peer-review started:** November 2, 2023

**First decision:** December 5, 2023

**Revised:** December 14, 2023

**Accepted:** January 23, 2024

**Article in press:** January 23, 2024

**Published online:** February 16, 2024



**Bao Qian, Zhan-Jun Chen, Xiao-Yan Hu, Xiao-Biao Hu, Yong-Hua Zheng,** Pulmonary Medicine, Shanghai Jinshan Tinglin Hospital, Shanghai 201505, China

**Yong-Sheng Wang,** Radiology Medicine, Shanghai Jinshan Tinglin Hospital, Shanghai 201505, China

**Corresponding author:** Yong-Hua Zheng, MD, Deputy Chief Physician, Pulmonary Medicine, Shanghai Jinshan Tinglin Hospital, No. 80 North Siping Road, Jinshan District, Shanghai 201505, China. [zhengyonghua0118@hotmail.com](mailto:zhengyonghua0118@hotmail.com)

## Abstract

### BACKGROUND

Obstructive sleep apnea-hypopnea syndrome (OSAHS) is primarily caused by airway obstruction due to narrowing and blockage in the nasal and nasopharyngeal, oropharyngeal, soft palate, and tongue base areas. The mid-frequency anti-snoring device is a new technology based on sublingual nerve stimulation. Its principle is to improve the degree of oropharyngeal airway stenosis in OSAHS patients under mid-frequency wave stimulation. Nevertheless, there is a lack of clinical application and imaging evidence.

### AIM

To investigate the clinical efficacy and mechanisms of a mid-frequency anti-snoring device in treating moderate OSAHS.

### METHODS

We selected 50 patients diagnosed with moderate OSAHS in our hospital between July 2022 and August 2023. They underwent a 4-wk treatment regimen involving the mid-frequency anti-snoring device during nighttime sleep. Following the treatment, we monitored and assessed the sleep apnea quality of life index and Epworth Sleepiness Scale scores. Additionally, we performed computed tomography scans of the oropharynx in the awake state, during snoring, and while using the mid-frequency anti-snoring device. Cross-sectional area measurements in different states were taken at the narrowest airway point in the soft palate posterior and retrolingual areas.

### RESULTS

Compared to pretreatment measurements, patients exhibited a significant reduction in the apnea-hypopnea index, the percentage of time with oxygen saturation below 90%, snoring frequency, and the duration of the most prolonged apnea event. The lowest oxygen saturation showed a notable increase, and both sleep apnea quality of life index and Epworth Sleepiness Scale scores improved. Oropharyngeal computed tomography scans revealed that in OSAHS patients cross-sectional areas of the oropharyngeal airway in the soft palate posterior area and retrolingual area decreased during snoring compared to the awake state. Conversely, during mid-frequency anti-snoring device treatment, these areas increased compared to snoring.

## CONCLUSION

The mid-frequency anti-snoring device demonstrates the potential to enhance various sleep parameters in patients with moderate OSAHS, thereby improving their quality of life and reducing daytime sleepiness. These therapeutic effects are attributed to the device's ability to ameliorate the narrowing of the oropharynx in OSAHS patients.

**Key Words:** Mid-frequency anti-snoring device; Obstructive sleep apnea-hypopnea syndrome; Sleep monitoring; Oropharyngeal computed tomography; Curative effect

©The Author(s) 2024. Published by Baishideng Publishing Group Inc. All rights reserved.

**Core Tip:** We investigated the clinical efficacy and underlying mechanisms of a mid-frequency anti-snoring device in treating 50 moderate obstructive sleep apnea-hypopnea syndrome patients for 4 wk. Our results indicated significant improvements in the apnea-hypopnea index, the percentage of time with oxygen saturation below 90%, and the sleep apnea quality of life index and Epworth Sleepiness Scale scores. Additionally, we found compelling evidence that the mid-frequency anti-snoring device positively influenced the narrowing of the oropharynx in sleep apnea-hypopnea syndrome patients during snoring.

**Citation:** Qian B, Chen ZJ, Wang YS, Hu XY, Hu XB, Zheng YH. Clinical efficacy and mechanism study of mid-frequency anti-snoring device in treating moderate obstructive sleep apnea-hypopnea syndrome. *World J Clin Cases* 2024; 12(5): 942-950

**URL:** <https://www.wjgnet.com/2307-8960/full/v12/i5/942.htm>

**DOI:** <https://dx.doi.org/10.12998/wjcc.v12.i5.942>

## INTRODUCTION

Obstructive sleep apnea-hypopnea syndrome (OSAHS) is primarily caused by airway obstruction due to narrowing and blockage in the nasal and nasopharyngeal, oropharyngeal, soft palate, and tongue base areas. Its main clinical manifestations include snoring and associated breathing pauses during nighttime sleep. Most patients experience dry mouth upon waking in the morning, and some may also have symptoms such as headaches, daytime sleepiness, fatigue, lack of concentration, *etc*[1].

