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Right ventricular dysfunction in obstructive sleep apnoea: reversal with nasal continuous positive airway pressure

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Right ventricular dysfunction in obstructive sleep apnoea: reversal with nasal continuous positive airway pressure. J. Nahmias, R. Lao, M. Karetzky. ©ERS Journals Ltd 1996.

ABSTRACT: The incidence and pathogenesis of right ventricular dysfunction in obstructive sleep apnoea (OSA) remains controversial. Using nuclear ventriculography, the prevalence of right ventricular dysfunction (RVD) was therefore determined in obese patients with OSA, as well as their clinical characteristics, arterial blood gas values, spirometry and sleep parameters. The reversibility of RVD was evaluated after long-term use of nasal continuous positive airway pressure (nCPAP).

We studied 112 obese patients with OSA by nuclear ventriculography, 35 with RVD (Group 1), 77 without RVD (Group 2), and 14 patients without OSA as controls (Group 3). Repeat nuclear ventriculography was performed in seven patients who used nCPAP nightly for 6–24 months.

The mean right ventricular ejection fractions (RVEF) were 31%, 47% and 44% in Groups 1, 2 and 3, respectively. Group 1 also had a lower left ventricular ejection fraction (LVEF) of 55 *vs* 63% in Group 2. The OSA groups did not differ in mean spirometric or arterial blood gas values. Group 1 had a lower mean nocturnal arterial oxygen saturation (S_aO_2) of 82 *vs* 87% in Group 2, and a longer apnoea duration of 22.3 *vs* 19.2 s. All but two patients in Group 1 had either awake alveolar hypoventilation or an apnoea + hypopnoea index >40 disordered breathing events·h^{-1}. Repeat nuclear ventriculography after nCPAP revealed an increase in RVEF from 30 to 39%.

In conclusion, right ventricular dysfunction is common in obstructive sleep apnoea, but it is reversible with nasal continuous positive airway pressure treatment and appears to be related to nocturnal oxygen desaturation.

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Patients with obstructive sleep apnoea (OSA) have increased cardiovascular morbidity and mortality [1–3] as a result of hypertension [4–6], myocardial infarction [7] and stroke [8]. In patients with OSA, left ventricular failure has been demonstrated to exist in the absence of ischaemic or valvular heart disease, and to be reversible with the long-term use of nasal continuous positive airway pressure [9–12]. Pulmonary hypertension and cor pulmonale have similarly been reported to be associated with OSA [13–16], but have been attributed to coexisting chronic obstructive pulmonary disease (COPD) [14, 15].

In a study of 50 patients with OSA, a 12% incidence of right ventricular failure (RVF) was found on the basis of clinical examination and radiological or electrocardiographic criteria [16]. The authors suggested that a "sustained hypoxaemia and/or hypercapnia over a 24 h period" was a necessary prerequisite for the development of RVF in patients with OSA [16]. Another study of 114 OSA patients reported similar relationships between pulmonary hypertension and obstructive lung disease, but 35% of the patients with pulmonary hypertension were not found to have lower airways obstruction [17].

To further define and characterize obese patients with OSA who are at increased risk of right (RVD) and left ventricular dysfunction (LVD), we prospectively investigated the sleep parameters, pulmonary function, arterial blood gas values and radionuclide ejection fractions in 126 patients. The effect of long-term treatment utilizing nCPAP on right and left ventricular function was evaluated in seven patients with RVD.

Methods

A population of 112 consecutive patients (88 males and 28 females), who were referred to the sleep centre for snoring and excessive daytime somnolence and found to have OSA were prospectively studied. None of the patients had a history or symptoms of COPD. All patients were obese, weighing >120% ideal body weight (IBW) [18], and each underwent all-night polysomnography. The control group consisted of an additional 14 obese subjects who were also referred for sleep apnoea evaluation and selected when they were found not to have OSA on polysomnographic testing. The all-night polysomnogram monitored in the laboratory consisted of a 2-lead electroencephalogram (C3/A2 and C4/A1), left and right electrooculograms, submental electromyogram, single-lead

electrocardiogram (V2), nasal and oral airflow signal *via* thermistor, ribcage and abdominal movement *via* strain gauge, and bilateral anterior tibialis electromyography. All studies were performed and scored using standard criteria [19].

