ELSEVIER

Sleep Medicine 1 (2000) 289–297

SLEEP MEDICINE

www.elsevier.com/locate/sleep

Original article

Normal pregnancy, daytime sleeping, snoring and blood pressure

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Received 10 April 2000; received in revised form 12 June 2000; accepted 14 June 2000

Abstract

Objective: Investigation of daytime sleepiness, blood pressure changes and presence of sleep disordered breathing, in healthy young women during pregnancy.

Methods: Young, healthy pregnant women between 18 and 32 years of age, seen in three different prenatal care clinics, were enlisted in a prospective study divided in two parts: part 1 of the study consisted of completing a standardized questionnaire on past and present sleep disorders. It also included filling out visual analog scales (VAS) for daytime sleepiness and snoring by the subject and bed partner. Blood pressure measurement was performed at 9 AM as per the WHO protocol. Similar data were collected again at the 6-month prenatal visit and at the 3-month post-delivery visit. At the 6-month visit, ambulatory monitoring of nocturnal sleep using a portable six-channel recorder (Edentrace®) was performed at home. Part 2 involved a subgroup of subjects that were randomly selected after stratification based on results of VAS and ambulatory monitoring. It included 1 night of nocturnal polysomnography with esophageal manometry and 24 h of ambulatory BP monitoring with portable equipment with cuff inflation every 30 min.

Results: Of the 267 women who participated in part 1 of the study , only 128 consented to enroll in part 2, from which 26 were selected to undergo polysomnography. At the 6-week prenatal visit 37.45% of the subjects reported daytime sleepiness of variable severity. At the 6-month visit, this was noted in 52% of the subjects. Bed-partners reported chronic, loud snoring prior to pregnancy in 3.7% of the study population, but this increased to 11.8% at the 6-month visit. Blood pressure (BP) remained below the pathological range, i.e. less than 150/95 mm Hg, during the entire pregnancy. However, ambulatory monitoring indicated that 37 women, including the loud chronic snorers, had some minor SaO_2 drops during sleep and this same group presented the largest increase in BP between the 6th week and the 6th month prenatal visits. Part 2 included 26 women, 13 from the above identified 37 women and 13 from the rest of the group, chosen randomly, age and body mass index (BMI) matched. Polysomnography did identify two abnormal breathing patterns during sleep: (1) esophageal pressure 'crescendos' associated predominantly with stage 1 and 2 NREM sleep, and (2) 'abnormal sustained efforts' seen predominantly with delta sleep. These abnormal breathing patterns were noted during a significantly longer time during sleep. This group of women with the abnormal breathing patterns were not only chronic snorers but also had significantly higher systolic and diastolic BP increases when compared to the 13 other non-snorers. Six out of the 13 snorers were 'non-dippers' at the 24-h BP recording.

Conclusion: Abnormal breathing during sleep (that is frequently, but not always, associated with loud, chronic snoring, and may be a consequence of edema induced by hormonal changes associated with pregnancy), can be seen in otherwise healthy young pregnant women. It may contribute to the symptom of daytime sleepiness. The changes in blood pressure noted were of

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PII: S1389-9457(00)00046-0

no pathological significance in our population but could be an added risk factor in high-risk pregnancies.

Keywords: Pregnancy; Young women; Daytime sleepiness; Chronic snoring; Abnormal breathing during sleep; Blood pressure; Non-dipper

1. Introduction

Chronic snoring has been considered to be a marker of sleep disordered breathing in many studies of sleep pathology. In 1996 Loube et al. [1] indicated that snoring increases during pregnancy, however, preliminary data obtained in the early 1980s on a small number of pregnant women, using calibrated induction respiratory plethysmography, had not identified the presence of significant obstructive sleep apneas. The current prospective study aimed to evaluate the severity of snoring as scored by the bed-partner at two different times (6 weeks and 6 months) during normal pregnancy. The second objective was to evaluate the potential association of oxygen saturation drops with changes in blood pressure during pregnancy in the chronic snorers as opposed to non-snoring pregnant women using an ambulatory blood pressure monitor. Finally, we also aimed to investigate the presence of any abnormal respiratory pattern during sleep in a sub-sample of the population who had chronic snoring, and to study the shape of the 24-h blood pressure curve in this group.

