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Review Article

Orthodontist and Obstructive Sleep Apnea Screening Tools

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Abstract

Obstructive sleep apnea (OSA) is a sleep disorder that contributes to disrupted sleep due to a cessation of breathing or a decrease in airflow. OSA is diagnosed by polysomnography (PSG), which is considered to be the gold standard. However, conducting a PSG has limitations that include, time consumption, inconvenience, and cost. Also, all institutions may not have the equipment, technicians, or expert sleep physicians for a definitive diagnosis of OSA. Patients who have subclinical symptoms may go undiagnosed because of its non-specificity and patient unawareness. OSA should be examined in a timely manner. If the disease goes undiagnosed for an extended time, many short- and long-term unsatisfactory outcomes may occur that affect a person's lifestyle leading to dramatic consequences. Recent literature encourages orthodontists to know how to investigate OSA and the upper airway using questionnaires and radiography as screening tools before undergoing polysomnography.

Keywords: Cone beam computed tomography, Obstructive sleep apnea, Questionnaire, Screening, Upper airway

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Introduction

Obstructive sleep apnea (OSA) is a disorder that causes difficulty sleeping. On a spectrum of increasing severity sleep disorders, OSA is at the top. Its characteristics are either partial or total constriction of the upper airway. The two main reasons that cause OSA are anatomical and non-anatomical. When the upper airway does not allow normal respiratory flow, the availability of oxygen is reduced and the level of carbon dioxide increases,[1,2] which activates the brain and sympathetic nervous system. The upper airway dilating muscle then contracts sufficiently to widen the respiratory tract for normal air flow. A recuring cycle of this situation leads to sleep deprivation,[3] which causes a person to feel sleepy all day that may result in work-related and vehicle accidents in addition to memory impairment and inappropriate behavior. Snoring is one of the distinctive symptoms of the disease that disturbs a person who sleeps nearby. This recurrent sympathetic nervous system overactivation can lead to adverse health outcomes such as hypertension, cardiovascular disease, and metabolic disease.[2]

According to a population-based prevalence study among middle-aged people, OSA occurs in 24 % and 9 % of males and females, respectively.[4] Surprisingly, one-third of formerly undiagnosed OSA patients who attended a primary health care system were found to have moderate to severe OSA.[5] From an exploratory prevalence research study in a southern Thailand population, 85.60 % of subjects had experienced OSA.[6] In central Thailand, a study revealed OSA in 11.40 % of the population.[7] Other population groups susceptible to obstructive sleep apnea include children and patients with cleft lip and palate.[8] For a definitive diagnosis using the polysomnography sleep test, information from patients includes clinical symptoms related to sleep, sleep performance, history of OSA, predisposing conditions, and a physical examination of the respiratory, cardiovascular, and nervous systems.[1] Due to the unavailability of the

