Effect of body position on tongue posture in awake patients with obstructive sleep apnoea

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Abstract

Background – Snoring and obstructive sleep apnoea (OSA) are worse or may only occur in the supine position. The effect of body position on upper airway size has been reported, but the effect on tongue posture has not previously been examined. **Methods** – Detailed measurements were made of tongue posture from upright and supine lateral cephalograms on 24 men with OSA and 13 men with non-apnoeic snoring matched for age, body mass index, and craniofacial skeletal pattern. Patients with OSA had apnoea/hypopnoea indices (AHI) of >50/hour and/or apnoea indices (AI) of >25/hour while non-apnoeic snorers had AHI of <10/hour and AI of <5/hour.

Results – In non-apnoeic snorers the tongue depth measurements for the superior-posterior portion of the tongue were larger in the supine than in the upright position ($p < 0.05$). There was no significant difference in tongue depth measurements between the upright and the supine position in the patients with OSA.

Conclusions – When awake patients with OSA move from the upright to the supine position they maintain their upright tongue posture which may tend to protect against upper airway collapse secondary to the increased gravitational load on the tongue. In contrast, when awake non-apnoeic snorers move from the upright to the supine position a significant dorsal movement in the superior-posterior portion of the tongue is observed.

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Keywords: tongue, obstructive sleep apnoea, body position.

Martin *et al*¹² have recently reported the effects of a change in the body position on upper airway size. Patients with OSA in the upright position had smaller upper airway cross-sectional areas than either snorers or normal subjects, but there were no differences between subject groups in the supine position. Patients with OSA showed smaller decreases in upper airway cross-sectional area from the upright to the supine position. Martin *et al*¹² proposed that patients with OSA have to maintain their upper airway size in order to prevent their upper airways from becoming compromised. There have been no studies in which the effect of a change in body position on tongue posture have been compared between patients with OSA and control subjects. As tongue posture (size, shape, and position) may be significantly influenced by gravitational forces because of the lack of a bony supporting structure, we hypothesised that tongue posture would remain unchanged when awake patients with OSA lie down.

Tongue posture in the upright and supine positions was compared between patients with OSA and non-apnoeic snorers, and the effect of a change in body position from upright to supine on tongue posture was examined in both groups.

Methods

SUBJECTS

Twenty four men with OSA and 13 non-apnoeic snorers matched for age, body mass index, and craniofacial skeletal pattern were recruited (table 1). All subjects underwent detailed overnight polysomnography.¹³ The severity of OSA was assessed in terms of the apnoea/hypopnoea index (AHI) and apnoea index (AI). Patients with OSA had an AHI

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Obstructive sleep apnoea (OSA) is caused by recurrent occlusion of the upper airway during sleep.¹ Snoring and OSA are worse or may only occur in the supine position.^{2,3} Patients with OSA have increased upper airway resistance in the supine position compared with the upright position, and the upper airway resistance is also higher than that determined in asymptomatic controls.⁴ Acoustic reflection studies have demonstrated that the cross-sectional area of the upper airway is narrower in the supine position.⁵⁻⁷ Studies using cephalometric methods have also shown that the superior-posterior (retropalatal) airway space is reduced in the supine position in both patients with OSA and control subjects.⁸⁻¹¹

Table 1 Mean (SD) demographic data and craniofacial skeletal pattern for men with obstructive sleep apnoea (OSA) and male non-apnoeic snorers

	OSA (n = 24)	Snorers (n = 13)
Demographic data		
Age (years)	48.8 (9.1)	53.1 (9.1)
Body mass index (kg/m ²)	30.3 (4.3)	29.7 (3.5)
AHI	60.0 (14.5)	5.5 (3.4)
AI	37.3 (16.1)	0.9 (1.2)
Craniofacial skeletal pattern		
ANB (°)	2.9 (1.4)	2.7 (1.5)
SNA (°)	80.2 (3.8)	81.7 (3.2)
SNB (°)	77.3 (4.1)	79.1 (3.5)
NSLPP (°)	9.1 (2.8)	8.2 (3.2)
PPMP (°)	25.0 (5.7)	24.1 (5.2)

AHI = apnoea/hypopnoea index (number of apnoeas and hypopnoeas/hour); AI = apnoea index (number of apnoeas/hour). For definitions of angles in craniofacial skeletal pattern see legend to fig 1. Only the AHI and AI were significantly different between the two groups.