The crucial question that needed to be answered was 'should we pay more attention to chronic snoring during pregnancy due to its common association with sleep disordered breathing?'

2. Methods

2.1. Population

The proposal called for investigation of healthy young pregnant women between 18 and 32 years of age. The women were recruited from three different clinics. All were enlisted in health insurance plans that requested regular clinic visits during the course of their pregnancy. A first visit with collection of general health information was scheduled near 6 weeks of gestation. At this visit an informed consent was obtained. The consent outlined a two-part protocol. Subjects could give informed consent to either one or both parts.

Exclusion criteria included prior history of cesarean section, current significant medical or psychiatric disorder, presence of medical or obstetric problems at the first visit and recent immigration, with the presence of linguistic or cultural barriers. Finally, obstetricians could withdraw subjects from the study if it was felt to be an undue burden of any type.

2.2. Protocol

All subjects seen during the survey period, consented to participate in part 1 of the study, which included:

1. Medical and obstetric chart review;
2. completion of a sleep disorders questionnaire (SDQ) [2], previously used in France and USA, at each clinic visit;
3. blood pressure (BP) monitoring during the scheduled visits. At the 6-week and 6-month visits, BP was measured as per the WHO protocol at 9 AM [3];
4. subjects were asked to come with their bed-partners at the 6-week and 6-month prenatal and the 3-month post-natal consultations. Both pregnant women and bed-partners completed visual analog scales (VAS) [4] on the severity of daytime sleepiness, the degree of nocturnal sleep disruption and loudness and frequency of occurrence during the week of snoring;
5. finally, at 6-month prenatal visit they underwent a nocturnal ambulatory recording, using a 'light' equipment (Edentrace®), without EEG monitor, but with a pulse oximeter, thoraco-abdominal respiratory impedance measurement device and a microphone taped to the anterior part of the neck [5].

The second part of the two-part consent form emphasized that:

1. subjects could opt to participate in just part 1 of the study as described above, or;
2. they could opt to participate in part 2 of the study in

addition to part 1. In part 2, at the 6-month visit, a random sample of subjects who had already completed part 1 would be asked to undergo a polysomnogram (PSG) which would including measurements of EEG, respiratory effort using esophageal manometry, and airflow using nasal pressure cannula. They were also informed that a 24-h measurement of BP would be done following the PSG recording using a portable device with cuff inflation every 30 min.

The study had been designed with the understanding that some pregnant women may refuse to participate or would be concerned about submitting to a PSG recording including esophageal manometry, during their pregnancy. Based on the expected number of deliveries performed annually in the three clinics, it had been calculated that 10% of the total women would be asked to participate in part 2 of the protocol throughout the 9 months of recruitment. In order to include an appropriate representation of snoring and non-snoring women stratification of subjects was integrated into the protocol. If a woman, randomly selected to be in the 10% polygraphic sample refused to participate in part 2 of the study, the subsequent subject who had consented to both parts of the study would be recruited, taking into account the need to include a balanced population of chronic snorers and non-snorers.

2.3. Polygraphic protocol (part 2)

After the 6-month clinic visit and ambulatory recordings, the subjects were asked to spend one night in the sleep laboratory. The following variables were monitored: EEG (C3/A2, C4/A1 leads) EOG, chin and leg EMG, ECG (V_2 lead), and body position. Respiration was monitored using thoracic and abdominal bands; airflow was measured via a nasal cannula with pressure transducer as well as a mouth thermistor and snoring via a microphone placed on the anterior part of the neck. Esophageal manometry and pulse oximetry (Nellcor™, Hayward, CA) were also included. On the morning following the PSG, subjects were equipped with an ambulatory blood pressure monitoring system (ABPM 630, Colin, San Antonio, TX). The equipment provided oscillometric and auscultatory measurements, which allowed for rejection of artifactual values. Data and events were stored in a solid state memory and were transferred to a computer for analysis. The equipment stored data every 30 min. Event markers were used to determine bedtime, wake-up time, standing up and daytime rest periods while supine.

