ELSEVIER

Sleep Medicine 5 (2004) 43–51

SLEEP MEDICINE

www.elsevier.com/locate/sleep

Original article

Pregnancy, sleep disordered breathing and treatment with nasal continuous positive airway pressure

Christian Guilleminault*, Martina Kreutzer, Judy L. Chang

Stanford University Sleep Disorders Clinic, 401 Quarry Road, Suite 3301, Stanford, CA 94305, USA

Received 10 March 2003; received in revised form 25 June 2003; accepted 15 July 2003

Abstract

Objective: To investigate the tolerance, compliance and problems associated with usage of nasal continuous positive airway pressure (CPAP) by pregnant women with sleep disordered breathing (SDB).

Patients and method: Twelve pregnant women diagnosed with SDB received polysomnography (PSG) at entry, CPAP titration, repeat PSG at 6 months gestation (GA) and home monitoring of cardio-respiratory variables at 8 months GA. Compliance was verified by the pressure at the mask. Results from the Epworth sleepiness scale, fatigue scale and visual analogue scales (VAS) for sleepiness, fatigue, and snoring were compared over time.

Results: All of the subjects had full term pregnancies and healthy infants. Nightly compliance was at least 4 h initially and 6.5 h at 6 months GA. Nasal CPAP significantly improved all scales compared to entry. VAS scores remained lower at 6 months GA compared to entry. Re-adjustment of CPAP pressure was needed in six subjects at 6 months GA.

Conclusion: Nasal CPAP is a safe and effective treatment of SDB during pregnancy.

Keywords: Pregnancy; Sleep apnea; Nasal continuous positive airway pressure; Sleepiness; Fatigue; Compliance

1. Introduction

We previously reported on 267 pregnant women who were polygraphically monitored during sleep [1]. Snoring was observed at least intermittently in 52% of the women in their sixth month of pregnancy. Airflow limitation and increased respiratory effort were documented in a subgroup of these women. Bourne et al. [2] have also noted small drops in oxygen saturation (SaO_2) during otherwise normal pregnancies. Although none of the women required treatment, our studies demonstrate that pregnancy affects breathing patterns during sleep.

We now report on a small group of women who presented with clinical complaints prior to or during early pregnancy and were diagnosed with either obstructive sleep apnea syndrome (OSAS) or upper airway resistance syndrome (UARS) [3]. We will consider both of these conditions as 'sleep disordered breathing' (SDB). The selected treatment—nasal continuous positive airway pressure (CPAP) during sleep—was initiated based on symptomatology and the clinical evaluation. This report details patient course, indicated intervention, and pregnancy outcome with nasal CPAP as the treatment modality during pregnancy.

2. Methodology

2.1. Subjects

Of the 12 women (mean age 28.4 years) included in the report, seven were diagnosed with SDB prior to pregnancy and the others were diagnosed early in their first trimester. Two were pregnant for the second time. The mean body mass index (BMI) of the total group just prior to or close to conception was 24.03 kg/m^2 (range 22.4–26.2) (Table 1). None of the women was taking prescription medications at initial visit.

On gynecologic history, menarche was reported between age 10.5 and 12.5 years. All of the subjects had used oral contraceptives. None had undergone an abortion or had any

* Corresponding author. Tel.: +1-650-723-6601; fax: +1-650-725-8910.
E-mail address: cguil@leland.stanford.edu (C. Guilleminault).

1389-9457/$ - see front matter © 2003 Elsevier B.V. All rights reserved.
doi:10.1016/j.sleep.2003.07.001

Table 1
Medical history, subjective scores of upper airway anatomy and scale scores at entry

S. no.	Age at first preg. (years)	No. of preg.	BMI (kg/m^2)	Med. hist.	T/A	Ortho-dontic braces	Wisdom teeth extraction	Tonsils	Enlarged inf turb	Oro-pharynx	Hard palate	Kushida index	ESS	Fa scale	SN VAS	Fa VAS	Sl VAS
1	27	1	23.5	Resp all.	+	+	0	0	+	2 +	2 +	78	11	19	70	50	40
2	26	1	22.6	Asthma	+	+	+	0	+	3 +	3 +	98	12	20	60	50	30
3[a]	31	2	24.2	N/A	0	0	0	2 +	+	2 +	2 +	83	11	21	55	60	40
4	24	1	23.1	Resp all.	+	+	+	0	+	3 +	3 +	99	11	19	65	70	50
5	33	1	26.2	N/A	+	0	0	2 +	0	2 +	2 +	87	10	18	50	50	30
6[a]	25	1	22.4	Resp all. asthma	0	+	+	1 +	+	3 +	3 +	101	12	20	70	65	35
7	29	1	23.8	Resp all.	0	0	0	1 +	+	2 +	3 +	85	11	21	40	60	30
8	32	1	24.7	N/A	+	0	0	0 +	0	2 +	3 +	92	11	17	55	50	30
9[a]	28	1	24.3	N/A	0	0	0	3 +	0	2 +	1 +	81	11	16	70	50	25
10[a]	27	1	23.6	Resp all.	0	+	+	1 +	+	2 +	3 +	93	12	17	70	55	35
11	29	1	24.1	N/A	+	0	0	1 +	0	3 +	1 +	85	11	20	40	50	30
12[a]	30	2	25.9	N/A	+	0	0	2 +	0	2 +	1 +	89	10	22	60	60	40
Mean	(28.4)		(24.0)									89.25	11.1	19.2	58.75	55.8	34.6

