Axial CT Measurements of the Cross-sectional Area of the Oropharynx in Adults with Obstructive Sleep Apnea Syndrome

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PURPOSE: To determine whether narrowing of the oropharynx increases during relaxation in patients with severe obstructive sleep apnea syndrome. **MATERIALS:** The study included 23 adult men in whom polysomnography had established a diagnosis of obstructive sleep apnea syndrome. Subjects had an average of 53 episodes of sleep apnea per hour, with each episode lasting 40 seconds or more. Oxygen saturation dropped an average of 22% during sleep. Hypnotic relaxation was induced in all patients, and high-resolution CT scans with sagittal and coronal reconstruction of the oropharynx were obtained in the awake state and during the relaxation state using the same parameters. The cross-sectional area of the oropharynx was measured in a minimum of 10 CT axial sections in each case. **RESULTS:** In all patients, the narrowest cross-sectional area of the oropharynx was smaller during hypnotic relaxation than in the awake state. The average difference between both measures was 42%. In the awake state, the measurements ranged from 15 to 55 mm^2 (average, 38 mm^2). During hypnotic relaxation, they ranged from 0 to 35 mm^2. Oxygen saturation during hypnotic relaxation dropped in all patients from 9% to 17% (average, 14%). No episodes of sleep apnea were observed during hypnotic relaxation. **CONCLUSIONS:** In patients with obstructive sleep apnea, airways were demonstrably smaller in diameter during hypnotic relaxation than during the awake state.

Index terms: Pharynx, computed tomography; Sleep studies

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Narrowing of the oropharynx is responsible for obstructive sleep apnea syndrome (OSAS). It may occur at the level of the uvula–soft palate complex or at the base of the tongue. The condition can be idiopathic or result from the pickwickian syndrome, pharyngeal tumors, tonsillar hypertrophy, macrognathia, micrognathia, or central nervous system disturbances (1–9).

Clinical symptoms of OSAS include episodes of apnea during sleep, daytime hypersomnolence, tiredness, snoring, headache, nocturnal enuresis, impotence, cognitive dysfunction, hallucinations, and cardiovascular disturbances (10–16). Corrective surgical procedures for severe OSAS may include uvulopalatopharyngoplasty, tonsillectomy, or maxillomandibular advancement surgery (17–23).

In a previous study, we established that the measurement of the narrowest axial cross-sectional area of the oropharynx on computed tomographic (CT) scans corresponds well to the severity of OSAS (24). The measurements in that study were obtained in the awake state.

In the present study, we tried to produce a condition mimicking natural sleep that was safe and that enabled CT examinations to be performed easily. We also wanted to investigate the possibility that the relaxation of the pharyngeal musculature during hypnotic relaxation results in further narrowing of the oropharynx, a hypothesis that may explain the severe OSAS in some patients.

Subjects and Methods

This prospective study included 23 men, 44 to 61 years old, in whom severe OSAS had been diagnosed clinically and by polysomnography. All subjects had had 44 to 69

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TABLE 1: Oxygen saturation in 23 patients with severe obstructive sleep apnea syndrome

Patient	Minimal Oxygen Saturation before Hypnotic Relaxation	Minimal Oxygen Saturation during Sleep (Difference)	Minimal Oxygen Saturation during Hypnotic Relaxation (Difference)
1	100	82 (−18)	85 (−15)
2	99	80 (−19)	85 (−14)
3	98	78 (−20)	89 (−9)
4	98	77 (−21)	86 (−12)
5	100	77 (−23)	88 (−12)
6	99	76 (−23)	84 (−15)
7	98	74 (−24)	85 (−13)
8	100	75 (−25)	83 (−17)
9	99	76 (−23)	83 (−16)
10	99	81 (−18)	86 (−13)
11	98	80 (−18)	83 (−15)
12	98	79 (−19)	84 (−14)
13	99	76 (−23)	84 (−15)
14	100	79 (−21)	86 (−14)
15	98	79 (−19)	78 (−20)
16	98	73 (−25)	86 (−12)
17	99	75 (−24)	88 (−11)
18	100	74 (−26)	88 (−12)
19	100	76 (−24)	84 (−16)
20	98	76 (−22)	89 (−9)
21	98	78 (−20)	82 (−16)
22	100	80 (−20)	89 (−11)
23	99	79 (−20)	88 (−11)
Average	**99**	**77 (−22)**	**85 (−14)**

apneic episodes per hour (average, 53) during sleep, each with a duration of 40 seconds or more. Oxygen saturation dropped an average of 22% during sleep (Table 1). Verbal suggestions were used for inducing hypnosis, and suggestions for relaxation were given.