Simultaneously, subjects also filled out a log of their daytime activities. The BP recording was always performed after the PSG recording to avoid any interference between cuff inflation and nocturnal sleep. The fact that BP monitoring started right after awakening allowed for some habituation to cuff inflation during the course of the day.

2.4. Data analysis

Definitions:

- Hypertension was defined as BP of 155/95 mmHg or more, measured as per the WHO protocol, near 9 AM [3].
- Chronic snoring was defined as the presence of snoring reported for more than 60% of the time by spouse/bed-partner, whereas, loud snoring was scored when the bed-partner noted the loudness to be $\geq$60 mm on the visual analogue scale (with 0 mm = never audible and 100 mm = very loud and continuously disturbing bed-partner) [4].

Edentrace® recording was manually scored for the presence and frequency of snoring, and/or apneas, and/or oxygen saturation drops [5].

Polysomnography was scored using the international classifications for sleep/wake, and micro-arousals [6,7]. Published definitions for apneas/hypopneas and their types were also used [8]. Finally, increases in respiratory effort, esophageal pressure crescendos and flow limitation [9,10] were scored by the same individual for all records. The scorers were blinded to the subjects' identity and clinical presentation.

2.5. Statistical analysis

Data are presented as mean $\pm$ SD. Comparisons were performed using the Student *t*-test for independent samples. Differences between proportions were calculated using the Chi-square test.

3. Results

3.1. Population

Two hundred and sixty-seven women consented to participate in part 1 of the study. This includes all women presented with the consent form by their obstetricians. Only 128 women (48%) signed up for both parts (1 and 2). The main difference between the two groups was related to the number of pregnancies: out of 139 women who signed up for part 1 only, 98 were primipara women (76.6%), whereas only 14 (11%) were primipara in part 2 of the study. Concern about the PSG recording in some way 'disrupting the pregnancy', was the main reason cited for non-participation in part 2 of the study. The second most common reason for not participating was the inconvenience caused by sleeping away from home.

The mean age of the total group was 25.6 ± 3.4 years. The mean age of the group who signed for both parts 1 and 2 was 26.2 ± 3.6 years (n.s.).

The mean body mass index (BMI) at entry was 23.7 ± 0.8 kg/m$^{2.}$ Per definition, all women were considered healthy and no medical problem was foreseen at the beginning of pregnancy. Ethnicity (based on report) was: 69 (25.8%) North-African ancestry (Algeria, Morocco, Tunisia); 68 (25.5) Caucasian, European ancestry; 49 (18.35%) West-Indian ancestry; 43 (16.1%) Black-African ancestry; and 38 (14.25%) Eastern-Asian ancestry (Vietnam and China). All multipara women reported normal delivery during prior pregnancies, at 37–41 weeks of gestation. The ethnicity distribution of part 2 group was not significantly different from the total group.

3.2. Results of the 6-week visit (see Table 1)

3.2.1. Questionnaires

3.2.1.1. SDQ. At the 6-week visit five women acknowledged intermittent bouts of insomnia that they had experienced prior to the current pregnancy which may have been treated with over-the-counter medications during the acute phase. No other sleep disorder was listed.

3.2.1.2. Smoking habits. Nearly half the women ($n = 128$, 47.9%) admitted to smoking intermittently during the year just prior to their pregnancy. However, at the time of the 6-week visit, only 28 women (10.5%) referred to a variable amount of daily cigarette smoking.

3.2.2. Visual analog scales

3.2.2.1. Pregnancy and daytime sleepiness. The recent occurrence (mean, 4 ± 1 week of pregnancy) of mid-afternoon and early evening sleepiness was indicated by 100 women (37.46%) according to the VAS, with 0 mm = no sleepiness and 100 mm = very disabling sleepiness. (Sleepiness was scored between 30 and 45 mm by 52 /100 (19.47%) women and between >45 and <60 mm by 48 /100 (18%) women).

3.2.2.2. Pregnancy and snoring. Prior to the onset of current pregnancy, bed-partners reported (via VAS) the existence of some snoring, commonly intermittent and non-disturbing in 48 women (18%). However, chronic, loud snoring was reported in ten women (3.7%). At the 6-week visit, snoring was rated between 6 and 8 cm on a 0–10-cm scale; scores were the same as prior to pregnancy.

