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ORIGINAL ARTICLE

Obstructive sleep apnoea and non-restorative sleep induced by the interface

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Abstract
Background There are only few data about the influence of interfaces on restorative sleep and required CPAP/APAP levels in patients with obstructive sleep apnoea (OSA). Observations of obstructive apnoeas when using oro-nasal masks with normalisation of respiratory disturbance index (RDI) under nasal masks and of non-restorative sleep under oro-nasal masks in spite of normal RDI led to a registration of patients with such findings.
Methods This study is a cohort analysis (June 1, 2006 to April 30, 2014) of patients with OSA using an oro-nasal mask and normalisation of the RDI after changing to a nasal mask and of patients complaining about a non-restorative sleep under an oro-nasal mask despite normal RDI.
Results Sixty-five patients (BMI 32.2±8.1 kg/m^2; 64.4±12.8 years) with OSA (n=54) and non-restorative sleep with normal RDI (n=11) under oro-nasal masks were included. In the group of patients with pathologic RDI under oro-nasal masks (n=54), switching the interface to a nasal mask normalised RDI (31.8±16.3 to 6.0±3.6/h [p<0.001]) and arousal index (p<0.001); slow-wave and REM sleep increased (p<0.05). In the patient group with a pathological RDI under CPAP/APAP therapy (n=45), the pressure decreased from 9.5±2.2 to 7.3±2.0 cm hPa (p<0.001), and in the group with normal RDI (n=11) from 10.1±2.4 to 6.8±1.2 hPa (p<0.01).
Conclusion The usage of an oro-nasal mask can result in a paradoxical induction of obstructive hypopnoeas or apnoeas. Clinicians should be aware of this phenomenon. When adapting patients to a PAP therapy, a nasal mask should be preferred even if patients report mouth breathing.

Keywords Obstructive sleep apnoea · Nasal mask · Full-face mask · Oro-nasal mask · CPAP therapy · Non-restorative sleep

Introduction

The adherence to CPAP therapy in addition to an optimal pressure setting is crucial for long-term therapeutic effects. Discontinuation rates of CPAP therapy of about 20–25 % [1, 2] require a detailed analysis of the underlying causes, especially the influence of the type of mask has to be considered.

In clinical practice, nasal masks are mainly preferred in 62.4 % of patients [3]. There are only few data about the influence of an interface on the CPAP setting and adherence. According to a Cochrane analysis of four studies from 2006 [4], there was no difference between different mask types with respect to apnoea hypopnoea index (AHI), Epworth Sleepiness Scale (ESS) or quality of life. However, the analysis included studies with a comparison of nasal and mouth masks [5, 6] and of a nasal mask and nasal pillows [7] and only one study with a comparison of a nasal mask and an oro-nasal mask [8]. Although these studies pointed out a preference of the nasal mask, the authors conclude that it remains unclear what is the optimal interface.

In contrast to this, Borel et al. [3] reported higher pressure requirements, significantly higher leakage and more side effects under long-term use of an oro-nasal mask. The induction, respectively, facilitation of obstructive apnoeas by an oro-

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nasal mask has not been studied in more detail. Only in a recent study of 14 patients did Ebben et al. [9] find that using an oro-nasal mask resulted in a higher residual AHI and a need for pressure adjustments compared to a nasal mask.

In clinical practice, we repeatedly observed that patients with obstructive sleep-related breathing disorder and pathological respiratory disturbance index (RDI) under a full-face mask (resp. oro-nasal mask) experienced a normalisation of RDI and needed lower CPAP levels by switching to a nasal mask. On the other hand, we found that patients developed further obstructive events with an increase of RDI even under higher therapeutic pressure settings when switching from a nasal to an oro-nasal mask. And we saw patients who had a normal RDI under the use of an oro-nasal mask but complained about persistent daytime symptoms. After changing the interface to a nasal mask, they reported a marked clinical benefit and needed lower therapeutic pressures despite a normal RDI. In order to assess such events, the frequency of non-restorative sleep under an oro-nasal mask despite normal RDI and the possible clinical relevance, we started a systematic recording and evaluation of such cases.

Methods

Study design

From June 1, 2006 to April 30, 2014, patients with the following characteristics were systematically recorded: (1) patients referred to our sleep centre with obstructive sleep apnoea (RDI≥15/h) using an oro-nasal (full-face) mask and normalisation of the RDI after changing to a nasal mask, (2) patients with a previously normal RDI under a nasal mask who wished to switch the interface to an oro-nasal mask and developed a subsequent pathological increase in RDI (RDI≥15/h), and (3) patients referred to us complaining about a non-restorative sleep under an oro-nasal mask despite an apparently well-treated obstructive sleep apnoea (RDI<10/h).