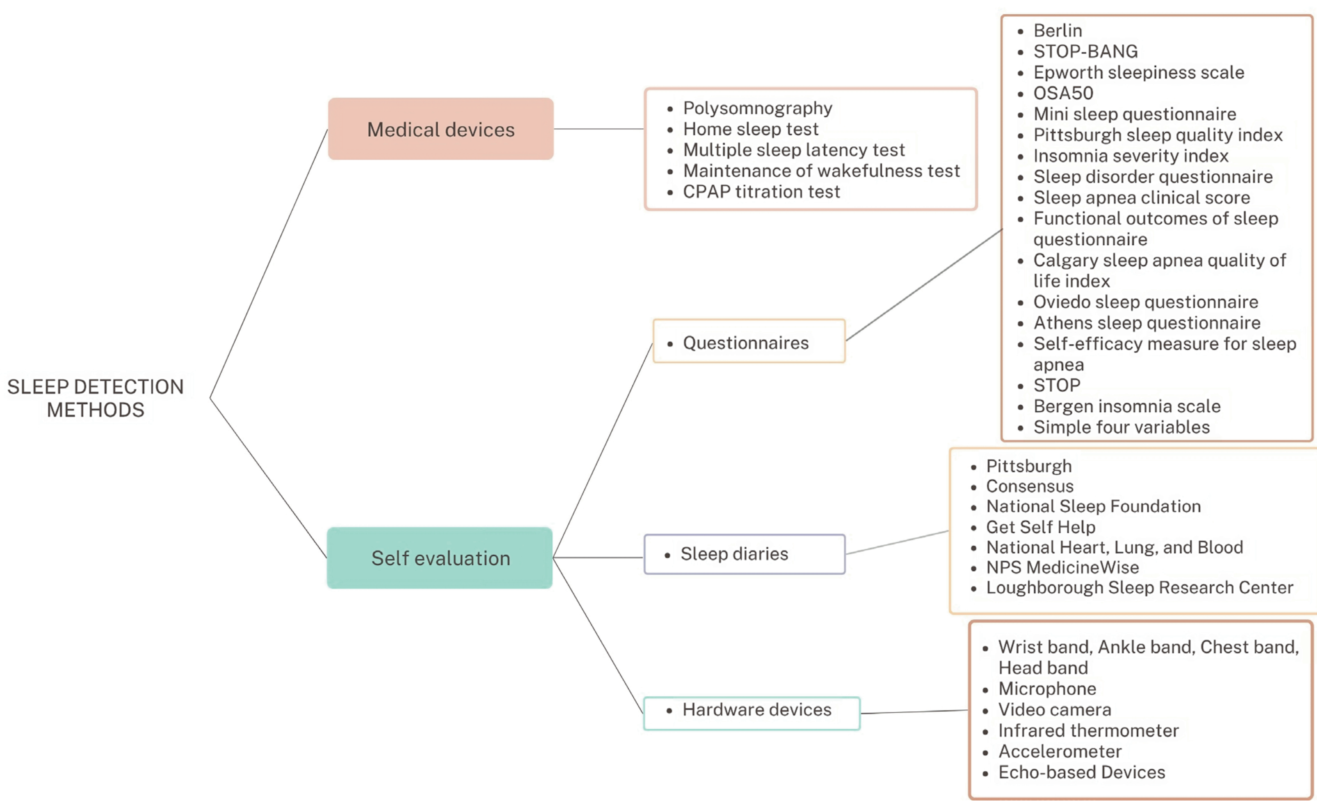

Figure 1 Sleep detection methods[10]

proper equipment and expert technicians and doctors, researchers have attempted to create tools for an initial diagnosis.

An orthodontist is part of a multidisciplinary team in OSA clinical care because of the opportunities to see many patients who may have symptoms of OSA but lack knowledge for treatment. Many adult patients who need orthodontic treatment may simultaneously have symptoms of OSA that can be evaluated by diagnostic tools. Furthermore, the orthodontist can educate patients concerning the disease. If any serious concerns arise from the objective tools, patients can be referred to a sleep specialist for a definitive diagnosis.[9] The objective of this current literature review is to collect evaluation methods that focus on questionnaires and radiographic methods for a tentative diagnosis of OSA in orthodontic practice.

Literature review

Questionnaire methods

Figure 1 Showed the questionnaires as one of the methods used to evaluate day and night clinical symptoms.[10]

Self-evaluation by questionnaires is a preliminary assessment tool used in primary care because it is inexpensive and fast. However, the drawback is perception bias of the respondents that yields low accuracy. In fact, this type of tool has the lowest accuracy among other sleep detection methods. Currently, there is no agreement on which questionnaire should be the primary questionnaire. Selection of a questionnaire should be dependent on the purpose of the questionnaire with academic evidence on the sensitivity and specificity, and convenience in its utilization. Questionnaires that contain too many questions, complex score evaluations, and computer calculations will lead to disuse of such questionnaires.[11]

STOP-BANG questionnaire (SBQ)[10]