Review of clinical charts revealed that 5/10 women had been treated for respiratory allergies previously.

3.2.2.3. Blood pressure measurements. No abnormal BP readings were noted at the 6-week visit. The mean BP by the WHO protocol at 9 AM was 109 ± 8/72 ± 6 mmHg. The ten women, who were reported to be loud, chronic snorers were within the scatter of the total group.

3.3. Results of the 6-month visit (see Table 1)

All women were between 25 and 27 gestation weeks when seen and monitored with Edentrace®. Gestation was considered to be normal in all of them.

3.3.1. Daytime sleepiness

VAS indicated that 139 women (52%) had a score ≥30 mm and <100 mm (scale from 0 (never) to 100 (continuous)), whereas 100 women (37.45%) had a score ≥50 mm on the same scale. Sleepiness was reported after lunch and early evening. The proportion of women reporting sleepiness at ≥25 weeks vs. 6 weeks gestational age was significantly higher ($P = 0.001$).

3.3.2. Snoring (VAS)

Chronic, loud snoring was present with scores between 5 and 9 cm (scale 0 to 10 cm) in 30 women (11.2%). This subgroup included the 10 women reported to snore before pregnancy. Pregnancy was, thus, associated with the onset of loud and chronic snoring in 20 women (7.5%). Intermittent snoring was reported in an additional 109 women (40.8%). Compared to the initial report of 18% at the 6-week pregnancy visit, this was a clear increase in intermittent noisy breathing ($p = 0.001$).

3.3.3. Weight

There was an increase in weight compared to baseline. The mean increase was 10.1 ± 3.3 kg and the differences were unrelated to snoring or BP.

3.3.4. Ambulatory recording

The ambulatory recording at 6 months confirmed the presence of chronic loud snoring in the 30 women identified by VAS. It also indicated intermittent snoring in an additional 117 subjects (43.8%). It did not demonstrate the presence of an abnormal apnea-hypopnea index (selected as a cut-off point of 5 events/h of sleep). But it showed that the chronic, loud snorers spent between 61 and 92% of the calculated sleep time snoring. Also 35 women, including eight non-snoring women, presented SaO_2 drops $\geq$5%, at least once during the night. The oxygen desaturation index (ODI) defined as the number of SaO_2 drops of 3% or more per hour of sleep, had a mean of 2 ± 5/h (range of O_2 saturation drop was 3–7%). The subgroup that had a SaO_2 drop $\geq$5%, at least once during the night, presented a mean ODI of 7 ± 3 events/h. As mentioned in the methods section, ODI was based on a SaO_2 drop of 3% and events were counted after deletion of all movement artifact-related SaO_2 drops. Due to dispersion of the data and the small number of subjects in that subgroup, there were no significant demonstrable differences.

3.3.5. Blood pressure measurements

All BP measurements were considered to be within normal limits, at the 6-month visit. The mean BP was slightly higher at $116 \pm 10/77 \pm 9$ mmHg compared to baseline, however, these changes were not significant.

A sub-analysis was performed on (a) women reported to have chronic loud snoring and (b) women with at least one SaO_2 drop $\geq$5% during the monitored night. The mean BP was always higher in both subgroups. These two subgroups had a large population overlap: 28 of the 30 chronic, loud snorers presented at least one SaO_2 drop $\geq 5\%$ during the night. More surprising was that four of the 35 subjects with at least one SaO_2 drop $\geq$5% had no indication of snoring at VAS and ambulatory monitoring. The mean BP for the chronic snorers group was $124 \pm 5/83 \pm 4$ mm Hg. It was not significantly different (and very much the same considering the very large overlap between the two populations) for the SaO_2 of $\geq$5% drop subgroup.

The comparison between these small subgroups with other pregnant women was non-significant. The low number of subjects in each subgroup compared to the total number of the subjects explains the absence of any difference among the groups.

To have a better overview of possible interactions, subjects were distributed per quartile, based on BP findings at the 6-month visit. All chronic snorers and $\geq$5% SaO_2 drop subjects (i.e. 37 subjects) were in the upper quartile of the BP measurement distribution.

