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4 Position-dependent obstructive sleep apnea and its influence on treatment success of mandibular advancement devices

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ABSTRACT

Purpose: Depending on the severity of pre-treatment obstructive sleep apnea (OSA) and the criteria used to define treatment success, the efficacy of mandibular advancement devices (MADs) ranges from 30% to 69%. Identifying suitable candidates is the key to increasing the efficacy of a MAD. Positive predictors include a low body mass index, a low apnea-hypopnea index (AHI) and low age. Another consideration is whether a patient's OSA is position dependent. To evaluate the impact of such dependency on MAD treatment success, we studied the following: treatment success across the patient's total AHI and in the supine and non-supine sleeping positions; the influence of pre-treatment position dependency on MAD treatment success; and the impact of MAD treatment on post-treatment shifts in position dependency.

Methods: Single-center retrospective study of patients with OSA. Patients were diagnosed through an overnight polysomnography and treated with a MAD between February 2015 and January 2018. They were defined as being positional if the AHI in supine sleeping position was at least twice as high as in the non-supine position.

Results: Complete treatment success was achieved in 32.3% of study population (n=96) and partial success in 54.2%. Complete treatment success was significantly higher (p=0.004) when a patient was sleeping in the non-supine position. Treatment success did not differ significantly between patients who were position dependent and those who were not. When treated with a MAD, patients did not spend significantly more time in supine position. Neither did we find any post-treatment shifts in position dependency.

Conclusion: A MAD is an effective treatment modality that significantly reduces the total AHI, supine and non-supine AHI. Since position dependency has no impact on MAD treatment success, it does not determine whether or not a patient is a suitable candidate for MAD treatment.

Keywords: obstructive sleep apnea, sleep-disordered breathing, mandibular advancement device, treatment success, positional, position dependency

INTRODUCTION

Mandibular advancement devices (MAD) are part of the therapeutic arsenal for patients with obstructive sleep apnea (OSA), in particular in case of mild or moderate disease.

Depending on the severity of pre-treatment OSA and the criteria used to define treatment success, the efficacy of mandibular advancement devices (MADs) ranges from 30% to 69% (1-5). Identifying suitable candidates for a MAD is the key to increasing their efficacy. Positive predictors include a low body mass index, mild disease as expressed in a low apnea-hypopnea index (AHI) and younger age". Gender; cephalometric outcomes and polysomnographic (PSG) outcomes; and specific observations made during drug-induced sleep endoscopy (DISE) have also been described in the literature as predictive variables (6-12).

Another consideration is pre-treatment position dependency. Generally apneic events occur more severe and frequent when OSA patients sleep in the supine position compared to other sleeping positions (12). Various criteria exist to define position dependency. Most commonly patients are considered being positional (PP) if the AHI in supine sleeping position is twice as high as in the non-supine position. (13, 14). In non-positional patients (NPP) breathing abnormalities occur independent from sleeping position and are more severe (higher AHI) compared to PP(15).

The impact of position dependency on treatment outcome of OSA has been reported for upper airway surgery, but also a few studies on MADs have been performed reporting different outcomes and often contradict each other (2-5, 16, 17). There is room for a better understanding of the impact of this clinical phenotype on treatment success. Differences in characteristics between NPP and PP encourage further research.

Bearing this in mind and using the standardized framework (16) for research evaluating position dependency in OSA patients, we aim to evaluate a) MAD treatment success across the patient's total AHI and in the supine and non-supine sleeping positions b) the influence of pre-treatment position dependency on MAD treatment outcome, c) the impact of MAD treatment on position dependency posttreatment.

METHODS

Study participants

In this single-center retrospective study, patients with OSA were diagnosed through an overnight polysomnography (PSG) and treated with a MAD between February 2015 and January 2018. They were included if 18 years or older and if pre-treatment PSG data were available together with posttreatment PSG data with a MAD *in situ*. Patients were excluded if they spent less than 10% of their total sleeping time (TST) in either of the two positions during the pre-treatment PSG, as the measurement of respiratory indices would then be deemed less reliable. Patients were also excluded if they used a MAD as part of combination therapy for their OSA.

Definitions

Patients were identified as being PP if the AHI in supine position was at least twice as high as the non-supine position (13).

Complete MAD treatment success was achieved if the AHI post-treatment was <5 events/hr. Partial success was defined as a minimum decrease in AHI of 50% and a posttreatment AHI of less than 15 events/hr. Patients were considered non-responders if they did not meet the criteria for complete or partial treatment success

To be able to calculate post-treatment shifts in position dependency, we excluded patients from this particular analysis if they had spent less than 10% of the TST in the supine or non-supine position during the post-treatment PSG.

