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Original article

Mandibular plane to hyoid in lateral cephalometry as a predictive parameter for severity of obstructive sleep apnea

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Background: Obstructive sleep apnea (OSA) is a common disorder affect-ing at least 2.0% to 4.0% of the adult population. Early diagnosis and treatment can reduce patient burden. A lateral cephalometric radiograph (LCR) is one method to evaluate upper airway obstruction in patients with OSA.
Objective: This cross-sectional study was aimed to investigate the predictive performance of mandibular plane to hyoid (MP-H) in LCR for determining the OSA severity.
Methods: One hundred and three adult subjects were analyzed. LCR was performed under standardized processes and measured twice on separate occasions. Receiver operating characteristic (ROC) curve analysis was performed to obtain the optimal threshold values. Sensitivity, specificity and predictive values were calculated.
Results: The predictive performances of MP-H for detecting OSA severity are as follows; for mild OSA, the area under the ROC curve (AUC) was 0.747. A cutoff MP-H of 12.875 mm provided sensitivity of 54.6%, specificity of 100.0%, positive predictive values (PPV) of 100.0% and negative predictive values (NPV) of 12.0%. For moderate OSA, AUC was 0.773. A cutoff MP-H of 13.665 mm. provided sensitivity of 59.8%, specificity of 90.5%, PPV of 96.1% and NPV of 36.5%. As for severe OSA, AUC was 0.787. A cutoff MP-H of 16.035 mm provided sensitivity of 62.5%, specificity of 83.6%, PPV of 76.9% and NPV of 71.9%.
Conclusions: MP-H in LCR is a good predictive parameter for OSA, it provides high accuracy, high specificity and high PPV. However, as sensitivity values were low, this parameter may not be an appropriate screening tool.

Keywords: Lateral cephalometric, mandibular plane to hyoid, OSA, predictive parameter.

Obstructive sleep apnea (OSA) is a common disorder affect-ing at least 2.0% to 4.0% of the adult population and is emerging as a major health problem. [(1)] It is characterized by recurrent episodes of complete or partial obstruction of the upper airway during sleep, resulting in oxygen desaturation and arousals. If left untreated, it can lead to several health consequences such as hypertension, cardiovascular diseases, metabolic disorder, psychiatric disorder and impaired quality of life. [(2)] The pathogenesis of OSA has been proved involving several structural and physiological factors. Craniofacial and soft tissue characteristics is one of the major factors that may affect the pharyngeal collapse and contribute to episodes of obstructive respiratory events.[(3)]

Early diagnosis and treatment can reduce patient burden. Although polysomnography (PSG) is considered a gold standard diagnostic investigation for OSA, it is expensive and in some regions, the waiting queue for this investigation is too long. PSG reports respiratory disorders during sleep, mainly in terms of frequency of the respiratory events, severity of oxygen desaturation, associated abnormal behaviors, positional or sleep stage related severity of the respiratory events and sleep architecture. However, it does not explain upper airway structural problems during sleep.

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A lateral cephalometric radiograph (LCR) is one method to evaluate upper airway obstruction in patients with OSA. It is a noninvasive, inexpensive, easy to perform, and widely available test for upper airway anatomy evaluation. The information obtained from LCR may provide useful information for sleep surgery planning. Recently, studies have demonstrated that multiple LCR parameters including angle between the anterior cranial base and the mandible (SNB), the posterior airway space (PAS), the length of soft palate (PNS-P) and the distance from the hyoid bone to the mandibular plane (MP-H) are associated with the severity of OSA.[4-6] However, the predictive performance of LCR parameters to diagnose OSA was not well established. Measuring all LCR parameters may be too difficult and time consuming. MP-H is one of LCR parameters that had the strongest association with the severity of OSA. This parameter is also easily measurable and quite constant. Therefore, the objective of this study was to evaluate the predictive parameters between mandibular plane to hyoid (MP-H) and PSG indices in determining OSA severity.