Polysomnography

Attended polysomnography was performed with the Alice 3.5® and Alice 6.0® system (Respironics®) recording body position, eye and leg movements, nasal and oral airflow, chest and abdominal effort, cardiotocography and arterial oxyhaemoglobin saturation. Sleep stages and arousals were analysed according to the criteria of Rechtschaffen and Kales [10] and the American Sleep Disorders Association [11]. The apnoea and hypopnoea definition was maintained over the whole period. A central apnoea was defined as an absence of airflow for ≥10 s associated with an absence of chest and abdominal movement; obstructive apnoea was defined as an absence of respiratory flow for ≥10 s despite ongoing respiratory effort. Hypopnoea was defined as a reduction in airflow of at least 50 % compared with baseline for ≥10 s or a <50 % amplitude reduction associated with either an oxygen desaturation of >3 % or an arousal [12, 13]. An RERA was defined as an event with decreasing effort or flattening and a duration ≥10 s, leading to an arousal, but not meeting the criteria of hypopnoea or apnoea. The RDI was defined as the total number of apnoeas, hypopnoeas and RERAs based on the total sleep time and expressed as number of events per hour. Patients referred to the sleep centre with ongoing complaints and/or a pathologic RDI under an initiated therapy spent the first night with their device, the actual pressure settings and the oro-nasal mask. In the second night, they were switched to a nasal mask and had an optimization of their therapy or even a new titration. Decisions about switching the therapy mode and pressure settings also considered the results of the former polysomnographies in external sleep laboratories. Patients with a normal RDI under a nasal mask who wished an oro-nasal mask had polysomnographies with each interface. CPAP resp. APAP therapy and adaptive servo-ventilation were applied using a standardised protocol [12, 13] and a nasal mask as first choice in our sleep centre.

Statistical analysis

The results were statistically analysed (SPSS, version 16.0; SPSS, Inc., Chicago, IL, USA). The data are shown as means with standard deviation. To assess differences in the number of respiratory events, CPAP pressures, oxygen saturation and polysomnographic measures of sleep quality between the treatment with an oro-nasal mask and the treatment with a nasal mask, the corresponding values were tested for normal distribution. A repeated measures analysis of variance (ANOVA) was carried out with post hoc contrast using *t* tests. A two-sided *p* value of less than 0.05 was considered to indicate statistical significance.

Results

From June 1, 2006 to April 30, 2014, 65 patients (BMI 32.2±8.12 kg/m^2; 64.4±12.8 years) with residual obstructive sleep apnoea and/or non-restorative sleep under oro-nasal mask despite a normal RDI could be evaluated. Four of these were women (62.5±5.1 years; BMI 32.3±9.3 kg/m^2) and 61 men (64.6±13.2 years; BMI 31.9±5.9 kg/m^2). Fifty-five patients were assigned externally due to problems with their therapy. Out of 4204 patients of our sleep laboratory, who had a newly diagnosed sleep apnoea and initiation of CPAP, APAP or adaptive servo-ventilation, 10 patients wished another therapeutic trial with an oro-nasal mask and exhibited significant

obstructive events. In the same period, 170 patients of the 4204 patients were fitted to an oro-nasal mask without developing upper airway obstructions. The main complaints under the oro-nasal (full-face) mask were daytime fatigue, sleepiness (mean ESS from 12), uncomfortable pressure, treatment intolerance, poor sleep as well as abdominal distension or dry mouth. In Table 1, the patients are listed according to their therapy under oro-nasal mask and the definite therapy under nasal mask at discharge.

Effect of switching from an oro-nasal to a nasal mask on RDI, arousal index, sleep stages, oxygen saturation and pressure settings

In the cohort of patients with abnormal RDI under an oro-nasal mask (n=54), changing an oro-nasal to a nasal mask resulted in a significant decrease in RDI and the arousal index associated with a significant increase in the lowest oxygen saturation and a significant improvement in the sleep structure as well as pressure reduction (Fig. 1).

In the subgroup of patients with normal RDI of 4.2/h (n=11) under oro-nasal mask, but complaining about subjective symptoms under their current therapy, a change of interface did not lead to a noticeable change in sleep parameters and oxygen saturation, but a significant pressure reduction from 10.1±2.4 to 6.8±1.2 hPa (p<0.001) in a mean (Fig. 2). For patients with bilevel and trilevel therapy as well as adaptive servo-ventilation, the expiratory pressures (mean or fixed) were chosen for calculation.