S. no., subject number; preg., pregnancy; BMI, body mass index at initial visit; resp. all., respiratory allergy; med. hist., medical history; T/A, tonsillectomy and/or adenoidectomy; N/A, not applicable. Tonsils: 0, atrophic/non-visible; 3 + , kissing tonsils; inf turb, inferior turbinates. Oro-pharynx: 0, very large; 3 + , very narrow with little visible passage. Hard palate: 1 + , normal height, 3 + , abnormally high and narrow. ESS, Epworth sleepiness scale; Fa scale, fatigue scale; Sn VAS, snoring on visual analogue scale by bed partner in mm: 0, none; 100, very severe; Fa VAS, fatigue on visual analogue scale by subject in mm: 0, none; 100, very severe; Sl VAS, sleepiness on visual analogue scale by subject in mm, 0, none, 100, very severe.

[a] Diagnosed after pregnancy onset.

known history of gynecological or obstetrical disorder, except for one who required treatment for a chlamydia infection in the past.

2.2. Clinical evaluation at entry

All subjects had private obstetricians providing care throughout pregnancy. The specialized SDB evaluations included a medical, oto-laryngological, and orthodontic history. Each subject completed a 190-item validated questionnaire with a 5-point Likert scale, the *sleep disorders questionnaire* (SDQ) [4], and the *Epworth sleepiness scale* (ESS) [5] (a scale evaluating the overall daytime sleepiness based on eight situations, each with a score from 0 to 3, with a maximum score of 24 and normal score up to 10). Each subject also completed the Chervin et al. 'fatigue scale' [6] and a visual analogue scale (VAS) to indicate the quality of nocturnal sleep and daytime fatigue (0 mm, great/absent; 100 mm, very poor/very important). A snoring VAS score was obtained from the bed partner (0, completely absent; 100 mm, continuous and very loud, leading to separate bedrooms) (Table 1). The bed partners were also interviewed for the presence/absence of any abnormal behavior exhibited by the women during sleep (e.g. restless sleep, abnormal movements or leg kicking).

The physical examination included a cardiovascular, respiratory, and neurological evaluation. Subjects also received an oto-laryngological and a clinical cranio-facial morphometric evaluation [7]. All subjects were seen by the same specialists. Scales were used to subjectively evaluate the tonsils (0, non-visible; 3 +, 'kissing tonsils'), oropharynx (0, wide with small uvula, above base of tongue at rest; 3 +, very narrow oro-pharynx with uvula occluded by the base of tongue), and hard palate (0, wide mid-portion; 3 +, high arched and narrow). The *validated clinical index* reported by Kushida et al. [7] and based on overjet measurement (upper and lower inter-canine distance), height of the hard palate, lateral inter-molar distance, BMI, and neck circumference, was obtained. The nose was evaluated for the presence/absence of inferior turbinate enlargement and nasal septal deviation (Table 1).

2.3. Polysomnography

Each subject underwent all night PSG. The following variables were continuously monitored on a Sandman™ sleep system: EEG (C3/A2, C4/A1, O1/A1, Fz/A1-A2) based on the 10–20 international electrode placement system, right and left electro-oculogram, chin and leg EMG, ECG (modified V2 lead), and respiration. Respiration was monitored with thoracic and abdominal uncalibrated inductive respiratory plethysmography bands, nasal cannula/pressure transducer system (Protec™, Winstonville, OR), mouth thermistor, neck microphone, esophageal manometry (Pes) (Medex pressure transducer system), and pulse oximetry (Nellcor™, Alameda, CA). The esophageal pressure was calibrated in cmH_2O at the beginning and end of recording. A minimum of 8 h of recording was obtained.

Based on initial results, subjects were placed on nasal CPAP. The size of the nasal mask and use of *Adam Circuit*™ (i.e. *nasal pillows*, supple hollow tubes placed just inside the nostril) were based on the subject's preference and comfort. A second night of PSG was recorded (as indicated above, with Pes but without nasal cannula/pressure transducer due to CPAP mask) to determine the appropriate level of CPAP pressure. If a subject had been previously diagnosed and placed on nasal CPAP, a new recording was performed at the onset of pregnancy; it involved systematic re-calibration of CPAP. Subjects had clinical follow-up 3–4 weeks after nasal CPAP calibration and between 6 and 8 weeks thereafter.

