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Original article

Modulation of upper and lower esophageal sphincter tone during sleep

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Abstract

Background and purpose: The pressures generated within the upper esophageal sphincter (P_{UES}) and lower esophageal sphincter (P_{LES}) reflect the integrity of these barriers to gastroesophageal and pharyngoesophageal reflux, respectively. This study sought to describe the effects of sleep, respiration and posture on the function of the UES and the LES and the pressure differentials developed across them.

Methods: Ten healthy volunteers (7M, 3F: 38 ± 10 yr) without a history of sleep-disordered breathing or reflux underwent overnight polysomnography with simultaneous measurement of P_{LES} and P_{UES} using a purpose-built sleeve device (Dentsleeve). Posture was recorded but not controlled.

Results: Subjects slept for 4.3 ± 1.6 h. Compared to waking values, both end-inspiratory and end-expiratory PUES were significantly less during slow wave sleep (SWS) ($p < 0.05$). However, P_{LES} was unaffected by sleep stage. During wakefulness and all stages of sleep, both P_{UES} and P_{LES} were greater at end-inspiration than end-expiration ($p < 0.05$). Similar relationships were observed whether subjects were supine or in the lateral decubitus position.

Conclusion: Sleep decreases the effectiveness of the UES to act as a barrier to pharyngoesophageal reflux, particularly during slow wave sleep (SWS). UES pressure varies with respiration, with minimal values observed during expiration. Hence, barrier function of the UES appears most impaired during SWS, in the expiratory phase of the respiratory cycle. The LES pressure and its barrier pressure also vary with respiration, being least during expiration. However, unlike the UES, the function of the LES was unaffected by sleep.

Keywords: Upper esophageal sphincter; Lower esophageal sphincter; Sleep; Respiration; Inspiration; Expiration

1. Introduction

Sleep has major effects on gastroesophageal function, including decreased swallowing, saliva production and esophageal motor activity [1–3]. Accompanying these changes are sleep-related decreases in the activity of skeletal muscles, including the cricopharyngeus and diaphragm muscles. These two muscles contribute to the pressure generated within the upper and lower esophageal sphincters (UES and LES), respectively. An important role of these sphincters is to prevent regurgitation of gastric contents into the esophagus (gastroesophageal reflux) in the case of the LES, and regurgitation and potential aspiration of esophageal contents into the larynx and pharynx (pharyngoesophageal reflux) in the case of the UES.

To date only two studies have examined the function of the UES during sleep in healthy individuals [4,5]. While both studies showed a depressant effect of sleep on UES

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Table 1
Subject characteristics and sleep architecture

Subject	Sex	Age (yr)	BMI (kg/m^2)	Total sleep period (h)	Stage 1 (%)	Stage 2 (%)	Stage 3 (%)	Stage 4 (%)	REM (%)	AHI (/h)	Sleep efficiency (%)
1	M	39	27.3	5.5	7	52	9	10	21	5.1	68
2	F	37	19.4	4.1	2	46	5	27	20	1.5	55
3	M	41	26.1	5.1	5	43	5	28	18	1.4	75
4	M	30	19.5	2.2	7	68	11	1	12	0.9	36
5	M	29	21.0	5.0	0.8	52	15	13	19	0.2	82
6	M	52	26.4	3.8	0	46	10	27	17	2.4	63
7	M	48	22.7	3.6	2	54	11	15	18	2.2	46
8	F	31	22.4	5.7	11	67	12	3	7	0.0	78
9	F	25	20.8	4.2	2	52	18	8	19	0.0	62
10	M	50	28.0	4.0	0.2	50	13	27	10	0.0	66
Avg		38	23.4	4.3	4	53	11	16	16	1.4	63
SD		10	3.3	1.0	4	8	4	11	5	1.6	14

BMI, body mass index; REM, rapid eye movement; AHI, apnea/hypopnea index; Sleep efficiency (% of time spent asleep).

pressure, Bajaj et al. [4] reported a progressive decline in UES pressure with deeper sleep stages, reaching a nadir during slow wave sleep (SWS), whereas Kahrilas et al. [5] found no difference in UES pressure among the various stages of sleep. Only two studies have examined the effect of sleep on pressures generated within the LES. Avots-Avotins et al. reported no significant differences in LES pressure in healthy volunteers between day and night studies [6] and Dent et al. reported substantial variability in basal LES pressure over the course of a night's sleep in healthy volunteers [7]. However, neither of these studies specifically reported changes in LES pressure with respect to the different stages of sleep.

In all of these studies, little attention was paid to the influence of the phase of respiration or posture on the capacity of the UES and LES to act as barriers to pharyngoesophageal and gastroesophageal reflux, respectively. Furthermore, no study to date has performed simultaneous measurements of UES and LES function in the same sleeping individual. Therefore, the aim of this study was to describe, in healthy volunteers, the effects of sleep, respiration and posture on the function of the UES and LES and the pressure differentials developed across them.

2. Methods

2.1. Subjects and protocol

Ten healthy volunteers (7M, 3F: 38 ± 10 yr) without a history of sleep-disordered breathing or gastroesophageal reflux were recruited (Table 1). Informed consent was obtained before subjects participated in the study, which was approved by the Human Research Ethics Committee of Sir Charles Gairdner Hospital. Each subject was studied on a single night while instrumented for overnight polysomnography and manometric measurement of pressures within the pharynx, UES, esophagus, LES and stomach. Prior to the study, subjects had dinner at the usual time but refrained from ingesting caffeine or smoking for the preceding 12 h.

2.1.1. Polysomnography

Sleep recordings were made using a computerized data acquisition system (Compumedics, Melbourne, Australia) and displayed on a high-resolution 20-in monitor. Monitored variables included electroencephalogram (EEG), electro-oculogram (EOG) and submental electromyogram (EMG) (125 Hz digital sampling speeds for each). A two-lead electrocardiogram (ECG), pulse oximetry (Criticare 504; Criticare Systems, Inc., Waukesha, WI), leg movements (movement sensors; Compumedics), body position (mercury switch position sensor; Compumedics), and thoracic and abdominal movements (inductance plethysmography) were also recorded (50 Hz digital sampling speed). Sleep staging was performed by