Table 1 Treatment method under oro-nasal and nasal mask, broken down by group of patients with abnormal and normal RDI under the use of an oro-nasal mask

Therapy under oro-nasal mask/therapy under nasal mask		
	Pathologic RDI (n)	54
APAP/APAP	24	
APAP/CPAP	2	
CPAP/CPAP	8	
CPAP/APAP	11	
ASV/ASV	1	
ASV/APAP	2	
Bilevel/APAP	3	
Bilevel/bilevel	3	
	Normal RDI (n)	11
APAP/APAP	4	
APAP/CPAP	2	
CPAP/CPAP	2	
ASV/APAP	2	
Bilevel/CPAP	1	

Effect of mask type on the different therapeutic devices and pressure settings

The influence of a change of the interface on the therapeutic pressure depends on the treatment modality which was applied under the different masks.

Patients with CPAP or APAP therapy

In patients with CPAP or APAP therapy and an abnormal RDI under an oro-nasal mask who had a further optimization of CPAP or APAP therapy after switching to a nasal mask (n=45), the definitive CPAP levels and the mean APAP levels were chosen for a comparison of the groups. There was a significant decline in the treatment pressure from 9.5±2.2 to 7.3±2.0 hPa (p<0.001) associated with an improvement in the sleep structure, an increase in minimum SaO_2 and a normalisation of the RDI (Fig. 2). The results only of the patients with APAP therapy under oro-nasal and nasal mask (n=24) are shown in Fig. 3. Patients of the subgroup with CPAP therapy using an oro-nasal mask and APAP therapy using a nasal mask (n=11) had a significant reduction of mean therapeutic pressures, RDI and arousal index and an increase in slow-wave sleep (Fig. 4).

The subgroup of eight patients with fixed CPAP and a change of the interface (five patients with maintaining fixed CPAP level, three patients with a new pressure titration of fixed CPAP) showed a normalisation of the RDI from 31.0±9.8 to 4.5±3.3/h and of the arousal index from 34.8±5.3 to 17.9±2.9/h, associated with a significant increase in minimum SaO_2 (81.6±9.3 to 87.9±2.6 %), but without a change in sleep stage distribution (Fig. 5).

Patients with adaptive servo-ventilation

All five patients, including the two patients with a normal RDI, complained about persistent daytime symptoms or an intolerance of pressure. Four out of them had a variable EPAP. Three patients had a pathological RDI of 36.8/h in a mean, which was reduced to 9.4/h, after changing the interface and the therapy. Four patients with ASV and a variable EPAP could be treated with APAP therapy alone. Furthermore, the mean pressure decreased to 7.7 hPa after the EPAP had been 12 hPa in a mean under adaptive servo-ventilation.

Patients with bilevel therapy

Four out of seven patients with bilevel therapy and pathological RDI (20.4±16.6/h) could be switched to APAP therapy with normalisation of the RDI (5.4±3.8/h). The initial mean inspiratory pressure under bilevel therapy was 18 hPa, the mean EPAP 11 hPa. Under APAP therapy with a nasal mask, the mean pressure was 6.0±1.5 hPa. The reasons for applying the bilevel therapy in the referring sleep labs had been a

