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# Sleep Apnea and Body Position during Sleep

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**Summary:** In patients with obstructive sleep apnea, it is believed that body position influences apnea frequency. Sleeping in the lateral decubitus position often results in significantly fewer apneas, and some have recommended sleeping on the side as the major treatment intervention. Previous studies, although calculating apnea–hypopnea index (AHI) for supine and lateral decubitus positions, have not taken sleep stage into account. To examine the effect of both sleep stage and body position on apnea duration (AD) and frequency, we determined AHI and AD in all spontaneous body positions during rapid eye movement (REM) and non-REM (NREM) sleep by reviewing videotapes and polysomnograms from 11 overnight studies of 7 obese patients with severe sleep apnea. Consistent with previous work, AD was significantly longer in REM then in NREM (32.5 ± 2.3 s versus 23.5 ± 1.9 s; $p < 0.05$). This difference persisted when adjusting for body position. AHI was greater on the back than on the sides (84.4 ± 4.9/h versus 73.6 ± 7.5/h, $p < 0.05$), but after accounting for sleep stage, this difference remained only for NREM (103 ± 4.8/h versus 80.3 ± 9.2/h, $p < 0.05$) and not for REM (83.6 ± 5.3/h versus 71.1 ± 4.2/h, p NS). Although reduced, AHI on the sides still remained clinically very high. Body position changed frequently throughout the night, but some patients spent little or no time on their back. We conclude that AD is longer in REM than NREM, regardless of position, and AHI is higher on the back only in NREM. As AHI remains very high on the sides, favoring the lateral decubitus position may not be as beneficial as previously thought in very obese patients. Less obese patients are more likely to benefit by position changes. **Key Words:** Sleep apnea—Body position—Apnea index—Apnea duration.

It is widely believed that the supine posture exacerbates obstructive sleep apnea. Most investigators have found that the apnea–hypopnea index decreases significantly by changing from the supine to the lateral position (1–6), and some have suggested that this might be an effective therapeutic maneuver (7). Maintaining the lateral position, or preventing the supine position, however, can be difficult, as most people have a favored sleeping position, and body position changes frequently throughout the night (8). In the published studies, body position has been enforced throughout the sleep period, changed half-way through the course of a night's study, or spontaneous changes have been allowed with the position being recorded and subsequent apnea–hypopnea in-

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dices calculated for the supine and lateral positions (1–7). None of these studies, however, have taken sleep stage into account and examined the relationship of position within rapid eye movement (REM) or non-REM (NREM) sleep. During REM, apneas are usually more prolonged and hypoxemia more severe. One might expect that apneas on the back are most severe in REM and, if body position was important, that apneas would be less frequent and less severe off the back, even in REM. However, because of the profound loss of upper airway muscle tone in REM, the transmural pressure required to close the airway is very small (9); thus, we hypothesized that the factors promoting upper airway occlusion in REM would be independent of position. Therefore, we examined the relationship of body position and sleep stage to duration and frequency of apnea in patients with obstructive sleep apnea.

## METHODS

We examined 11 overnight polysomnograms from 7 obstructive sleep apnea patients for whom position data were available. These patients were not aware that body position was being recorded. The body positions were those spontaneously assumed by the patients. No position was enforced, and patients were free to move in the bed during sleep within the limits of the instruments. Patients were instrumented in standard fashion for overnight polysomnography. This included recording the electroencephalogram (EEG) (C3/A2, C4/A1), the electrooculogram (EOG), submental electromyogram (EMG), electrocardiogram (EKG), heart rate, oxygen saturation ($S_aO_2$) with an ear oximeter (Hewlett-Packard no. 47201A), respiration with an inductance plethysmograph (Respitrace, Ambulatory Monitoring Inc.), and expired $CO_2$ as a measure of airflow. All variables were recorded on a polygraph while a microcomputer stored values for respiratory timing, $S_aO_2$, and heart rate twice for each breath (10). Body position was continuously monitored by an infrared-sensitive camera (RCA Model TC 2000) and stored on a videotape for subsequent playback. A time and date generator (RCA Model TC1440B) imprinted clock time directly onto the videotape. The Beta III format of a video cassette recorder (Sony SL-2700) was used, which allowed 5 h to be recorded on a single tape. Only one tape was used per patient, and although time in bed and/or total sleep time usually exceeded 5 h, more than 75% of a night's sleep was recorded on videotape.