Materials and methods

Patient population

The study was conducted in the OSA clinic, King Chulalongkorn Memorial Hospital. Ethical approval was granted by the Institutional Review Board (IRB), Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand. Patients who visited the clinic between June 2018 and May 2019, aged more than 18 years old and had performed standard PSG and LCR were included in this study. The definitions of PSG parameters followed the recommended criteria in the manual of the American Academy of Sleep Medicine for the scoring of sleep and associated events 2012.[7] Patients with history of known previous maxillofacial injuries, craniofacial abnormalities, head and neck neoplasm, those who had undergone upper airway surgery, and had time difference between PSG and LCR of more than one year were not recruited in the study.

Lateral cephalometric radiograph

Mandibular plane to hyoid measurement

Mandibular plane to hyoid is a linear distance along a perpendicular line from hyoid to the mandibular plane as shown in Figure 1.[8] This parameter was measured twice by two investigators on separate occasions.

Statistical analysis

Statistical analysis was done using SPSS version 22.0 for Windows software package. Descriptive statistics included mean and standard deviation (SD). The qualitative data were analyzed by Chi-square test.

Sensitivity and specificity were used in order to estimate the diagnostic accuracy of the MP-H compared to the polysomnography in mild (respiratory disturbance index (RDI) $\geq$ 5), moderate (RDI $\geq$ 15), and severe (RDI $\geq$ 30) OSA. Receiver operating characteristic (ROC) curve was plotted by all sensitivity values on the *y*-axis against their equivalent 1- specificity values on the *x*-axis for all available thresholds. The area under the ROC curve (95%CI) was evaluated according to the Swets classification.[9]

Figure 1. Lateral cephalometric radiograph landmark and parameter. MPH; mandibular plane to hyoid.

The best cutoffs of the MP-H for diagnosis of mild, moderate and severe OSA were used as the highest accuracy value.

Results

A total of 115 patients were initially recruited into the study. Twelve patients were later excluded due to excessive time difference between LCR and PSG. Of the 103 patients, 60 were male (58.0%) and 43 were female (42.0%). The mean age was 45.20 ± 12.48 years with a range from 22 to 72 years. The mean body mass index (BMI) was 26.01 ± 4.26 kg/m^2. Six patients were primary snoring, 15 patients were mild OSA, 34 patients were moderate OSA, and 48 patients were severe OSA. The mean RDI was 36.19 events per hour, mean minimum oxygen (O_2) was 82.7% and mean MP-H distance was 14.34 mm. Patient characteristics of this study are presented in Table 1.

As shown in Table 2, in the predictive parameter analysis of MPH for RDI ≥ 5, the best cutoff MP-H of 12.875 mm obtained sensitivity of 54.6%, specificity of 100.0%, positive predictive value (PPV) of 100.0%, negative predictive value (NPV) of 12.0% and accuracy of 57.3%. The area under the ROC curve was 0.747 (fairly accurate).

As for RDI ≥ 15, the best cutoff MP-H of 13.665 mm obtained sensitivity of 59.8%, specificity of 90.5%, PPV of 96.1%, NPV of 36.5% and accuracy of 66.0%. The area under the ROC curve was 0.773 (fairly accurate).

As for RDI ≥ 30, the best cutoff MP-H of 16.035 mm obtained sensitivity of 62.5%, specificity of 83.6%, PPV of 76.9%, NPV of 71.9% and accuracy of 73.8%. The area under the ROC curve was 0.787 (fairly accurate).

Regarding the sensitivity, specificity, PPV, NPV and accuracy in other cutoff MP-H. The Receiver-operator curves for the diagnosis of mild, moderate and severe OSA by the MP-H are reported in Figure 2.

Table 1. Patient demographics and characteristics.