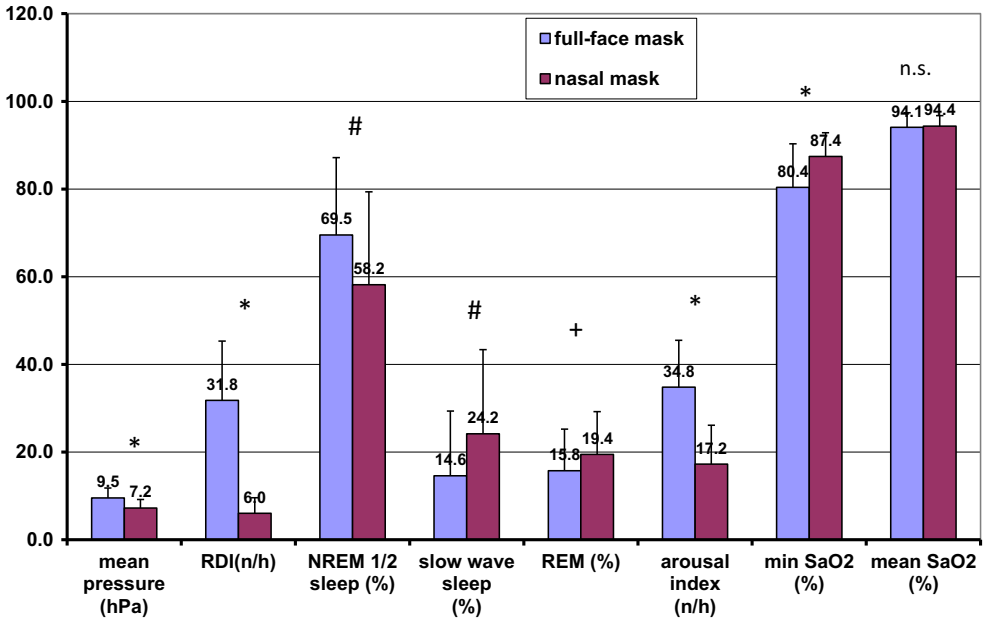

Fig. 1 Effect of mask supply on therapeutic pressure, RDI, sleep stages, arousal index and SaO_2 in patients with abnormal RDI using an oro-nasal mask (n=54). *p<0.001, #p<0.01, +p<0.05, *n.s.* not significant

residual sleep apnoea with mainly mixed and central apnoeas under CPAP therapy with an oro-nasal mask.

In two patients with an overlap syndrome of OSAS and COPD or OHS and another patient with OSAS, bilevel therapy was maintained. In all patients, a significant decrease of the RDI from initially 30.5±22.8 to 6.9±6.2/h was achieved. The initial EPAP pressure of 7 hPa in both patients with concomitant ventilatory failure remained unchanged, whereas the therapeutic pressure of the patient with mere OSA could be reduced from 17/12 to 10/7 hPa.

Another patient who used a device with variable EPAP and IPAP (so-called trilevel system) and complained about persisting daytime sleepiness and insomnia despite a nearly normalised RDI (12/h) experienced a normalisation of the RDI (4.4/h) and arousal index, paralleled with a reduction of the mean therapeutic pressure from 10 to 8 hPa by switching to an APAP therapy with a nasal mask.

Discussion

Recording daily clinical practice in a large group of patients, we could show that in patients with sleep apnoea, the use of a full-face mask can lead to a persistence or even increase of

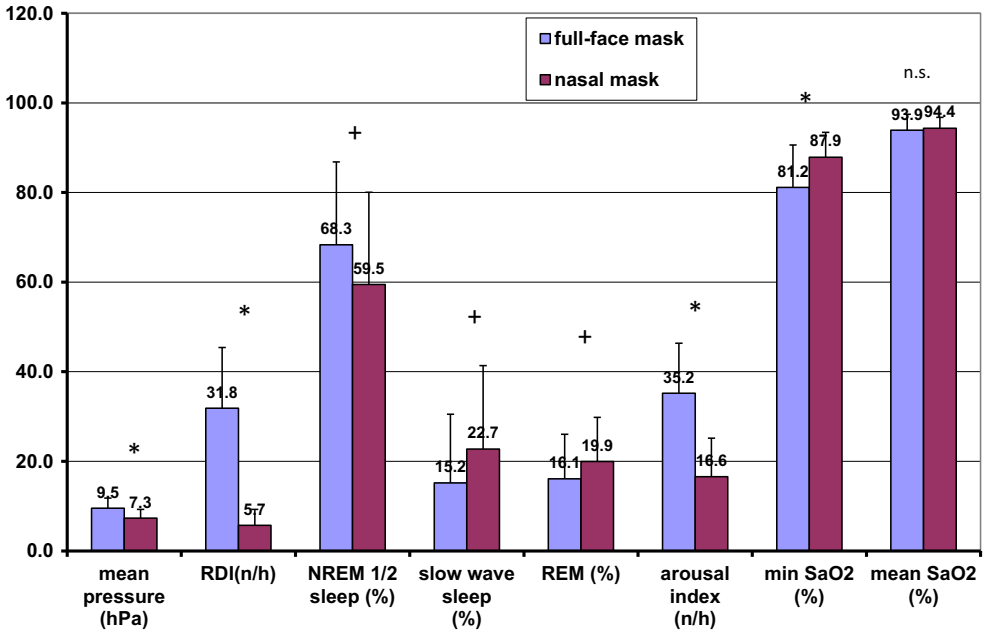

Fig. 2 Influence of changing the interface on therapeutic pressure, RDI, sleep stages, arousal index and SaO_2 in the subgroup of patients with pathological RDI under fixed CPAP or APAP therapy using an oro-nasal mask (n=45). *p<0.001, #p<0.01, +p<0.05, *n.s.* not significant