Sleep was staged according to standard criteria (11), and apneas/hypopneas were determined manually and/or automatically by computer analysis of $S_aO_2$ time series data. In our laboratory, we can accurately detect abnormal respiratory events by scanning $S_aO_2$ data as a time series (12), and this computer-generated apnea–hypopnea index (AHI) compares with the manually derived index with a very high degree of sensitivity and specificity and very low false-positive and false-negative rates. In addition, apnea duration can be accurately determined using this method.

Body position was determined by viewing the video tapes and was synchronized with the polygraphic data using the time–date stamp on the video and a computer-generated time stamp on the polygraph chart. Major body positions scored were back, lateral decubitus, and prone; however, some patients spent some time in intermediate positions. The back/lateral decubitus position was scored when the patient was not clearly flat on the back or in the true lateral decubitus position and the pelvis and/or upper trunk tilted 45°. During REM, only one patient had any time in the prone position (6.5 min). During NREM, three patients spent small amounts of time in the prone position. As these times were short (total for all three: 46.0 min) and the calculated apnea–hypopnea indices were similar to those for lateral decubitus, they were included with the lateral decubitus data for the purpose of apnea frequency and duration analysis. Apnea duration and AHIs were derived in each body position during REM and NREM. The AHI was expressed as the number of apneas and/or hypopneas per hour and was determined for REM and NREM in each position.

### Statistical analysis

The AHIs for back and lateral decubitus positions were compared using unpaired *t* tests. As it could be argued that time spent in the intermediate back/lateral decubitus position could be either back or lateral decubitus, these data were combined first with back data (and then compared to lateral decubitus) and secondly with lateral decubitus data (and then compared to back) for unpaired *t* testing. We also examined apnea/hypopnea-related oxygen desaturation by position, by sleep stage, and then by position within a stage as done for AHI.

## RESULTS

The patients were all obese men [mean age 45.1 ± 2.9 (SEM) years, weight as percent ideal 163 ± 32%] with an overnight apnea index of 83.7 ± 6.4. The total sleep time was 345.2 ± 11.4 min, during which body position was known for 75.6% or 260.9 ± 10.8 min. The average REM time was 67 ± 4.9 min, during which body position was known for 49.4 ± 4.4 min (73.7% of REM). Non-REM time was made up predominantly of stages 1 and 2, as these patients had almost no slow-wave sleep. Thus, NREM time refers to all NREM stages 1–4 collectively. The NREM time was 278.2 ± 11.4 min, and position was known for 212.6 ± 9.0 min (76.4% of NREM).

The distribution of sleep position during REM and NREM in each study is shown in Fig. 1. Initial sleep position was on the back in all but one patient. Although there were multiple arousals and associated movements throughout the night (associated with apneas), major sleep position changed less often (mean position changes 11 ± 7, range 3–24). All patients changed positions during the night. Some slept almost exclusively in one position during REM, whereas time per position was more equally divided in NREM.

### Apnea duration

Figure 2 compares apnea duration (AD) between back and sides. As there was no significant difference between lateral decubitus and the intermediate back/lateral positions, they are combined as sides. Without specifying sleep stage, there is no difference in apnea duration (23.4 ± 1.7 s versus 24.1 ± 1.5 s, p NS). If sleep stage is specified, but position is not (Fig. 3), then, as expected from many previous studies, apneic events were longer in REM than NREM (32.5 ± 2.3 s versus 23.5 ± 1.9 s, $p < 0.05$).