The SBQ was developed by a Canadian anesthesiologist to assess patients before surgery. It is one of the popular questionnaires used for a preliminary diagnosis because it is simple. The patient can complete the questionnaire within 5 minutes. The questionnaire contains yes-no questions on eight topics: snoring, fatigue, sleep apnea, hypertension, body mass index over 35 kg/m^2, age > 50 years, neck circumference > 40 cm, and male gender. A score of 3 out of 8 identifies OSA patients from patients without OSA. Therefore, this questionnaire is considered to have the best sensitivity. However, the specificity was found to be < 50 % since it yields false positive results in patients with OSA in the moderate to severe level. Hence, Banhiran et al.[11] suggested adding one more parameter, the waist-to-height ratio since it is a good indicator for the moderate to severe level of OSA.

Berlin questionnaire (BQ)[12]

The BQ was the first questionnaire available to general practitioners in Berlin, Germany in 1996 by U.S. and German pulmonary and primary care physicians. It consists of 11 questions with three categories of questions: witnessed apneas, daytime sleepiness or fatigue, and hypertension and obesity. This questionnaire divides patients into two categories: patients with high and low risk of OSA. There was reported the internal validity of the first two categories that category 1 = 0.92 and category 2 = 0.63.[13] Moreover, it was found that this questionnaire has 76 % sensitivity and 45 % specificity with apnea-hypopnea index (AHI) cut off ≥ 15.[1]

Aged over 50 (OSA50)[12]

The OSA50 questionnaire was created by a group of physicians who were sleep specialists in Australia, and their aim was to create a short and concise questionnaire for primary care providers. The questionnaire consists of only 4 topics that predict the severity level of OSA derived from logistic regression analysis: obesity measured by waist circumference, snoring, witnessed apneas, and age > 50 years. If the score ≥ 5, it is identified moderate to severe OSA with 100 % sensitivity and 29 % specificity. From ROC curve analysis, the OSA50 questionnaire was significantly predictive of moderate to severe OSA. However, this questionnaire alone is not enough accuracy for with and without OSA differentiation.[14] The OSA50 questionnaire is illustrated in Table 1.

Epworth Sleepiness Scale (ESS)[12]

The ESS questionnaire aims to determine daytime sleepiness through eight scenarios by rating the level of sleepiness from 0 to 3 in each scenario. The total score is 24. A higher score indicates a higher level of daytime sleepiness. If the score is ≥ 8, it indicates a low level of daytime sleepiness. The ESS score is not correlated with the AHI. The patient with daytime sleepiness may not be detected by this questionnaire. Furthermore, daytime sleepiness is not necessarily caused by OSA. It may be caused by other types of sleep disorders or depression as well. Therefore, this questionnaire should be used together with another questionnaire to identify clinical symptoms with high risks of illness and to gain benefit from the treatment. Moreover, it was found that patients with OSA usually score < 8 in the ESS.

Assessment by radiography

Since the abnormality of craniofacial and respiratory structures is one of the causes of OSA, plenty of previous studies focused on the relationship between them and OSA using various radiographic tools.

Lateral cephalometry

Anatomical abnormality in craniofacial regions and upper airway is a possible risk factor of OSA.[2,15] Combination of skeletal and soft tissue anatomy and

Table 1 OSA50 screening questionnaire

Factor	Question	If yes, score
Obesity	Waist circumference measured at the umbilicus level (> 102 cm for males or > 88 cm for females)	3
Snoring	Has your snoring ever bothered other people?	3
Apneas	Has anyone noticed that you stop breathing during your sleep?	2
Age	Are you over 50 years of age?	2
	Total score	10 points