Finally, the change in BP between 6 weeks and 6 months gestational age visit was analyzed. The analysis included the 37 women (30 chronic snorers and seven non-chronic snorers but with at least one SaO_2 drop $\geq$5%) found to be in the upper quartile of BP distribution at the 6-month visit compared to the other women. It tabulated the change in systolic and diastolic BP from the 6-week pre-natal visit. The mean systolic BP increase for the 230 women without nocturnal changes in snoring or SaO_2 was 8 ± 4 mmHg, and it was 14 ± 3 mmHg for the other 37 women. Therefore, there was an increase in BP with pregnancy in that group ($P = 0.052$).

3.4. Part 2 results

3.4.1. PSG and 24-h BP monitoring

As indicated above there were only 128/267 women (48%) available for this part of the protocol. Twenty-six women were to be enlisted in the study considering the initial population. The planned stratification at the 6 months pre-natal visit was to have 13 chronic snorers and 13 non-chronic snorers. The protocol was modified based on the availability of subjects and the

final stratification was based on report of chronic loud snoring and/or presence of SaO_2 drop $\geq$5% at ambulatory monitoring. This enlargement of possible subject enlistment increased the potential pool from 30 to 37 subjects. Twenty-six subjects were enlisted. They were not significantly different in age than the total population. As mentioned above, compared to the total number of primipara, there was an under-representation primipara subjects in the sub-sample. The 26 women who were enlisted had a mean age of 25.5 ± 4.6 years. This group included 11 women with chronic, loud snoring at the 6-month pre-natal visit, eight of whom were already chronic, loud snorers at the 6 weeks pre-natal visit. Two women were not chronic, loud snorers but presented at least one SaO_2 drop $\geq$5% at ambulatory recording at the 6 months visit; the remaining 13 women had no report of chronic, loud, snoring and no evidence of clear SaO_2 drop during the ambulatory recording.

3.4.2. PSG results

3.4.2.1. Sleep architecture. The mean total sleep time (TST), using Rechtschaffen and Kales international criteria [4] was 408 ± 28 min. There was no significant difference between the two groups. The mean total REM sleep time was 70.2 ± 9 min (17.2%). The mean duration of stages 3 and 4 NREM sleep time was 76.5 ± 9 min (18.7%), while that for stage 2 NREM was 235 ± 20 min (57.6%).

There was a significant difference in the duration of stages 3 and 4 NREM sleep between the chronic snorer and non-snorer groups ($P = 0.05$). The snorer group had a mean of 82.5 ± 6 min of slow wave sleep compared to 70.3 ± 6 min for the non-snorer group. This was associated with a non-significant increase in stage 1 and stage 2 NREM sleep in the non-snorer group. The total number of arousals was not significantly different between the two groups. Polysomnography revealed that one of the non-snoring subjects had 239 periodic limb movements during sleep. Post study interview revealed that the spouse had noted leg jerks but had not attributed any significance to the symptoms. The index case had noted more frequent arousals but had believed that it was related to pregnancy.

3.4.2.2. Respiratory patterns. Snorers presented two polygraphic features that were not seen in the non-snorers. One feature that has been previously described as 'crescendos' [9], in patients with 'upper airway resistance', consists of progressive increase in respiratory effort, indicated by monitoring of esophageal pressure (P_{es}) over at least five successive breaths. A 'crescendo' is terminated by an abrupt drop in effort (P_{es} reversal) and frequently, but not always, associated with a visual EEG change (micro-arousal) and flow limitation noted at the end of the crescendo on one to three breaths. Typically, crescendos are not associated with any clear SaO_2 drop. The second feature observed (see Fig. 1) was a succession of breaths (>4) showing increased effort as indicated by measurement of P_{es}. But instead of presenting a progressive increase in effort as in a 'crescendo', there is an abrupt increase and this increased effort stays at the same level for the successive breaths, sometimes even continuing for 1 to several min (see Fig. 1). We called this pattern 'abnormal sustained effort'. It is terminated in the same manner as the crescendo: by an abrupt P_{es} reversal. Flow limitation may or may not be seen with the nasal cannula. If present, the flow-limitation is very limited and again seen on only one to three breaths before the P_{es} reversal. The P_{es} reversal is associated variably with a visual EEG change (micro-arousal or typical arousal). A slight variation in SaO_2 (up to 3%) may be seen with flow limitation, similar to a crescendo, (but not always).