All hypnosis sessions were conducted by the same person, who had had 33 years' experience. The patients had four to six sessions of hypnosis with a duration of 20 minutes each before undergoing CT examination. During these sessions, an audiocassette recording that reproduced the noise of the CT scanner was played. The patients were induced into hypnotic relaxation on the CT examination table. The duration of hypnotic relaxation induction varied from 5 to 10 minutes among subjects.

In each patient, high-resolution axial CT studies of the oropharynx were obtained once with the patient awake and another time with the patient under hypnotic relaxation, using the same imaging parameters and area.

The CT studies were obtained with the patient in a supine position. Consecutive axial sections were obtained with a 2.5-mm width and in 2-mm increments followed by sagittal and coronal reconstruction. The computer window of the axial sections was set to 500 Hounsfield units with a baseline of 30 Hounsfield units. The images were photographed with a multiimager unit with the film divided into 16 exposures. The computer zoom was set to 3.05 until 1 cm of the computer scale became equal to 1 real centimeter in the photographed image.

TABLE 2: The minimal cross-sectional area of the oropharynx in 23 patients with severe obstructive sleep apnea syndrome

Patient	Narrowest Area before HR, mm^2	Narrowest Area during HR, mm^2	Difference, mm^2	Difference, %
1	48	32	16	33
2	36	24	12	33
3	15	8	7	47
4	51	35	16	31
5	29	16	13	45
6	25	20	5	20
7	33	0	33	100
8	41	31	10	24
9	38	28	10	26
10	26	16	10	38
11	58	34	24	41
12	52	35	17	33
13	29	19	10	34
14	24	0	24	100
15	30	19	11	37
16	56	32	24	43
17	42	26	16	38
18	37	24	13	35
19	40	18	22	55
20	39	0	39	100
21	46	35	11	24
22	42	0	42	100
23	54	29	25	46
Average	**38**	**22**	**16**	**42**

Measurements were made of the airway area on the axial sections of the oropharynx in square millimeters. Only the smallest measurement in each case was used for the study. The measurements were done in the same way as in the previous study (24), using the computer program and a transparent grid in square millimeters.

The drop in oxygen saturation during hypnotic relaxation was not permanent. The degree of the drop in oxygen saturation was an indicator of the depth of the state of relaxation. The lower the drop, the deeper the state of relaxation. Oxygen saturation was measured before and during relaxation. During hypnotic relaxation, CT was always performed when oxygen saturation was lowest.

Results

Sizes of the narrowest cross-sectional area of the oropharynx in the awake state ranged from 15 to 58 mm^2, with the average 38 mm^2 (Table 2). This area was measured in 18 patients in the uvula–soft palate complex and in 5 patients at the base of the tongue. In each of the 23 patients, the narrowest cross-sectional area of the oropharynx was smaller during hypnotic relaxation than during the awake state. It ranged from 0 to 35 mm^2, with an average of 22 mm^2 (Table 2; Figs 1 and 2). In four patients, CT scans obtained during hypnotic relaxation