Transcutaneous electrical stimulation of the genioglossus muscle is a non-invasive treatment method for OSAHS [2]. Recently, a mid-frequency anti-snoring device has been developed that delivers specific pulse-modulated compound waves to provide intermittent electrical stimulation to the genioglossus muscle and its sublingual nerve branches. This leads to a responsive contraction of the genioglossus muscle, an increase in upper airway tension, a reduction in the severity of oropharyngeal upper airway collapse, and the maintenance of an open upper airway, ultimately terminating snoring. This device is beneficial for improving the quality of sleep in OSAHS patients.

This study focused on patients with moderate OSAHS and investigated whether the treatment with a mid-frequency anti-snoring device can improve various sleep parameters in OSAHS patients and enhance their quality of daily life. Additionally, it explores whether the airways in the oropharyngeal region expand under the stimulation of mid-frequency waves. Currently, there is a lack of imaging evidence in this regard. Therefore, this study conducted oropharyngeal computed tomography (CT) scans in OSAHS patients in awake, snoring, and mid-frequency anti-snoring device treatment states to measure the cross-sectional area at the narrowest points in the soft palate posterior and retrolingual areas. This approach aimed to provide imaging-based confirmation of the working mechanism of this technology in treating OSAHS.

## MATERIALS AND METHODS

### General information

This study was conducted on 50 patients diagnosed with moderate OSAHS in our hospital from July 2022 to August 2023. The primary patient information is shown in Table 1. Upon diagnosis, patients began wearing a mid-frequency anti-snoring device during nighttime sleep. Before treatment, the study's purpose and relevant precautions were explained to the patients. Upon the patients' understanding and agreement, informed consent forms were signed.



**Table 1** Baseline characteristics of the study participants

Variable	Data
Male/female	35/15
Age in yr	38.5 ± 6.8
Height in cm	170.3 ± 10.8
Weight in kg	89.7 ± 15.6
BMI in kg/m <sup>2</sup>	29.5 ± 3.4
Systolic blood pressure in mmHg	122.3 ± 11.4
Diastolic blood pressure in mmHg	71.6 ± 10.2

Data are mean ± SD or *n*/*N*. BMI: Body mass index.

**Inclusion criteria:** (1) An apnea-hypopnea index (AHI) ≥ 30 events per hour during 7 h of sleep at night or an AHI ≥ 5 events per hour. The criterion for moderate OSAHS was an AHI index of 15-30 events per hour; (2) Voluntary participation and signed informed consent; (3) Complete clinical data; and (4) Good patient compliance and the ability to fully participate in the entire study.

**Exclusion criteria:** (1) Patients with mild or severe OSAHS; (2) Patients who have recently experienced acute illness and received related treatments; (3) Patients with severe cardiovascular or cerebrovascular diseases or multiorgan dysfunction; (4) Patients with mental illnesses or cognitive communication disorders; (5) Patients who have participated in other clinical studies in the past 3 months; and (6) Contraindications for the mid-frequency anti-snoring device, including acute purulent inflammation in the submental region, bleeding tendency, malignant tumors, severe heart diseases, severe cardiopulmonary diseases, airway obstruction due to nasal disorders, the presence of implantable devices such as pacemakers, skin allergies, and inability to express self-awareness, such as infants.