Ethical considerations

All procedures followed were in accordance with the ethical standards for human experimentation, and with the 1975 Declaration of Helsinki. To protect personal information, data on study subjects was encoded after collection, and then stored. Informed consent was not required for this type of study.

Statistical analysis

Statistical analysis was performed using SPSS (version 26), SPSS Inc, Chicago, IL. Quantitative data were reported as mean and standard deviation (SD), or, if not normally distributed, as median (Q1, Q3). The Kolmogorov-Smirnov Test was used to determine whether continuous variables were normally distributed. A p-value of < 0.05 was considered to indicate statistical significance. To compare baseline characteristics between NPP and PP, the unpaired t-test was used if data was normally distributed, and the Mann-Whitney U test if it was not normally distributed. A Pearson's chi-squared test was used to determine whether position dependency and MAD treatment success were correlated. If data was normally distributed, a paired *t*-test was used to compare values prior to MAD treatment and with MAD *in situ*. If data was not normally distributed, a Wilcoxon signed rank test was used. To compare differences in MAD treatment success between groups, an unpaired *t*-test was used if the data was normally distributed, or the Mann-Whitney U test if it was not.

RESULTS

Baseline characteristics

In total, 124 patients were prescribed a MAD between February 2015 and January 2018. Twenty-eight patients were excluded from analysis due to a TST less than 10% in the supine or non-supine position based on the PSG results prior to MAD treatment. Nighty-six patients were included in the study.

Sixty-nine patients were male (71.9%), the mean age was 55.0 ± 10.4 years, the mean BMI was 27.4 ± 3.8 kg/m2. Prior to MAD treatment, patients had a median AHI of 21.5 events/hr (16.8; 27.3), a median supine AHI of 39.1 events/hr (23.8; 52.2) and a median non-supine AHI of 11.8 events/hr (6.4; 20.0). The TST in the supine position was 32.7% (23.1; 46.1).

Baseline characteristics comparing positional and non-positional patients

Sixty-seven percent of all patients were PP. Gender, BMI, total AHI, time spent in supine position (TST) and ODI did not significantly differ when comparing PP to NPP. Mean age (p= 0.016), the total AI (p= 0.026) and the AHI in supine position ($p<0.001$) were significantly higher in PP. The non-supine AHI ($p<0.001$) was significantly lower in PP. Baseline characteristics are shown in table 1.

Table 1. Baseline characteristics of the total population, the positional patients (PP) and the non-positional patients (NPP)

	Total population	PP	NPP	p value
Number of patients (N)	96	64	32	-
Sex (male:female)	69:27	48:16	21:11	0.336
Age (years)	55.0 ± 10.4	56.7 ± 9.8	51.4 ± 10.6	0.016*
BMI (kg/m^2)	27.4 ± 3.8	27.3 ± 3.4	27.6 ± 4.7	0.752
Total AI (events/hr)	10.4 [4.0; 15.6]	11.6 [4.8; 16.6]	5.6 [2.7; 11.9]	0.026*
Total AHI (events/hr)	21.5 [16.8; 27.3]	22.4 [17.3; 26.4]	18.9 [13.2;31.7]	0.608
Supine AHI (events/hr)	39.1 [23.8; 52.2]	42.6 [29.7; 58.9]	24.0 [13.5;44.2]	<0.001*
Non-supine AHI (events/hr)	11.8 [6.4; 20.0]	10.1 [3.5; 18.1]	17.8 [10.9; 26.7]	<0.001*
% of TST in the supine position	32.7 [23.1;46.1]	35.4 [24.8; 46.6]	30.9 [20.0; 45.9]	0.563
ODI (3%, events/hr)	22.0 [15.9;31.3]	23.3 [15.3; 31.1]	21.3 [17.1; 35.7]	0.709

Data presented as mean ± standard deviation or median [Q1, Q3]
* p value <0.05 comparing PP and NPP
AI apnea index, *AHI* apnea-hypopnea index, *BMI* body mass index, *NPP* non-positional patients, *PP* positional patients, *ODI* oxygen desaturation index, *TST* total sleeping time

Respiratory parameters pre-treatment and posttreatment

In the total study population, the median AI and AHI were both significantly reduced from 10.4 [4.0; 15.6] to 1.4 [0.5; 4.3] events/hr and 21.5 [16.8; 27.3] to 8.7 [4.1; 16.6] events/hr ($p<0.001$), respectively. In the supine position the AHI decreased from 39.1 [23.8; 52.2] to 13.4 [4.7; 27.9] events/hr, and in the non-supine position the AHI decreased from 11.8 [6.4; 20.0] to 5.4 [1.6; 10.2] events/hr, both reductions were significant. The ODI decreased significantly from 22.0 [15.9; 31.2] to 13.4 [6.5; 22.6] events/hr. **Table 2.** provides an overview of pre-treatment and posttreatment respiratory parameters.

