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Cephalometric Analyses and Flow-Volume Loops in Obstructive Sleep Apnea Patients

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Summary: Fifteen patients with obstructive sleep apnea syndrome (OSAS) and 10 controls were studied. Polygraphic monitoring during sleep confirmed the presence or absence of OSAS. Ten OSAS patients and five controls had cephalometric analysis and 12 OSAS patients and five controls had a flow-volume loop study during wakefulness. Seven OSAS patients were submitted to both analyses. Flow-volume loops were unable to detect extrathoracic airway obstruction in six out of 12 OSAS patients. One control was found with positive results. Six out of seven subjects with positive flow-volume loops were overweight (≥30% ideal weight). Cephalograms were very useful in demonstrating mandibular deficiencies in OSAS patients. The length of the soft palate and the position of the hyoid bone, together with the measurement of the posterior airway space, are criteria of great interest in OSAS patients. Cephalometric analysis is recommended in all OSAS patients scheduled for surgical procedure. None of these tests, however, whether alone or in combination, is capable of identifying all cases of OSAS. **Key Words:** Cephalogram—Flow-volume loops—Sleep apnea—Hyoid bone—Imaging technique.

In the recent past, efforts have been made to find daytime laboratory examinations that would help determine the presence of obstructive sleep apnea syndrome (OSAS). A great emphasis has been placed on flow-volume loop results performed in pulmonary function laboratories (1,2). The study reported here compares results obtained from the daytime use of flow-volume loop with cephalometric analysis in patients with OSAS. It gives new cephalometric measurements that we have found to be of value in the evaluation of some OSAS patients. Finally, it emphasizes once more that OSAS is a multi-faceted problem, with repetitive obstruction and subobstruction during sleep being the common denominators.

Patient population (see Table 1)

A total of 15 patients with obstructive sleep apnea and 10 controls with documented absence of nocturnal symptoms participated in the study. All were men aged 18 to 65 years. This population was subdivided into two groups, since not all subjects underwent both tests. The Cephalometric Study Group included 15 subjects, 10 with OSAS

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and five controls. The Flow-Volume Loop Study Group included 17 subjects, 12 with OSAS and five controls. Only seven OSAS patients received both flow-volume loop and cephalometric analyses. Five of the seven OSAS patients presented with a strong clinical suspicion of mandibular deficiencies at clinical examination and a typical clinical history of obstructive sleep apnea with heavy snoring. Based on this clinical impression, these five OSAS patients were specifically selected to undergo both tests before any polygraphic recording. None of the controls was subjected to the two investigative tests.

METHODS; TECHNIQUE OF ANALYSIS

Sleep monitoring

All patients were monitored for at least 1 night during sleep. The following variables were systematically monitored: electroencephalogram (EEG C3/A2–C4/A1 of the 10–20 International Placement System), digastric electromyogram (EMG), electrooculogram (EOG), and electrocardiogram (lead III). Respiration was measured using inductance respiratory plethysmography (Respitrace®), air-flow (thermistors), and ear oximetry (Hewlett-Packard ear oximeter).

Sleep apnea scoring

The polygraphic records were scored for sleep in 30-s epochs according to the standard criteria outlined by Rechtschaffen and Kales (3). Respiration during sleep was scored for apnea, hypopnea, and oxygen desaturation, following criteria previously outlined by Guilleminault et al. (4).

Flow-volume loop

Each patient given this test was first given a standard spirometric evaluation. The flow-volume loops were performed as part of a research protocol. The investigator knew that patients were suspected of having obstructive sleep apnea but was unaware of the polygraphic results at the time of flow-volume loop interpretation. The flow-volume loops were performed in the pulmonary function laboratory with patients in a sitting position. Two flow-volume curves (FVC) were systematically obtained with two different pneumotachographs (i.e., a total of four FVCs) (Jeger, Inc. and Bear-Cavitron, Inc.). Patients were instructed to breathe through a heated pneumotachograph, and flow was integrated as the primary signal. The FVC was constructed by integrating the flow signal to obtain volume. Following the definition given by Sanders et al. (1), FVCs were considered indicative of variable extrathoracic airway obstruction if there was a sawtooth pattern, which is defined as three or more consecutive peaks and troughs of similar configuration occurring at regular intervals of no greater than 300 cc during the middle half of the vital capacity in expiration, inspiration, or both. Extrathoracic obstruction was also suggested by a flattened configuration of the inspiratory curve of the flow-volume loop and a ratio of expiratory flow to inspiratory flow at mid-vital capacity (FEF 50/FIF 50) exceeding 1. Each curve was scored for any of these findings.