### Sleep monitoring

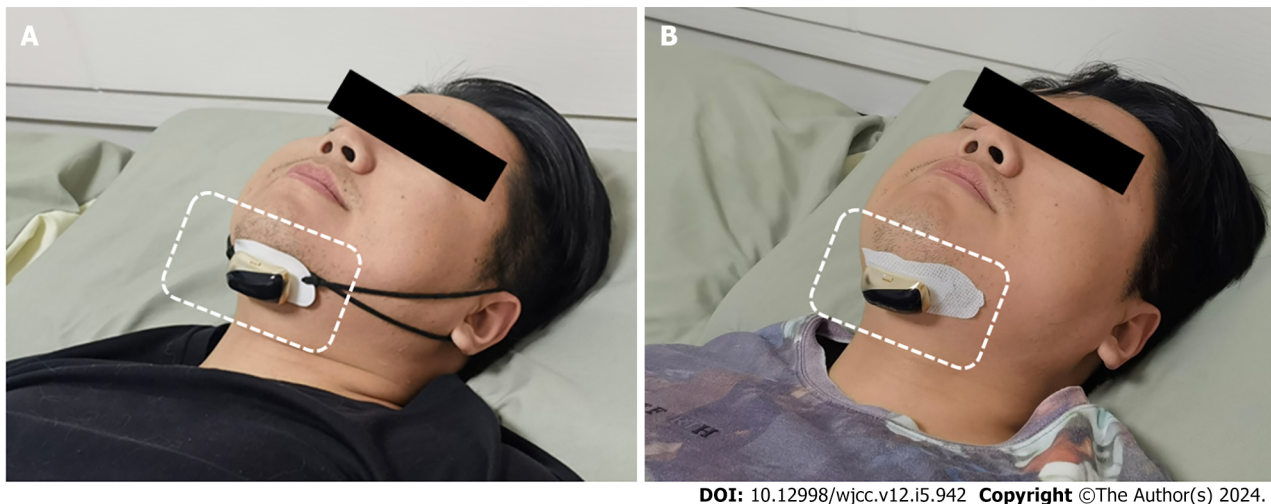
Sleep monitoring was conducted using a Sleep-Disordered Breathing Analyzer (SOMNOcheck micro, Weinmann, Germany). The first monitoring was performed before the mid-frequency anti-snoring device treatment to establish the diagnosis and assess severity. Subsequently, the mid-frequency anti-snoring device was used during nighttime sleep for 4 wk. The second sleep monitoring was conducted after the treatment and compared with the data from the first monitoring. Key sleep monitoring parameters included the AHI, lowest pulse oxygen saturation (LSPO<sub>2</sub>), and snoring percentage (the percentage of time spent snoring during sleep).

### Mid-frequency anti-snoring device treatment

Treatment was performed using a mid-frequency anti-snoring device (JLY-Y3 or JLY-Z3, Taizhou Jinliyou Medical Technology Co. Ltd.). The device parameters included a rated voltage of D.C 3.7 V, a power of 0.1 W, a modulation waveform of bidirectional symmetric trapezoidal waves, and a frequency of 20 KHz. The treatment process involved fixing the anti-snoring device to the lower jaw using either the ear-worn (Figure 1A) or patch (Figure 1B) method. After wearing the device, it was powered on by pressing and holding the device's switch for approximately 3 s. The power indicator would blink to confirm a successful startup. Patients would lie flat for sleep, and the anti-snoring device would automatically operate. If snoring or breathing pauses were detected, it would provide mid-frequency electrical pulses for intervention.

### Oropharyngeal CT

To better detect upper airway obstruction or narrowing in patients, overnight upper airway CT scans were conducted while they were sleeping. The United Imaging uCT760-64 slice spiral CT scanner and its matching workstation were used. Patients were placed supine, with their eyes closed, and proper positioning was ensured. The scanning range extended from the top of the maxillary sinus to 5 cm below the hyoid bone. The scanning parameters were set at 125 KV, 200 mA, a scanning pitch of 1.5, a slice thickness of 5.0 mm, and an interlayer spacing of 5.0 mm. Reconstructed images included coronal and sagittal multiplanar reformation images and three-dimensional maximum intensity projection images. The narrowest cross-sectional area of the upper airway (soft palate and retrolingual airway) was measured three times using multi-slice spiral CT 3D software. Measurements were taken with a fixed window width and window level. Upper airway CT scans were conducted 1 wk after mid-frequency anti-snoring device treatment. Patients wore the device and laid flat on the CT examination bed. The first upper airway CT scan was performed while the patient was awake. The second scan was performed when the patient started snoring, with the device switched off, and the third scan was completed when snoring ceased with the device switched on.



DOI: 10.12998/wjcc.v12.i5.942 Copyright ©The Author(s) 2024.

**Figure 1** Proper method of wearing the mid-frequency anti-snoring device. A: Ear-worn style; B: Patch style.

### Ethical permission

The study protocol was approved by the medical ethics committee of Shanghai Jinshan Tinglin Hospital for research ethics. Each patient was informed of the nature of the study and signed an informed consent form.

### Statistical analysis

SPSS 22.0 software was used for analysis. Quantitative data were represented as (mean  $\pm$  SEM). Self-matching paired *t*-tests were employed, with  $P < 0.05$  considered statistically significant.

## RESULTS

### Comparison of sleep monitoring parameters

After 4 wk of treatment with the mid-frequency anti-snoring device, the patient's sleep monitoring parameters, including AHI, snoring percentage, the most prolonged apnea duration(s), and the duration of  $\text{SPO}_2 < 90\%$ , decreased compared to before treatment ( $P < 0.05$ ).  $\text{LSPO}_2$  increased compared to before treatment ( $P < 0.05$ ). Various indicators of the autonomous arousal index (AAI resp) improved, with AAI resp decreased compared to before treatment ( $P < 0.05$ ). AAI non-resp also decreased compared to before treatment ( $P < 0.05$ ), as did respiratory effort-related arousals ( $P < 0.05$ ), as shown in [Table 2](#).