None of the 26 subjects presented an abnormal AHI $\geq$5 events/h. The 'abnormal breathing' group presented a mean AHI = 2.5 ± 1 vs. 1.2 ± 1 for the other group ($P = 0.05$). The rare hypopneas were responsible for the observed SaO_2 drops $\geq$5% noted. Interestingly these events were seen not only in chronic snorers but also in the two non-snoring women. They were always obstructive hypopneas with a mean duration of 22 ± 5 s and were always terminated by clear EEG arousal. The maximum SaO_2 drop observed was 7% and lowest SaO_2 monitored was 90%. As can be seen, the classically-defined events were far apart. And the most common findings were 'crescendos' and 'abnormal sustained efforts'. These patterns were tabulated as percentage of TST. They represented a mean of 19.5 ± 4.5% of TST, compared to 2.5 ± 1% in the non-snoring group. There was a sleep stage relationship between patterns, with 'crescendos' more limited to stages 1

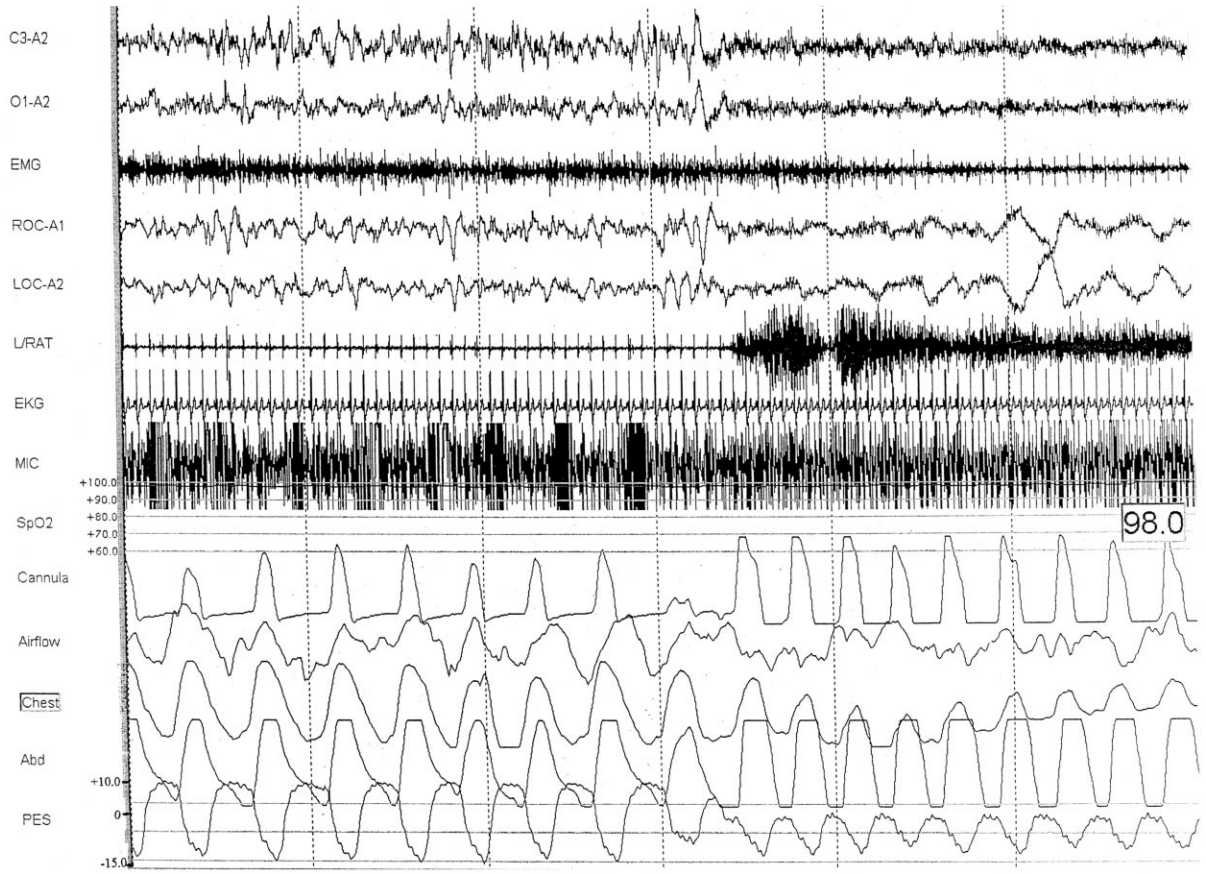

Fig. 1. Example of 'abnormal sustained respiratory effort'. A succession of 25 breaths, with snoring (MIC channel), was associated with an increase in inspiratory and expiratory efforts (indicated by esophageal pressure monitoring-PES channel). No clear flow limitation is seen on the 'cannula' channel (signal obtained from pressure transducer). At arousal (EEG, C3/A2, and EMG channels) an abrupt decrease in effort can be observed.

and 2 NREM sleep, and 'abnormal sustained effort' to stages 3–4 NREM sleep. One of these two patterns was noted at least in all 13 women in the snoring group and both were observed in 11/13 of the subjects.

3.4.2.3. Twenty-four-hour BP monitoring. Recording confirmed the findings noted with the WHO BP monitoring protocol [3]. There were no abnormal BP readings. But two features were noted: the mean 24-h BP calculated from all 30-min values was significantly higher for the 'abnormal breathing group'. This was seen not only for the systolic BP 118 ± 6 mmHg (vs. 110 ± 10 mmHg) ($P = 0.05$), but also for the diastolic values 79 ± 8 mmHg (vs. 71 ± 6 mm Hg) (n.s.). A second abnormal finding was noted in 6/13 of the 'abnormal breathing group', and the six subjects