Patients were classified as having OSA if their apnoea + hypopnoea index (AHI) was greater than 10 disordered breathing events (DBE) (apnoea + hypopnoeas) per hour of total sleep time (TST). Disordered breathing events were scored using the criteria described previously [20, 21]. Following the all-night polysomnogram, 95 patients underwent a multiple sleep latency test (MSLT) consisting of 4–5 naps [22]. Arterial blood samples were obtained whilst awake in 109 patients and the arterial oxygen tension (P_{a,O_2}), pH, arterial carbon dioxide tension (P_{a,CO_2}), arterial oxygen saturation (S_{a,O_2}) and haemoglobin (Hb) were measured. Maximal inspiratory and expiratory flow-volume loops, which were generated in the upright posture, were also obtained in 112 patients. Table 1 summarizes the number of patients completing each test.

Radionuclide ventriculography

Each patient underwent radionuclide ventriculography the morning after the all-night polysomnogram (between 8. and 10 a.m.) with measurements both of right and left ventricular ejection fractions. The interpretations were performed by a single nuclear medicine radiologist (RL), who was blinded to the patients and their polysomnographic results.

Radionuclide ventriculography was performed with *in vivo* tagging of red blood cells by the intravenous administration of 1.5 mL cold pyrophosphate followed in 30 min by 25 mCi technetium-99m (^{99m}Tc)-pertechnate. Gated data acquisition was initiated shortly after ^{99m}Tc-pertechnate infusion at 16 frames per cardiac cycle. A septal left anterior oblique view was utilized for the determination of left ventricular ejection fraction (LVEF), whilst a shallower left anterior oblique view was obtained for the right ventricular ejection fraction (RVEF). The LVEF was computer-generated, whilst the RVEF was calculated manually.

RVD was defined as a RVEF <40%, whilst LVD was defined as a LVEF <50% [23]. The patients were classified into three groups: Group 1, patients with OSA and RVD (n=35); Group 2, patients with OSA and normal right ventricular function (n=77); and Group 3, patients with no OSA (n=14). Repeat radionuclide studies were offered to all of the patients with RVD who utilized nCPAP.

Table 1. – Number of patients studied

	PSG	ABG	PFT	MSLT
Group 1	35	31	32	24
Group 2	77	67	69	63
Group 3	14	11	10	8

Group 1: patients with OSA and RVD; Group 2: patients with OSA and normal RVEF; Group 3: patients without OSA. PSG: polysomnography; ABG: arterial blood gas samples; PFT: pulmonary function tests (spirometry, flow-volume loops); MSLT: multiple sleep latency test; OSA: obstructive sleep apnoea syndrome; RVD: right ventricular dysfunction; RVEF: right ventricular ejection fraction.

Seven patients with OSA and RVD were restudied with radionuclide ventriculography after treatment with nCPAP. There was no weight loss in these patients between the baseline and follow-up studies and no change in medication. All patients were contacted 6–12 months after initiation of nCPAP and performed the repeat studies after 6–24 months of nCPAP use.

Exclusion criteria

Patients with known cardiac disease of ischaemic or valvular aetiology or with an identified specific cardiomyopathy were excluded. Patients with known COPD or those with moderate or severe airway obstruction on pulmonary function testing were also excluded.

Statistical methods

Statistical comparisons were made with analysis of variance (ANOVA), with a p-value of less than 0.05 considered significant. Comparisons before and after nCPAP treatment were performed using the Student's t-test for paired values. Linear regression analyses were performed using the Pearson correlates coefficient. All numbers are expressed as mean±SEM.

The study was approved by the institutional review board at Newark Beth Israel Medical Center and necessary consents were obtained.

Results

Thirty five patients (31%) comprised Group 1 with OSA and RVD, whilst 77 patients (69%) were classified in Group 2. Fourteen patients without OSA served as the control group, Group 3. The three groups did not differ with respect to age, weight, %IBW, awake systolic (SBP) and diastolic (DBP) blood pressure or heart rate (table 2).