Table 2. Pre-treatment and posttreatment PSG results (total population)

Total population (N=96)	Pre-treatment	Posttreatment	p value
BMI (kg/m²)	27.4 ± 3.8	27.7 ± 4.0	0.336
Total AI (events/hr)	10.4 [4.0; 15.6]	1.4 [0.5; 4.3]	<0.001*
Total AHI (events/hr)	21.5 [16.8; 27.3]	8.7 [4.1; 16.6]	<0.001*
Supine AHI (events/hr)	39.1 [23.8; 52.2]	13.4 [4.7; 27.9]	<0.001*
Non-supine AHI (events/hr)	11.8 [6.4; 20.0]	5.4 [1.6; 10.2]	<0.001*
% of TST in supine position	32.7 [23.1;46.1]	38.4 [16.4; 55.7]	0.695
ODI (events/hr)	22.0 [15.9;31.3]	13.4 [6.5; 22.6]	<0.001*

Data presented as mean ± standard deviation or median [Q1, Q3]
* p value <0.05 comparing pre- and posttreatment outcomes
AI apnea index, *AHI* apnea-hypopnea index, *BMI* body mass index, *ODI* oxygen desaturation index, *TST* total sleeping time

Comparable outcomes were found when evaluating the same parameters individually for NPP and PP. In both subgroups the total AI, total AHI, supine AHI, non-supine AHI and ODI decreased significantly. There was a significantly greater reduction of the total AI and supine AHI in PP, whilst in NPP this was only the case for the non-supine AHI. No other significant differences between PP and NPP were found. A detailed overview can be found in **table 3.**

Table 3. Comparison of pre-treatment and posttreatment PSG results for the positional patients (PP) and non-positional patients (NPP)

	PP (N=64)				NPP (N=32)				NPP vs PP
	Pre-treatment	Post-treatment	Δ	p value	Pre-treatment	Post-treatment	Δ	p value	p value
BMI (kg/m²)	27.3 ± 3.4	27.6 ± 3.9	-0.3 [-0.9; 0.6]	0.385	27.6 ± 4.7	27.8 ± 4.4	-0.2 [-0.9; 0.9]	0.690	0.761
Total AI (events/hr)	11.6 [4.8; 16.6]	1.4 [0.5; 3.4]	7.8 [3.4; 14.0]	<0.001*	5.6 [2.7; 11.9]	1.9 [0.3; 16.3]	3.0 [0.5; 7.9]	0.002*	0.004*
Total AHI (events/hr)	22.4 [17.3; 26.4]	8.6 [4.1; 17.0]	11.6 [4.3; 18.0]	<0.001*	18.9 [13.2;31.7]	9.2 [4.1; 16.3]	9.1 [2.8; 21.9]	0.001*	0.649
Supine AHI (events/hr)	42.6 [29.7; 58.9]	14.0 [5.3; 29.2]	24.4 [9.7; 35.6]	<0.001*	24.0 [13.5;44.2]	10.0 [2.5; 27.7]	8.3 [-2.8; 23.6]	0.040*	0.002*
Non-supine AHI (events/hr)	10.1 [3.5; 18.1]	4.8 [1.3; 9.4]	2.3 [-0.6; 9.7]	0.001*	17.8 [10.9; 26.7]	7.9 [2.8; 12.6]	10.5 [2.8; 18.9]	<0.001*	0.002*
% of TST in supine position	35.4 [24.8; 46.6]	42.2 [23.5; 57.5]	-5.2 [-18.0; 9.3]	0.116	30.9 [20.0; 45.9]	25.4 [6.9; 51.2]	5.9 [-17.0; 25.3]	0.204	0.065
ODI (events/hr)	23.3 [15.3; 31.1]	12.2 [6.7; 22.6]	6.9 [0.2; 18.0]	<0.001*	21.3 [17.1; 35.7]	14.0 [6.2; 22.7]	5.9 [1.5; 16.7]	0.002*	0.984