### Comparison of sleep apnea quality of life index and Epworth Sleepiness Scale scores

After 4 wk of treatment with the mid-frequency anti-snoring device, patients showed improvements in sleep apnea quality of life index scale scores, including social activity, emotional state, and symptom scores, all of which increased compared to before treatment. Epworth Sleepiness Scale scores decreased, and these differences were statistically significant ( $P < 0.05$ ), as shown in [Table 3](#).

### Analysis of oropharyngeal CT examination results

In this study, we selected the narrowest points of the oropharyngeal airway in the soft palate posterior area and retrolingual area of OSAHS patients as the measurement points. These two areas were relatively stable during CT scanning and less susceptible to external interference. In the awake, snoring, and mid-frequency anti-snoring device treatment states, the cross-sectional areas of the narrowest part of the soft palate airway in OSAHS patients were  $80.47 \pm 18.56 \text{ mm}^2$ ,  $22.05 \pm 16.47 \text{ mm}^2$ , and  $71.61 \pm 17.38 \text{ mm}^2$ , respectively.

Compared to the awake state, OSAHS patients had a reduction in the cross-sectional areas of the soft palate posterior area and retrolingual area during snoring ( $P < 0.05$ ), as shown in [Table 4](#) and [Figure 2A-C](#). The cross-sectional areas of the narrowest part of the retrolingual airway in OSAHS patients were  $155.36 \pm 13.29 \text{ mm}^2$ ,  $120.45 \pm 12.23 \text{ mm}^2$ , and  $150.61 \pm 12.35 \text{ mm}^2$  in the awake, snoring, and mid-frequency anti-snoring device treatment states, respectively. Compared to snoring, OSAHS patients experienced an increase in the cross-sectional areas of the soft palate and retrolingual airways during treatment with the mid-frequency anti-snoring device ( $P < 0.05$ ), as shown in [Table 4](#) and [Figure 2D-F](#).

## DISCUSSION

With the advancement of medical diagnostic technology and increased awareness of personal health, the incidence of



**Table 2 Comparison of sleep monitoring parameters before and after treatment (mean  $\pm$  SD)**

Parameter	Before treatment	After treatment	t value	P value
AHI, %	24.38 $\pm$ 9.16	12.63 $\pm$ 8.27	7.47	< 0.05
LSPO <sub>2</sub> , %	72.62 $\pm$ 9.53	84.84 $\pm$ 8.71	4.32	< 0.05
SPO <sub>2</sub> < 90%, %	14.65 $\pm$ 7.26	10.33 $\pm$ 5.32	3.15	< 0.05
Snoring, %	44.54 $\pm$ 26.13	15.07 $\pm$ 9.25	3.37	< 0.05
Most prolonged apnea duration in s	56.08 $\pm$ 20.11	25.58 $\pm$ 11.27	4.21	< 0.05
AAI resp as events/h	19.89 $\pm$ 11.61	11.74 $\pm$ 6.39	5.01	< 0.05
AAI non resp as events/h	15.71 $\pm$ 7.18	9.37 $\pm$ 4.27	6.11	< 0.05
RERA as events/h	5.91 $\pm$ 3.99	2.61 $\pm$ 2.65	5.69	< 0.05

Data are mean  $\pm$  SD. AAI: Autonomous arousal index; AHI: Apnea-hypopnea index; LSPO<sub>2</sub>: Lowest pulse oxygen saturation; RERA: Respiratory effort-related arousals; SPO<sub>2</sub>: Oxygen saturation.

**Table 3 Comparison of sleep apnea quality of life index and Epworth Sleepiness Scale before and after treatment (mean  $\pm$  SD)**

Index	Before treatment	After treatment	t value	P value
Daily life activity rating	3.8 $\pm$ 0.9	5.4 $\pm$ 1.3	5.67	< 0.05
Social activity rating	3.7 $\pm$ 1.0	4.8 $\pm$ 0.7	5.92	< 0.05
Emotional state score	4.6 $\pm$ 1.1	5.3 $\pm$ 1.2	3.15	< 0.05
Symptom score	4.4 $\pm$ 1.2	5.2 $\pm$ 0.9	3.37	< 0.05
SAQLI scale score	4.2 $\pm$ 0.5	4.8 $\pm$ 0.4	8.94	< 0.05
ESS scale score	14.8 $\pm$ 5.7	10.2 $\pm$ 4.3	3.31	< 0.05

ESS: Epworth Sleepiness Scale; SAQLI: Sleep apnea quality of life index.