A new polysomnographic recording with monitoring of the same variables as during the initial CPAP calibration was scheduled around the beginning of the sixth month of gestation (GA). A follow-up evaluation was performed around the eighth month using ambulatory monitoring (Edentrace™, Eden-Prairie, MN). This equipment records pulse-oximetry, thoraco-abdominal impedance, oro-nasal airflow (thermistors), neck microphone, heart rate and body position.

From the beginning, subjects were instructed to come to the CPAP clinic or to contact the on-call sleep specialist if they experienced problems. At each visit, a physical examination was performed. Sleep quality, fatigue, and snoring reported by the bed partners were evaluated using VAS at the initial visit, 4 weeks after CPAP titration and around the sixth and eighth months of GA. Difficulties with nasal CPAP were systematically documented. If questions concerning the appropriateness of the CPAP pressure were raised, an additional CPAP titration polysomnogram was scheduled.

2.4. Data analysis

All data were analyzed after each session for clinical decision-making, and they were re-analyzed for this review by one scorer blind to the order of CPAP titration. The longitudinal data were analyzed after the completion of scoring for group tabulation and statistical analysis. Sleep/wakefulness was tabulated using the Rechtschaffen and Kales international criteria [8]. Short arousals were scored using the American Sleep Disorders Association (ASDA) criteria [9]. Respiratory events [10] were scored using the American Academy of Sleep Medicine recommendations.

2.5. Definitions of abnormal breathing patterns

Apneas and hypopneas were scored and divided into central, obstructive, and mixed types. Apnea is an absence of air exchange at the nose and mouth. *Hypopnea* was

defined, based on nasal cannula/pressure transducer recording, as a 50% or more decrease in nasal flow, followed by either an EEG arousal of at least 3 s or a drop in SaO_2 of at least 2%.

Nasal flow limitation, indicated by a flattening of the nasal cannula/pressure transducer recording with a decrease in flow of less than 50%, was also scored. This breathing pattern is typically associated with either an abnormal Pes pattern called a *Pes Crescendo* [11] or a *continuous sustained effort* [12]. A Pes crescendo is caused by flow limitation in the upper airway, and appears as a sequence of breaths with successively more negative peak end inspiratory pressure. Continuous sustained effort is a sequence of breaths with a more negative peak end inspiratory pressure compared to the most recent prior recording without a crescendo pattern; persistence of the same abnormal effort with each breath may last for several minutes. Both patterns end with a *Pes reversal* [12,13], an end-inspiratory esophageal pressure abruptly less negative and indicative of less respiratory effort. These patterns are typically associated with flattening of the nasal cannula/pressure transducer recording and a limited decrease in nasal flow which may be difficult to see. Abnormal breathing was better detected with Pes monitoring. These last polysomnographic patterns were commonly observed without concurrent changes in SaO_2, in contrast to apneas and hypopneas.

Tachypnea, the last pattern noted, was defined in comparison to prior breathing frequencies in the same sleep stage as a mean increase in respiratory rate of three breaths in NREM sleep and four breaths in REM sleep in a 30-s epoch of recording [14]. It was not associated with more negative peak end inspiratory Pes or with a SaO_2 change. (Tachypnea was previously reported [14] as an abnormal breathing pattern.)

The EEG showed variable patterns in association with Pes reversals or termination of tachypnea: either an arousal, defined as the presence of α or α and β waves for at least 3 s in the central EEG leads but also the presence of δ waves (mostly high frequency δ EEG: 2–4 Hz) [13], or no visually seen change.

2.6. Respiratory event tabulation

The *apnea–hypopnea index* (AHI) is the number of apneas and hypopneas per hour of sleep; the *respiratory disturbance index* (RDI) represents the number of abnormal breathing events per hour of sleep. The RDI included Pes crescendos, continuous sustained effort and tachypnea, in addition to apneas and hypopneas. Use of Edentrace™ monitoring at 8 months GA allowed us to score only apnea, hypopnea and tachypnea based on oro-nasal thermocouple, chest impedance system and pulse oximetry. Periodic limb movements (PLM) were analyzed following the ASDA recommendations [9]. They were divided into PLM with and without arousal. The presence of restless leg syndrome was based on the subject's report of leg paresthesias combined with the polygraphic pattern of PLM, but the latter was not mandatory. Bruxism was determined based on masseteric muscle activity during sleep in addition to dental findings.

Appropriate nasal CPAP pressure was determined based on resolution of abnormal respiratory polygraphic features (i.e. an RDI < 3) while the subject was sleeping supine.

2.7. Statistical analysis

Univariate repeated measures analysis was used to compare VAS scores at baseline and after onset of pregnancy. Wilcoxon Signed Rank test was used to compare VAS scores before and after nasal CPAP treatment.