Radionuclide ventriculography

The mean RVEF, by definition, was decreased below 40% in Group 1 (31±1%), whilst Group 2 (47±1%) and

Table 2. – Clinical features of patients

	Group 1 (n=35)	Group 2 (n=77)	Group 3 (n=14)
Age yrs	47±2	46±1	45±1
Sex M/F	30/5	54/23	7/7
% IBW	174±7	180±4	166±9
SBP mmHg	140.2±3.1	141.4±2.2	135.3±4.0
DBP mmHg	91.1±2.8	90.4±1.5	89.1±2.4
Pulse beats·min^{-1}	76.7±3.7	82.9±1.6	80.6±1.6
RVEF %	31±1*	47±1	44±2
LVEF %	55±2*	63±1	65±2

Values are presented as mean±SEM. IBW: ideal body weight; M: male; F: female; SBP: systolic blood pressure; DBP: diastolic blood pressure; LVEF: left ventricular ejection fraction. *: p<0.001 Group 1 *vs* Group 2 and Group 1 *vs* Group 3. For explanation of groups and further definitions see legend to figure 1.

Group 3 (44±2%) were not significantly different. The Group 1 patients also demonstrated a significantly lower mean LVEF than Group 2 patients, 55±2% *versus* 63±1%, respectively (p<0.001) (table 2). There was no difference in LVEF between Group 2 and the control group (table 2). Ten patients (29%) in Group 1 had LVD as compared to three patients in Group 2 (4%) (p<0.05). None of the patients in Group 3 had LVD. There was a positive correlation between RVEF and LVEF in the OSA population as a whole (r=0.33; p<0.05). However, RVEF did not correlate with awake oxygenation, P_{a,O_2} (r=0.13); effective alveolar ventilation, P_{a,CO_2} (r=0.08); nocturnal oxygenation, oxygen saturation nadir (r=0.11) or severity of the sleep disorder, (AHI) (r=0.10) (p>0.05). All but two of the patients with OSA and RVD demonstrated either severe OSA (AHI >40 DBE·h^{-1} TST) or awake alveolar hypoventilation, with a P_{a,CO_2} kPa (>45 mmHg) (fig. 1a). However, patients without RVD (Group 2) could not be distinguished from patients in Group 1 on this basis (fig. 1b).

Sleep studies

There was no difference in sleep efficiency or sleep architecture between the two groups with OSA. However, the (nonapnoeic) control group had a greater percentage of stage 3/4 sleep and rapid eye movement (REM) sleep when compared to the two OSA groups (table 3). Analysis of disordered breathing events (AI or AHI) could not distinguish the two OSA groups. However, Group 1 patients had a lower mean S_{a,O_2} during sleep of 82±2% as compared to Group 2 with a mean S_{a,O_2} of 87±1 (p<0.02), which was related to their longer mean apnoea duration of 22.3±1.4 s as compared to Group 2 patients who had a mean apnoea duration of 19.2±0.5 s (p<0.02) (table 3).

Daytime MSLT results revealed Group 2 patients to be sleepier than Group 1, but the difference did not achieve statistical significance, whilst both of these groups had a shorter mean sleep latency than the control group (table 3).