Figure 1 Anatomical reference points and variables for craniofacial skeletal patterns and craniocervical posture. S=centre of the sella turcica; N=nasion; A=deepest point on the anterior contour of the maxillary alveolar bone; B=deepest point on the anterior surface of the mandibular alveolar bone; ANS=tip of the anterior nasal spine; PNS=tip of the posterior spine of the palatine bone; Gn=centre of the inferior contour of the chin; Go=centre of the inferior contour of the mandibular angle; cv2sp=superior posterior point of the second cervical vertebra; cv2ip, cv4ip=inferior posterior points of the second and fourth cervical vertebrae. (1) ANB=angle between the line from A to N and the line from B to N; (2) SNA=angle between the nasion-sella line (NSL) and the line from A to N; (3) SNB=angle between NSL and the line from B to N; (4) NSLPP=angle between NSL and the palatal plane (the line through ANS and PNS); (5) PPMP=angle between the palatal plane and the mandibular plane (line through Gn and Go); (6) NSLCVT=angle between NSL and the cervical vertebrae tangent which passes through cv2sp and cv4ip; (7) NSLOPT=angle between NSL and the odontoid process tangent which passes through cv2sp and cv2ip.

of >50/hour and/or an AI of >25/hour, non-apnoeic snorers had an AHI of <10/hour and an AI of <5/hour. (Non-apnoeic snorers had been referred to the sleep disorder centre because of their symptoms of a respiratory sleep disorder, mainly snoring, and did not show significant apnoea/hypopnoea.)

CEPHALOMETRY

Upright and supine cephalometric films, which had been taken with the same cephalostat (Counterbalanced Cephalometer Model W-105, Wehmer Co., Franklin Park, Illinois,

USA), were analysed.¹³ The dorsum of the tongue and upper pharyngeal airway were coated by asking the subject to swallow a spoonful of radio-opaque cream (Nicholas Laboratories Ltd, Slough, UK) to enhance the outline of the tongue. Upright films were taken in the natural head posture in a standing position determined by visual feedback in a mirror.¹⁴ Each patient was instructed to lightly contact his molars. To obtain the supine films the subject was instructed to lie down on a stretcher, mimic his usual sleeping position and height of pillow, and maintain his teeth slightly apart in the rest position. Cephalograms were taken at the end of expiration after three tidal breaths.

The reference points and lines on the cephalograms are shown in figs 1 and 2. The following variables were determined:

(1) Antero-posterior (ANB, SNA, SNB) and vertical (NSLPP, PPMP) craniofacial skeletal patterns (fig 1). Five variables (see figure legends for definitions) were determined from upright cephalograms to evaluate craniofacial skeletal patterns.

(2) Mandibular position (SNB, PPMP) and craniocervical posture (NSLCVT, NSLOPT) (fig 1).¹⁴ Four variables (see figure legends for definitions) were determined from both upright and supine cephalograms to assess mandibular position and craniocervical posture.

(3) Tongue posture measurements (fig 2). Twelve variables were determined. Two reference lines were constructed to perform the measurements: (a) E-RGN line – the reference line between E (the deepest point of the epiglottis) and RGN (the most posterior point of the mandibular symphysis along a line perpendicular to the Frankfort horizontal plane), and (b) E-RGN-VER line – the reference line vertical to the E-RGN line through RGN.

Figure 2 Tongue posture measurements. E=deepest point of the epiglottis; RGN=most posterior point of the mandibular symphysis along a line perpendicular to the Frankfort horizontal plane; MTH=maximum tongue height from the E-RGN line down to the dorsum of the tongue perpendicular to the E-RGN line; E-RGN=linear distance between E and RGN; TD1–10=linear distances from the 10 points on the E-RGN-VER line (the line vertical to the E-RGN line through RGN) located at 5 mm increments superior to RGN to the dorsum of the tongue.

RELIABILITY

All cephalograms were traced and digitised twice by the same investigator who was unaware of the subject's group. Single factor analyses of variance (ANOVA) were performed and showed no significant difference between the first and second measurements. In addition, intraclass correlation coefficients between the two measurements for each variable ranged from 0.86 to 0.98. The average of the first and second measurements was accepted as the final measurement.

DATA ANALYSIS

Two tailed paired *t* tests were used to compare differences between the upright and the supine position for each variable within the same group. Unpaired *t* tests were used for comparison between the two subject groups. Bonferroni's inequality corrections for significance levels were used when multiple simultaneous comparisons were made.