Cephalometric technique

Each patient was placed in a sitting position. The patient's eyes were directed forward in a natural head position so that the gaze was parallel to the floor (5–7). The patients were upright. The teeth were together and the lips relaxed. The standard position for the x-ray cone was exactly 5 ft from the film, which was placed next to

the left side of the face. The following cephalometric landmarks were identified (see Fig. 1): sella (S), midpoint of sella tursica; nasion (N), the most anterior point of the nasofrontal suture; anterior nasal spine (ANS), the most anterior point of the nasal floor; posterior nasal spine (PNS), the most posterior part of the contour of the hard palate; subspinale (A), the deepest point of contour of the premaxilla between anterior nasal spine and central incisors; pogonion (Pg), the most anterior point of the contour of the chin; supramentale (B), the deepest point of contour of the mandibular alveolus between pogonion and central incisor; gnathion (Gn), the most inferior point in the contour of the chin; gonion (Go), the most posterior/inferior point on the convexity of the angle of the mandible; mandibular plane (MP), a plane constructed from gnathion through gonion; hyoid (H), the most anterior/superior point on the body of the hyoid bone. Soft tissue outlines, corresponding to posterior pharyngeal wall, soft palate, and base of tongue-vallecula, were traced.

General rules for cephalometric analysis. Skeletal discrepancies are evaluated with reference to the cranial base. This is a plane drawn from sella through nasion with the patient in a natural head position; the SN line should be within 7 of the true horizontal. This is a check of the natural head position. A correction is necessary if the SN line is greater than 7 (example, when SN plane is 15 from horizontal plane, 8 is added to the SN plane measurements).

Mandibular or maxillary discrepancies can be evaluated by the angles SNA (M = 82, SD ± 2) and SNB (M = 80, SD ± 2). Angles less than the mean for SNA and SNB suggest a maxillary or mandibular deficiency. Discrepancies between the maxilla and mandible are evaluated by the ANB measurement (M = 2). Patients with a mandibular deficiency and a normally positioned maxilla will commonly have significant A and B measurements.

Vertical skeletal discrepancies are examined by measuring the distance from N-ANS (M = 57 mm, SD ± 4 mm) and AN-Gn (M = 68 mm, SD ± 4 mm). Patients with excessive vertical growth of the maxilla, and also mandibular deficiency, will very commonly have large ANS-Gn measurements.

The posterior airway space is evaluated by a line drawn from point B through Go. This line will intersect the base of the tongue and posterior pharyngeal wall. The linear measurement between the base of the tongue and the posterior pharyngeal wall is the posterior airway space (PAS, M = 11.0 mm, SD ± 1 mm). The soft palate is evaluated by a line constructed from PNS to the tip of the soft palate contour (M = 37 mm, SD ± 3 mm). The position of the hyoid is determined by a line perpendicular to the mandibular plane (MP) through the hyoid (M = 15.4 mm, SD ± 3 mm).

These measurements, including the rarely looked at hyoid position, were obtained for all patients studied.

RESULTS

Patients with OSAS had polygraphically documented results during nocturnal sleep. Based upon the results of the polygraphic recording during sleep, the severity of the problem varied. The Apnea-Hypopnea Index [(A + H)I], defined as the number of apneas and hypopneas × 60/total sleep time in minutes (4), ranged from 11 to 76 in the total OSAS patient population. None of the control patients had an (A + H)I above 5, by the principle of selection. One control subject was 37% overweight, but all others were below this selected weight criterion.