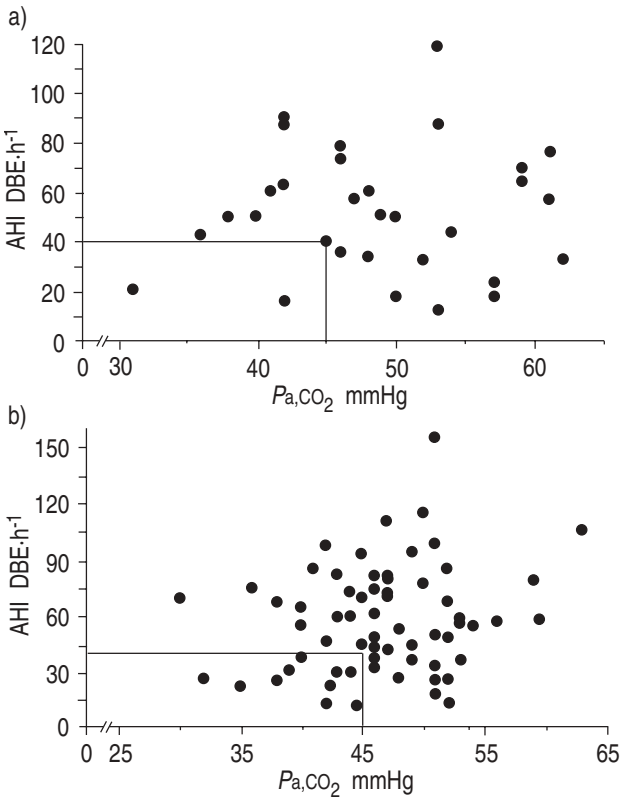

Fig. 1. – Relationship of severity of sleep-disordered breathing expressed as disordered breathing events (DBE)·h^{-1} *versus* effective alveolar ventilation expressed as P_{a,CO_2} whilst awake: a) in patients with RVD (Group 1); and b) in patients without RVD (Group 2). The areas within rectangles represent patients who were eucapnic and had mild-to-moderate OSA. Note, only two patients with RVD fall within the rectangular area. AHI: apnoea/hypopnoea index; RVD: right ventricular dysfunction; P_{a,CO_2}: arterial carbon dioxide tension; OSA: obstructive sleep apnoea. (7.5006 mmHg=1 kPa). Note that abscissa are cut off from zero.

Spirometry and arterial blood gases

No differences in forced expiratory volume in one second (FEV1), FEV1% predicted, forced vital capacity (FVC) or FVC% predicted were observed between the three groups (table 4). Although there was no difference in P_{a,CO_2} or P_{a,O_2} between Groups 1 and 2, both groups had a lower mean P_{a,O_2} and higher P_{a,CO_2} than the control group (table 4).

nCPAP treatment

Seven patients with RVD who utilized nCPAP for 6–24 months returned for repeat nuclear ventriculography. The nCPAP pressure required to eliminate the DBE was determined during a second all-night polysomnogram within 5 weeks of the first sleep study. They all tolerated nCPAP well and used it on a nightly basis. Of the 28 patients who were not restudied, all were initially placed on nCPAP with seven unable to tolerate it. The remainder

Table 3. – PSG characteristics of patients

	Group 1	Group 2	Group 3
AHI DBE·h^{-1} TST	53.3±4.2	56.3±3.2	5.6±0.9$^{\#\#}$
Mean PSG S_{a,O_2} %	82±2*	87±1	89±1
S_{a,O_2} nadir %	54±4	60±2	84±2$^{\#\#}$
Apnoea duration s	22.3±1.4*	19.2±0.5	17.0±3.0
TST min	303±13	312±10	303±24
SE %	72±3	74±2	74±6
Stage 1 %	12±2	12±2	6±2
Stage 2 %	52±3	54±2	55±6
Stage 3/4 %	1±1	2±1	6±3$^{\#}$
REM %	11±1	11±1	14±2
MSLT SL min	5.3±0.8	4.5±0.5	9.0±1.3$^{\#}$

Values are presented as mean±SEM. AHI: apnoea/hypopnoea index; TST: total sleep time; DBE: disordered breathing event; S_{a,O_2}: arterial oxygen saturation; SE: sleep efficiency; Stage 1–4%: percentage of TST in each non-rapid eye movement sleep stage; REM %: percentage of TST in rapid eye movement sleep stage; MSLT SL: mean sleep latency of multiple sleep latency test. For explanation of groups and further definitions see legend to table 1. *: p<0.02, Group 1 *vs* Group 2 and Group 1 *vs* Group 3; $^{\#\#}$: p<0.0001, Group 3 *vs* Group 1 and Group 3 *vs* group 2; $^{\#}$: p<0.05, Group 3 *vs* Group 1 and Group 3 *vs* Group 2.