3. Results

Data concerning the 12 women included in the report are presented in Table 1.

3.1. Reason for referral

Patient #3 was diagnosed with OSAS and treated with nasal CPAP during her first pregnancy, but the data were not collected systematically at that time and were unavailable. She stopped using nasal CPAP post-partum. She returned 14 months after her first delivery due to clinical complaints. Of the other 11 women, six were diagnosed with SDB prior to pregnancy.

Of the seven previously diagnosed women, three had opted for weight loss only (#5, 8) (despite absence of obesity) or use of a dental appliance (#11). These three women returned to the clinic when considering pregnancy, with concerns of additional risks with pregnancy and worsening of OSAS symptoms with limited treatment of OSAS. The other four women had selected nasal CPAP treatment at the time of diagnosis, and it had been used for a mean of 8.4 months (range 4–16 months) prior to pregnancy.

The remaining five women were evaluated after conception, early in the first trimester; CPAP was initiated at a mean of 10 weeks GA (between the 8th and 13th week of GA) due to a significant increase in snoring ($n = 4$), observation of apneas by the bed partners ($n = 5$), and daytime fatigue ($n = 4$). Subject #12 was noted to have an increase in blood pressure, with measurements of 138–142/90–91 at her obstetrical visits. All other women had normal blood pressure readings. In summary, all women were known chronic snorers before pregnancy, seven had already been diagnosed prior to onset of pregnancy, and five were diagnosed using PSG during the first 8 weeks of GA.

3.2. Clinical history and presentation

None of the women was obese. Only two subjects had BMI slightly above 25 kg/m^2 (#5, 12) (Table 1).

Patients #6, 12 had a positive history of childhood allergic rhinitis and/or asthma. Patients #7, 12 had undergone tonsillectomy and adenoidectomy in the past. Patients #5, 12 had orthodontia during their teenage years, and #4, 5 had had extractions of all four impacted wisdom teeth. (Impacted wisdom teeth and overlapping teeth are suggestive of a lack of space for normal dental growth and may be associated with a small mandible or maxilla.) (Table 1)

Physical examination revealed abnormal oro-pharyngeal anatomy with a small oropharynx in all subjects. All patients were scored with either 2+ or 3+ for both *narrow oropharynx* ($n = 12$) and *high arched and narrow hard palate* ($n = 9/12$), as well as an abnormal mean Kushida et al. index, based on a neck index of 89.25 [7]. ESS scores were mildly elevated at entry with a mean score of 11/24, but fatigue scale score (mean = 19/25) and fatigue VAS scores (66.25/100 mm) were high. Snoring VAS scores completed by bed partners were also high, indicative of loud, chronic snoring.

3.3. Polysomnography

Results of nocturnal PSG at the time of diagnosis are presented in Table 2. *Wake after sleep onset* (WASO) times are presented. This measure includes arousals of 3 s and longer. All of the apneas and hypopneas were mixed or obstructive. The lowest SaO_2 was seen with apneic events. The mean AHI was 21 events/h of sleep (range 9–31) with a mean lowest SaO_2 of 84.4% (range 81–88%). The RDI was elevated to a greater extent than the AHI, with a mean of 33 events/h of sleep. Three subjects (#4, 6, 9) had a low AHI but exhibited SDB with repetitive *continuous sustained effort* and constant heavy snoring. (Fig. 1). Two women (#4, 9) displayed numerous PLM, mostly unassociated with arousals.

3.4. Nasal CPAP pressure

Final CPAP pressures determined by titration are presented in Table 3. The mean initial CPAP pressure was 8 cmH_2O (range 6–10). All women were simultaneously prescribed cold humidification via the CPAP mask. The CPAP equipment monitored compliance.

3.5. One-month follow-up

The follow-up recording was performed about 6–7 weeks after conception in the seven women previously diagnosed and 1 month after the initial titration for the five women referred after conception. Overall, the 1-month follow-up was performed between weeks 6 and 17 of GA. Subjects #4, 6 switched to a heated humidifier due to nasal complaints. Compliance, verified by pressure measurement at the mask, indicated a mean nightly use of 6 h 35 min. A repeat PSG verified the appropriateness of the nasal CPAP setting.

None of the bed partners reported snoring and the VAS showed a variable degree of improvement with a decrease in the scores compared to scores without CPAP (Table 3). The changes were significant for VAS ($P = 0.0001$), and VAS sleepiness ($P = 0.0001$). The ESS decreased ($P = 0.0001$), and the fatigue scale decreased ($P = 0.002$).

3.6. Six-month follow-up

All of the women were scheduled to undergo a systematic clinical evaluation and polysomnogram with evaluation of the nasal CPAP settings near the beginning of the sixth month of GA. No emergencies or equipment complaints arose during the interim. Clinical and obstetrical evaluations were normal with normal BP.