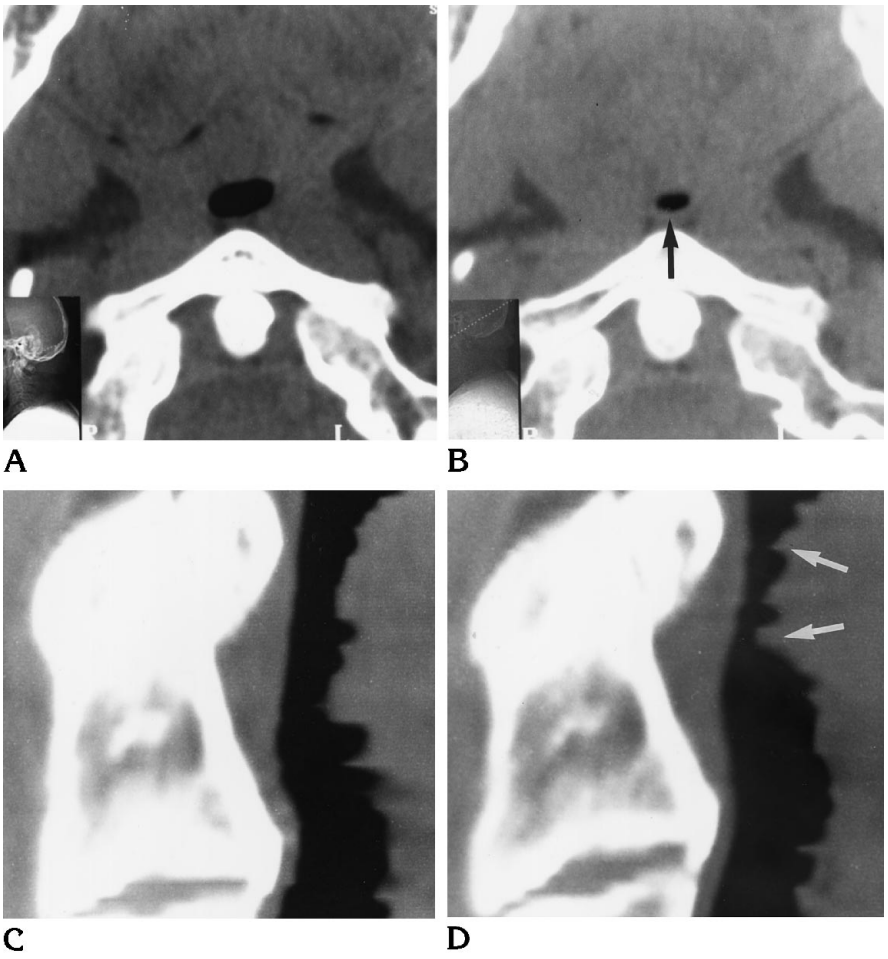

Fig 1. A 49-year-old man with severe obstructive sleep apnea syndrome.

A, Axial CT scan of the oropharynx obtained in the awake state.

B, Axial CT scan at the same level as A obtained during hypnotic relaxation shows obvious narrowing of the oropharynx (*arrow*).

C, Sagittal CT reconstruction of the oropharynx obtained in the awake state.

D, Sagittal CT reconstruction of the oropharynx obtained during hypnotic relaxation shows narrowing of the uvula–soft palate complex (*arrows*).

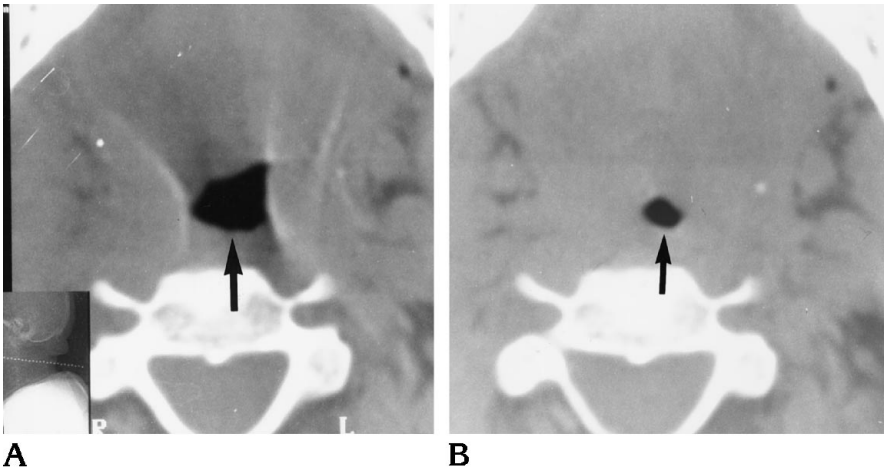

Fig 2. A 52-year-old man with severe obstructive sleep apnea syndrome.