**Table 4 Comparison of soft palate posterior airway area and retrolingual airway area computed tomography scan results in obstructive sleep apnea-hypopnea syndrome patients in different states (mean  $\pm$  SD)**

Position	Awake	Snoring	Anti-snoring
Soft palate posterior airway area	80.47 $\pm$ 18.56	22.05 $\pm$ 16.47 <sup>1</sup>	71.61 $\pm$ 17.38 <sup>2</sup>
Retrolingual airway area	155.36 $\pm$ 13.29	120.45 $\pm$ 12.23 <sup>3</sup>	150.61 $\pm$ 12.35 <sup>4</sup>

<sup>1</sup>Compared to the awake state, the airway cross-sectional area decreased during snoring ( $t = 5.301$ ,  $P = 0.000$ ).

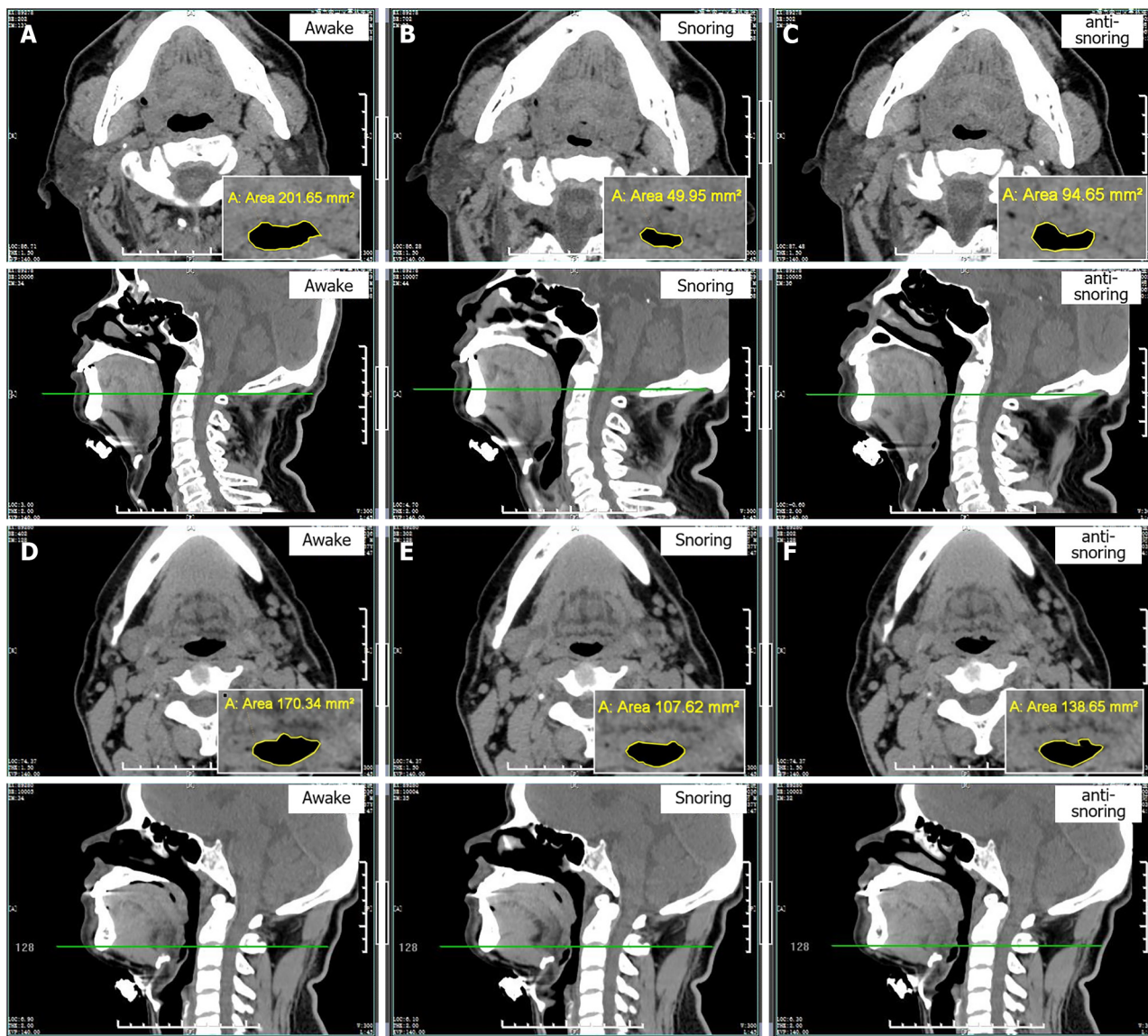
<sup>2</sup>Compared to the snoring state, the airway cross-sectional area increased ( $t = 2.806$ ,  $P = 0.021$ ).