Data presented as mean ± standard deviation or median [Q1, Q3]
* p value <0.05 comparing preoperative and postoperative PSG values
** p value <0.05 comparing Δ (preoperative and postoperative change) in PP and NPP
AI apnea index, *AHI* apnea-hypopnea index, *BMI* body mass index, *NPP* non-positional patients, *ODI* oxygen desaturation index, *PP* positional patients, *PSG* polysomnography, , *TST* total sleeping time

Treatment success of the total AHI, the AHI in supine and in non-supine sleeping positions, and the influence of position dependency

Total AHI

Complete MAD treatment success based on the total AHI was achieved in 31 out of 96 patients (32.3%); 52 patients (54.2%) had a partial treatment success. In NPP, MAD treatment was completely successful in 11 (34.4%) and partially successful in 16 (50.0%) out of 32 patients. In PP 20 (31.0%) had complete and 36 (56.3%) had partial treatment success out of 64 patients had. No significant difference was found in complete or partial treatment success of the total AHI when comparing NPP to PP (p=0.758 and 0.562).

AHI in supine position

Criteria for complete success of a MAD regarding AHI in patients in the supine position were met in 24 patients (26.4%). Although the complete treatment success rate was slightly higher for NPP (31%) than for PP (24.2%), this difference was not statistically significant (p=0.490).

AHI in non-supine position

Criteria for complete success regarding AHI in patients in the non-supine AHI were met in 47 patients (49.0%), specifically in 13 NPP (40.6%) and in 34 PP (53.1%) [not statistically significant (p=0.248)]. **Table 4** provides an overview of the percentages in complete and partial MAD treatment success.

Significantly more complete treatment success was found when patients were sleeping in the non-supine position the total group (p=0.004) and in PP (p=0.017). In the group of NPP more partial treatment success was found when patients were sleeping in de non-supine position than when in supine position (p=0.040). For PP there was no significant difference in partial success regarding supine or non-supine position.

No significant differences were found in baseline age, AHI and changes in TST comparing responders to non-responders. We found a significantly lower BMI in responders to MAD treatment. See also **table 5**.

Table 4. Treatment success for the total AHI and the AHI in supine and non-supine position in the total population and comparing positional patients (PP) and non-positional patients (NPP)

MAD complete treatment success	Total (n=96)	PP (n=64)	NPP (n=32)	p-value
Total AHI (events/hr)	31 (32,3%)	20 (31,3%)	11 (34,4%)	0.758
Supine AHI[†] (events/hr)	24 (26,4%)	15 (24,2%)	9 (31,0%)	0.490
Non-supine AHI (events/hr)	47 (49,0%)	34 (53,1%)	13 (40,6%)	0.248
p-value	0,004**	0,017**	0,064	
MAD partial treatment success	**Total (n=96)**	**PP (n=64)**	**NPP (n=32)**	**p-value**
Total AHI (events/hr)	52 (54,2%)	36 (56,3%)	16 (50,0%)	0.562
Supine AHI[†] (events/hr)	46 (50,5%)	32 (51,6%)	14 (48,3%)	0.767
Non-supine AHI (events/hr)	47 (49,0%)	29 (45,3%)	18 (56,3%)	0.312
p-value	0,090	0,070	0,040**	

Data presented as number of patients (%)
* p value <0.05 comparing NPP and PP
** p value <0.05 comparing supine AHI and non-supine AHI
[†] 5 patients did not sleep in supine position during the 2nd PSG
AHI apnea-hypopnea index, MAD mandibular advancement device, *NPP* non-positional patients, *PP* positional patients

Table 5. Differences in potential predictors for responders and non-responders

	Responders (n=56)	Non-responders (n=40)	p-value
Age	54.0 ± 9.6	56.4 ± 11.3	0.265
BMI (kg/m²)	26.6 ± 3.4	28.6 ± 4.2	0.009*
AHI (events/hr)	21.5 [17.4; 26.9]	21.4 [15.8; 29.4]	0.976
ΔTST	4.0 [-13.9; 18.2]	-6.6 [-20.4; 8.5]	0.127

Data presented as mean ± standard deviation or median [Q1, Q3]
* p value <0.05 comparing responders and non-responders
AHI apnea-hypopnea index, *BMI* body mass index, *ΔTST* change in percentage of total sleeping time in supine position

Post-treatment changes in total sleeping time in supine position

Post-treatment NPP spent less time in supine position compared to pre-treatment PSG, PP spent more time in supine position, both findings were not significant. Also, the difference between these groups was not significant (Table 3). ‘’To determine if an increase in TST in supine position caused a negative treatment outcome, the change in TST in supine position was compared for responders versus non-responders. Although not statistically significant, post-treatment non-responders spent more time in supine position (difference of TST -6.6) than pre-treatment, whilst responders spent less time in supine position (difference of TST 4.0) **(table 5)**.