Table 2 Mean (SD) mandibular position and craniocervical posture for the upright and supine positions in patients with obstructive sleep apnoea (OSA) and non-apnoeic snorers

Variables (°)	OSA		Snorers	
	Upright	Supine	Upright	Supine
Mandibular position				
SNB	77.3 (4.1)	76.8 (4.0)	79.1 (3.5)	78.4 (3.7)
PPMP	25.0 (5.7)	26.3 (5.8)	24.1 (5.2)	25.2 (5.5)
Craniocervical posture				
NSLCVT	112.8 (7.0)	114.8 (8.4)	109.1 (8.5)	110.0 (10.9)
NSLOPT	109.2 (7.5)	112.0 (9.1)	105.1 (8.3)	107.0 (11.2)

For definition of angles see legend to fig 1. There were no significant differences in the angles between the two groups in either the upright or supine position.

Table 3 Comparisons of mean (SD) tongue posture measurements for the upright and supine positions in patients with obstructive sleep apnoea (OSA) and non-apnoeic snorers

Variables (mm)	OSA			Snorers		
	Upright	Supine	p value	Upright	Supine	p value
MTH	57.6 (4.6)	58.7 (4.7)	NS	57.7 (6.4)	59.2 (5.1)	NS
E-RGN	58.8 (6.0)	58.6 (5.3)	NS	61.5 (6.1)	59.4 (8.4)	NS
TD1	59.8 (5.5)	59.5 (5.8)	NS	62.1 (5.8)	60.6 (8.0)	NS
TD2	61.3 (5.7)	61.7 (5.4)	NS	62.7 (5.8)	62.6 (7.8)	NS
TD3	61.3 (6.0)	62.4 (5.2)	NS	61.9 (5.6)	62.7 (7.7)	NS
TD4	60.1 (6.3)	61.4 (5.3)	NS	59.8 (6.0)	61.6 (7.8)	NS
TD5	58.1 (6.5)	59.3 (5.4)	NS	57.2 (5.7)	59.6 (7.8)	NS
TD6	55.3 (6.2)	56.5 (5.6)	NS	54.3 (5.6)	57.2 (7.9)	NS
TD7	51.9 (6.1)	53.1 (5.8)	NS	50.8 (6.1)	54.5 (7.6)	<0.05
TD8	47.9 (6.7)	49.6 (6.0)	NS	46.4 (7.4)	51.2 (7.7)	<0.01
TD9	42.9 (7.9)	44.1 (7.6)	NS	39.3 (13.7)	46.9 (8.0)	<0.05
TD10	35.3 (9.7)	36.8 (10.0)	NS	31.6 (14.0)	40.5 (9.7)	<0.01

None of the variables showed any significant difference between patients with OSA and non-apnoeic snorers in either the upright or supine position.

Results

Patients with OSA and non-apnoeic snorers were not significantly different in age and body mass index (table 1). In addition, since there were no differences in ANB, SNA, SNB, NSLPP and PPMP, the two groups had similar antero-posterior and vertical craniofacial skeletal patterns (table 1). Antero-posterior (SNB) and vertical (PPMP) mandibular position and craniocervical posture (NSLCVT, NSLOPT), which may affect the size and shape of the upper airway, oral cavity and tongue posture, were not significantly different between the two groups in either the upright or the supine position (table 2). Consequently, it was not necessary to consider an effect of either mandibular position or craniocervical posture on the tongue posture measurements.

TONGUE POSTURE

Comparisons of tongue posture between the upright and supine positions within the same group

The maximum tongue height (MTH) and the distance between E and RGN (E-RGN) showed no significant differences between the upright and the supine position in both patients with OSA and non-apnoeic snorers (table 3). In non-apnoeic snorers the superior part of the tongue depth measurements (TD7–TD10) were larger ($p<0.05$ – 0.01) in the supine than in the upright position (fig 3). However, the tongue depth measurements in patients with OSA did not show any significant differences between the upright and the supine positions.

Figure 3 Tongue depth measurements for patients with OSA and non-apnoeic snorers in the upright and supine positions. * $p<0.05$, ** $p<0.01$ (upright versus supine positions in non-apnoeic snorers).

Comparisons of tongue posture in the upright and supine positions between the two groups

In both the upright and supine positions MTH, E-RGN, and tongue depth measurements showed no significant differences between patients with OSA and non-apnoeic snorers.

Comparisons of changes in tongue posture from the upright to the supine position between the two groups

The changes in TD9 and TD10 were significantly higher in non-apnoeic snorers than in patients with OSA ($p<0.05$) when the changes in tongue depth measurements from the upright to the supine position were compared.