When looking only at events in a particular position, again, events were longer in REM than NREM (Fig. 4). However, within a particular stage, sleep position had no effect on the duration of apnea–hypopnea events: AD (in seconds) REM/back 30.1 ± 2.5, REM/sides 31.7 ± 2.6, NREM/back 20.5 ± 1.7, NREM/sides 22.8 ± 2.1. Body position did not influence the percent of sleep time that patients were apneic in REM (back 63.8 ± 2.2%, sides 59.7 ± 3.4%), but did in NREM (back 61.5 ± 3.8%, sides 51.3 ± 6.1% $p < 0.05$) (Fig. 5). However, in only two studies did apnea time decrease by more than 50% on the side in NREM. One of these patients was recorded twice, and this reduction was not repeated. As a group, the patients were still apneic for over 50% of the time on the side in NREM.

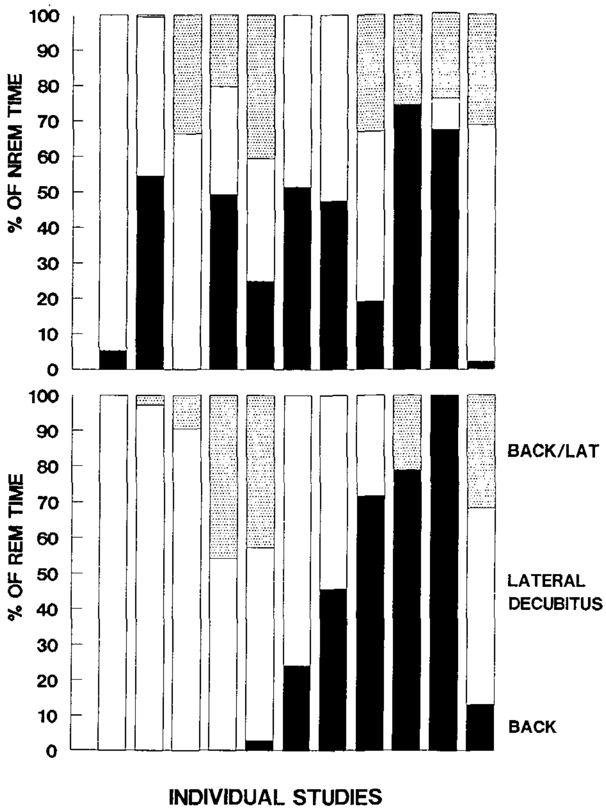


FIG. 1. Distribution of body positions for NREM (top half) and REM (bottom half), based on 75% of total sleep time where body position was known. Back, lateral decubitus, and back/lateral decubitus (back/lat) positions are represented by solid, open, and stippled bars, respectively.

## Apnea index

Without accounting for sleep stage, AHI was greater on the back than the sides (84.4 ± 4.9/h versus 73.6 ± 7.5/h, $p < 0.05$). Without specifying position, AHI was less in REM than NREM (72.6 ± 3.8 versus 89.7 ± 7.2, $p < 0.05$). The AHI for each body position in both REM and NREM represents the number of events per hour of sleep stage in that position. From previous published studies, one might expect a higher index on the back than on the sides. This seemed to be the case only in NREM (Fig. 6, Table 1), but not in REM. Even if the intermediate back/lateral data were included with back or with lateral decubitus data, this did not change the finding that AH index in REM did not change with position (Table 2).

Given our video recording limitations, for about 25% of the night, the position is unknown, whereas the sleep stage is known. One might argue that the AHI results would be different and that AHI on the back still exceeds AHI on the sides. We therefore determined the AHI for REM and NREM where the position was not known. Then, assuming that all the "unknown" data were either all on the back or "lateral decubitus," we calculated additional AHIs for back and lateral decubitus in REM and NREM. Even doing this, there was no change in the results: AHI was not different by position in REM, but was greater on the back in NREM (Table 2).