<sup>3</sup>Compared to the awake state, the airway cross-sectional area decreased during snoring ( $t = 5.021$ ,  $P = 0.001$ ).

<sup>4</sup>In contrast, when compared to the snoring state, the airway cross-sectional area increased ( $t = 5.029$ ,  $P = 0.001$ ).

OSAHS in the population has increased. For example, a recent study found that out of 38000 Russian citizens (aged 30-70 years), 48.9% suffered from an AHI  $\geq 5$ , 18.1% from an AHI  $\geq 15$ , and 4.5% from an AHI  $\geq 30$ [3]. OSAHS significantly impacts people's safety, quality of life, social interactions, and relationships with family members. As such, it requires active intervention and treatment[4]. The pathological mechanism of OSAHS lies in the obstruction and collapse of the upper airway during sleep. The obstruction can occur in the nasopharynx, oropharynx, or hypopharynx, with over 80% of patients experiencing combined oropharyngeal obstruction[5]. Therefore, the core of OSAHS treatment is to relieve narrowing in the oropharyngeal region and keep the airway open.

Currently, OSAHS treatment includes general therapy, medication, devices, surgery, and rehabilitation[6]. Each treatment method has its advantages and limitations, and the treatment choice should be based on the patient's specific condition. Hypoglossal nerve stimulation is one effective method for treating OSAHS, where a nerve stimulator is implanted under the patient's skin in the neck and is connected to a sublingual nerve[7]. It stimulates the sublingual nerve to generate nerve signals synchronized with inhalation, helping the muscles tighten, pulling the tongue forward, expanding the pharynx, and relieving airway narrowing caused by the posterior displacement of the tongue root. However, this method is only effective in the short term, with limited long-term efficacy, and the equipment is expensive,



DOI: 10.12998/wjcc.v12.i5.942 Copyright ©The Author(s) 2024.

**Figure 2 Computed tomography scan.** A-C: Computed tomography (CT) scan representation and cross-sectional area measurement of the soft palate posterior airway in wakefulness, snoring, and during treatment with the middle-frequency anti-snoring device; D-F: CT scan representation and cross-sectional area measurements of the retrolingual airway area in wakefulness, snoring, and during treatment with the middle-frequency anti-snoring device.

restricting its clinical use[8].

In recent years, the mid-frequency anti-snoring device has been developed based on hypoglossal nerve stimulation, and it is a new technology used to treat OSAHS. It delivers specific frequency pulse-modulated composite waves and provides intermittent electrical stimulation to the genioglossus muscle and its sublingual nerve branches. This stimulates the genioglossus muscle to contract responsively, increases the tension of the upper airway, reduces airway collapse, and maintains airway patency, thus terminating snoring and apnea and improving sleep quality. While this method is theoretically feasible, it lacks clinical practice and research support. Therefore, this study aimed to explore this issue.

In the preliminary experiments of this study, it was found that mild OSAHS patients had low treatment willingness, poor compliance, and could not complete the entire study due to their mild symptoms. Therefore, they were not included in the study. Severe OSAHS patients, on the other hand, had more severe symptoms and showed unclear effects of the mid-frequency anti-snoring device. Clinically, they were mainly treated with non-invasive positive pressure ventilation. Therefore, they were not included either. Nevertheless, moderate OSAHS patients had a strong willingness to be treated, good compliance, and could complete the study. Therefore, they were chosen as the subjects of this study. The results of this study indicated that after 4 wk of treatment with the mid-frequency anti-snoring device, the AHI of moderate OSAHS patients decreased, the time of snoring during nighttime sleep decreased, the duration of the most prolonged apnea decreased, the duration of  $\text{SPO}_2 < 90\%$  decreased, and the  $\text{LSPO}_2$  increased, confirming a significant improvement in the patients' nighttime sleep quality. The study results also indicated that the sleep apnea quality of life index scores of patients increased after treatment compared to before treatment, including social activity scores, emotional state scores, and symptom scores. The Epworth Sleepiness Scale scores decreased, confirming that this treatment improved the patient's clinical symptoms and quality of life.

The study results also showed that after using the mid-frequency anti-snoring device, the number of AAI resp occurrences decreased, AAI non-resp decreased, and respiratory effort-related arousals decreased. OSAHS patients experience repeated awakenings during sleep, which hurts sleep quality. During the initial treatment phase, this study found that mid-frequency anti-snoring treatment increased patient awakenings, affecting sleep quality. The main reasons were that the initial stimulation intensity was too high, and patients had a low tolerance for stimulation. The study continuously adjusted stimulation intensity based on patients' actual experiences. After a period, patients fully adapted, and the number of awakenings significantly decreased.