	Primary snoring (n = 6)	**Mild OSA (n = 15)**	**Moderate OSA (n = 34)**	**Severe OSA (n = 48)**	**Total (n = 103)**
Male/female	1/5	5/10	18/16	36/12	60/43
Age (mean ± SD)	49.00 ± 18.96	43.93 ± 12.87	46.41 ± 13.18	44.27 ± 11.14	45.20 ± 12.48
BMI (mean ± SD)	20.92 ± 2.26	24.88 ± 4.19	25.83 ± 3.74	27.13 ± 4.33	26.01 ± 4.26
RDI (mean ± SD)	3.53 ± 1.82	9.95 ± 2.72	21.95 ± 4.45	58.56 ± 19.24	36.19 ± 25.40
minO2 (mean ± SD)	90.17 ± 4.62	89.93 ± 4.64	85.53 ± 7.33	77.44 ± 13.94	82.67 ± 11.73
MP-H (mean ± SD)	8.49 ± 3.95	8.94 ± 5.66	12.15 ± 6.04	18.32 ± 7.02	14.34 ± 7.42

BMI: body mass index; RDI: respiratory disturbance index; OSA: obstructive sleep apnea;
minO2: minimal oxygen saturation; SD: standard deviation

Table 2. Sensitivity, specificity, accuracy, and AUC values for diagnosis of moderate, and severe OSA with MP-H.

	RDI ≥ 5, cutoff MP-H = 12.875	**RDI ≥ 15, cutoff MP-H = 13.665**	**RDI ≥ 30, cutoff MP-H = 16.035**
Sensitivity (95% CI)	0.546 (0.447 – 0.642)	0.598 (0.489 – 0.697)	0.625 (0.483 – 0.748)
Specificity (95% CI)	1.000 (0.552 – 1.000)	0.905 (0.696 – 0.984)	0.836 (0.714 – 0.913)
Positive predictive value (PPV)	1.000	0.961	0.769
Negative predictive value (NPV)	0.120	0.365	0.719
Accuracy	0.573	0.660	0.738
AUC (95% CI)	0.747 (0.580 – 0.915)	0.773 (0.675 – 0.871)	0.787 (0.697 – 0.877)

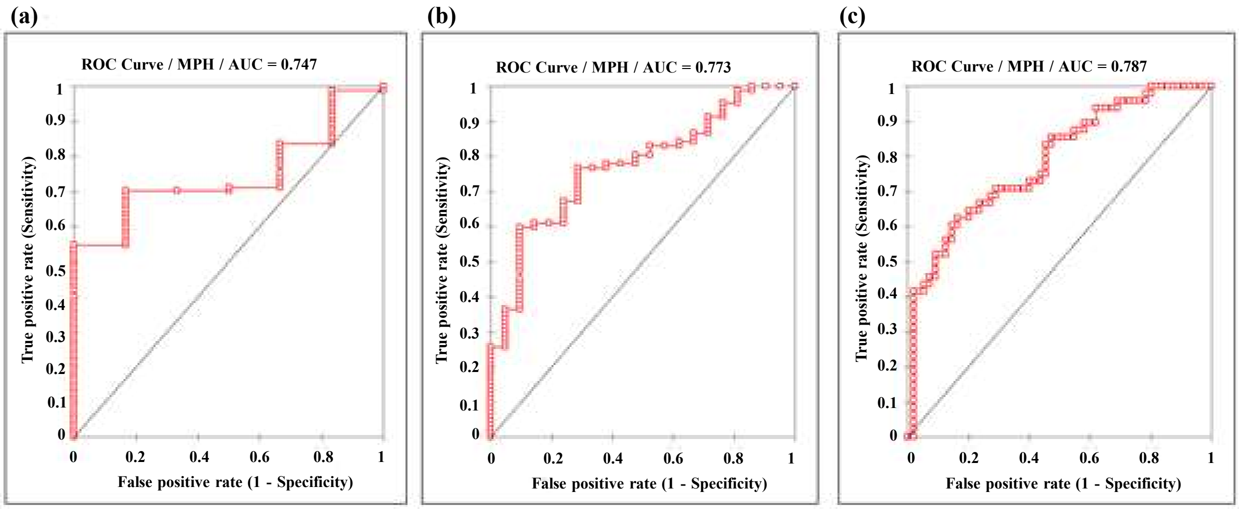

Figure 2. Receiver curves for diagnosis of mild **(a)** moderate **(b)** and severe **(c)** OSA with mandibular plane to hyoid distance (MPH).