The oxygen desaturation profile for the apnea/hypopnea events is given in Tables 3

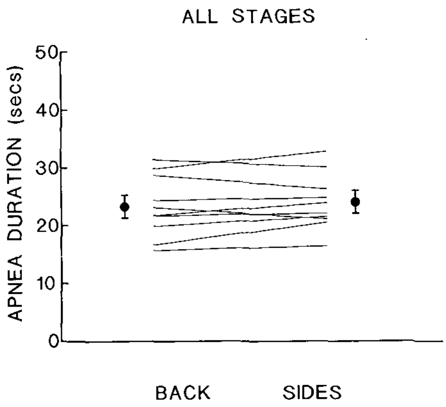


FIG. 2. Comparison of apnea duration (s) on the back and on the sides (sides include lateral decubitus, back/lateral decubitus, and prone, see text). Closed circles and error bars represent mean and standard error (SE). There is no difference in apnea duration by position if sleep stage is not specified.

and 4. Consistent with previous studies, the average drop in saturation was much greater in REM than NREM (26.2 ± 3.7 versus 14.6 ± 2.23 $p < 0.05$). As $S_aO_2$ at the beginning of events was similar, the greater duration of events in REM likely accounts for this $S_aO_2$ difference. However, by stage, there was no effect of position on the average desaturation (Table 4).

## DISCUSSION

The major new findings in this study are that apneas are more frequent on the back only during NREM and, within NREM or REM, apneas have the same duration whether on the back or the sides. The fact that apneas are not more frequent on the back than other positions during REM, at first glance, is at odds with previous studies. However, none of these studies looked specifically within REM or NREM for differences by position. If we had not done this, we would have simply confirmed previous results. Also, all our patients were very obese (163 ± 32% ideal weight), whereas those of other studies were less obese (1–3). Why there should be no systematic difference in

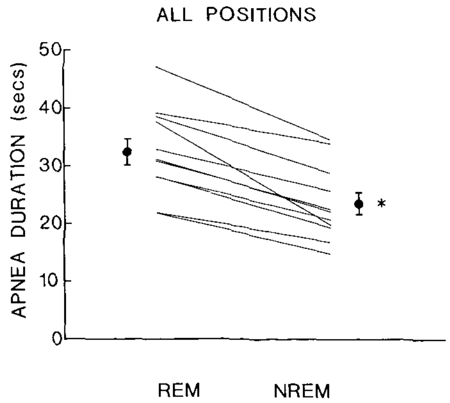


FIG. 3. Apnea duration is longer in REM than NREM. Body position not specified. Closed circles and error bars represent mean and SE. $^*p < 0.05$.

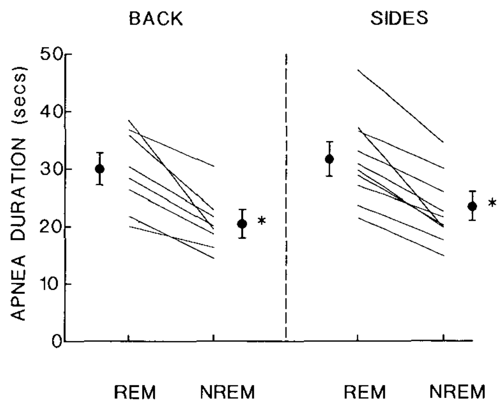


FIG. 4. Apnea duration specifying both sleep stage and position. On back or sides, apneas are uniformly longer in REM. $*p < 0.05$.

REM is unexplained, but we can speculate about possibilities. With inspiration, the upper airway is subjected to a negative intrathoracic pressure that tends to collapse the upper airway. This tendency to collapse is opposed by active contraction of upper airway muscles that help to maintain airway patency. If the upper airway resistance is increased, then intrathoracic pressure will increase to counteract the change in resistance and maintain flow. If upper airway muscle tone does not similarly increase, then the tendency to collapse is greater (9).