This study conducted oropharyngeal CT examinations on OSAHS patients in awake, snoring, and mid-frequency anti-snoring treatment states to confirm that the mid-frequency anti-snoring device worked by expanding the narrow oropharyngeal airway. The narrowest points of the airway in the soft palate posterior area and retrolingual area were chosen as measurement points, and the cross-sectional areas of the airways were measured. The results showed that in the awake state the cross-sectional area of the narrowest part of the soft palate posterior airway was  $80.47 \pm 18.56 \text{ mm}^2$  and the narrowest part of the retrolingual airway was  $155.36 \pm 13.29 \text{ mm}^2$ . When patients snored during sleep, there was evidence of tongue root or uvula collapse, leading to oropharyngeal airway narrowing or obstruction. The cross-sectional area of the narrowest part of the soft palate posterior airway decreased to  $22.05 \pm 16.47 \text{ mm}^2$ , and the cross-sectional area of the retrolingual airway decreased to  $120.45 \pm 12.23 \text{ mm}^2$  showing significant reductions. During mid-frequency anti-snoring treatment, the cross-sectional area of the narrowest part of the soft palate posterior airway was  $71.61 \pm 17.38 \text{ mm}^2$ , and the cross-sectional area of the retrolingual airway was  $150.61 \pm 12.35 \text{ mm}^2$ , showing significant improvement compared to the snoring state. The study results confirmed that during treatment with the anti-snoring device, the relaxation of the tongue root and uvula was alleviated, and the degree of oropharyngeal airway narrowing was significantly improved, providing strong evidence from an imaging perspective for the working mechanism of the mid-frequency anti-snoring device.

Several objective issues were encountered throughout this study, resulting in some limitations in the examination results. First, this study employed a natural sleep approach and did not use sedative-hypnotic drugs to induce sleep. The examination process was time-consuming and challenging. In addition, patients were influenced by unfamiliar environments, such as the low temperature and high noise in the CT examination room, making it difficult for OSAHS patients to fall asleep naturally. Consequently, CT examinations were prone to interruptions and were not reflective of the patient's actual home sleep state, potentially affecting the accuracy of the examination results. Second, the number of cases included in this study was relatively small, which may lead to statistical bias. Third, differences in patient height, weight, and disease severity, as well as differences in upper airway anatomy, could impact CT examination results. Fourth, during treatment with the anti-snoring device, high pulse stimulation intensity could cause patient awakenings, affecting the accuracy of CT examinations. Resolving the above issues requires further increasing the number of patients, expanding the sample size, improving the environment in the CT examination room, optimizing the CT examination process, and using sedative-hypnotic drugs to induce sleep if necessary.

## CONCLUSION

In conclusion, this study confirmed that the mid-frequency anti-snoring device can expand the oropharyngeal airway in patients with moderate OSAHS, thereby improving their clinical symptoms and sleep quality. Our study provided a new method for the clinical treatment of OSAHS.

## ARTICLE HIGHLIGHTS

### Research background

The mid-frequency anti-snoring device is a new technology based on sublingual nerve stimulation. Its principle is to improve the degree of oropharyngeal airway stenosis in obstructive sleep apnea-hypopnea syndrome (OSAHS) patients under mid-frequency wave stimulation.

### Research motivation

There is a lack of clinical application and imaging evidence for the use of mid-frequency anti-snoring devices in the treatment of moderate OSAHS.

### Research objectives

To provide imaging-based confirmation of the working mechanism of mid-frequency anti-snoring devices in treating OSAHS. This study also aimed to observe the clinical efficacy of medium-frequency anti-snoring devices in treating moderate obstructive OSAHS.

### Research methods

Fifty patients diagnosed with moderate OSAHS underwent a 4-wk treatment regimen involving the mid-frequency anti-snoring device during nighttime sleep. Following the treatment, we monitored and assessed the sleep apnea quality of life index and Epworth Sleepiness Scale scores. Additionally, we performed computed tomography scans of the

oropharynx in the awake state, during snoring, and while using the mid-frequency anti-snoring device. Cross-sectional area measurements in different states were taken at the narrowest airway point in the soft palate posterior and retrolingual areas.

### Research results

Compared to pretreatment measurements, patients exhibited a significant reduction in the apnea-hypopnea index, the percentage of time with oxygen saturation below 90%, snoring frequency, and the duration of the most prolonged apnea event. The lowest oxygen saturation (%) showed a notable increase, and both sleep apnea quality of life index and Epworth Sleepiness Scale scores improved. Oropharyngeal computed tomography scans revealed that in OSAHS patients the cross-sectional areas of the oropharyngeal airway in the soft palate posterior area and retrolingual area decreased during snoring compared to the awake state. Conversely, during mid-frequency anti-snoring device treatment, these areas increased compared to snoring.