Discussion

The association between inferiorly placed hyoid bone and adult OSA patients was well studied. MP-H is described as one of the most relevant cephalometric variables that may be associated with OSA with highly potential diagnostic accuracies in a meta-analysis by Miles PG, *et al.* [4] Although inconsistency of this association has been reported later in a study by Cillo JE, *et al* who found no statistically significant associations between MP-H and apnea hypopnea index in a retrospective study of 89 OSA patients.[10] Multiple studies reported longer MP-H distance of OSA patients in comparison with controls who had no OSA[5] or had milder degree of OSA.[6] A statistically significant positive correlation between the MP-H and apnea-hypopnea index was also described. [8] Bilici S, *et al*. described that the mentum to hyoid distance of patients with severe OSA was longer in comparison with primary snoring patients. [11] Banhiran W, *et al*. demonstrated that at a MP-H cutoff point of over18 mm had at least 17 times increased risk of having moderate OSA. [12] Stipa C, *et al*. revealed that soft palate length and vertical position of the hyoid bone were significant predictors of apnea hypopnea index (AHI) in adult Caucasian OSA patients. [15] Our study is consistent with most of earlier studies in which significant longer MP-H was observed in the MP-H distance in severe OSA group when compared with primary snoring and mild OSA group. Our hypotheses are that some of the suprahyoid and tongue muscles might be longer in patients with more severe forms of OSA due to hyoid bone serves as a central anchorage for the suprahyoid and tongue muscle. It may be implied that patients with longer MP-H will have greater suprahyoid and tongue mass that will reduce upper airway space which increases the severity of OSA.

Our study demonstrated that MP-H is a good predictive parameter for determining OSA severity. At MP-H cutoff point of 12.875mm, 13.665 mm and 16.035 mm had high specificity and high PPV to identify mild (RDI $\geq$ 5), moderate (RDI $\geq$ 15) and severe (RDI $\geq$ 30) OSA, respectively. Unlike multiple earlier studies, we are the first study to demonstrate the predictive parameters between mandibular plane to hyoid (MP-H) and respiratory disturbance index in determining OSA severity. Although this parameter had a low sensitivity and may not be a good screening tool, the high specificity and high PPV may provide some beneficial clinical points. A combination of this parameter with a high sensitivity and user-friendly questionnaire such as the STOP Bang questionnaire [9, 13, 14] might further improve the predictive performance for OSA diagnosis. Further study exploring predictive performance of these combined tools should be performed in the future.

This study has some limitations. First, the populations in this study were only Thai patients (Asian). A variation of the results may exist among different ethnic populations; so the MP-H cutoff point from in this study may not be generalized worldwide. Second, this study was performed in a tertiary care center. The high PPV in the study might be explained by having more prevalence of diagnostic OSA than in primary care center. However, the high specificity value is not affected by the prevalence thus usefulness for generalization to another setting still persists.

Conclusion

It is known that polysomnography is the gold standard for OSA diagnosis. However, some patients cannot easily access PSG due to high cost and long waiting queue. From this study, a MP-H distance from lateral cephalometric radiograph is a good predictive parameter for moderate and severe OSA because of its high accuracy, high specificity, high PPV and high AUC. In highly suspicious OSA with cut off value MP-H of severe disease, faster accessibility to investigation can lead to achieving faster treatment.

Conflict of interest statement

Each of the authors has completed an ICMJE disclosure form. None of the authors declare any potential or actual relationship, activity, or interest related to the content of this article.

Data sharing statement

The present review is based on the reference cited. Further details, opinions, and interpretation are available from the corresponding authors on reasonable request.

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