Table 4. – Spirometric and blood gas values

	Group 1	Group 2	Group 3
FEV1 L	2.13±0.17	2.17±0.10	1.86±0.27
FEV1 % pred	68±4	69±3	63±6
FVC L	2.66±0.20	2.66±0.12	2.33±0.34
FVC % pred	66±4	67±4	63±6
FEV1/FVC	81.3±1.4	81.7±0.9	81.0±1.5
P_{a,O_2} kPa	9.0±0.3	9.2±0.2	10.6±0.5*
mmHg	67.2±2.5	69.2±1.4	79.5±3.8*
P_{a,CO_2} kPa	6.5±0.2	6.2±0.1	5.4±0.1**
mmHg	48.5±1.4	46.6±0.8	40.7±1.0**

FEV1: forced expiratory volume in one second; FVC: forced vital capacity; % pred: percentage of predicted value; P_{a,O_2}: arterial oxygen tension; P_{a,CO_2}: arterial carbon dioxide tension. For explanation of groups see legend to table 1. *: p<0.02, Group 3 *vs* Group 1 and Group 3 *vs* Group 2; **: p<0.01, Group 3 *vs* Group 1 and Group 3 *vs* Group 2.

either refused repeat nuclear ventriculography studies (n=15) or were lost to follow-up (n=4). Repeat ventriculography revealed an increase in RVEF from 30±3 to 39±3% (p=0.01), with nCPAP use. The LVEF also increased from 58±4 to 61±3%. The increase in mean LVEF between pre- and post- nCPAP was not significant, as three of the patients had normal LVEFs of 74, 64 and 67% prior to treatment. The individual changes in RVEF and LVEF are depicted in figure 2a and b, respectively.

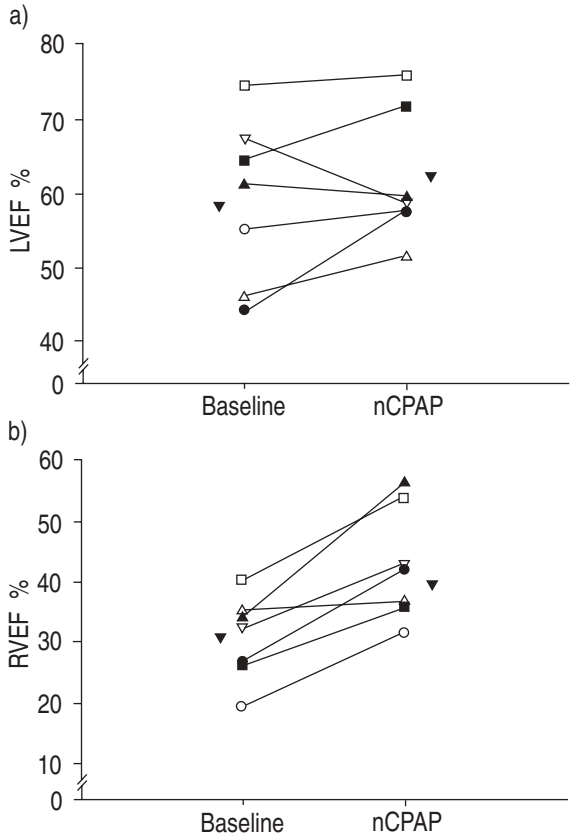

Fig. 2. – The effect of nCPAP treatment in seven patients: a) on the LVEF; and b) on the RVEF, between baseline polysomnograms and follow-up polysomnograms after nCPAP use. Inverted filled triangles (▼) are means. All patients with a LVEF <55% realized improvement after nCPAP use, whilst 6 of the 7 patients with RVD demonstrated an increase in RVEF. nCPAP: nasal continuous positive airway pressure; LVEF: left ventricular ejection fraction; RVEF: right ventricular ejection fraction; RVD: right ventricular dysfunction. Note that ordinates are cut off from zero.

Gender

Five of the 28 female patients with OSA had RVD, as compared with 30 of the 84 male patients (p<0.05). Although the female patients with OSA had a greater % IBW than the male patients (190±8 *vs* 174±4%, respectively; p<0.05), there were no differences in AHI, RVEF, P_{a,O_2}, P_{a,CO_2} or spirometric values, between the genders. The male patients with OSA did have a lower LVEF of 59±1% as compared to the female patients with a mean LVEF of 64±2% (p<0.05).