Table 2
Polysomnographic data at diagnosis

Subject no.	RT	TST	WASO	AHI	RDI	Lowest SaO_2	Total no. PLM	PLM arousal index
1	478	381	33	19	29	84	0	0
2	482	370	24	24	33	86	0	0
3	465	391	19	27	39	82	12	0
4	472	386	27	10	26	86	98	5
5	468	378	17	29	38	81	0	0
6	485	363	22	11	23	88	0	0
7	470	395	16	28	40	86	0	0
8	485	369	37	31	38	83	26	1
9	470	365	28	9	25	83	118	6
10	476	377	22	12	30	86	0	0
11	483	384	17	26	39	85	0	0
12	477	366	31	26	37	83	0	0
(Mean)	452.5	377	24.4	21	33	84.4	–	–

RT, recording time; TST, total sleep time (min); WASO, wake after sleep onset (min); AHI, apnea–hypopnea index; RDI, respiratory disturbance index; SaO_2, oxygen saturation; PLM, periodic leg movement; PLM arousal index, no. arousals/h due to PLM.

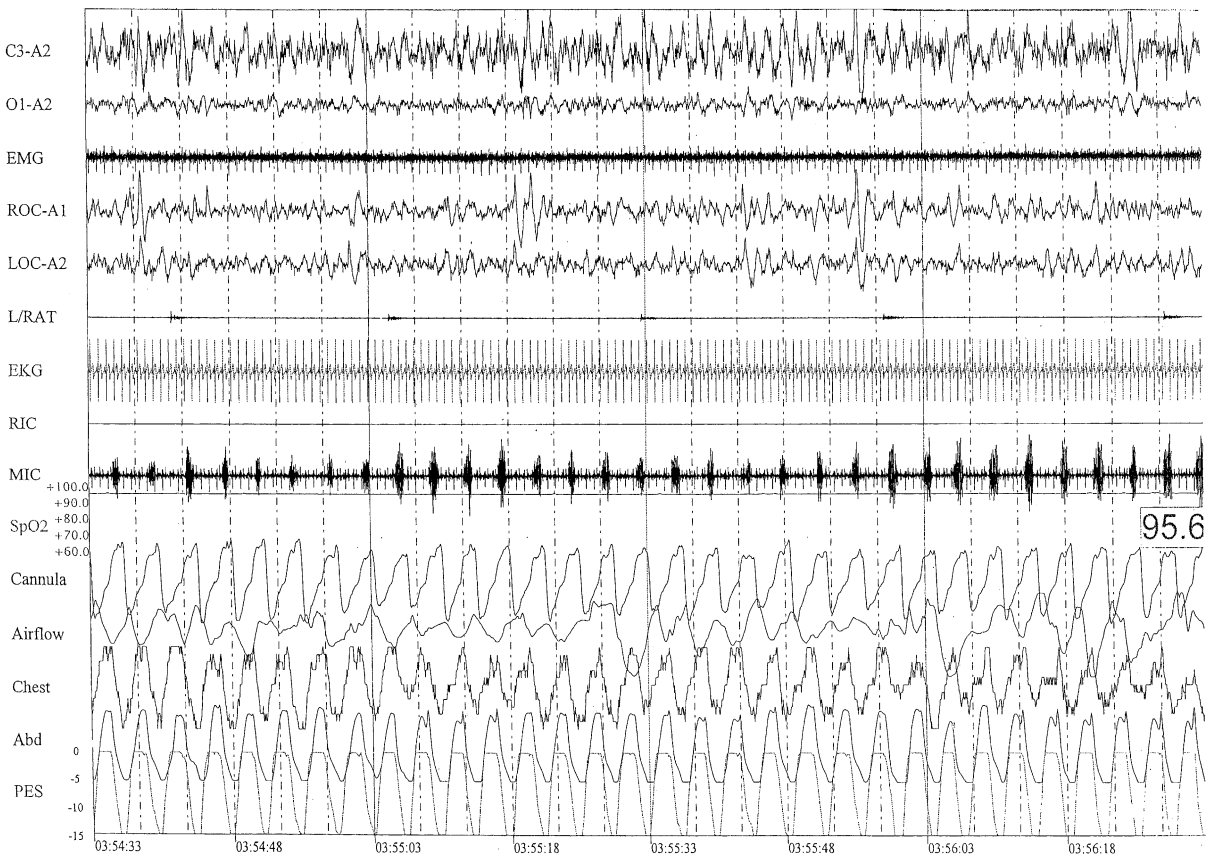

Fig. 1. Abnormal recording at 4 weeks pregnancy during stage 2 NREM sleep. Presence of snoring (MIC), *continuous sustained effort* with end inspiratory Pes at 16 cm H_2O (PES), flow limitation (Cannula), and periodic limb movement (L/R AT). Oxygen saturation (SaO_2) (scale: 100–60%) is normal at 98%. Duration of segment: 120 s.

