

Examinations of the use of medical imaging methods in diagnosing obstructive sleep apnoea

Ph.D. thesis

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1. Introduction

Obstructive sleep apnoea (OSA) is the most common type of sleep-related breathing disorders; about 1 billion people between the ages of 30 and 69 of the world population are involved in OSA. The lack of treatment leads to comorbidities, just like cardiovascular diseases and neurological and psychiatric disorders, and there is a higher risk for traffic accidents. Regarding diagnosis, the 'gold standard' method is the nocturnal polysomnography (PSG), which is not an easily accessible and expensive examination. Despite the screening examinations, OSA is still an underdiagnosed disorder.

2. Objectives

Our study aimed to analyse the sites of the upper airway obstructions and diaphragm using imagine diagnostic methods. Furthermore, to develop a new and easily available method which can effectively help to diagnose

OSA. Therefore, the following hypotheses ('H') were created:

2.1. Examination of the correlation between the anthropometric parameters and chronic diseases and obstructive sleep apnoea

H1 A significant difference can be observed between the anthropometric parameters of the control and OSA patients.

H2 The anthropometric parameters of the male and female patients significantly differ in the control and OSA groups.

H3 Cardiovascular disorders, hypertension, pulmonary diseases, gastroesophageal reflux disease and type 2 diabetes mellitus, are more frequent in the OSA group contrasted to the control group.

H4 In the control group, correlations between the anthropometric parameters can be observed.

H5 A strong correlation between the anthropometric parameters in the OSA group can be observed.

2.2. Analysis of prediction of obstructive sleep apnoea based on ultrasound measurements and anthropometric parameters

H1 OSA can affect the thicknesses and the maximal displacement of the diaphragm, both during at rest and forced inspiration.

H2 The thicknesses and dilation of the diaphragm measured at rest and forced inspiration are not significantly affected by gender, age and Body Mass Index (BMI) in the control group.

H3 The thicknesses and displacement of the diaphragm measured at rest and forced inspiration are not significantly affected by gender, age and BMI in the OSA group.

H4 According to the diaphragm thicknesses and movements measured by ultrasound (US) and anthropometric parameters, OSA prediction is possible.

2.3. Identifying the predictive role of ultrasound and magnetic resonance imaging examinations of the tongue in diagnosing obstructive sleep apnoea

H1 The tongue diameters and volumes measured by US and MRI significantly differ between the OSA and the control groups.

H2 The gender, age and BMI significantly affect the tongue parameters measured by US in the OSA group.

H3 The gender, age and BMI significantly affect the tongue parameters measured by MRI in the OSA group.

H4 The correlation between BMI and the tongue parameters measured by US and MRI is strong in male and female patients as well.

H5 A strong correlation between apnoea-hypopnoea-index (AHI) and tongue parameters measured by MRI in male and female patients can be observed.

H6 Using a combination of anthropometric results and tongue US or MRI measurements OSA and tongue-based obstruction can be predicted.

2.4. Detection of the role of the ultrasound and magnetic resonance imaging in the prediction of the lateral pharyngeal wall-based obstruction and obstructive sleep apnoea

H1 The lateral pharyngeal wall thickness (LPWT) parameters are significantly different between the OSA and control groups.

H2 Gender, age, and BMI significantly affect the LPWT measured by US in the OSA group.

H3. The LPWT detected by MRI is significantly affected by age, gender and BMI in the OSA group.

H4 According to the results of anthropometric measurements and LPWT determined by US, the prediction of OSA and lateral LPW-based obstruction is possible.

H5 Based on the results of anthropometric measurements and LPWT determined by MRI, the prediction of OSA and LPW-based obstruction is possible.

3. Methods

One hundred patients (74 male and 26 females, mean age \pm SD, 42.15 years \pm 11.7) were enrolled in a cross-sectional study who visited the Department of Otorhinolaryngology and Head and Neck Surgery of Semmelweis University due to snoring and/or suspected OSA.

These patients underwent a PSG examination at the Institute of Pulmonology, Törökbálint. The examination results were analysed by the same sleep specialist, according to the American Academy of Sleep Medicine recommendation. Based on the PSG results, the participants were categorised as control (AHI<5) and OSA patients (AHI>5).

The medical imaging examinations were carried out at the Medical Imaging Centre of Semmelweis University. The MR examinations were performed using a Philips Ingenia 1.5 T MR device. In order to determine the tongue and LPW parameters, T2 TSE, STIR, T1 TSE, coronal T1 TSE, axial T2 SPIR, T1 TSE and DWI measurements were performed.