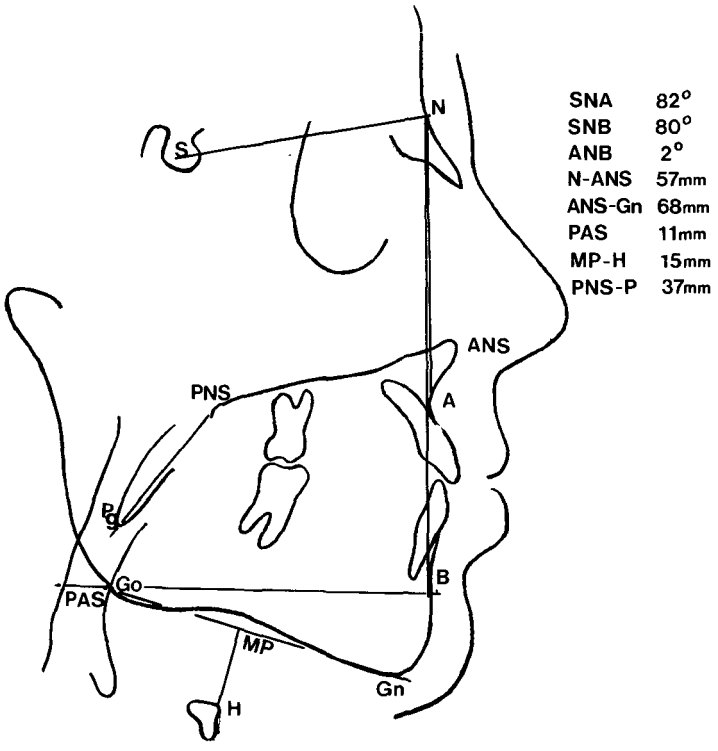

FIG. 1. Cephalogram of control patient with indication of different cephalometric landmarks. S = sella; N = nasion; ANS = anterior nasal spine; PNS = posterior nasal spine; A = subspinale; Pg = pogonion; B = supramentale; Gn = gnathion; Go = gonion; MP = mandibular plane; H = hyoid; PAS = posterior airway space. SNA = angle measurement from sella to nasium to point A; SNB = angle measurement from sella to nasium to point B; ANB = difference between SNA and SNB; N-ANS = vertical measurement from nasium to anterior nasal spine; ANS-Gn = vertical measurement from anterior nasal spine to gnathion; PAS = posterior airway space; MP-H = distance from point H (hyoid) to mandibular plane; PNS-P = distance from posterior nasal spine to tip of the soft palate.

Flow-volume loops

The overweight control subject fulfilled one of the selected criteria for being classified with positive results (i.e., evidence of extrathoracic airway obstruction). His (A + H)I was 5. All other controls had negative flow-volume loops.

As can be seen in Table 1, 50% of the OSAS population had negative results. These patients gave no evidence of any of the selected criteria after evaluation of four loops. Five out of six OSAS patients with "positive" results of the flow-volume loops were 30% overweight for age and height (3 were 70% above ideal weight for age and height) (6). Two of the five OSAS patients whose cephalometric evaluation indicated mandibular problems had "negative" results with flow-volume loops.

Cephalometric analysis

Fifteen subjects—five controls, and 10 obstructive sleep apneic patients—were analyzed. The presence of overjet ≥ 3 mm was clinically determined, and a clinical score of "possible mandibular involvement" based on this criterion was given by the clinical team that first saw the patient. Overjet is the horizontal overlap of the upper and lower incisors. Cephalometric analysis of three patients (MF, FF, and JW) disclosed no

TABLE 1. *Results of evaluation techniques for OSAS in 15 male patients*

				Results of testing during wakefulness		
					Mandibular deficiency	
Case	Age	(A + H)I	≥ 30% Overwt	Flow-volume loops	Clinical	Cephalometrics
1[a]	39	38	No	No	No	NA
2[a]	51	60	Yes	Yes	No	NA
3[a]	48	72	Yes	Yes	No	NA
4[a]	55	29	No	No	No	NA
5[a]	43	47	Yes	Yes	No	NA
JB[b]	33	52	Yes	Yes	Yes	Yes
GH[b]	30	76	Yes	Yes	Yes	Yes
AH[b]	40	20	No	No	Yes	Yes
TB[b]	18	75	No	Yes	Yes	Yes
WS[c]	50	30	No	NA	Yes	Yes
LP[b]	65	22	No	No	Yes	Yes
MF[c]	37	40	Yes	NA	Yes	No
FF[b]	45	20	No	No	Yes	No
AB[b]	49	11	No	No	No	No
JW[c]	53	60	Yes	NA	Yes	No

NA = Not available.
Mandibular deficiencies were suspected clinically (clinical score) and confirmed by cephalogram.
Results of testing during wakefulness: No = no abnormality, Yes = abnormalities indicating extrathoracic obstructions.
[a] Patients 1–5 had flow-volume loops only.
[b] Patients had flow-volume loops and cephalometrics.
[c] Patients had cephalometrics only.

abnormal hypopharyngeal airway despite an overjet equal to or greater than 3 mm; but there was a positive correlation between the clinical score of possible mandibular involvement based upon overjet measurement and secondary cephalometric analysis in the six other clinically suspected cases. The mandibular deficiency was confirmed by cephalometric analysis in only 66% of the cases clinically suspected (see Table 1). We have no data on the percentage of error related to absence of clinically detectable overjet and presence of mandibular deficiency at cephalometric analysis. Four patients had OSAS with no evidence of mandibular deficiency.

