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Cheyne-Stokes respiration and supine dependency

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ABSTRACT: The influence of position during sleep on central apnoeas during Cheyne-Stokes respiration has not previously been studied systematically. The current authors aimed to study the effect of body position and sleep stages on central sleep apnoeas during Cheyne-Stokes respiration.

A total of 20 consecutive patients with cardiovascular diseases and central sleep apnoea during Cheyne-Stokes respiration were investigated using nocturnal polysomnography, including a body position sensor mounted on the patient's sternum.

The mean central apnoea–hypopnoea index was significantly higher in the supine position than in nonsupine positions (41 ± 13 *versus* 26 ± 12). The central apnoea–hypopnoea index was highest in sleep stages 1 and 2, and lowest in slow-wave sleep and rapid eye movement sleep. In every sleep stage, central apnoeas and hypopnoeas were more prevalent in the supine position compared with nonsupine positions.

In conclusion, sleep in the supine body position increases the frequency of apnoeas and hypopnoeas in patients with Cheyne-Stokes respiration.

KEYWORDS: Cheyne-Stokes respiration, heart failure, polysomnography, sleep apnoea syndromes, supine position

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Many patients presenting with frequent central apnoeas suffer from congestive heart failure and Cheyne-Stokes respiration, with a typical waxing-and-waning breathing pattern followed by a central apnoea [1, 2]. As many as 40% of males with congestive heart failure suffer from Cheyne-Stokes respiration during sleep, and they have an increased ventilatory response to carbon dioxide tension (P_{CO_2}) [3, 4]. During Cheyne-Stokes respiration, there are simultaneous cyclical changes in cerebral blood flow, respiration and wakefulness, followed by changes in heart rate and blood pressure [5]. Central apnoeas and Cheyne-Stokes respiration are most frequent in sleep stages 1 and 2 [6, 7].

It is well known that obstructive apnoeas are most frequent in the supine position [8, 9], but the influence of body position on central apnoeas and Cheyne-Stokes respiration has not previously been studied systematically. The current authors aimed to study the effect of body position and sleep stages on central apnoeas during Cheyne-Stokes respiration.

METHODS

Consecutive patients with central sleep apnoea during Cheyne-Stokes respiration were identified from investigated patients referred for polysomnography under suspicion of sleep apnoea. The inclusion criteria were a central apnoea–hypopnoea index (AHI) of ≥ 15, an obstructive AHI of <5, an arterial carbon dioxide tension (P_{a,CO_2}) <6.0 kPa (<45 mmHg) and a typical waxing-and-waning respiratory pattern between the central apnoeas (fig. 1). Six patients were excluded as they slept for <20 min in either the lateral or the supine position, while two were excluded because their body position sensor was lost during polysomnography. A total of 20 consecutive patients who fulfilled the criteria were included. Approval for the study was obtained from the Medical Ethics Committee at the University of Umeå (Umeå, Sweden) and all the patients gave their written consent.

Polysomnography included electroencephalogram (C3–A2, C4–A1), electro-oculogram, chin electromyogram, nasal and oral airflow (three-port thermistor), respiratory effort from piezoelectric belts around the abdomen and chest (Resp-EZ; EPM Systems, Midlothian, VA, USA), finger oximetry (Biox 3740; Ohmeda, Monroeville, CO, USA) and electrocardiograms (V5). A body position sensor with a mercury switch and resistive network (Vitalog Monitoring Inc., Redwood City, CA, USA) was placed

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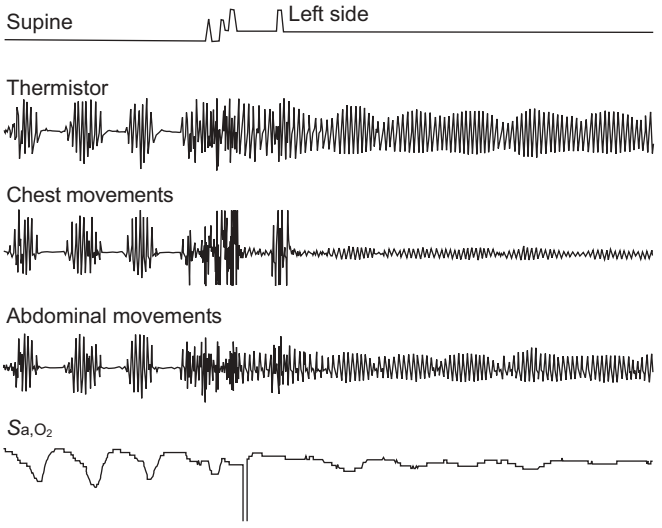

FIGURE 1. Respiratory patterns during sleep in a 59-yr-old male patient suffering from congestive heart failure. Cheyne-Stokes respiration was eliminated when the patient turned from the supine position to the left side. S_{a,O_2}: arterial oxygen saturation.

directly on the skin above the sternum with adhesive tape. After calibration, the patient was told to rotate in the bed in order to check that every position was recorded correctly. Arterial blood gases were taken in the supine position during the day after polysomnography.