A, Axial CT scan of the oropharynx (*arrow*) obtained in the awake state.

B, Axial CT scan of the oropharynx (*arrow*) at the same level as A obtained during hypnotic relaxation.

Fig 3. A 58-year-old man with severe obstructive sleep apnea syndrome.

A, Axial CT scan at the level of the uvula–soft palate complex (*arrow*) obtained in the awake state.

B, Axial CT scan at the same level as A obtained during hypnotic relaxation shows complete obstruction of the airway.

showed complete obstruction of the oropharynx (0 mm^2; Table 2 and Fig 3).

The difference between the measurements taken before and during hypnotic relaxation ranged from 5 to 42 mm^2 (average, 16 mm^2 or 42%) (Table 2). Oxygen saturation dropped an average of 14% in all 23 patients during hypnotic relaxation (range, 82% to 89%; average, 85%) (Table 1).

Discussion

On the basis of our previous study (24), we concluded that a size of about 50 mm^2 for the narrowest cross-sectional area of the oropharynx should be consistent with severe OSAS when 100 mm^2 represents the norm. It was unclear why some patients in that study had smaller oropharyngeal sizes yet suffered from severe OSAS while other control subjects and postoperative patients had oropharyngeal sizes above 100 mm^2 yet did not have OSAS (24). As mentioned, all measurements in our previous study were made while the patients were awake.

When imaged during hypnotic relaxation, the size of the narrowest cross-sectional area of the oropharynx in all 23 patients in this study was 35 mm^2 or less. In the awake state, this area measured more than 35 mm^2 in 16 of the patients, but in all of them, the measurement dropped below 35 mm^2 during hypnotic relaxation. All patients had a smaller cross-sectional area of the oropharynx during hypnotic relaxation than during the awake state, with measurements of 35 mm^2 or less (average reduction, 42%; Table 2). This reduction was associated with an average reduction of 14% in oxygen saturation. The same patients had a more severe reduction (average, 22%) in oxygen saturation during sleep (Table 1).

On the basis of these measurements, it may be concluded that patients in whom the minimal cross-sectional oropharyngeal measurement is 35 mm^2 or less do not need hypnotic relaxation in order for severe OSAS to be diagnosed by means of CT. In our study, patients who were thought to have severe OSAS but who had oropharyngeal measurements above 35 mm^2 in the awake state, had measurements below 35 mm^2 during hypnotic relaxation.

Although the use of hypnosis for facilitating radiographic investigation is well established (25), there is no documentation of the use of hypnotic relaxation in aiding diagnosis by CT. Probably polysomnography alone can document OSAS, but, in ambiguous cases, CT measurements during hypnotic relaxation may be helpful in examining potential surgical candidates.

The further narrowing of the oropharynx during hypnotic relaxation may be attributed to relaxation of the musculature of the mouth. Probably a similar event occurs during sleep. We found that the decrease in oxygen saturation in sleep corresponded to the decrease in the cross-sectional area of the nasopharyngeal airway. Correspondingly, in sleep, the decrease in oxygen saturation during hypnotic relaxation was not permanent, but when it did appear, it was the best indicator of the depth of the relaxation state. During relaxation, the tongue and the uvula drop posteriorly, narrowing the cross-sectional area of the oropharynx. In patients with severe OSAS, even a slight decrease in oropharyngeal width may be functionally significant.

The oropharynx may be narrowed at the level of the uvula–soft palate complex, below it (at the level of the base of the tongue), or at both levels. In this study, we used the smallest measurement taken of the cross-sectional area of the oropharynx, which is most important for the diagnosis of OSAS. During hypnotic relaxation, the decrease in oxygen saturation did not correspond to the degree of oropharyngeal narrowing, even in four patients with completely closed oropharynges. This is probably because patients under hypnotic relaxation do not have prolonged apneic episodes. The apneic episodes that occur during sleep may reduce oxygen saturation by 20%. Under hypnotic relaxation, the diameter of the airway in patients with OSAS was significantly decreased relative to a similar measurement taken in the awake state.