Discussion

These results confirm that, when awake patients with OSA move from the upright to the supine position, they maintain their upright tongue posture which may protect against upper airway collapse secondary to the increased gravitational load on the tongue (fig 4). In contrast, when awake non-apnoeic snorers move from the upright to the supine position there is a significant dorsal movement in the superior-posterior portion of the tongue.

Previous studies have suggested that dorsal movement of the tongue because of gravitational pull in the supine position may cause the upper airway to narrow and predispose to the development of OSA.¹⁵ Although several recent studies have performed upright and supine cephalometry to examine the effect of body position on upper airway size and soft tissues, these studies did not examine the effect of body position on tongue posture.^{8–11} They have measured upper airway size from the posterior pharyngeal wall to the soft palate, uvula or tongue on the upright and supine cephalograms.^{8–11} However, to examine the effect of a change in body position on tongue posture

Figure 4 Schematic summary of changes in tongue posture following a change in body position. When awake patients with OSA move from the upright to the supine position they maintain their upright tongue posture. In contrast, when awake non-apnoeic snorers move from the upright to the supine position there is a significant dorsal movement in the superior-posterior portion of the tongue.

the measurement from the posterior pharyngeal wall or the cervical line to the tongue is not appropriate because the craniocervical angle is changed from the upright to the supine position and might influence the rest of the craniofacial complex. We therefore used the RGN, located on the mandibular symphysis, as a reference point and evaluated the relationship between the tongue and the mandible because the tongue and the mandible are attached widely with the muscles and the relationship between them is relatively constant even when the mandibular position or the craniocervical angle are changed. On the other hand, the tongue consists of a bundle of muscles with a free end and moves in a complex fashion which causes difficulty in evaluating the size, shape, and position of the tongue on cephalometric films. The timing of the cephalograms was therefore regulated at the end of expiration to minimise the effect of the different phases of respiration and to control the effect of lung volume on upper airway size.

Martin *et al*¹² have recently shown smaller decreases in the upper airway cross-sectional area from the upright to the supine position in patients with OSA, which are consistent with our results. We have shown that, when patients with OSA lie down, they maintain the posture of the posterior portion of the tongue. Because patients with OSA might have a smaller upper airway they have to maintain tongue posture to protect their upper airway from becoming compromised even when awake. Non-apnoeic snorers may have a relatively larger upper airway so the dorsal movement of the tongue can occur without compromising the patency of the upper airway. This is in agreement with the relatively increased genioglossus muscle activity in patients with OSA. The tongue base corresponds to the insertion of the genioglossus muscle, which pulls the tongue forward and opposes pharyngeal collapse when activated.

Suratt *et al*¹⁶ and Mezzanotte *et al*¹⁷ have reported that patients with OSA have more phasic genioglossus muscle activity while awake and asleep compared with that seen in control subjects. Douglas *et al*¹⁸ demonstrated that the activity of the genioglossus muscle was higher in the supine than the upright position in both patients and control subjects. The cessation of this control mechanism during sleep, which maintains tongue posture and protects upper airway patency, may cause apnoea/hypopnoea.

In this study the difference in tongue depth measurements between patients with OSA and non-apnoeic snorers was not significantly different in either the upright or the supine position. However, using cephalometric analyses, there are several reports that the cross-sectional area of the tongue in the upright position was larger in patients with OSA than in control subjects.^{19–22} Computed tomographic scanning has been used to evaluate tongue volume and has shown that patients with more severe OSA tend to have larger tongues and smaller upper airways.²³ Another study using magnetic resonance imaging to determine the site and size of fat deposits has shown increased deposition of fat tissue in the tongues of obese patients with OSA.²⁴

Although, to our knowledge, this is the first study to evaluate the effect of a change in body position on detailed tongue posture measurements in patients with OSA, it contains several limitations. Cephalometric films were taken in awake patients, although OSA occurs when patients are asleep. The limitations of a two-dimensional image of a three-dimensional structure are obvious. However, the cephalometric techniques have been used to evaluate the size and shape of the tongue and the upper airway because of its simplicity, easy access, and low cost. Finally, non-apnoeic snorers in this study are different from normal controls because they had been referred to the sleep disorder centre with symptoms of a respiratory sleep disorder. To understand the pathogenesis of OSA fully, further investigations are required on tongue posture during sleep combined with the simultaneous recording of tongue muscle activity.

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