Sleep stages were scored manually according to RECHTSCHAFFEN and KALES [10]. An apnoea was defined as a cessation of airflow for $\geqslant$10 s and a hypopnoea as a 50% reduction in the thermistor tracing compared with baseline, in combination with an arousal, or an oxygen desaturation of $\geqslant$3% [11]. Cheyne-Stokes respiration was characterised by cyclical fluctuations in breathing, with periods of central apnoeas or hypopnoeas alternating with periods of hyperpnoea in a gradual waxing-and-waning fashion [1, 2, 12]. A central apnoea was scored at the cessation of thoraco-abdominal movements, whereas a central hypopnoea was scored when thoraco-abdominal movements decreased parallel to airflow during Cheyne-Stokes respiration [7]. Supine position was scored within a range of $\pm$45° between the supine and a lateral position.

Data were calculated as the mean$\pm$SD. The Mann-Whitney U-test was used to compare differences in sleep time. The rank sum test, nonparametrically related, was used to compare AHI in supine and nonsupine positions. A p-value $<$0.05 was considered significant. Friedman's test for related samples was used to compare the AHI in different sleep stages. Wilcoxon rank sum test with Bonferroni correction for multiple comparisons was used as a *post hoc* test.

RESULTS

Nineteen of 20 patients were males, aged 65$\pm$15 (range 19–80) yrs, with a mean body mass index (BMI) of 27$\pm$3 kg·m^{-2}. Two reported habitual snoring. Eighteen patients suffered from congestive heart failure and two patients with atrial fibrillation had experienced a stroke. The two latter patients had no signs of congestive heart failure, but their respiratory patterns, including Cheyne-Stokes respiration, were identical to those of the remaining patients with central sleep apnoea. The characteristics of patients are given in table 1 and the sleep data are given in table 2.

The central AHI was higher in the supine position compared with nonsupine positions in 17 out of 20 patients. The mean central AHI was 41$\pm$13 in the supine position and 26$\pm$12 in nonsupine positions ($p<0.001$; fig. 2). The central AHI was 28$\pm$17 while sleeping on the left side and 25$\pm$17 on the right side, and both were lower than the AHI in the supine position ($p<0.001$). In every sleep stage, central apnoeas and hypopnoeas were more prevalent in the supine position compared with lateral positions (table 3). BMI did not correlate with the postural effect of central sleep apnoea expressed as the ratio of central AHI supine:nonsupine.

Central sleep apnoeas were more frequent in sleep stages 1 and 2 compared with slow-wave sleep and rapid eye movement (REM; $p<0.001$). The apnoea frequency in various sleep stages was independent of body position (table 3).

The mean duration of central apnoeas, calculated from the mean for each patient, was 26$\pm$8 s. Central apnoeas were shortest during REM ($p<0.05$).

DISCUSSION

The main finding in this study was that central apnoeas and Cheyne-Stokes respiration are supine dependent in nonhypercapnic patients with cardiovascular problems. In a recent case report, it was suggested that Cheyne-Stokes respiration could be supine dependent in conformity with obstructive sleep apnoea [13]. In the present systematic study of patients with Cheyne-Stokes respiration, central apnoeas were found to be supine dependent, which is a novel finding. There is, however, no obvious explanation for the high frequency of central apnoeas in the supine position.

In 1986, ISSA and SULLIVAN [14] presented a case series of eight snoring patients, with a combination of obstructive and idiopathic central sleep apnoea, who were treated with nasal continuous positive airway pressure. These patients had obstructive apnoeas and snoring predominantly in the lateral position, and central and mixed apnoeas in the supine position. They concluded that upper airway collapse in the supine position plays a key role in the induction of central apnoea. BRADLEY *et al.* [15] observed that five out of 13 overweight snoring patients with idiopathic central sleep apnoeas presented apnoeas exclusively in the supine position. It was suggested that upper airway narrowing may have resulted in sufficient stimulation of upper airway receptors to inhibit central respiratory output. The previous studies included patients with idiopathic central sleep apnoea and clinical signs of increased upper airway resistance. ALEX *et al.* [16] observed that central apnoeas often terminated with an upper airway occlusion among subjects with Cheyne-Stokes respiration, and BADR *et al.* [17] demonstrated pharyngeal occlusion during central apnoeas. The current study did not include any patients with idiopathic central sleep apnoea. All of the current patients with central sleep apnoea suffered from Cheyne-Stokes respiration and cardiovascular diseases. They were not obese, none had obstructive sleep apnoea, and only

