Effect of continuous positive airway pressure therapy on hypothalamic-pituitary-adrenal axis function and 24-h blood pressure profile in obese men with obstructive sleep apnea syndrome

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Carneiro G, Togeiro SM, Hayashi LF, Ribeiro-Filho FF, Ribeiro AB, Tufik S, Zanella MT. Effect of continuous positive airway pressure therapy on hypothalamic-pituitary-adrenal axis function and 24-h blood pressure profile in obese men with obstructive sleep apnea syndrome. Am J Physiol Endocrinol Metab 295: E380–E384, 2008. First published June 3, 2008; doi:10.1152/ajpendo.00780.2007.—Obstructive sleep apnea syndrome (OSAS) increases the risk of cardiovascular events. Sympathetic nervous system and hypothalamic-pituitary-adrenal (HPA) axis activation may be the mechanism of this relationship. The aim of this study was to evaluate HPA axis and ambulatory blood pressure monitoring in obese men with and without OSAS and to determine whether nasal continuous positive airway pressure therapy (nCPAP) influenced responses. Twenty-four-hour ambulatory blood pressure monitoring and overnight cortisol suppression test with 0.25 mg of dexamethasone were performed in 16 obese men with OSAS and 13 obese men controls. Nine men with severe apnea were reevaluated 3 mo after nCPAP therapy. Body mass index and blood pressure of OSAS patients and obese controls were similar. In OSAS patients, the percentage of fall in systolic blood pressure at night (P = 0.027) and salivary cortisol suppression postdexamethasone (P = 0.038) were lower, whereas heart rate (P = 0.022) was higher compared with obese controls. After nCPAP therapy, patients showed a reduction in heart rate (P = 0.036) and a greater cortisol suppression after dexamethasone (P = 0.001). No difference in arterial blood pressure (P = 0.183) was observed after 3 mo of nCPAP therapy. Improvement in cortisol suppression was positively correlated with an improvement in apnea-hypopnea index during nCPAP therapy (r = 0.799, P = 0.010). In conclusion, men with OSAS present increased postdexamethasone cortisol levels and heart rate, which were recovered by nCPAP.

sleep disorders; low-dose dexamethasone test; ambulatory blood pressure monitoring

OBSTRUCTIVE SLEEP APNEA SYNDROME (OSAS) is receiving increased attention because it seems to be associated with a variety of long-term consequences, such as high rates of morbidity and mortality, mostly due to cardiovascular disease (23). Although obesity is the main risk factor for OSAS (39), it has been demonstrated that OSAS may increase the risk for hypertension, myocardial infarction, congestive heart failure, and stroke independently of obesity. Continuous positive airway pressure (CPAP) therapy is the treatment of choice for patients with moderate-to-severe OSAS, since it is highly effective in improving nocturnal hypoxia and sleep fragmenta-

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and rifampicin, which reduce plasma dexamethasone concentrations (17). Anti-hypertensive medications remained unchanged during the study period.

A questionnaire included demographic data, sleep symptoms, medical history, and medications in use. Physical examinations and anthropometric measurements, including weight (in kg) and height (in m), were recorded. Body mass index was calculated as the weight divided by the height squared.

Polysomnograms were recorded by the Sleep Analyzer Computer (Alice 3 Diagnostics system), including one for OSAS diagnosis and another for positive airway pressure titration. An experienced sleep physician scored all sleep stages (28), arousals, and respiratory events according to American Sleep Disorders Association criteria (1, 1a).

In healthy individuals, glucocorticoid synthesis and secretion follow a circadian rhythm, with the highest levels in the morning and the nadir at around midnight. Overnight administration of dexamethasone (DEX), a potent exogenous glucocorticoid, suppresses the nocturnal surge in ACTH production and cortisol levels when measured the next morning (22). Dexamethasone is the most commonly used method to evaluate the sensitivity of the HPA axis to negative feedback. However, the conventional dose of 1 mg completely suppresses cortisol secretion in normal people. For this reason, low-dose DEX test (<1 mg) has been used by some authors to induce a more modest suppression, enabling the detection of subtle differences in feedback sensitivity of glucocorticoid on the HPA axis (7, 15, 19, 25, 29, 33).