Hypercapnic vs *eucapnic patients*

To differentiate OSA patients who had awake alveolar obesity-hypoventilation (OH) from those who were eucapnic whilst awake, statistical comparisons were performed. Table 5 reveals that the OH group had a lower P_{a,O_2}, with a concomitantly lower nocturnal S_{a,O_2} nadir and mean S_{a,O_2} than the eucapnic patients. However, there were no differences in mean RVEF or LVEF between the two groups. In fact, 24 patients in the OH group and 12 patients in the eucapnic group had RVD, which did not represent a significant difference (p=0.28).

Table 5. – Comparison between patients who had awake alveolar-hypoventilation and those who were eucapnic whilst awake

	OH	Eucap	OH+RVD	Eucap+RVD
P_{a,O_2} kPa	8.6±0.2	10.1±0.2*	8.2±0.4	10.3±0.3#
mmHg	64.4±0.1	75.4±1.7*	61.8±3.1	77.2±2.5#
P_{a,CO_2} kPa	6.8±0.1	5.4±0.1	7.1±0.2	5.3±0.2#
mmHg	51.2±0.6	40.6±0.6*	52.9±1.2	40.1±1.2#
S_{a,O_2} nadir %	53±2	64±3*	53±4	62±6
Mean S_{a,O_2} %	83±1	88±1*	81±3	89±1
RVEF %	42±1	42±1	30±1	33±1†
LVEF %	61±1	59±2	57±2	53±4

Values are presented as mean±SEM. OH: obesity-hypoventilation patients; Eucap: eucapnic patients. For further definitions see legends to tables 1, 3 and 4. *: p<0.001 OH *vs* Eucap; #: p<0.001 OH+RVD *vs* Eucap+RVD; †: p<0.05 OH+RVD *vs* Eucap+RVD.

When we examined only those OSA patients with RVD, the OH group had a lower mean RVEF of 30±1 *vs* 33±1% ($p<0.05$) in the eucapnic RVD patients. However, the nocturnal S_{a,O_2} nadirs and means did not differ throughout the night (table 5).

Discussion

In our study, we found a high percentage of RVD (31%) in patients with OSA. The major difference between those patients with and without RVD was a lower mean nocturnal S_{a,O_2} and longer apnoea duration in the former group. The groups could not be differentiated by awake arterial blood gas values, spirometric values or AHI. However, with two exceptions, all patients with RVD had either awake alveolar hypoventilation or severe OSA. One of the most important findings in this study was the reversibility of RVD utilizing nCPAP on a nightly basis.

Repetitive apnoeic events with concomitant oxygen desaturation give rise to paroxysms of pulmonary and systemic hypertension that are thought to become fixed with resultant cor pulmonale and/or systemic hypertension [14–16]. Neither the actual incidence of impaired right ventricular function in OSA nor its pathogenesis are known. Similarly, elucidation of the significance of associated COPD and its relationship to the severity of nocturnal desaturation remains elusive. In our patient population, patients with RVD did have a lower mean nocturnal oxygen saturation, which appeared to be a function of the longer duration of their apnoeic episodes and not related to awake P_{a,O_2}. Only two patients in each group had diminished values for expiratory flow rates consistent with mild obstructive airway disease. When these patients were excluded from analysis, the statistical relationships of arterial blood gas values, pulmonary function tests (PFT) and ventricular function data between the three groups remained the same. With the exclusion of patients who did not have PFT differences in apnoea duration, mean nocturnal O_2 saturation and O_2 nadir were no longer significant, however, all other relationships remained unchanged. The resting arterial hypoxaemia while awake was presumed to be related to both the distortion of ventilation-perfusion relationships associated with obesity and to alveolar hypoventilation [24–26].

The present study differs from others in that the RVD was assessed by nuclear ventriculography in an obese population of OSA patients without apparent lung disease that could result in pulmonary hypertension or cor pulmonale. Therefore, the greater incidence of RVD observed than previously suggested presumably reflects the sensitivity of nuclear scanning in the detection of ventricular dysfunction, not, however, distinguishing between a primary decrease in contractility and increase in afterload.