TABLE 1 Characteristics of patients

Patient No.	Age yrs	BMI kg·m^{-2}	Cerebrovascular diseases	Left ventricular function#	CHF class NYHA	P_{a,O_2} kPa	P_{a,CO_2} kPa
1	19	27	Corr transposition	Poor	III	9.0	4.8
2	74	27	MI	Poor	III	7.4	5.6
3	74	21	AF, HT, MI, stroke	Impaired	III	13.8	4.1
4	39	22	MI, stroke	Poor	III	11.0	5.6
5	51	26	DCM	Poor	III	8.3	4.8
6	74	26	HT, MI, PM, stroke	Poor	II	10.6	4.7
7	71	31	HT, MI	Impaired	III	10.0	4.7
8	60	31	HT, stroke	Poor	III	8.3	5.0
9	61	26	AF, HT, MI, VD	Poor	III	11.2	4.8
10	74	24	AF, HT, stroke	Normal		12.4	3.9
11	69	33	MI, AP, HT, stroke	Poor	III	8.8	5.2
12	76	26	AF, AP, stroke	Normal		13.7	4.8
13	68	26	MI, PM	Poor	III	8.5	4.3
14	80	24	AF, AP, HT	Impaired	II	10.8	5.0
15	65	25	AF, MI, VD, stroke	Impaired	II	13.7	4.2
16	68	25	AF	Impaired	II	8.5	5.4
17	63	31	MI, HT	Impaired	III	9.5	4.7
18	68	26	PH, VD	Poor	III	8.8	5.9
19	73	31	AF, AP, HT	Impaired	III	11.8	4.9
20	80	23	MI, PM, VD	Impaired	III	7.9	4.5

BMI: body mass index; CHF: congestive heart failure; NYHA: New York Heart Association; P_{a,O_2}: arterial oxygen tension; P_{a,CO_2}: arterial carbon dioxide tension; MI: previous myocardial infarction; AF: atrial fibrillation; HT: hypertension; DCM: dilated cardiomyopathy; PM: pacemaker; VD: valvular disease; AP: angina pectoris; PH: pulmonary hypertension. #: visually scored by echocardiography with poor left ventricular ejection fraction <30%, impaired 30–<45% and normal ⩾45%.

two subjects reported that they snored. Even though the current authors did not find any evidence of upper airway obstruction among the studied patients, it is still possible that the position dependency in central apnoea can be explained, at least in part, by an obstructive component.

Increased circulation time and a change in automatic respiratory chemical control are the most common theories for explaining Cheyne-Stokes respiration. P_{a,CO_2} is slightly lower and the ventilatory response to P_{CO_2} is increased among patients with central sleep apnoea and Cheyne-Stokes respiration [2, 4–6]. Central apnoeas are also eliminated after the inhalation of carbon dioxide [18, 19]. Furthermore, Cheyne-Stokes respiration occurs predominantly in subjects with a low cardiac output. NAUGHTON *et al.* [6] reported that there is a progressive fall in AHI from sleep stages 1 and 2 to slow-wave

TABLE 2 Sleep data

Central AHI	31±9
Central apnoea index	28±11
Central hypopnoea index	3±4
Obstructive AHI	2±2
TST h	6.5±1.0
Sleep efficiency %	75±12
REM sleep % of TST	13±6
Sleep stage 1 % of TST	36±20
Sleep stage 2 % of TST	45±15
Slow-wave sleep % of TST	5±5
Right side % of TST	33±27
Prone % of TST	10±18
Left side % of TST	26±25
Supine % of TST	30±24

Data are presented as mean±SD. AHI: apnoea–hypopnoea index; TST: total sleep time; REM: rapid eye movement.

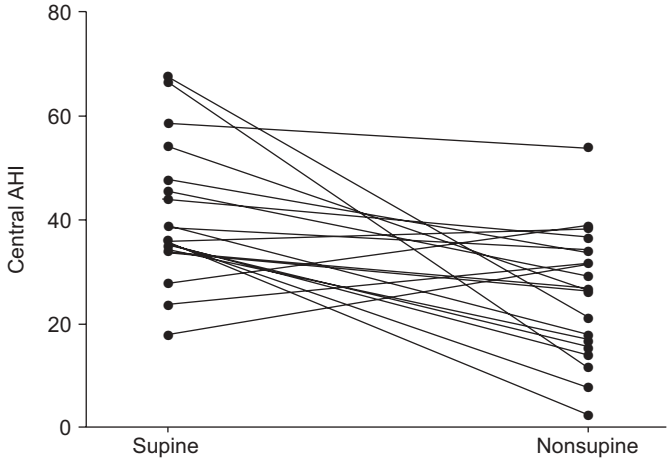

FIGURE 2. Central apnoea–hypopnoea index (AHI) in supine and nonsupine positions among patients with Cheyne-Stokes respiration.