The US examinations were conducted using a Samsung RS85 device. A CA1-7A convex (1-7 MHz) transducer was applied in the case of the tongue and LPW measurement during rest and Müller's manoeuvre (MM), while an L3-12A linear transducer (3-12MHz) to analyse diaphragm thicknesses.

The DISE results were interpreted using the VOTE (=velum, oropharynx, tongue base, epiglottis) classification.

The IBM SPSS 27 integrated statistical software was applied for data processing. Significance levels were set as $p \leq 0.1$, $p \leq 0.05$ and $p \leq 0.01$. Artificial intelligence methods were applied using the R software.

4. Results

4.1. Population characteristics

The neck, abdomen and hip circumferences significantly differed ($p \leq 0.01$) in the OSA and control groups. In the control group, males presented significantly higher neck ($p=0.000$), while in the OSA group, neck ($p=0.001$) and hip circumferences contrasted to females ($p=0.028$). The frequency of hypertension was triple in the OSA group. Type 2 diabetes mellitus and bronchial asthma have not occurred in the OSA but had a frequency of 6.4% and 4.7% in the OSA group, respectively. Cardiovascular disorders were more frequent in the control group. The occurrence of pulmonology disease and gastroesophageal reflux was similar in the two groups. BMI values significantly positively correlated with neck, abdomen and hip circumferences ($p < 0.05$) in the control group. HDL (high-density lipoprotein) cholesterol levels were significantly negatively correlated with the neck and abdomen circumferences, BMI values and triglyceride levels ($p < 0.05$). The BMI values significantly positively correlated with the neck, abdomen and hip circumferences

in the OSA group. Neck circumference and triglyceride levels were also positively correlated ($p < 0.05$).

4.2. Ultrasound examinations of the diaphragm

Based on our examinations, OSA has influenced diaphragm thicknesses ($p = 0.02$) but has not its dilation. In the OSA group, gender significantly affected the diaphragm dilations ($p < 0.04$). Although, nutritional status and age have only influenced diaphragm thicknesses ($p = 0.069$). In the OSA group, nutritional status affected the thickness of the right hemidiaphragm dilation during rest ($p = 0.074$). Gender and age did not significantly influence the thicknesses and dilation of the diaphragm. Out of US diaphragm parameters, the thickness of the right hemidiaphragm ($p = 0.027$) and the dilation measured during rest and deep inspiration ($p < 0.005$) showed the strongest correlation with the AHI values. Including diaphragm parameters and basic anthropometric values, the applied algorithm was able to predict OSA in 87%. This algorithm determined the BMI values as the most essential parameter, followed by US diaphragm values.

The algorithm showed a sensitivity of 91% and a specificity of 83%.

4.3. Ultrasound and MRI examinations of the tongue

Significantly higher diameters and tongue volume were observed in the OSA group, both during rest and MM ($p \leq 0.05$). Of the MRI parameters, OSA influenced the anteroposterior diameter, the mediansagittal area and the mediansagittal fat% values ($p \leq 0.03$). In the OSA group, gender has influenced the tongue volume US parameters during rest and MM ($p = 0.07$).

4.4. MRI and ultrasound examinations of the lateral pharyngeal wall

Contrasted to the control group, most of the LPWT MRI parameters in the OSA group significantly differed. In contrast, only LPWT on the left side during MM differed significantly from the US parameters. Male OSA patients presented significantly LPWT values, contrasted to females ($p < 0.05$). Age did not significantly influence LPWT, while obese patients showed

significantly higher LPWT values than patients with a normal BMI ($p=0.05$). In the OSA group, LPWT parameters of males measured by MRI were significantly higher ($p\leq 0.01$). Age significantly affected these parameters ($p\leq 0.01$), although BMI parameters had not. Using anthropometric parameters and US LPWT values, ismeretében OSA could have been predicted in 93% and LPW based obstruction in 89%. In the case of LPW based obstruction, a sensitivity of 87% and a specificity of 94% was determined. In the prognostication of OSA, a sensitivity of 93% and a specificity of 94% were calculated. Using MRI values and anthropometric parameters we were able to detect OSA in 90% and LPW based obstruction in 84%. In the case of LPW based obstruction, 75% sensitivity and 81% specificity values were observed. OSA could have been predicted with a 93% sensitivity and an 83% specificity.