Post-treatment shifts in position dependency

When excluding patients (n=24), who spent less than 10% of the TST in the supine or non-supine position during the post-treatment PSG with MAD *in situ,* 53 patients (73.6%) had a persistent AHI ≥ 5 (events/hr) with MAD. Out of the 21 NPP prior to MAD treatment 6 (28.6%) had complete treatment success, 8 remained NPP and 7 became PP. For PP complete success was achieved in 13 (25.5%) patients. In this group 24 patients remained PP and 13 patients shifted to NPP.

DISCUSSION

This study confirms that MAD therapy is often effective for treating OSA. Complete treatment success was achieved in 32.3%; partial success in 54.2%. Complete treatment success was higher in the non-supine sleeping position than when patients slept on their back. Treatment success did not differ significantly between non-positional patients and positional patients. When treated with MAD, patients did not spend significantly more time in supine position. Neither were any post-treatment shifts in position dependency found.

Similar results to ours were found in two previously published studies that used the same criteria to define treatment success. Sutherland et al. found complete success in 37% of patients and partial success in 52%; Dieltjens found complete success in 39% and partial success in 60% (2, 5).

In contrast to our findings, several studies did find differences in treatment success between NPP and PP. Two studies by Lee et al. and Chung et al. (3, 4) reported a greater success in PP, while Sutherland et al. found a better treatment outcome in NPP(2). A possible explanation for these differences could be the great difference in mean baseline AHI between NPP and PP in these studies. Dieltjens et al. (5) found no difference in treatment success between NPP and PP, which is in line with our results.

More complete treatment success was achieved in non-supine position as compared to supine position, both in PP and NPP; although the difference was only statistically significant for PP. Sutherland et al. also found the same difference in decrease of effect in NPP, but not in PP. Vonk et al. (17), who studied treatment success and position dependency after maxillomandibular advancement, found that, due to a greater reduction of the AHI in the non-supine position than in the supine position, the group of non-responders shifted from severe NPP to less severe PP. They also found no significant difference in treatment success between PP and NPP. In general, when OSA severity decreases due to treatment, the percentage of POSA increases (12, 14). In our population, the majority (66.7%) was already positional prior to MAD treatment. Post-treatment the majority of patients remained PP, but we did not find a significant effect on therapy success.

The supine position is for many patients the preferred sleeping position. In case of OSA this is the position in which the apneic events are the most severe. Bearing this in mind we hypothesized that when (adequately) treated, patients might shift to more supine position, which would negatively influence their treatment outcome because of the higher number of apneic events in the supine position. However, although the responders spent less time and the non-responders more time in supine position, these outcomes were not significant.

Limitations

There are some limitations to take into consideration when interpreting these results. Due to its retrospective design no detailed information on MAD titration was available. Since we only included patients who also had a post-treatment PSG, we might be missing patients who were displeased with the treatment due to insufficient effect or adverse events. On the other hand, we may be missing patients who were pleased with their MAD and deemed a post-treatment PSG unnecessary. Due to the retrospective nature of this study the time of the duration until the follow-up PSG varied greatly. According to the current Dutch OSA treatment guidelines, patients with an AHI > 15 events/hr are recommended to undergo a post-treatment PSG. Therefore, fewer cases with mild OSA are included and the mean baseline AHI in our population is higher.

Clinical relevance

Since we found that position dependency is not negatively related to MAD treatment outcome, we see no reason to reject either NPP or PP as suitable candidates for

MAD. Dieltjens et al. (5) concluded the same. In this study 31 non-responders were PP, and adding PT could be of added value in this group. Other studies showed that patients with a total AHI of 1.4 times higher than non-supine were most likely to demonstrate an important reduction in AHI by using PT (10, 18).

CONCLUSION

MAD is an effective treatment modality for significantly reducing the total AHI, supine and non-supine AHI and ODI. Since position dependency has no impact on MAD treatment success, positional and non-positional patients are both suitable candidates for MAD treatment.