It has been shown that upper airway resistance is increased in obstructive apnea patients and that this further increases in the supine posture (13). During sleep, there is reduced tone in upper airway muscles that will increase resistance. Add to this the increase related to the change from upright to supine posture, and the resistance may be substantially elevated. The effect on resistance of posterior displacement of the tongue and/or soft palate in the supine position is felt to contribute in a major way to the higher resistance in supine position (13).

In the lateral decubitus position, there is likely less posterior displacement of tongue and soft tissue structures. One could thus expect less narrowing, and consequently,

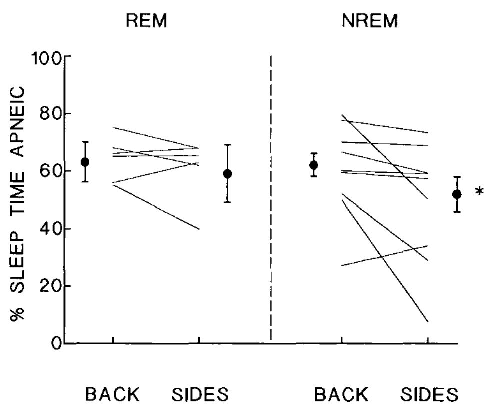


FIG. 5. Percent of sleep time spent apneic. Only in NREM is the percent of time apneic less on the side. Note that only two subjects reduced apnea time by more than 50%. $*p < 0.05$.

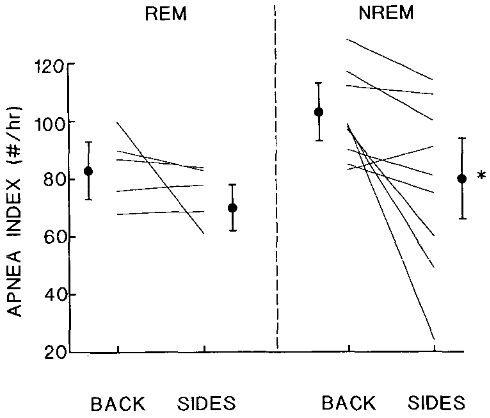


FIG. 6. Apnea index in REM and NREM by position. Index lower on the sides in NREM but not in REM. Matched data points are fewer in REM, as some patients spent no time on the back or the sides (see Fig. 1.).

less increase in upper airway resistance. Thus, one would expect the tendency for the airway to occlude would be less in the lateral decubitus position, and this may explain the reduced frequency of apneas in this position during NREM. During REM, there is further reduction in upper airway muscle tone, and this would tend to increase resistance (9). It is hypothesized that the upper airway resistance and the very low closing pressure during REM interact such that the added component due to gravitational displacement of tongue and soft tissue structures will not significantly influence the resistance and tendency for the airway to be closed. In other words, the upper airway resistance in REM is already at a level that the airway will collapse, so that adding the positional component will not increase this tendency any further. Indeed, Issa and Sullivan have shown that the pressure at which the airway closes is very small in obstructive sleep apnea (OSA) patients compared with normals and that it is smallest in REM (9). However, they showed that the closing pressure was lower on the back than

TABLE 1. *Apnea–hypopnea index by stage for various sleep positions*

| | REM | | | NREM | | |
|---|---|---|---|---|---|---|
| Study | Back | Lat | Back/Lat | Back | Lat | Back/Lat |
| 1 | —[a] | 88 | — | 112 | 109 | 114 |
| 2 | 87 | 84 | — | 117 | 111 | — |
| 3 | — | 65 | 62 | 97 | 60 | 78 |
| 4 | 66 | — | — | 83 | 91 | 75 |
| 5 | 100 | — | 91 | 114 | — | 105 |
| 6 | 99 | 61 | — | 109 | 26 | — |
| 7 | 68 | 69 | 63 | 90 | 81 | 80 |
| 8 | 76 | 78 | — | 85 | 74 | 106 |
| 9 | — | 52 | — | 98 | 49 | — |
| 10 | — | 60 | — | — | 86 | 21 |
| 11 | 90 | 83 | 73 | 130 | 116 | 114 |
| Mean | 83.6 | 71.1 | 72.3 | 103.5[b] | 80.3 | 86.6 |
| SEM | 5.3 | 4.2 | 6.7 | 4.8 | 9.2 | 10.9 |