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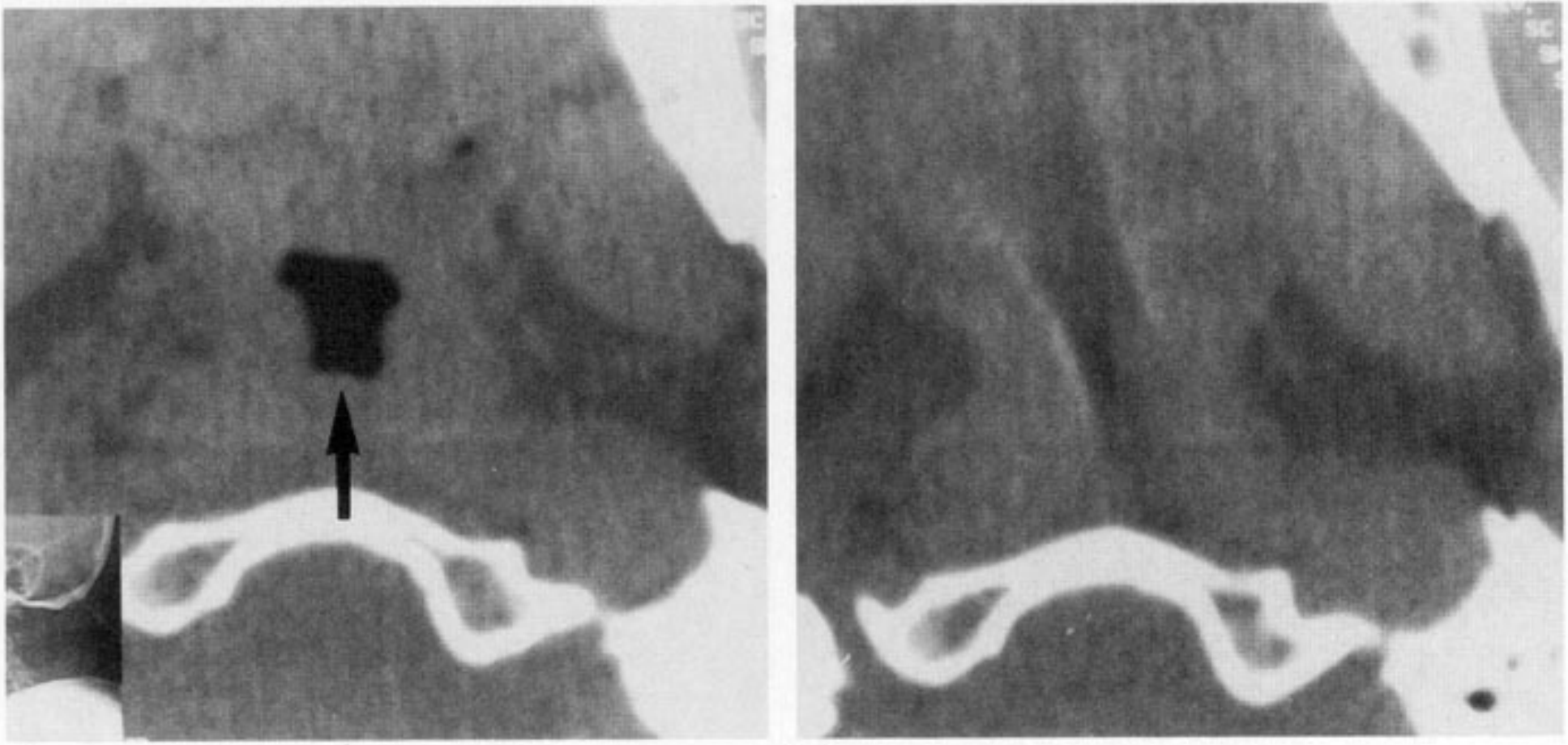

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