The assessment of the HPA axis function in this study included low-dose (0.25 mg) DEX suppression test and the circadian rhythm of cortisol secretion. Salivary cortisol measurement reflects the free fraction of cortisol in plasma. Advantages are the easy and noninvasive collection procedure and its stability at room temperature for ≥7 days (5, 36, 37). The subjects were given three Salivettes (Sarstedt, Rommelsdorf, Germany), which consist of small cotton swabs inside centrifugation tubes used to collect saliva, and a half-tablet of 0.5 mg DEX (Decadron, Ache´, Brazil). Salivary sample was obtained in the morning (8:00 AM) and at bedtime, ~11:00 PM, for all patients just before the administration of DEX. The next morning, more salivary and blood samples were collected at 8:00 AM to measure cortisol and DEX concentrations by RIA to confirm the ingestion of the drug. To analyze the results, we used an index of percentage of salivary cortisol suppression (%cortisol suppression) calculated as the difference between the post-DEX cortisol levels and baseline cortisol levels at 8:00 AM divided by baseline cortisol levels at 8:00 AM.

Twenty-four-hour ambulatory blood pressure monitoring was recorded with a SpaceLabs model 90202 ambulatory blood pressure monitor (Redmond, WA). An appropriately sized cuff was applied. Blood pressure was registered every 15 min during daytime (awake) and every 20 min during nighttime (asleep) on the basis of the patient’s reports on their activities during day and night. The percentage of fall in systolic blood pressure at night was calculated by dividing the difference between mean daytime and mean nighttime systolic blood pressures by the mean daytime systolic blood pressure (24). Blood pressure was considered to be controlled in those patients with 24-h mean blood pressure values <135/85 mmHg (6).

Six patients with mild or moderate OSAS immediately underwent bariatric surgery, and 10 patients with severe OSAS (AHI of >30 events/h of sleep) were advised to follow nasal CPAP (nCPAP) therapy before bariatric surgery (mean nCPAP pressure of 11.2 ± 0.7 cm of H2O) to avoid surgery complications related to sleep apnea. One man who failed to use the device was excluded from the study before the followup analysis. Therefore, after 3 mo of nCPAP therapy, nine patients with severe OSAS were reassessed and all measurements were repeated. The average nightly use of nCPAP was measured with a run time course that ran when the patient was breathing through the machine and not just when the machine was switched on.

This study was approved by the Univesidade Federal de Sao Paulo Ethics Committee, and written informed consent was obtained from all participants.

Normally distributed variables are expressed as means ± SE or percentiles when appropriate. Continuous variable comparisons between OSAS and control obese groups were performed using unpaired Student’s t-test. Analysis of covariance tests were used to adjust comparisons for body mass index. To assess differences between categorical variables, we used chi-square statistics. The results before and after nCPAP therapy were compared using paired a t-test. Correlations between variables were assessed by Pearson coefficient. A P value of <0.05 was considered statistically significant. Data analysis was performed using SPSS for Windows version 13.0.

RESULTS

As shown in Table 1, no differences between groups for age, body mass index, and prevalence of hypertension were observed. In OSAS men, the mean 24-h heart rate was higher (P = 0.022) and the percentage fall in blood pressure during sleep time lower compared with obese men controls (P = 0.027). Mean 24-h systolic and diastolic blood pressure values were similar in the two groups.

Although basal salivary cortisol values at 8:00 AM (P = 0.715) and at bedtime (P = 0.388) were not different between groups, a smaller cortisol suppression post-DEX (%cortisol suppression) was evident in OSAS patients compared with obese controls (P = 0.012) (Fig. 1). As a consequence, salivary cortisol post-DEX was significantly higher in OSAS patients than in obese control (P = 0.038). Comparisons between groups were adjusted for body mass index (Table 1).

All patients had detectable circulating plasma DEX level, indicating that all participants had ingested the DEX tablets (Table 1). DEX levels did not differ between OSAS patients and obese controls (84.5 ± 9.3 vs. 101 ± 10.5, P = 0.241), and in the total group, DEX levels did not correlate to plasma cortisol levels post-DEX (r = −0.219, P = 0.328).