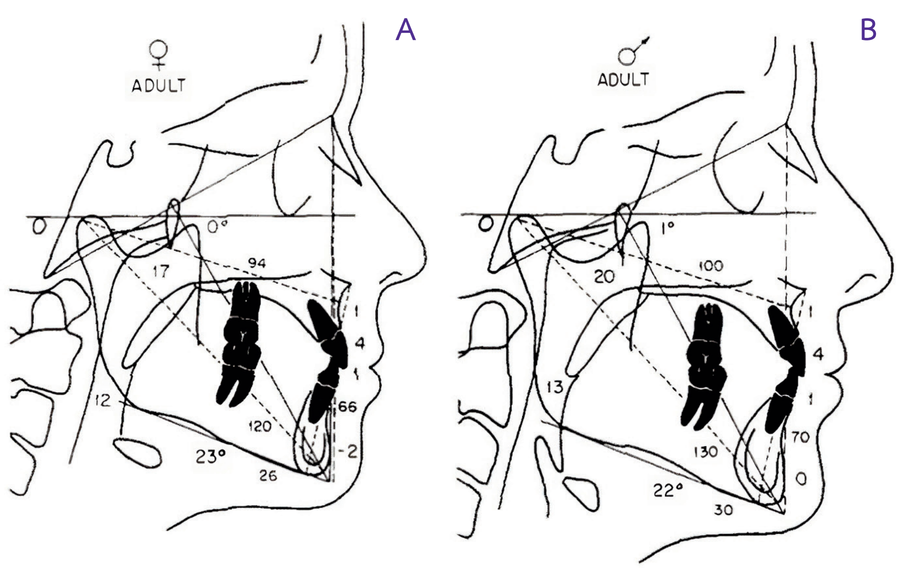

Figure 2 Lateral cephalometric upper airway analysis by McNamara: (A) ideal female; (B) ideal male[16]

function determines upper airway patency. Lateral cephalometry is the routine radiograph in orthodontic practice to analyze craniofacial region and broadly used in oropharyngeal airway area.[15]

In 1984, McNamara conducted a study that analyzed the probability of an abnormal airway. The tongue is believed to be the organ that causes obstruction in the upper airway, which can be observed in a lateral cephalogram. Measurement of lateral cephalograms was conducted to obtain normal values. Measurement from the posterior part of the soft palate to the closest posterior pharyngeal wall was 5 mm or less while the average sagittal dimension of the upper airway of the samples was 17.40 mm and increased with age. At the lower airway, the average measurement from the intersection between the posterior tongue and the posterior border position to the closest posterior pharyngeal wall was 10-12 mm, which did not increase with age.[16] Lateral cephalometric upper airway analysis by McNamara is displayed in Figure 2.

Studies were conducted by otolaryngologists and radiologists on the structures of the cranial bones, face, jaw, and upper airway based on lateral cephalograms of 105 samples who were of Thai ethnicity with no

Table 2 Normal values of lateral cephalometric data of the upper airway in Thai non-OSA population.

Parameters (Mean ± SD)	Males	Females	*P* value
HP/SP (degree)	124.80 ± 7.00	126.10 ± 7.60	0.42
N-ANS (mm)	58.60 ± 3.80	55.70 ± 3.60	0.02*
ANS-GN (mm)	73.50 ± 4.60	71.30 ± 6.0	0.60
GN-GO (mm)	84.80 ± 4.70	80.40 ± 4.30	< 0.01*
PNS-PP (mm)	26.60 ± 3.50	26.90 ± 3.20	0.68
H-PP (mm)	35.60 ± 4.40	29.00 ± 2.90	< 0.01
H-GN (mm)	50.90 ± 6.50	50.00 ± 7.20	0.59
MPH (mm)	16.10 ± 5.30	10.80 ± 4.90	< 0.01*
PAS (mm)	14.20 ± 3.40	11.10 ± 3.30	< 0.01*
PNS-P (mm)	34.80 ± 6.10	32.30 ± 3.10	0.05
TL (mm)	81.00 ± 5.40	76.70 ± 4.70	< 0.01*

The significant difference between genders at $P < 0.05$.