Upon evaluation, four women reported 'morning nasal congestion,' and five bed partners gave snoring VAS scores between 10 and 20. Snoring suggested mask leaks, mouth breathing or inadequate nasal CPAP pressure. During interviews, five bed partners reported intermittent low intensity noise despite nasal CPAP treatment. Mean fatigue VAS score was 35.4 (still lower than at entry, $P = 0.01$). Mean 'fatigue scale' score was 12.8 compared to 19.2 at entry ($P = 0.05$). Mean sleepiness VAS was 47.1 mm ($P = 0.001$ from entry) but increased from the initial CPAP titration ($P = 0.01$). ENT examination revealed nasal mucosal engorgement in all subjects.

Table 3
Follow-up after 1 month of CPAP

Subject no.	No. months used prior pregnancy	Initial pressure	Hours used per night	% Time of CPAP usage	ESS	Sleepiness VAS	Fatigue VAS	Snoring VAS	GA week
1	6	8	6	80	4	0	30	0	4
2	8	7	5.5	73	5	5	25	0	5
3	14	8	6	80	5	0	30	0	4
4	[8 weeks]	6	5	72.5	5	10	35	0	12
5	5	9	6.5	90	4	0	25	0	5
6	[13 weeks]	7	4	71	6	20	35	0	17
7	16	9	7	93	6	0	25	0	4
8	4	9	7.5	98	5	0	25	0	5
9	[10 weeks]	7	7.2	94	6	15	30	0	14
10	[9 weeks]	7	7	90	5	10	25	0	13
11	6	8	7.5	100	6	0	25	0	4
12	[12 weeks]	10	7	92	7	20	35	0	16

[*x* weeks], no. weeks after calculated beginning of pregnancy; pressure, cmH_2O. Sn VAS, snoring on visual analogue scale by bed partner in mm: 0, none; 100, very severe; Fa VAS, fatigue on visual analogue scale by subject in mm: 0, none; 100, very severe; Sl VAS, sleepiness on visual analogue scale by subject in mm: 0, none; 100, very severe; GA week, gestational week at time of indicated CPAP pressure.

Table 4
Follow-up at 6 and 8 months gestation

At 6 months gestation												At 8 months gestation			
S. no.	GA wk	Mask	Pill.	Hum.	Fa Scale	Sn VAS	Fa VAS	Sl VAS	% Use	No. PLM	PLM index	CPAP level	Ga wk	Sn VAS	Fa VAS	Sl VAS
1	24	+	0	0	11	0	35	45	>90	0	0	8	32	0	60	45
2	25	+	0	0	14	0	30	45	>90	0	0	8	33	0	65	45
3	25	+	0	0	13	10	35	45	>90	0	0	9	32	5	55	45
4	26	0	+	+	14	20	35	50	>80	150	18	7	32	15	60	50
5	26	+	0	0	12	0	40	50	>90	10	10	9	33	0	65	50
6	26	0	+	+	12	15	40	55	>80	0	0	8	33	10	60	55
7	27	+	0	0	13	0	35	40	>90	0	0	9	34	0	65	40
8	25	+	0	0	11	0	35	45	>90	112	16	9	32	0	60	45
9	26	+	0	+	12	10	35	50	>90	24	18	8	32	5	60	50
10	25	0	+	0	14	0	30	45	>90	0	0	7	32	0	60	45
11	27	+	0	0	16	0	35	40	>90	0	0	8	32	0	60	40
12	26	+	0	0	12	20	40	55	>90	0	0	12	32	15	60	55

S. no., subject number; GA wk, gestational week; pill., use of nasal pillows; hum., usage of humidifier; Fa scale, fatigue scale; Sn VAS, snoring on visual analogue scale; Fa VAS, fatigue on visual analogue scale; Sl VAS, sleepiness on visual analogue scale; no. PLM, number of periodic leg movements.

Inferior turbinates were considered abnormally enlarged in subjects #3, 6, 9, and 11.

All of the subjects used nasal CPAP over 7.5 h every night during the 4 weeks prior to testing (except for subjects #4, 6 who used nasal CPAP at least 6.5 h per night). PSG showed moderate worsening of PLM scores and snoring in subjects #4, 8, 9. CPAP pressure was increased in subjects #2, 3, 4, 6, 9, 12 with the largest increase in pressure (2 cm H_2O) in #12. One subject (#9) was switched to heated humidification (Table 4).