Three months of nCPAP therapy was associated with a significant reduction in salivary cortisol after DEX (P = 0.009) and heart rate (P = 0.036) compared with baseline. Also, a greater cortisol suppression (%cortisol suppression) post-DEX

| Table 1. Clinical and laboratory characteristics of obese men with and without sleep apnea |
|-----------------------------------------------|-------------------|-------------------|-----------------|
|                                 | OSAS |                |                |
|                                 | No (n = 13) | Yes (n = 16) | P Value* |
| AHI events/h                    | 3.2±0.5 | 65.7±9.9 | <0.001 |
| Age, yr                        | 38.8±3.3 | 40.1±2.8 | 0.378 |
| BMI, kg/m²                     | 42.8±1.3 | 46.9±2.0 | 0.116 |
| 24-h SBP, mmHg                 | 127.6±2.3 | 131.3±3.3 | 0.492 |
| 24-h DBP, mmHg                 | 76.1±1.9 | 79.6±2.3 | 0.349 |
| 24-h Heart rate, beats/min     | 76.3±2.8 | 89.3±3.4 | 0.022 |
| Heart rate, beats/min          | 11.5±1.8 | 5.5±1.2 | 0.027 |
| Hypertension, n (%)            | 7 (53.8) | 11 (68.8) | 0.466 |
| Salivary cortisol, ng/dl       | 483.9±77.5 | 442.2±57.5 | 0.715 |
| Basal                          | 177.8±53.5 | 233.5±63.6 | 0.388 |
| 11:00 PM                       | 233.2±65.6 | 445.4±61.6 | 0.038 |
| DEX                            | −48.8±10.5 | −16.6±6.1 | 0.012 |
| %cortisol suppression          | 101±10.5 | 84.5±9.3 | 0.241 |
| DEX, ng/dl                     | 3.6±1.0 | 6.9±1.0 | 0.059 |

Data are expressed as means ± SE or n (%). OSAS, obstructive sleep apnea syndrome; AHI, apnea-hypopnea index; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; ΔBP, %fall in systolic blood pressure at night; %cortisol suppression, cortisol post-dexamethasone (DEX) minus cortisol basal at 8:00 AM/cortisol basal at 8:00 AM. *Significance after adjustment for BMI.
was evident in apneic patients following the use of nCPAP (P < 0.001). This was similar to the levels of obese controls (Fig. 1). Average body mass index (P = 0.913) did not change, and no differences in sleep blood pressure fall and blood pressure values were observed after nCPAP therapy (Table 2).

Table 2. Characteristics of men with sleep apnea before and after 3 mo of nCPAP therapy

<table>
<thead>
<tr>
<th></th>
<th>CPAP (n = 9)</th>
<th>Change from Baseline</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHI, events/h</td>
<td>Pre: 92±7.6, Post: 21.1±9.7</td>
<td>-70.8±5.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>Pre: 44.3±2.4, Post: 44.4±2.5</td>
<td>0.07±0.70</td>
<td>0.913</td>
</tr>
<tr>
<td>24-h SBP, mmHg</td>
<td>Pre: 131.5±3.7, Post: 125.7±1.9</td>
<td>-5.7±3.9</td>
<td>0.183</td>
</tr>
<tr>
<td>24-h DBP, mmHg</td>
<td>Pre: 77.3±2.5, Post: 76.0±2.7</td>
<td>-1.3±2.9</td>
<td>0.665</td>
</tr>
<tr>
<td>24-h Heart rate,</td>
<td>Pre: 8.2±3.3, Post: 74.3±3.5</td>
<td>-7.7±3.8</td>
<td>0.036</td>
</tr>
<tr>
<td>beats/min</td>
<td>Pre: 6.2±1.9, Post: 7.3±1.5</td>
<td>1.2±2.1</td>
<td>0.440</td>
</tr>
<tr>
<td>Salivary cortisol, ng/dl</td>
<td>Pre: 501.1±89.0, Post: 521.2±58.6</td>
<td>20.1±89.0</td>
<td>0.827</td>
</tr>
<tr>
<td>% Cortisol suppression</td>
<td>Pre: 438.6±70.4, Post: 168.1±41.4</td>
<td>-270±78.4</td>
<td>0.009</td>
</tr>
</tbody>
</table>

Data are expressed as means ± SE. CPAP, continuous positive airway pressure; nCPAP, nasal CPAP.

Improvement of AHI in response to nCPAP was positively correlated with the improvement of cortisol suppression after oral DEX (r = 0.799, P = 0.010) and negatively correlated with cortisol suppression before nCPAP (r = -0.883, P = 0.002) (Fig. 2).