The measurements of the control group are shown in Table 2. All the patients had normally positioned maxillas and mandibles as shown by the SNA, SNB, and ANS-Gn measurements. The mean posterior airway space was 11 mm. The MP-H mean was 16 mm, and the PNS-P mean was 37 mm. The cephalometric measurements of the group defined as OSAS–mandibular-deficient are shown in Table 2. All of the patients in this group had a skeletal mandibular deficiency, as shown by the SNB measurements. The posterior airway space was significantly less in all the patients (mean 4.6 mm) when compared with the control group. On examination of the hyoid measurements, the patients appeared to have a more inferiorly positioned hyoid bone (mean 29 mm). The soft palate (PNS-P) was also longer than the control group (mean 44 mm) (see Fig. 2).

The cephalometric results of the group denoted "OSAS without mandibular deficiency" is shown in Table 2. All of the patients had a posterior airway space comparable to the control group (mean 11 mm). The hyoid position measurements were variable

TABLE 2. *Results of cephalometric analysis for controls and OSAS patients*

	OSAS with mandibular deficiency						OSAS without mandibular deficiency				Control group				
Patient:	JB	GH	AH	TB	WS	LP	MF	FF	AB	JW	CS	NP	BP	BR	PH
SNA	85	77	80	80	84	80	86	86	76	82	80	80	81	83	80
SNB	73	72	75	75	77	75	84	82	80	82	78	78	80	81	78
ANB	8	5	5	5	7	5	2	4	4	—	2	2	1	2	2
N-ANS	56	58	55	60	53	61	58	57	52	62	52	59	50	52	55
ANS-Gn	76	78	76	87	78	76	75	75	85	82	63	72	68	68	75
PAS	4	4	4	5	5	5	10	9	13	13	14	11	10	10	10
MP-H	34	24	24	32	26	35	32	21	18	34	21	16	17	15	8
PNS-P	—	38	47	47	44	43	47	45	—	49	42	37	37	36	34

The subdivisions *with* and *without* mandibular deficiency are based on results obtained. Each measurement is presented in mm. SNA = angle measurement from sella to nasion to point A; SNB = angle measurement from sella to nasion to point B; ANB = difference between SNA and SNB; N-ANS = vertical measurement from nasion to anterior nasal spine; ANS-Gn = vertical measurement from anterior nasal spine to gnathion; MP-H = distance from H to mandibular plane; PNS-P = distance from posterior nasal spine to tip of the soft palate. All measurements are expressed in millimeters.

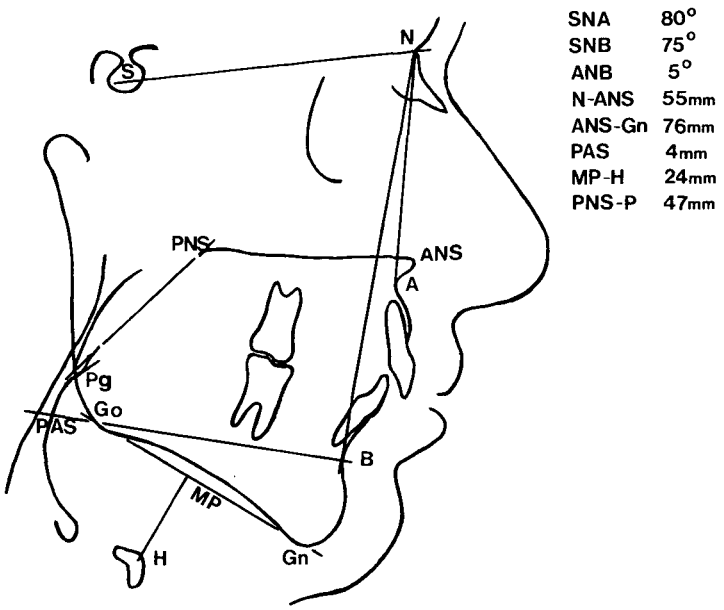

FIG. 2. Cephalogram of patient AH, who had a (A + H)I of 20, no abnormal findings of flow-volume loops, abnormally long soft palate, and mandibular deficiency. Cephalometric landmarks are defined as for Fig. 1.