HP/SP = angle between hard palate and soft palate; N-ANS distance between nasion and anterior nasal spine; ANS-GN = distance between anterior nasal spine and gnathion; GN-GO = distance between gnathion and gonion, PNS-PP = the shortest distance between posterior nasal spine and posterior pharyngeal wall; H-PP = the shortest distance from hyoid bone to posterior pharyngeal wall; H-GN distance from hyoid bone to gnathion; MPH = distance from mandibular plane to hyoid bone; PAS = the shortest distance between base of tongue and posterior pharyngeal wall; PNS-P = length of soft palate, distance between posterior nasal spine and tip of soft palate; TL = distance between tip of tongue and valleculae, the intersection of epiglottis and base of tongue symptoms of OSA confirmed by ESS score ≤ 8. Table 2 showed the lateral cephalometric data of the normal values of the upper airway in Thai non-OSA population.[17]

From the study by Sforza et al.,[18] the relationship between pharyngeal collapsibility and cephalometric parameters was found in PNS-P, H-PP, and MPH. From the logistic regression analysis, patients with MP-H ≥ 18 mm, NSBa ≤ 130 degree, and PAS ≤ 10 mm tend to increase risk of AHI ≥ 15 (moderate to severe OSA).[19] Moreover, there is strength of the correlation between some of the adult craniofacial morphology and upper airway found by meta-analysis. OSA patients have a significant decrease in cranial base angle (S-N-Ba) and length (S-N). Decreasing cranial base angle made posterior pharyngeal wall more anterior position. Decreasing cranial base length made maxilla more retrusion and upper airway space was consequently reduced. Longer facial height (SN-GoMe, ANS-Me, N-Me, SN-MP), normal maxillary position (SNA) but reduced maxillary length (ANS-PNS), smaller and retruded mandible (SNB, Go-Me, Go-Gn, mandibular length), coexistence of acute cranial base angle with bimaxillary retrusion leads to less airway space. Increased area and length of tongue and soft palate, also increased with aging will be more posterior position of tongue that invade upper airway space. Upper airway length (UAL), posterior airway space (PAS), and PNS-Pharyngeal wall are decreased in OSA patients from intrusion of surrounding skeletal and soft tissue structures. The inferior position of hyoid bone (GoMe-H, MPH) made the upper airway longer leading upper airway tended to collapse.[15] To sum up, according to these studies, cephalometric parameters which indicate OSA could focus on SNB, NSBA, Gn-Go, PNS-PP, MPH, PAS, and PNS-P.

The data from studies on cephalometric radiographs against a preliminary diagnosis of adenoid hypertrophy revealed that the sensitivity and specificity were 61-75 % and 41-55 %, respectively.[20,21] The researcher suggested that the studies and analysis should be done by a 3D device in the future because that would likely yield more accurate results.[15] Lateral cephalometric radiograph may not provide complete information on respiratory structures from an axial plane or transverse dimension and cannot assess complications of the airway.[22] Moreover, a 2D-radiographic device may also cause misinterpretation[23] due to magnification and overlapping of the structures. However, the advantage of this type of radiographic device is that it emits low radiation, and it is less expensive.

Three-dimensional radiography

Conventional computed tomography (CT) versus cone beam computed tomography (CBCT)

In the past, conventional CT was used to study the structures of the upper airway in relation to OSA. However, since the introduction of cone beam computed tomography (CBCT) in the late 1990s, CBCT has been used for measurements of the upper airway. The advantage of CBCT is that it uses less radiation,[24] Furthermore, it takes less time, which results in a lower amount of radiation exposure to the patients.[25] The device moves only in one cycle to collect all data in a total of 8-40 seconds,[26] which results in approximately 10 times less radiation than a conventional CT. Even though it offers low resolution of soft tissue,[27] it does not cause problems on measurements for accuracy and re-measuring[28] because there is a high contrast between the bone, space, and soft tissue, which is considered good information. Therefore, it is commonly used in oral and maxillofacial surgery. Moreover, the radiographic procedure is simple and compatible with Digital Imaging and Communications in Medicine files[29] that can be easily accessed by dentists[30] with a low cost.[25]

Assessment of the upper airway by CBCT

In addition to using CBCT to compare patients with OSA and without OSA, it is also used to compare changes in the airway after certain types of treatment, such as maxillary expansion or jaw surgery.[31]

Focus on the anatomy, no statistically significant differences were reported between craniofacial structures farther from the airway among those with and without OSA.[32,33] Therefore, the studies usually done in the area of upper airway.