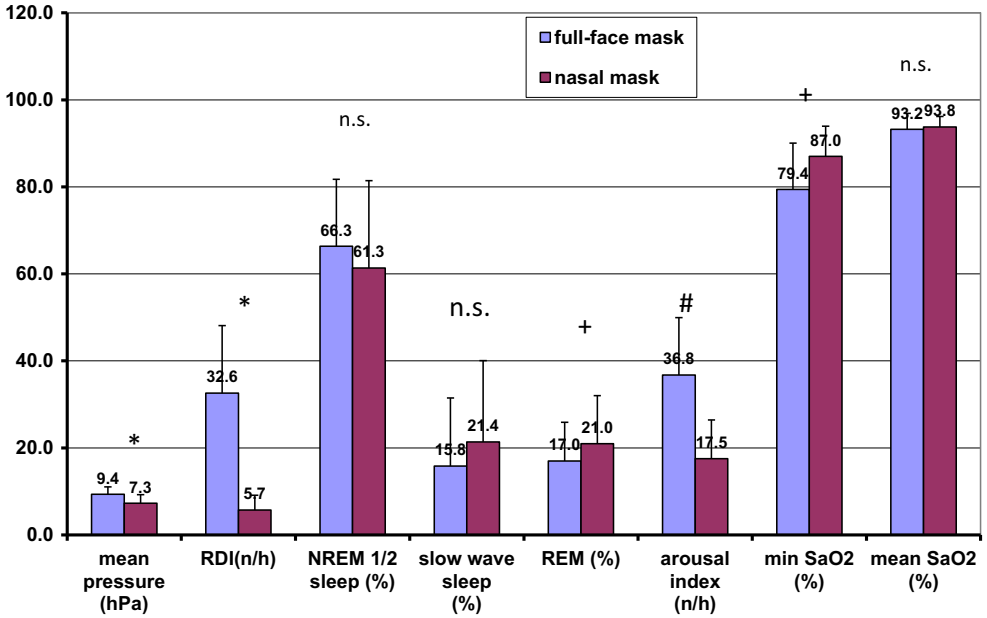

Fig. 3 Influence of changing the interface on therapeutic pressure, RDI, sleep stages, arousal index and SaO_2 in the subgroup of patients with pathological RDI under APAP using an oro-nasal mask and maintaining APAP therapy under a nasal mask (n=24). *p<0.001, $^{\#}p$<0.01, ^{+}p<0.05, *n.s.* not significant

obstructive events. In fact, changing the interface from a nasal mask to a full-face mask can induce an upper airway obstruction accompanied by clinical symptoms. In most of the patients referred to us, we saw that instead of changing the interface to a nasal mask, the persistence of an elevated RDI had even resulted in a change of the therapeutic device to a bilevel or an adaptive servo-ventilation, or even an auto-adaptive trilevel system, which remained ineffective and especially in auto-adaptive devices resulted in an inadequate increase in therapeutic pressures.

We also identified a group of patients who had a normal RDI but complained about a non-restorative sleep because of inadequate high therapeutic pressures. They reported a clinical benefit by a pressure reduction after using a nasal mask. These patients would not have been detected by polysomnography, but only by their complaints. Although they only represented a small group of patients, the clinician should be aware of them. Reasons for the use of an oro-nasal mask in externally assigned patients had either been reports about a nasal obstruction or a general preference of an oro-nasal mask as interface.

In contrast, in our own sleep lab, patients are primarily supplied with a nasal mask. This results in a low incidence (<0.3 %) of interface-related sleep apnoea or non-restorative sleep compared to about 1.3 %, if the referred patients are related to all patients. The interface is only switched to an