upon examination. Two patients had an inferiorly positioned hyoid similar to the mandibular deficiency group, and two patients had the hyoid in normal position. The soft palate could only be evaluated in three of the four patients [one patient could not be evaluated with respect to palatal length because of previous palatopharyngoplasty (PPP)]. All of the patients in this subgroup had an excessively long soft palate, the mean PNS-P measurement being 47 mm.

All patients with polygraphically demonstrated OSAS were not detected by cephalometric analysis, but this imaging test did give the following valuable information: indication of the length of the soft palate, and size of the pharyngeal airway. The results from the test also indicate that patients with mandibular deficiency and OSAS had not only a narrow posterior airway but also a long soft palate and an inferiorly positioned hyoid bone. However, there was no good correlation between the (A + H)I taken as a measure of severity of OSAS and any of the cephalometric indices in the mandibular-deficient group.

Combination of different analysis tests

Of the seven patients who had both cephalometric analyses and flow-volume loops, two (AB, FF) had completely negative findings at daytime evaluation. Their (A + H)Is during sleep were 20 and 40, respectively. Both patients were below the 30% overweight mark.

DISCUSSION

This study, despite the small number of patients (15 OSAS, 10 control), emphasizes several important points. First, despite simultaneous use of two different techniques (i.e., flow-volume loops and cephalometric analyses) on seven awake patients clinically

suspected of OSAS and later polygraphically demonstrated to have (A + H)I equal to or above 11, two (28%) had negative awake findings.

Half of the 12 polygraphically documented OSAS patients who underwent flow-volume loop analysis had negative results for extrathoracic airway obstruction, despite the focus upon and emphasis given to analysis of these loops and comparison with all published criteria. Moreover, two of the five OSAS patients with small hypopharyngeal airway documented by cephalometric analysis had flow-volume loops interpreted as "normal" by the selected investigator. Five of six OSAS patients and one control subject with (A + H)Is equal to 5 and flow-volume loops scored as "abnormal" (i.e., indicative of extrathoracic airway obstruction) were 30% above ideal weight. One may question if positive flow-volume loops do not correlate more with obesity than with OSAS. As overweight male patients tend to be more prone to OSAS, there would be an overlap between the two populations. It would be of interest to perform systematic flow-volume loop tests on overweight premenopausal women, who, at least in our experience, appear to be much less prone to OSAS, in order to study this issue. On the other hand, now that several different surgical approaches can be offered to OSAS patients, the importance of cephalometric analysis must be emphasized, particularly in patients considered for PPP.

Cephalometric analysis has been used for years in evaluation of facial growth and development (8–12). It provides analysis of dental and developmental skeletal anomalies. In addition, soft tissue structures are visualized, and therefore facial form can be evaluated. Popovich and Thompson (13) have also derived normative data from a random sample of 120 men and 90 women, which may be useful for comparison of anatomic landmarks. In recent years the treatment of developmental abnormalities has blossomed. Cephalometric analysis has become the most important diagnostic method for their evaluation.

We have reported, as have several other authors (14–16), that mandibular deficiency contributes to OSAS. An important retrognathia can be easily recognized, and the presence of significant overjet, detected clinically, may be a helpful indicator. This clinical finding did not correlate with decreased size of pharyngeal airway space in three out of nine subjects (33%). However, all patients with deficiency by cephalogram did have a decreased pharyngeal airway space. Considering the published results—that up to 50% of patients treated with PPP (17) have not fully benefited from the procedure and that patients with mandibular deficiency have uniformly failed (17)—cephalometric analysis appears to be highly recommended.

Finally, two cephalometric anatomical landmarks have been found to be of interest in OSAS patients: the length of the soft palate and the position of the hyoid bone, which seems to be inferiorly positioned. We suggest that all patients with OSAS scheduled for a surgical procedure undergo a cephalometric analysis, and warn against eliminating the diagnosis of OSAS when based solely on flow-volume loops.

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