Lat, lateral decubitus.
[a] Indicates no time or apneas in this position.
[b] Back versus Lat (NREM) $p < 0.05$.

**TABLE 2.** *Derived apnea–hypopnea index by stage assuming all positions known*

| | REM | | | | | | NREM | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Study | Back | Back1 | Back2 | Lat | Lat1 | Lat2 | Back | Back1 | Back2 | Lat | Lat1 | Lat2 |
| 1 | —[a] | — | 78 | 88 | 88 | 81 | 112 | 112 | 111 | 109 | 109 | 109 |
| 2 | 87 | 87 | 87 | 84 | 84 | 84 | 117 | 117 | 120 | 111 | 111 | 114 |
| 3 | — | 62 | 59 | 65 | 64 | 62 | 97 | 92 | 93 | 60 | 67 | 77 |
| 4 | 66 | 66 | 66 | — | — | 66 | 83 | 81 | 92 | 92 | 79 | 105 |
| 5 | 100 | 98 | 97 | — | 91 | 96 | 114 | 88 | 98 | — | 105 | 33 |
| 6 | 99 | 99 | 85 | 61 | 61 | 68 | 109 | 109 | 71 | 26 | 26 | 24 |
| 7 | 68 | 64 | 67 | 69 | 67 | 68 | 90 | 81 | 82 | 81 | 80 | 81 |
| 8 | 77 | 77 | 78 | 78 | 78 | 79 | 85 | 98 | 73 | 74 | 86 | 71 |
| 9 | — | — | 60 | 52 | 52 | 63 | 98 | 98 | 71 | 49 | 49 | 52 |
| 10 | — | — | 59 | 60 | 60 | 60 | — | 21 | 78 | 86 | 73 | 83 |
| 11 | 90 | 74 | 79 | 83 | 78 | 81 | 130 | 120 | 111 | 116 | 115 | 107 |
| Mean | 83.6 | 78.4 | 74.1 | 71.1 | 71.1 | 73.4 | 103.5[b] | 92.5 | 90.9 | 80.3 | 80.4 | 77.8 |
| SEM | 5.3 | 5.2 | 3.9 | 4.2 | 4.2 | 3.4 | 4.8 | 8.2 | 5.3 | 9.2 | 9.2 | 9.3 |

Back1, combines positions back and back/lat; Back2, combines positions back and unknown; Lat1, combines positions lat and back/lat; Lat2, combines positions lat and unknown.

There are no significant differences between any of the columns in REM.

[a] Indicates no time or apneas in this position.

[b] Back versus Lat NREM $p < 0.05$.

the lateral decubitus position in both NREM and REM. Thus, other unknown factors must be contributing to change the apnea frequently in different positions.

The fact that apnea and hypopneas were of similar duration in REM or NREM regardless of position suggests that once apneas and upper airway obstructions are established, similar mechanisms to terminate events come into play, independent of position or stage. Recently, inspiratory muscle fatigue has been suggested to trigger the opening of the upper airway (14).