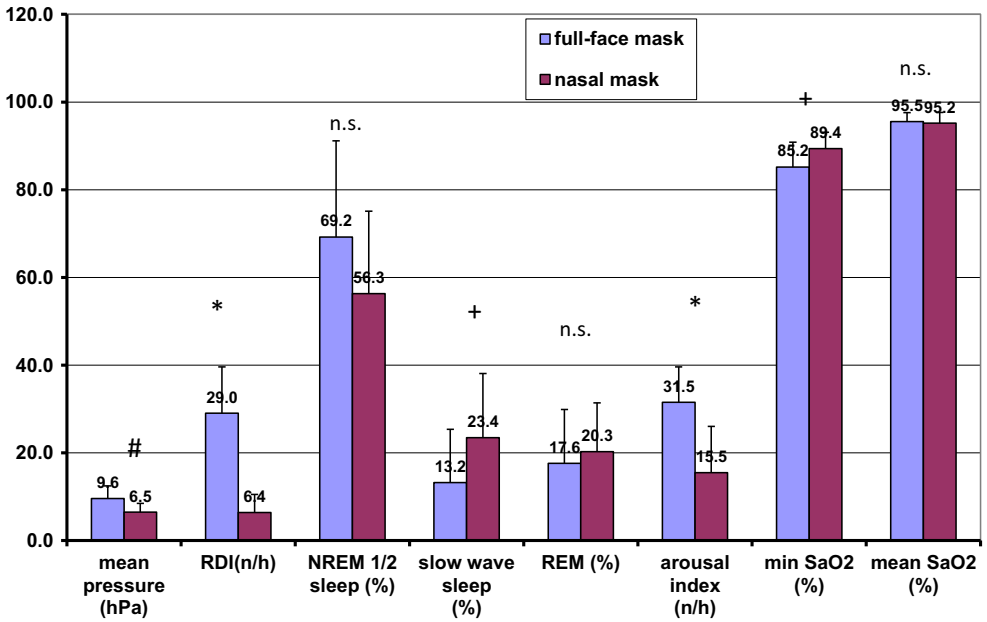

Fig. 4 Influence of changing the interface on therapeutic pressure, RDI, sleep stages, arousal index and SaO_2 in the subgroup of patients under CPAP therapy with an oro-nasal mask and APAP therapy with a nasal mask (n=11). *p<0.001, $^{\#}p$<0.01, ^{+}p<0.05, *n.s.* not significant

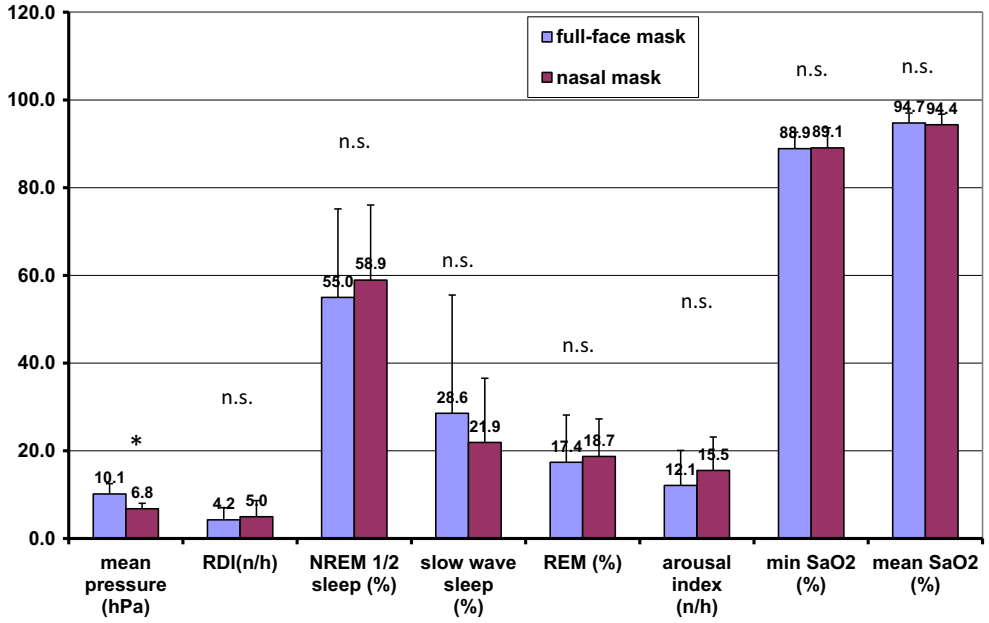

Fig. 5 Effect of mask supply on therapeutic pressure, RDI, sleep stages, arousal index and SaO_2 in patients with normal RDI using an oro-nasal mask (n=11). *p<0.001, #p<0.01, +p<0.05, *n.s.* not significant

oro-nasal mask if there is an intolerance of the nasal mask or an explicit request by the patient, and it is always followed by a polysomnography. However, preferring the use of a full-face mask may result in a higher incidence of both patients with persistent pathological RDI and patients with normal RDI, but inadequate high therapeutic pressures.

Comparable data on the frequency of such phenomena and systematic studies on the influence of a full-face mask on the development or triggering of obstructive sleep apnoea in a larger collective in clinical practice are not yet available. This might be explained by the fact that several comparative studies in OSA and patients with ventilator failure have attributed similar effectiveness to the full-face and nasal mask [3, 4, 8, 14–16]. However, the current study implicates that a differentiated consideration of the influences of a mask supply is required.