3.7. Home monitoring at 8 months

The mean GA at this time was 33.4 weeks (range 32–35) (Table 4). All subjects used nasal CPAP more than 7 h per night, as determined by compliance data recorded by the CPAP machine. Bed partners reported that all of the subjects slept on their sides at least part of the night. No complaints were reported other than tiredness and fatigue. VAS scores were higher than at 25 weeks. The mean fatigue VAS score was 60.8 mm, and the mean sleepiness VAS score was 47.1 mm. Both scores were significantly higher than after nasal CPAP titration and 6-month re-titration (univariate repeated measure analysis, $P = 0.0001$). These changes were likely related to the pregnancy itself. Five bed partners reported snoring, although mild (between 5 and 15 mm on the VAS), which was confirmed orally. Home monitoring did not reveal oxygen desaturation, apnea, hypopnea or tachypnea. (As mentioned above, Edentrace™ records are unable to evaluate presence of upper airway resistance, but were otherwise non-pathological.) CPAP pressures remained unchanged until delivery.

3.8. Delivery

Deliveries occurred between 38 and 40.5 weeks GA. All infants were healthy. Apgar scores were all above 8. All mothers returned home within 72 h following delivery.

4. Comments

Nasal CPAP is a well-documented treatment of SDB. Placebo controlled studies have demonstrated the efficacy of CPAP in improving various measures of sleepiness, including the multiple sleep latency test (MSLT) and cognitive functioning [15]. Treatment of OSA with tracheostomy has had a benefit on hypertension [16,17]. Studies with nasal CPAP have demonstrated similar blood pressure improvements [18]. When women with SDB become pregnant, the question of nasal CPAP tolerance during pregnancy and its effect on the mother's sleep is frequently raised. Furthermore, in the more recent past, significant interest has emerged in treating gravid women with SDB, as SDB may affect the occurrence of pre-eclampsia [19].

We have previously reported on the common finding of snoring in healthy, pregnant women [1]. Snoring can be associated with abnormal breathing and an increase in respiratory effort during sleep. Polysomnograms with nasal cannula/pressure transducer and esophageal manometry performed between the 5th and 6th month of pregnancy on 26 women randomly selected from a group of 267 shows the frequent occurrence of nasal flow limitation, Pes crescendos, continuous sustained respiratory effort and respiratory event related arousals (RERAs) [1]. Mild oxygen desaturations during sleep in otherwise normal pregnancies have also been reported [2]. It was hypothesized that hormonal changes during pregnancy may be responsible for mucosal changes in the upper respiratory tract and resultant respiratory flow limitation [1]. Risk factors for breathing impairment during pregnancy include a small upper airway due to a large soft palate, enlargement of the inferior turbinates associated with upper airway allergies, incomplete maxillary or mandibular growth during childhood (sometimes indicated by a history of wisdom teeth extraction) and obesity. Our subjects had all of these risk factors, except obesity.

PLM have anecdotally been reported to be exacerbated by pregnancy. Our data do not show any significant relationship ($P = 0.8$), but our sample of pregnant women with PLM is too small to provide valid information.

All our subjects treated their SDB with nasal CPAP. One subject had borderline hypertension when referred; her blood pressure, as that of the 11 other subjects, remained normal using nasal CPAP during the pregnancy.

Compliance, as measured by an internal program within the CPAP machine that measured pressure at the nasal mask, was excellent. Problems reported by the women were comparable to those seen in any nasal CPAP user and were handled by appropriate support, use of *nasal pillows* and humidification.

It is important to note that during the normal evolution of their pregnancies, six of these women required increases in their nasal CPAP pressure at about 24 weeks of GA. This adjustment was important for the subjects' comfort and continuing complete resolution of upper airway occlusion during sleep. This adjustment was modest (1 cmH_2O) in subjects #5, 6. The subject who required a greater increase of 2 cmH_2O experienced the greatest weight gain. Investigations show that nasal congestion increases with GA. However, as fetal size increases, abdominal enlargement and possible slight diaphragmatic repositioning when sleeping recumbent may also impact breathing. These factors may explain the need for increases in CPAP pressure in our pregnant SDB women.

Home monitoring during the eighth month of GA indicated normal SaO_2 during sleep and absence of apnea, hypopnea and tachypnea, confirming that CPAP was at the correct pressure setting to control at least these manifestations of SDB.

The subjective VAS scores were helpful in monitoring snoring. They are easy to obtain by asking subjects and bed partners to put a perpendicular mark on a horizontal 100 mm line, from 0 (none) to 100 (very severe). A nurse can also obtain these measurements while taking vital signs.

'Fatigue' measurements (VAS and independent scale) suggest an increase in fatigue during pregnancy; measures of fatigue and sleepiness were much worse in the last 3–4 weeks of pregnancy. We recently published a study on a large group of women with normal pregnancies, recruited during the same period as our 12 subjects and undergoing the same polygraphic investigation at the beginning and Edentrace™ recording at the sixth month of pregnancy. The same VAS scales for snoring and sleepiness were used. Women with normal pregnancies had higher scores on VAS sleepiness at 6 months than at the beginning of pregnancy. A range of results was seen at 6 months GA. Of 267 women, 52% ($n = 139$) had VAS sleepiness scores between 30 and 50 mm (mean 39 mm), 37.5% ($n = 100$) had scores between 50 and 65 mm (mean 56 mm), and the last 10.5% ($n = 28$) had scores <30 mm [1]. Our women with nasal CPAP would be within the range of what has been seen in normal pregnancy at 6 months: the mean VAS sleepiness score was 47 mm.