included one non-chronic loud, snorer. There was an absence of the normal nocturnal dip in systolic BP [11]. All other 20 snorers and non-snorers subjects presented a normal circadian oscillation of systolic BP with a BP decrease of at least 20 mmHg during the nocturnal period. The remaining 6 patients did not present this systolic BP dip.

A comparison between the presence of abnormal breathing during sleep and the presence of non-dipping indicated that these six subjects were part of

Table 1
Changes in snoring, sleepiness and BP noted during pregnancy in 267 women

	6/7-week prenatal visit	6-month prenatal visit	3-month post-delivery visit
Women with chronic snoring (%)	3.7 ($n = 10$)	11.2 ($n = 30$)	4.1 ($n = 11$)
Women with intermittent snoring (%)	18 ($n = 48$)	40.8 ($n = 109$)	40 ($n = 107$)
Women reporting daytime sleepiness	37.4 ($n = 100$)	52 ($n = 139$)	32.6 ($n = 87$)
Systolic BP (mmHg, mean ± SD)	109 ± 8	116 ± 10	110 ± 9
Diastolic BP (mmHg, mean ± SD)	72 ± 6	77 ± 9	74 ± 7
Increase of weight in kg from baseline (6 weeks) (mean ± SD)	–	10 ± 3	5.7 ± 2.8

a group of seven who spent the longest percentage of total sleep time with abnormal breathing.

3.4.2.4. Three months post-delivery follow-up.

- All women delivered healthy infants. Termination of pregnancy varied between 37 and 41 weeks of gestation. The mean birth weight was 3221 ± 252 g with a range of 2631–3586 g. There was no significant correlation between any of the collected variables and infant delivery, except for a insignificant trend for infants of chronic snorers to be at lower birth weight (mean of 2972 ± 161 g). The lowest weight was seen in a non-snoring mother.
- VAS indicated that chronic loud snoring was reported in 11 women (one more than at entry) but was not noted anymore in the other reported cases during pregnancy.
- Daytime sleepiness was still mentioned by 87 women. There was a positive trend between breast feeding and daytime sleepiness score. Interestingly the presence of PLMS was not noted by the polygraphically documented index case and spouse, post-delivery.
- Changes in BP noted at 6 months were not noted any more and the results were similar to baseline (Table 1).