TABLE 3 Central apnoea–hypopnoea index at different sleep stages and in different positions

	REM	Stage 1	Stage 2	SWS	p-value
Supine	28±30	43±15	37±18	23±41	0.007
Nonsupine	7±12	32±19	30±17	12±19	<0.001
p-value	0.01	0.04	0.40	1.0	

Data are presented as mean±SD, unless otherwise stated. REM: rapid eye movement; SWS: slow-wave sleep.

sleep and REM, associated with a progressive rise in P_{a,CO_2} among patients with Cheyne-Stokes respiration. In support of these findings, the current authors found that the central AHI was highest in stages 1 and 2, and lowest in slow-wave sleep and REM.

Since the present study is entirely descriptive, the mechanisms of supine dependence in central apnoea and Cheyne-Stokes respiration can only be speculated about. Position-dependent changes in heart function, lung function, blood gases and ventilatory response to P_{CO_2} are possible mechanisms. Low expiratory reserve volume is related to obstructive sleep apnoea, and the expiratory reserve volume is lower in the supine position compared with the sitting position in sleep apnoea patients [20, 21]. The current authors are, however, unaware of any studies of lung function or blood gases in the supine and lateral position among patients with sleep apnoea or congestive heart failure. If lung function or blood gases are different in the supine position compared with the lateral position, the present authors think it is most probable that the lung function is reduced in the supine position, with an increase in P_{CO_2} as a result. An increase in P_{CO_2} should reduce the frequency of central apnoeas, and it is, therefore, thought to be unlikely that changes in lung function or blood gases could explain the current results. It is also unlikely that supine-dependent Cheyne-Stokes respiration is due to changes in the ventilatory response to P_{CO_2}, since the apnoea frequency was reduced immediately when turning from the supine to the lateral position (fig. 1). It is speculated that a lower cardiac output in the supine position compared with the lateral position, which is due, for example, to a change in venous return, is a possible explanation of supine-dependent central apnoeas in Cheyne-Stokes respiration. Future studies investigating respiration, heart function, lung function, blood gases and upper airway collapsibility in the supine and lateral position among patients with Cheyne-Stokes respiration and intervention studies with changes in sleep position are desirable, as they could possibly answer some of the questions relating to mechanism raised in the present study.

In the present study, thermistors and piezo-electric belts were used to identify apnoeas and hypopnoeas. This may be regarded as a limitation, since piezo-electric belts only provide qualitative information about changes in respiration, and thermal sensors are not linearly related to airflow and generally overestimate ventilation [22]. Using this equipment instead of oesophageal pressure monitors, obstructive apnoeas can be falsely classified as central apnoeas [23]. In the present study, hypopnoeas were only scored when a 50% reduction in amplitude was accompanied by oxygen desaturations or arousals in order to improve the accuracy [11, 12], and the risk of overestimation should, therefore, be small. In spite of this, nasal pressures and inductance plethysmography would have been more reliable [12]. All of the current patients with central apnoeas suffered from congestive heart failure and they all had central apnoeas during Cheyne-Stokes respiration, with a typical crescendo-decrescendo pattern, which probably made it easier to score the central apnoeas and hypopnoeas than in the study with predominantly obstructive sleep apnoea patients [23].

Male sex, atrial fibrillation and age are known predictors of Cheyne-Stokes respiration [3, 24]. The results of the present study indicate that supine position is another factor that influences the degree of central apnoea in Cheyne-Stokes respiration. Oxygen treatment, continuous positive airway pressure treatment and noninvasive positive pressure ventilation are the main treatment modalities suggested for central sleep apnoea and Cheyne-Stokes respiration [2, 25–28]. It is possible that the avoidance of the supine position is another option in selected patients. Stroke victims often present with both obstructive and central apnoeas, but the compliance with continuous positive airway pressure is poor [29, 30]. Hemiplegia and the need for help in order to change body position in bed are common among these patients. If possible, the supine position should be avoided after a stroke to reduce the risk of all types of apnoea.

Conclusion

Sleep in the supine body position increases the frequency of apnoeas and hypopnoeas in patients with Cheyne-Stokes respiration.

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