We recognize that our patients represent only a segment of our social and cultural population. None of our pregnant women had challenging living conditions or were single mothers, and all had adequate health insurance. Moreover, all of those who knew about their OSA before gravidity (about 50%) were concerned about the potential impact of this syndrome on the fetus and sought medical attention when pregnancy was being considered. These conditions are probably optimal for successful treatment with nasal CPAP.

We made certain that our patients could have easy follow-up and did not rely on durable medical equipment or CPAP providers to resolve mask-related difficulties. The subjects could make arrangements with our clinic to deal with any CPAP problem. The nasal congestion seen during pregnancy, perhaps related to the hormonal changes, is a factor to keep in mind, and re-calibration of the CPAP pressure may be needed around 24–26 weeks of GA.

In summary, nasal CPAP is a safe and effective treatment of SDB during pregnancy but regular follow-up during pregnancy is needed.

Acknowledgements

Christian Guilleminault was supported by an Academic Award from the Sleep Research Center from NHLBI from NIH. Martina Kreutzer was the recipient of an unrestrictive educational grant from Respironics, Inc.

References

[1] Guilleminault C, Querra-Salva MA, Chowdhuri S, Poyares D. Normal pregnancy, daytime sleeping, snoring and blood pressure. Sleep Med 2000;1:289–97.

[2] Bourne T, Ogilvy AJ, Vickers R, Williamson K. Nocturnal hypoxaemia in late pregnancy. Br J Anaesthes 1995;75:678–82.

[3] Guilleminault C, Stoohs R, Clerk A, et al. A cause of daytime sleepiness, the upper airway resistance syndrome. Chest 1993;104: 781–787.

[4] Miles L. Sleep questionnaire and assessment of wakefulness. In: Guilleminault C, editor. Sleeping and waking disorders: indications and techniques. Menlo-Park, CA: Addison-Wesley; 1982. p. 383–413.

[5] Johns MW. A new method for measuring daytime sleepiness, the Epworth sleepiness scale. Sleep 1991;14:540–5.

[6] Chervin RD. Sleepiness, fatigue, tiredness and lack of energy in obstructive sleep apnea. Chest 2000;118:372–9.

[7] Kushida CA, Effron B, Guilleminault C. A predictive morphometric model for the obstructive sleep apnea syndrome. Ann Intern Med 1997;127:581–7.

[8] Rechtschaffen A, Kales A, editors. A manual of standardized terminology, techniques and scoring systems for sleep stages of human subjects. Los Angeles: Brain Information Service/Brain Research Institute, UCLA; 1968.

[9] Atlas Task Force of the American Sleep Disorders Association, EEG arousals scoring rules and examples. Sleep 1993;16:173–84.

[10] American Academy of Sleep Medicine (AASM) Task force, Sleep related breathing disorders in adults: recommendations for syndrome definition and measurements techniques in clinical research. Sleep 1999;22:667–89.

[11] Guilleminault C, Kim YD, Stoohs R. Upper airway resistance syndrome oral-max-fac. Surg Clin North Am 1995;7:243–56.

[12] Guilleminault C, Poyares D, Palombini L, et al. Variability of respiratory effort in relation to sleep stages in normal controls and upper airway resistance syndrome patients. Sleep Med 2001;2: 397–406.

[13] Black J, Guilleminault C, Colrain IM, Carillo O. Upper airway resistance syndrome, central EEG power and changes in breathing efforts. Am J Respir Crit Care Med 2000;162:406–6.

[14] Guilleminault C, Dement WC. Sleep apnea syndromes and related disorders. In: Williams RL, Karacan I, editors. Sleep disorders. New York: Wiley; 1978. p. 9–25.

[15] Engleman HM, Martin SE, Deary IJ, Douglas NJ. Effect of continuous positive airway pressure treatment on daytime function in sleep apnoea–hypopnoea syndrome. Thorax 1994;49:263–6.

[16] Coccagna G, Mantovani M, Brignani F, et al. Tracheostomy in hypersomnia with periodic breathing. Bull Pathophysiol Resp 1972;8: 1217–28.

[17] Motta J, Guilleminault C, Schroeder JS, Dement WC. Tracheostomy and hemodynamic changes in sleep induced apnea. Ann Intern Med 1978;89:454–8.

[18] Suzuki M, Otsuka K, Guilleminault C. Long term nasal continuous positive airway pressure administration can normalize hypertension in some obstructive sleep apneic patients. Sleep 1993;16:545–9.

[19] Franklin KA, Holmgren PA, Jonsson F, et al. Snoring, pregnancy induced hypertension and growth retardation in the fetus. Chest 2000; 117:137–41.