The pharynx of the upper airway can be categorized into four different sections from the upper part to the lower part: nasopharynx, velopharynx, oropharynx and hypopharynx.[26] Presently, the literature does not offer clear definitions of the referenced positions to determine the extent of the airway structure to analyze the upper airway. Therefore, measurements of the upper airway in each study can vary. In general, however, analyses are conducted at the position lower than the second cervical vertebra since a small window can be used which results in the reduction of radiation exposure to patients. It is also common to make assessments around the oropharynx because OSA is often found in this area.[23]

Airway assessments normally start from the nasopharynx down to the oropharynx. It is common to measure the following parameters: the minimum cross-sectional area, anteroposterior and lateral dimensions, shape, volume, and length,[3] which can be accurately measured and can be re-measured, using computer technology to create a 3D-image.[32,33] At the nasopharynx level, a deviation of nasal septum could be a radiographic marker in OSA screening.[34] Seeing that major septal deviation can contribute to severe nasal congestion, OSA could subsequently occur.[35] Meanwhile, in the study of Jafari-Pozve et al., not found significant difference in the anteroposterior and transverse dimension of nasopharynx, oropharynx, and hypopharynx.[36]

At the oropharynx level, Momany et al. discovered the airway narrowest cross-sectional area (CSA) showed a significant negative correlation with AHI and was a significant variable in OSA prediction by multiple regression analysis.[37] One study that presented a correlation between the cross-sectional area dimension and the level of risk of OSA concluded that if the minimum cross-sectional retropalatal area is < 52 mm^2, the risk of OSA would be high. If the minimum cross-sectional retropalatal area is <110 mm^2, the risk of OSA would be low.[38]

The studies on the upper airway structure found that the minimum cross-sectional area is a statistically significant[3,22] parameter that involves the pathophysiology of OSA explained by Poiseuille's Law. This law states that the resistance to airflow is proportional to the fourth power of the airway radius but inversely proportional to airway length, which means a small airway radius results in increased resistance to air flow.[39]

According to Poiseuille's Law, the parameter of total airway volume may not provide sufficient data on the upper airway in line with OSA as much as the cross-sectional area of the airway.[40] However, according to previous studies, it was found that the average airway volume and the total airway volume in patients with OSA was statistically significantly[24] lower than subjects without OSA. Consequently, the assessment of airway volume is also important.

Studies on the shape of the cross-sectional area of the upper airway found that subjects with OSA had a concave cross-sectional area. However, in normal individuals, the cross-sectional area of the airway appeared in various shapes, such as concave, circular, or square.[22]

Enciso et al, developed prediction model to determine OSA risk factors from CBCT with Berlin questionnaire. They found age > 57 years, male, high risk Berlin questionnaire, narrow lateral dimension of the upper airway (< 17 mm) were risk factors to present OSA.[41]

Limitations of CBCT

CBCT is a static analysis that captures the image by recording when the patient is in the sitting position and awake and does not involve the sleeping process. Moreover, CBCT does not offer the best soft tissue contrast. It is difficult to clearly differentiate soft tissues such as the tonsils, lymph nodes, muscles, tendons, blood vessels, salivary glands, and connective tissues from hard tissues. However, CBCT offers high spatial resolution enough that can be used for preliminary examination. Additionally, some errors in interpretation of CBCT images may be caused by the breathing phases and position of the head and tongue. Other errors may be due to craniocervical inclination, which affects the cross-sectional dimension of the airway despite attempts to set the same criteria for everyone.[3]