### Research conclusions

This study confirmed that the mid-frequency anti-snoring device can expand the oropharyngeal airway in patients with moderate OSAHS, thereby improving their clinical symptoms and sleep quality.

### Research perspectives

The sample size of this study was limited, and there may be statistical bias. Further efforts are needed to increase the number of patients, expand the sample size, and conduct in-depth research on some scientific issues, such as the therapeutic effect of mid-frequency anti-snoring devices on patients with only snoring, the patient dependency and efficacy of long-term use, the impact on the anatomical structure of the upper airway of the oropharynx, and the impact of long-term use on abnormal lipid metabolism in patients.

## FOOTNOTES

**Co-first authors:** Bao Qian and Zhan-Jun Chen.

**Author contributions:** Qian B and Chen ZJ contributed equally to this work; Qian B and Chen ZJ performed the study; Wang YS performed the computed tomography scan examination; Hu XY and Hu XB analyzed the data; Zheng YH designed the research and wrote the manuscript; all authors read and approve the final manuscript.

**Institutional review board statement:** The study was reviewed and approved by the Institutional Review Board of the Shanghai Jinshan Tinglin Hospital (Approval No. 2022-06-01).

**Informed consent statement:** All study participants, or their legal guardian, provided informed written consent before enrollment.

**Conflict-of-interest statement:** The authors declare that they have no conflicts of interest.

**Data sharing statement:** No additional data are available.

**STROBE statement:** The authors have read the STROBE Statement – checklist of items, and the manuscript was prepared and revised according to the STROBE Statement – checklist of items.

**Open-Access:** This article is an open-access article that was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution NonCommercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <https://creativecommons.org/licenses/by-nc/4.0/>

**Country/Territory of origin:** China

**ORCID number:** Yong-Hua Zheng 0000-0002-7799-9612.

**S-Editor:** Chen YL

**L-Editor:** Filipodia

**P-Editor:** Yu HG

## REFERENCES

- Gottlieb DJ, Punjabi NM. Diagnosis and Management of Obstructive Sleep Apnea: A Review. *JAMA* 2020; **323**: 1389-1400 [PMID: 32286648 DOI: 10.1001/jama.2020.3514]
- Olson MD, Junna MR. Hypoglossal Nerve Stimulation Therapy for the Treatment of Obstructive Sleep Apnea. *Neurotherapeutics* 2021; **18**: 91-99 [PMID: 33559036 DOI: 10.1007/s13311-021-01012-x]
- Khokhrina A, Andreeva E, Degryse JM. The prevalence of sleep-disordered breathing in Northwest Russia: The ARKHsleep study. *Chron*



- Respir Dis* 2020; **17**: 1479973120928103 [PMID: 32666810 DOI: 10.1177/1479973120928103]
- 4 **Lee JJ**, Sundar KM. Evaluation and Management of Adults with Obstructive Sleep Apnea Syndrome. *Lung* 2021; **199**: 87-101 [PMID: 33713177 DOI: 10.1007/s00408-021-00426-w]
- 5 **Lv R**, Liu X, Zhang Y, Dong N, Wang X, He Y, Yue H, Yin Q. Pathophysiological mechanisms and therapeutic approaches in obstructive sleep apnea syndrome. *Signal Transduct Target Ther* 2023; **8**: 218 [PMID: 37230968 DOI: 10.1038/s41392-023-01496-3]
- 6 **Gambino F**, Zammuto MM, Virzi A, Conti G, Bonsignore MR. Treatment options in obstructive sleep apnea. *Intern Emerg Med* 2022; **17**: 971-978 [PMID: 35460431 DOI: 10.1007/s11739-022-02983-1]
- 7 **Mashaqi S**, Patel SI, Combs D, Estep L, Helmick S, Machamer J, Parthasarathy S. The Hypoglossal Nerve Stimulation as a Novel Therapy for Treating Obstructive Sleep Apnea-A Literature Review. *Int J Environ Res Public Health* 2021; **18** [PMID: 33572156 DOI: 10.3390/ijerph18041642]
- 8 **Zhu Z**, Hofauer B, Wirth M, Heiser C. Long-term changes of stimulation intensities in hypoglossal nerve stimulation. *J Clin Sleep Med* 2020; **16**: 1775-1780 [PMID: 32026804 DOI: 10.5664/jcsm.8320]





Published by **Baishideng Publishing Group Inc**  
7041 Koll Center Parkway, Suite 160, Pleasanton, CA 94566, USA

**Telephone:** +1-925-3991568

**E-mail:** [office@baishideng.com](mailto:office@baishideng.com)

**Help Desk:** <https://www.f6publishing.com/helpdesk>

<https://www.wjgnet.com>