It has been suggested that training patients to sleep off the back and on the sides or to physically enforce the lateral position will lead to reduction of AHI and presumably improvement in symptoms (7). From our results, we would contest this notion for a couple of reasons. First, 5 of our 7 patients had less than 25% of spontaneous sleep on

**TABLE 3.** *Average $O_2$ desaturation (%) per event*

| Study | REM | NREM |
|---|---|---|
| 1 | 33.4 | 17.2 |
| 2 | 34.5 | 12.7 |
| 3 | 34.4 | 22.1 |
| 4 | 30.1 | 17.7 |
| 5 | 15.9 | 6.8 |
| 6 | 9.3 | 7.5 |
| 7 | 15.5 | 9.5 |
| 8 | 12.9 | 9.5 |
| 9 | 16.8 | 7.0 |
| 10 | 39.1 | 21.8 |
| 11 | 46.1 | 28.8 |
| Mean | 26.2 | 14.6 |
| SEM | 3.7 | 2.2 |

TABLE 4. *Average $O_2$ desaturation (%) per event per body position*

| Study | REM | | | NREM | | |
|---|---|---|---|---|---|---|
| | Back | Lat | Back/Lat | Back | Lat | Back/Lat |
| 1 | — | 33.4 | — | 20.7 | 12.4 | 13.5 |
| 2 | 34.3 | 34.7 | — | 11.8 | 13.9 | — |
| 3 | — | 37.1 | 33.9 | 22.0 | 22.2 | 22.1 |
| 4 | 30.1 | — | — | 20.2 | 14.3 | 20.4 |
| 5 | 14.8 | — | 20.3 | 7.4 | — | 5.6 |
| 6 | 14.3 | 9.1 | — | 8.4 | 5.3 | — |
| 7 | 19.1 | 12.7 | 18.9 | 11.3 | 9.4 | 10.6 |
| 8 | 13.4 | 10.9 | — | 9.2 | 9.1 | 9.5 |
| 9 | — | 16.8 | — | 8.9 | 6.8 | — |
| 10 | — | 39.1 | — | — | 21.3 | 24.7 |
| 11 | 45.6 | 48.3 | 52.1 | 27.6 | 30.9 | 31.1 |
| Mean | 24.5 | 26.9 | 31.8 | 14.7 | 14.5 | 17.1 |
| SE | 4.7 | 4.8 | 7.8 | 2.3 | 2.5 | 3.1 |

their backs. Although we observed that four had no time on the back in REM, we must be cautious about generalizing, as, in fact, our results are based on 75% of the REM period, the remainder having an unknown position because of the limitations of our records. Only if all of the remaining sleep time with position unknown was spent on the back would the percent of either REM or NREM on the back be greater than any other position. This seems unlikely, although we admit this is a limitation in our study. Given that some patients spend little time on their back in NREM, then training to assume or enforcing the lateral decubitus position will have little impact on overall apneas. Indeed AHI on the sides was still very high despite a statistically significant reduction from the back, and only two subjects reduced their apnea time by more than 50%. Also, there will be little influence when the patient enters REM, as AHIs were not different between back and lateral decubitus positions.

It is important to point out that all of our patients were very obese and that less obese patients are more likely to show position-sensitive apneas. Cartwright has suggested that those with only minor degrees of obesity (<25% above ideal weight) are more likely to benefit by sleeping on the side. As our patients were all >25% above ideal, this may be one reason why we did not find much effect of position. Another reason is that these studies may not be comparable. Some of Cartwright's patients (1) had very low AHIs (7,5,8,10,12). Even if we exclude them, AHI for our group is still greater than her's (83.7 ± 6.4 versus 63.5 ± 7.2). It is therefore the less obese and the less severe patients that will likely benefit by sleeping on the side. However, there are undoubtedly many factors [position-induced reflexes, such as occur with nasal patency (15), size of pharynx, upper airway resistance, sleep stage] that interact to contribute to the rate of apneas. Further investigation will be necessary to unravel the interactions.

In conclusion, we have found that in obese sleep apnea patients, apneas and hypopneas occur more frequently on the back only during NREM, not during REM. Regardless of stage, once established, apneas have similar duration independent of body position. Enforcing the lateral decubitus position or training patients to sleep off the back may not be as useful as previously thought, especially in patients with severe sleep apnea who are also very obese.

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