DISCUSSION

In the present study, we demonstrated a blunted response of cortisol suppression after dexamethasone and a higher 24-h heart rate in obese men with obstructive sleep apnea syndrome compared with obese male controls. These findings may reflect activation of sympathetic nervous and stress system in apneic patients, which could be due to nocturnal hypoxia and sleep fragmentation, with several awakening and arousal episodes. In addition, we showed a significant reduction in heart rate and a marked improvement in dexamethasone-induced salivary cortisol suppression in patients with OSAS after 3 mo of nCPAP therapy. The reduction of apnea-hypopnea index after nCPAP therapy was positively correlated with cortisol suppression in response to low-dose oral dexamethasone.

Stress-related disorders such as depression, anorexia, alcoholism, excessive exercising, malnutrition, and premenstrual tension syndrome may be associated with increased corticotropin-releasing hormone activity and ACTH secretion, resulting in chronic exposure to circulating cortisol levels and loss of...
the normal negative feedback of the HPA axis by glucocorticoids (8). In accordance with this hypothesis, it was expected that OSAS would be associated with an activation of HPA axis in response to stress caused by recurrent intermittent hypoxia, sleep fragmentation, and frequent cerebral arousals during apnoeic events. However, only a few studies have assessed the relationship between sleep apnea and HPA axis, and the results are still controversial (9, 12, 13, 18, 35). In the majority of these studies, the HPA axis was assessed by a single morning plasma cortisol measurement, which might not reflect the episodic nature of cortisol secretion and its appropriate elevations during the hypoxemia stress (8). Two recent studies (9, 35) have evaluated the 24-h circadian secretory pattern of cortisol in obese patients with and without sleep apnea. In agreement with our results, both studies have demonstrated that salivary and plasma cortisol secretion was circadian in OSAS patients and obese controls. However, Dadoun et al. (9) failed to find any significant differences for overnight cortisol secretion between obese patients with or without sleep apnea syndrome. Our results match those who have demonstrated that sleep apnea in obese men is associated with increased cortisol level during the nighttime period (11 PM to 7 AM) compared with obese controls, which is recovered after the use of nCPAP for 3 mo (35). Hence, we hypothesize that obstructive sleep apnea should be recognized by clinician and corrected before further clinical investigations of endocrine causes of hypercortisolism.

Long-term mild activation of HPA axis has been shown to alter important functions in patients with some evidence of hypercortisolism, i.e., adrenal incidentalomas, depression, or alcoholism, increasing the risk for chronic conditions such weight gain, lethargy, weakness, loss of libido, diabetes mellitus, hypertension, and osteoporosis (22). Thus, further prospective studies should explore these clinical manifestations in patients with OSAS and increased cortisol levels.

A positive and well-established relationship between sleep apnea and the prevalence and severity of hypertension has been reported (4, 14, 26, 38). Nevertheless, we did not find any differences in 24-h blood pressure values between patients with or without sleep apnea. Blood pressure fall during sleep, however, was smaller in OSAS patients than in obese controls. The reasons for these discrepancies might be the fact that, in our study, more than one-half of patients were on hypertensive medication, although none received β-blocker therapy.

Therapy with nCPAP is the most effective treatment for sleep apnea, preventing recurrent occlusion of the upper airway during sleep (32). However, the effects of nCPAP on blood pressure have shown conflicting results (1b, 3, 21). We did not find significant changes in blood pressure levels and blood pressure fall during sleep after nCPAP therapy in severe obese patients with OSAS. Because our patients were under antihypertensive therapy and blood pressure levels were controlled at baseline, this may be the reason for negative results. Consistent with our findings, Campos-Rodriguez et al. (3) reported that 24 mo of therapeutic nCPAP reduced 24-h ambulatory blood pressure measurements only in a subgroup of patients with incompletely controlled hypertension at baseline. They suggest that, in a group of controlled hypertensive patients, nCPAP therapy failed to reduce blood pressure.

Some limitations of the current study include the small sample size and lack of a post-nCPAP treatment control group. However, at the time of the study, sham-CPAP machines capable of use in a double-blinded setting were not available. Moreover, ethical approval to leave patients with severe symptomatic OSAS untreated before bariatric surgery was not forthcoming from university ethics committee.

In conclusion, our findings demonstrate that obstructive sleep apnea syndrome is associated with increased 24-h heart rate, decreased percentage of fall in systolic blood pressure at night, and lower cortisol suppression after low-dose dexamethasone, suggesting that there is an activation of sympathetic nervous system and HPA axis. Our results also show the beneficial effects of nCPAP on 24-h heart rate and salivary cortisol levels after a low-dose dexamethasone test, which may contribute to reducing cardiovascular and metabolic complications related to OSAS.

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REFERENCES