Compliance and acceptance depending on the interface

In many patients, the PAP therapy of obstructive sleep apnoea can basically be applied as effectively with a full-face mask as with a nasal mask [3, 4, 8, 14, 17].

Frequent reasons for a primary use of or a conversion to a full-face mask are patients' complaints about long-term mouth breathing or nasal obstruction, reasoned by the assumption of achieving a higher treatment compliance and acceptance by their use. Baltzan et al. [18] often saw a coincidence of mouth leak during CPAP, nasal congestion and premature discontinuation of the use of a nasal mask. On the other hand, other studies [3, 8, 19, 20] show that, despite frequent symptoms associated with mouth leakage, the nasal mask has less leakage and is subjectively considered to be more comfortable, which is reflected in the nightly compliance. There seems to be a problematic type of patient who tends to do more mouth breathing and a lower compliance due to nasal problems, but may be at risk of remaining a problematic patient even after switching to a full-face mask, especially if further full-face mask-related side effects emerge and impair the adherence.

According to the study by Borel et al. [3], offering the oro-nasal mask in a second intention to problematic patients who either had poor compliance and/or side effects under nasal CPAP, the oro-nasal mask neither solved the problems with the adherence to therapy nor the side effects adequately.

Mouth breathing and mask

The mouth opening pathophysiologically leads to an increased collapsability of the upper airway [21, 22]. This potentially causes higher therapy pressures. Comparative studies and the conclusions about full-face masks and nasal masks with open mouth have to be read carefully, because patients either had additional mouthpieces to keep the mouth open or chin straps to prevent mouth leaks [17, 23]. A distinction between mouth breathing and nasal breathing, respectively a detection of an open or closed mouth using a MNM, was not made in our study. There was no influence by a chin strap, so in patients receiving a nasal mask, a potential mouth leakage was tolerated. Since the RDI values normalised, a potential mouth leakage was not regarded as relevant for achieving therapeutic success in our patients. Moreover, a purely expiratory mouth leak can be interpreted as a physiological expiratory pressure reduction for exhalation relief.

The previous assumption that pre-existing mouth breathing during CPAP will persist generally or increase is refuted by

Bachour et al. [19]. Under CPAP therapy, they saw a significant decline in mouth breathing from 19.9±7.8 to 7.7±7.7 %. OSA patients showed no difference between the two types of respiration in terms of the required therapy pressure, the residual RDI, ODI or arousal index. Prosise and Berry [14] who studied flow phenomena through mouth and nose when patients used a full-face mask showed that the oral airflow decreased during the night compared to nasal breathing.

Pathophysiology of the upper airway under nasal and oro-nasal masks

The induction or persistence of upper airway obstruction by full-face mask is highlighted by a phrenic nerve stimulation study in patients with a "mandibular advancement" using nasal and oro-nasal masks [24]. Regardless of the CPAP level, a higher twitch-induced flow and lower velo-pharyngeal resistance were found under a therapy with a nasal mask and a mandibular advancement device. The oro-pharyngeal resistance was also lower under the NM than under the MNM and decreased with the additional application of a mandibular advancement device.

These results explain the findings of a case report from Schorr et al. [25] who endoscopically saw an open oropharynx under a nasal mask and a pressure of 7 hPa, whereas using an oro-nasal mask with a CPAP pressure of 16 cm H_2O led to a partial obstruction due to a backward displacement of the tongue. Although we did not examine our patients endoscopically in a similar manner, it has to be assumed that the oro-nasal mask led to an aggravation of OSA with increasing pressure requirement due to a partially obstructed airway, almost in the sense of a perpetuating auto-titration effect. Smith et al. [26] demonstrated that using nasal masks and raising nasal pressures above the Pcrit led to an increase in inspiratory airflow, which was proportional to the level of positive pressure until apnoeas were abolished. When pressures were applied to a full-face mask, inspiratory airflow did not occur and Pcrit could be obtained at pressures well above Pcrit demonstrated with the nasal mask. These altered flow characteristics must be assumed as causative for the respiratory events seen in our patients. The shift of the mandible (downward and backward) and maintenance of mouth opening result in an increase of Pcrit.