REFERENCES

1. Sher AE, Schechtman KB, Piccirillo JF. The efficacy of surgical modifications of the upper airway in adults with obstructive sleep apnea syndrome. Sleep. 1996;19(2):156-77.
2. Sutherland K, Takaya H, Qian J, Petocz P, Ng AT, Cistulli PA. Oral Appliance Treatment Response and Polysomnographic Phenotypes of Obstructive Sleep Apnea. Journal of clinical sleep medicine : JCSM : official publication of the American Academy of Sleep Medicine. 2015;11(8):861-8.
3. Lee CH, Jung HJ, Lee WH, Rhee CS, Yoon IY, Yun PY, et al. The effect of positional dependency on outcomes of treatment with a mandibular advancement device. Archives of otolaryngology--head & neck surgery. 2012;138(5):479-83.
4. Chung JW, Enciso R, Levendowski DJ, Morgan TD, Westbrook PR, Clark GT. Treatment outcomes of mandibular advancement devices in positional and nonpositional OSA patients. Oral surgery, oral medicine, oral pathology, oral radiology, and endodontics. 2010;109(5):724-31.
5. Dieltjens M, Braem MJ, Van de Heyning PH, Wouters K, Vanderveken OM. Prevalence and clinical significance of supine-dependent obstructive sleep apnea in patients using oral appliance therapy. Journal of clinical sleep medicine : JCSM : official publication of the American Academy of Sleep Medicine. 2014;10(9):959-64.
6. Vonk PE, Uniken Venema JAM, Hoekema A, Ravesloot MJL, van de Velde-Muusers JA, de Vries N. Jaw Thrust Versus the Use of a Boil-And-Bite Mandibular Advancement Device as a Screening Tool During Drug-Induced Sleep Endoscopy. Journal of clinical sleep medicine : JCSM : official publication of the American Academy of Sleep Medicine. 2020.
7. Rotenberg BW, Vicini C, Pang EB, Pang KP. Reconsidering first-line treatment for obstructive sleep apnea: a systematic review of the literature. Journal of otolaryngology - head & neck surgery = Le Journal d’oto-rhino-laryngologie et de chirurgie cervico-faciale. 2016;45:23.
8. Ravesloot MJ, de Vries N. Reliable calculation of the efficacy of non-surgical and surgical treatment of obstructive sleep apnea revisited. Sleep. 2011;34(1):105-10.
9. Al-Terki A, Abu-Farha M, AlKhairi I, Cherian PT, Sriraman D, Shyamsundar A, et al. Increased Level of Angiopoietin Like Proteins 4 and 8 in People With Sleep Apnea. Front Endocrinol (Lausanne). 2018;9:651.
10. Levendowski DJ, Oksenberg A, Vicini C, Penzel T, Levi M, Westbrook PR. A systematic comparison of factors that could impact treatment recommendations for patients with Positional Obstructive Sleep Apnea (POSA). Sleep medicine. 2018;50:145-51.
11. Oksenberg A, Gadoth N, Töyr™s J, Lepp™nen T. Prevalence and characteristics of positional obstructive sleep apnea (POSA) in patients with severe OSA. Sleep and Breathing. 2019:1-9.
12. Oksenberg A, Khamaysi I, Silverberg DS, Tarasiuk A. Association of body position with severity of apneic events in patients with severe nonpositional obstructive sleep apnea. Chest. 2000;118(4):1018-24.
13. Cartwright RD. Effect of sleep position on sleep apnea severity. Sleep. 1984;7(2):110-4.
14. Mador MJ, Kufel TJ, Magalang UJ, Rajesh SK, Watwe V, Grant BJ. Prevalence of positional sleep apnea in patients undergoing polysomnography. Chest. 2005;128(4):2130-7.

15. Itasaka Y, Miyazaki S, Ishikawa K, Togawa K. The influence of sleep position and obesity on sleep apnea. Psychiatry and clinical neurosciences. 2000;54(3):340-1.
16. Ravesloot MJL, Vonk PE, Maurer JT, Oksenberg A, de Vries N. Standardized framework to report on the role of sleeping position in sleep apnea patients. Sleep & breathing = Schlaf & Atmung. 2021.
17. Vonk PE. The role of drug-induced sleep endoscopy and position-dependency in the diagnostic work-up of obstructive sleep apnea2020.
18. Joosten SA, O'Donoghue FJ, Rochford PD, Barnes M, Hamza K, Churchward TJ, et al. Night-to-night repeatability of supine-related obstructive sleep apnea. Annals of the American Thoracic Society. 2014;11(5):761-9.