The utility of radionuclide ventriculography in the assessment of RVEF has been established previously in patients with COPD, pulmonary hypertension, coronary and valvular heart disease [27–29]. The reproducibility of the calculated ejection fraction over a wide range is less than three ejection fraction units [23]. Its high sensitivity, ease of acquisition, excellent reproducibility and non-invasive methodology make nuclear ventriculography one of the best alternatives to right and left heart catheterization for measurement of global ejection fractions.

A control group of 14 nonapnoeic, age- and weight-matched patients revealed normal right and left ventricular function utilizing MUGA (Multigated Acquisition) scans. These normal subjects did have a higher P_{a,O_2} and no evidence of awake alveolar hypoventilation as compared to both study groups. However, the spirometric data of the control group did not differ from either group with OSA. Thus, the abnormalities of awake oxygenation and ventilation could not be explained by differences in pulmonary function or weight, but rather by an abnormality in the central respiratory control mechanism. This same instability in central respiratory control may be responsible for the occurrence of apnoeic events, as suggested previously [30–32], as the inspiratory timing of the upper airway muscles and the diaphragm exhibits inco-ordination resulting in upper airway closure during sleep. Conversely, treatment with nCPAP has been shown to improve awake oxygenation and alveolar ventilation as the central chemoreceptor gain is reset toward eucapnia [33, 34].

RVD was demonstrated in 35% of the patient population on MUGA scanning at rest, which is somewhat lower that the 50% prevalence of pulmonary hypertension detected by right heart catheterization in OSA patients with exercise [14].

All but two of our patients with OSA and RVD had either awake hypercapnia or an AHI greater than 40 DBE·h^{-1} TST. Alveolar hypoventilation, an absolute criterion of the Pickwickian syndrome [35], was also reported in the majority of patients with RVD. However, hypercapnia alone could not distinguish the two groups, since 59% of the patients in Group 2 had awake alveolar hypoventilation. Conversely, the OH group did not have a higher prevalence of RVD than the eucapnic OSA patients. However, when the OH patients did have RVD it was more severe than the eucapnic group, despite a similar amount of nocturnal O_2 desaturation. It is probable that the more severe daytime hypoxaemia was the important factor resulting in the lower RVEF in these OH patients.

The RVD group was also found to have a significantly lower LVEF of 55%, which is similar to a previous report of a mean of 57% in a population of patients with OSA and cor pulmonale [15]. The aetiology of the LVD is uncertain, but has been reported to be invariably present in the Pickwickian syndrome [3], and may be secondary to the transient rise in systemic resistance during apnoeic episodes that subsequently becomes fixed [4–6]. Both obesity and hypertension have been shown to affect cardiac structure and function independently [36]. An alternative explanation for the apparent interdependence of the right and left ventricles, as suggested in this study, is the observation reported over 50 yrs ago that the left ventricular free wall thickness in emphysematous patients with no left-sided cardiac disease was abnormally increased [37]. Others have demonstrated anatomical as well as functional evidence indicating that LVD is not uncommon in patients with chronic right ventricular pressure overload [38, 39]. This, however remains controversial [40].

Another factor which may be responsible for LVD and RVD is systemic hypertension, as there is a high incidence of hypertension in patients with OSA [4, 5]. In

our patient population, the prevalence of hypertension (defined as SBP >150 mmHg or DBP >90 mmHg) was 52% in Group 1, 47% in Group 2 and 36% in Group 3, with no significant difference between groups. Thus, it is unlikely that hypertension alone is the determining factor of ventricular dysfunction in patients with OSA.

Patients with OSA and RVD and/or LVD, if identified early, can potentially experience reversal of cor pulmonale by aggressive long-term definitive treatment with weight loss following palliative correction of the DBE with nCPAP. Eventually, weight loss will presumably lead to resolution of the ventricular dysfunction with correction of nocturnal and awake arterial desaturation, similar to the observed resolution of the associated alveolar hypoventilation and upper airway obstruction.

In conclusion, it appears that obese patients with obstructive sleep apnoea who have either awake alveolar hypoventilation or severe sleep apnoea are at risk for the development of right ventricular dysfunction. However, nightly use of nasal continuous positive airway pressure can reverse the right ventricular dysfunction, as well as the left ventricular dysfunction, and should be strongly encouraged until weight loss effectively eliminates the apnoeic events.

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