4. Comments

Franklin et al. [12] have found that pre-eclampsia developed in 10% of chronic snorers compared with 4% of non-snorers and growth retardation of the fetus defined as small for gestational age had occurred in 7.1% of snoring mothers, a significant difference compared to non-snorers. In a logistic regression analysis controlling for weight, age and smoking, these authors calculated that habitual snoring was independently predictive of hypertension and growth retardation.

Our approach was a bit different. We focused on healthy young women with no known risk factors associated with eclampsia. The suspicion of eclampsia would have, anyway, eliminated the subject from the study, as requested by the ethics committee when the study was initially presented, to avoid interference of a research protocol that needed care.

Despite these restrictions, our investigation revealed several interesting findings. Firstly, daytime sleepiness is a clear burden of pregnancy. Franklin et al. [12] found that as many as 65% of their 502 women complained of daytime sleepiness at end of pregnancy. This is close to our 52% at the 6-month pre-natal visit, albeit in a younger population. Loube et al. [1] used the Epworth Sleepiness Scale (ESS) [13] on their group of pregnant women but compared the scores obtained using this scale to an age-matched group of non pregnant women. The mean score was 9.8 ±3.9 vs. 9.2 ±3.2 in non-pregnant women. Overall these two groups were mildly sleepy, but little can really be extracted from these data as there was no longitudinal comparison. Secondly, pregnancy may be associated with loud, chronic snoring. These symptoms may exist before pregnancy, but undoubtedly, as indicated by our prospective study, chronic loud snoring may appear during pregnancy. Interestingly, Loube et al. [1] reported that pregnant women, not only snored significantly more than their control group, but when those who snore 'often' and 'always' are pulled together, 47.8% of pregnant women are included, a percentage closely related to our 52% of continuous and intermittent snorers. The edema that may be

related to hormonal changes associated with pregnancy can explain the development of snoring and its reduction to baseline, post-delivery.

Thirdly, the most interesting finding, we believe, was the relationship between specific breathing patterns at 6 months of pregnancy and the increase in BP, even though the BP stayed within a non-pathological range. There is an increased amount of respiratory effort, in some pregnant women during sleep. This increased respiratory effort was seen mostly but not always with chronic loud snoring. We acknowledge that the technology that was used did not necessarily detect the flow limitation. Subjects with these breathing patterns presented a higher BP than those who did not. In certain subjects, these abnormal breathing patterns may be associated with disappearance of the normal nocturnal BP dipping. Finally, in the present study, the abnormal breathing patterns were sleep stage related, with one type more associated with delta sleep (sustain effort) than the other (crescendos).

Overall, independently of snoring or not snoring, an increase in delta sleep was noted in women with abnormal breathing patterns. The issue of why such increase in delta sleep was seen is unresolved, but has been already noted in upper airway resistance syndrome [14]. Interestingly, PLMS may also be augmented during pregnancy, and the chance-case found was not in the higher BP subject group, despite sleep fragmentation induced by the leg movements.

In conclusion, abnormal breathing during sleep may develop during pregnancy independently of association with chronic snoring. Abnormal breathing patterns during sleep do not systematically lead to hypertension or, worse, to pre-eclampsia. But there is a trend toward higher BP readings. Undoubtedly, in association with other factors, this BP change could be part of the pre-eclampsia risk factors, particularly in non-dippers, or may worsen the clinical pre-eclampsia picture. Our study indicates, however, that the relationship between loud, chronic snoring, hypertension and pre-eclampsia is not a simple one. Further large prospective studies with more polygraphic monitoring than that performed here, should be initiated. At least our study should reassure prospective pregnant women who would volunteer for study about the absence of harmful consequences of PSG with esophageal manometry during the first 27 weeks of pregnancy.

Acknowledgements

Dr Dalva Poyares was supported by a grant from FAPESP, Sao Paulo-Brazil. C. Guilleminault was supported by an Academic Award from the Center for Sleep Research from the NIHLB from the National Institutes of Health.

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