CBCT accuracy for upper airway measurement is high.[42] There was an erroneous of MCA and volume measurement by CBCT 11-20 % and less than 4 % respectively.[29] Result from another study showed 59 % of subjects in nasopharynx measurement found 0-10 % difference between twice CBCT scanning results. In oropharynx, 10-20 % difference in 44 cases, and hypopharynx, 0-10 % from 50 cases was found.[32] In terms of CBCT file exportation to Dolphin software for measurement, in oropharynx, there was overestimation 12 % and underestimation 23 %.[33] In addition, concerning reliability, CBCT also contributed to high.[29]

Discussion

Although PSG is the gold standard of OSA diagnosis and clinical characteristics alone could not be replaced, PSG still have several disadvantages in case of population-level on the ground of high cost, long waiting lists, and lacking experts.[37] Furthermore, sleep difficulty or “first-night effect” leads to less reliability results.[17]

The clinical symptoms of OSA can be investigated through questionnaires. Their advantages of short and concise form make them appropriate for primary care level. In addition, assessing posttreatment symptoms is often the purpose for application. From a previous study, even though several types of questionnaires have high sensitivity, the specificity varies from average to low contributing to false positive results. Thus, questionnaires are just methods in the initial diagnosis. They should be used in combination with radiograph and clinical examination for more accuracy.[43]

The Berlin questionnaire is not generally used due to the complex scoring system contributing to time consuming[12]and large number of false negative results (209 per 1000 patients).[1] In terms of STOP-BANG, the lower the cut point, the lower specificity leading to less true positive result. Moreover, some items in the questionnaire might inappropriately be used for everyone, for example, snoring and witness apnea, if the patients sleep alone, they cannot apparently know that they encounter with these symptoms. ESS emphasizes daytime sleepiness issue which does not relate to AHI. In addition, this symptom is not specific to only OSA but can be inferred to other sleep disorders.[12] Recommendation of American academy of sleep medicine (AASM) experts is clinical tools, questionnaires, and prediction algorithms not used to diagnose adult OSA without the conjunction with polysomnography or home sleep apnea testing because of low level of accuracy. They accentuated that the harms outweigh benefits on account of undiagnosed false negative and unimportant further investigation and treatment because of false positive.[1]

Prediction algorithm set by clinical and radiographic of risk factors may be helpful to differentiate high risk OSA from non-OSA patients in non-sleep clinic setting even if, they are less precision for OSA diagnosis.[1] Nonetheless, there are some issues that make utilization of this equipment confronted the difficulty. To use the CBCT data in conjunction with questionnaire, there is still controversy in the diagnosis. The study of Chaudry et al. found minimum cross-sectional area in retropalatal region is less than 110 mm^2, 90 % of subjects in STOP-Bang scores ≥ 3 subgroup considered to be OSA.[44] which differed from the study of Lowe et al, that indicated minimum cross-sectional area in retropalatal region less than 110 mm^2, would be low risk of OSA.[38] Differences in upper airway measurement boundaries in each study, until now, there is no consensus on which upper airway anatomical landmarks are related to OSA pathophysiology.[3] Due to dynamic changes of upper airway anatomical structures, researchers should be aware of different breathing stages, tongue positions, swallowing phases, occlusion indicating mandibular position, and the sleep-awake cycle[32] when lateral cephalogram and CBCT taken. These issues could make difficulty in daily practice.

Conclusion

Questionnaires and radiographic assessment for preliminary OSA diagnosis have several benefits in particular unavailable sleep specialist areas, unreadiness of equipment setting, general practitioner, and orthodontic practice. However, the limitations of these tools raise questions as to whether a questionnaire or radiography is better. Still, lateral cephalometric film is one of the advantages over questionnaires since it is a routine procedure for all patients before orthodontic treatment. According to the AASM recommendation, they should be used in conjunction with at least home sleep apnea testing regarding accuracy improvement.

Author contributions

TJ: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing-Original Draft, Writing-Review & Editing, Visualization, Supervision, and Project administration; BS: Conceptualization, Validation, Formal analysis, Writing - Review & Editing, and Supervision.

Disclosure statement

Authors have no the conflict of interest.

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