5. Conclusion

According to the results of our study, the following conclusions were made.

5.1. Is there any relation between the anthropometric parameters and chronic diseases and obstructive sleep apnoea?

By responding to the firstly supposed question, it can be concluded that a strong correlation between anthropometric parameters and OSA was observed. Although, a significant correlation was only detected in the case of hypertension and OSA.

Based on our analyses, it can be concluded that a correlation can be detected between the individual anthropometric parameters and OSA; however, they cannot be used for screening OSA in most cases by themselves.

5.2. Can the ultrasound examinations of the diaphragm verify the effects of obstructive sleep apnoea on the diaphragm, and is the prediction of the disorder possible according to the diaphragm parameters measured by ultrasound and combined with anthropometric parameters?

OSA significantly affects the diaphragm thicknesses by increased respiratory effort due to the apnoea events, which results in a higher thickness of the diaphragm. However, OSA did not significantly affect the dilation of the diaphragm.

Based on anthropometric and diaphragm ultrasound parameters, OSA could be predicted in 87% using the applied the algorithm.

5.3. Can the ultrasound and magnetic resonance imaging examinations of the tongue be used to predict obstructive sleep apnoea?

Using a combination of ultrasound values and anthropometric parameters, the presence of OSA and tongue-based obstruction could be predicted in 91% and 89%, respectively.

According to the combination of anthropometric and MRI parameters, the prediction of OSA and tongue-based obstruction was successful in 82% and 87%, respectively. Finally, it can be concluded that ultrasound and MRI examinations of the tongue can be used to predict OSA and prognosticate tongue-based obstruction.

5.4. The role of the ultrasound and magnetic resonance imaging examinations of the lateral pharyngeal wall in the prognostication of the lateral pharyngeal wall-based obstruction and obstructive sleep apnoea

Based on our results, using ultrasound examinations combined with anthropometric parameters, the presence of OSA and lateral pharyngeal wall-based obstruction can be predicted in 93% and 89%, respectively.

According to the statistical analysis, a combination of anthropometric measurements and MRI parameters, OSA and lateral pharyngeal wall-based obstruction can be predicted in 90% and 84%, respectively. The lateral pharyngeal wall thickness, measured by ultrasound and/or MRI can be helpful in predicting and prognosticating of OSA and lateral pharyngeal wall-based obstruction as well. Therefore, ultrasound can be an effective diagnostic option in detecting OSA.

5.5. Further conclusions:

1. The sensitivity and specificity of the algorithm applied in screening for OSA and tongue-based- or lateral pharyngeal wall-based obstruction were detected in over 80% of most cases.

2. Based on the results mentioned above, the ultrasound and MRI parameters of the diaphragm, tongue and lateral pharyngeal wall parameters can be used in the everyday diagnosis of OSA in order to allow adequate therapy or even surgical therapy planning.

3. Ultrasound is an easy, portable and easily available diagnostic method that makes OSA screening possible by measuring diaphragm, tongue and lateral pharyngeal wall thicknesses even in a general practitioner's surgery and other practices where ultrasound is available. This allows OSA screening in everyday clinical practice.

6. Publications related to the PhD thesis

Molnár V, Molnár A, Lakner Z, Tárnoki DL, Tárnoki ÁD, Jokkel Zs, Szabó H, Dienes A, Angyal E, Németh F, Kunos L, Tamás L. (2021) Examination of the diaphragm in obstructive sleep apnea, using ultrasound imaging Sleep Breath. doi: 10.1007/s11325-021-02472-3

(IF: 2.816)

Molnár V, Molnár A, Lakner Z, Tárnoki DL, Tárnoki ÁD, Jokkel Zs, Kunos L, Tamás L, (2022) The prognostic role of ultrasound and magnetic resonance imaging in obstructive sleep apnoea on lateral oropharyngeal wall obstruction Sleep Breath. doi:10.1007/s11325-022-02597-z **(IF: 2.816)**

Molnár V, Molnár A, Lakner Z, Kunos L, Angyal E, Németh F, Tamás L. (2022) Az obstruktív alvási apnoe főbb jellemzőinek vizsgálata [Analysis of the most important features of obstructive sleep apnoea]. Orv Hetil, 163: 586-592. doi: 10.1556/650.2022.32428 **(IF: 0.540)**

Cumulative IF: 6.172