Pressure requirement under nasal and oro-nasal mask

Although the findings of Smith et al. [26] show the correlation between mask type and pressure requirements, there are conflicting data about this item. Prosise and Berry [14] studied 10 subjects and showed AHI normalisation under treatment with a mean pressure of 12.1±3.4 cm H_2O using a full-face mask and of 12.8±2.5 cm H_2O using a nasal mask. In contrast to this, Ebben et al. [27] reported that CPAP applied through an oro-nasal mask required a significantly higher pressure compared to nasal masks to treat moderately severe (2.8± 2.1 cm H_2O) and severe (6.0±3.2 cm H_2O) obstructive sleep apnoea with the same effectiveness. These results are confirmed by a retrospective study of Bettinzoli et al. [28] in 109 subjects with OSA. There was a significant difference in the average auto-CPAP pressure between the group of patients using the nasal mask (10.0±2.0 cm H_2O) and the group which used the oral-nasal mask (11.2±2.1 cm H_2O). Teo et al. [23] observed no difference between the therapeutic pressure when using a nasal mask (11.4±1.9 cm H_2O) or a full-face mask (11.8±2.4 cm H_2O, p=0.46) and no difference in 95 % percentile pressure determined by CPAP or APAP devices (nasal mask 12.2±2.2 cm H_2O, full-face mask 11.9±1.4 cm H_2O; p=0.48). But a detailed consideration of the data gives a more differentiated picture. So in 11 of 24 patients using a full-face mask, the therapeutic pressure was 2 cm H_2O higher than under a nasal mask. In addition, the residual RDI and arousal index were significantly higher and the 95 % percentile leakage was doubled, with a trend towards lower sleep efficiency with the usage of a full-face mask. This confirms our own observations and their relevance for clinical practice. There is a group of patients who tend to run a problematic course of their sleep apnoea under a full-face mask.

In patients with a normal AHI under CPAP or APAP therapy and complaining about tolerance problems, a "too high CPAP pressure" ("sickness caused by CPAP") has to be taken into consideration.

Importance for non-invasive ventilation

Comparable to single reports [15], we were able to identify a small group of patients with non-invasive ventilation (NIV) who still had relevant obstructive sleep-disordered breathing when NIV was applied with a full-face mask, but improved when switching to a nasal mask. This allowed lowering the EPAP or even switching the therapy to CPAP or APAP, especially in those cases where NIV was chosen as an attempt to optimise therapy in case of CPAP failure.

In patients with NIV, a nasal mask is generally perceived as more pleasant, with no significant difference in the EPAP compared to a full-face mask [16, 29]. It even provides a significantly higher proportion of effective tidal volume and median tidal volume [30].

Relevant problems when using a full-face mask in respiratory medicine may arise when an obstruction of the upper airway is induced, facilitated or aggravated by the oro-nasal mask. In the case of obstructive apnoeas, a timed ventilation against a closed upper airway can be triggered, thus leading to an inefficient ventilation. This ultimately results in arousals and possibly a persistent hypercapnia, especially if patients present with an overlap syndrome (hypercapnic COPD with OSAS or even an OHS with OSAS).

Limitations

On the basis of our observational study, we cannot give a general statement on the actual prevalence or incidence of interface-induced sleep apnoea. As we primarily use a nasal mask, this leads to a low observation rate of less than 0.3 % in our own patients. Relating these patients to those leaving the sleep lab with an oro-nasal mask without obstructive events would mean a prevalence of 5.5 % interface-induced resp. aggravated obstructive sleep apnoea. However, it is questionable if these calculations really represent the true incidence of this phenomenon. This would require a further study.

An endoscopic diagnosis has not been made. However, taking into account the endoscopic findings of Schorr et al. [25] and the twitch tests by Borel et al. [24], the assumptions of an interface-related problem should be regarded as plausible.

A long-term observation of patients including compliance data has not been carried out, because most of the patients were followed up by their referring sleep labs. A follow-up might have given further insights, particularly with regard to a lasting therapy success, in patients with pathologic RDI as well as in those who only complained non-restorative sleep.

For all patients, a reduction of the RDI to <10/h could be achieved, for most of the patients even a reduction to <5/h. As respiratory arousals were taken into account by calculating RDI, this resulted in a higher value than considering the AHI. It could be discussed that by applying higher pressures under the treatment with a nasal mask, the RDI could have been reduced below 5/h in all patients, thus leading to mean pressures comparable to those using a full-face mask. This is refuted by the observation in the group of patients with APAP therapy; the change of the interface alone, without changing the APAP device and the pressure range, resulted in a significant reduction of therapeutic pressures and the RDI. Furthermore, it is refuted by the patients with normal RDI using a full-face mask who experienced a significant reduction in mean pressure of 2.6 hPa ($p<0.001$) only by switching to a nasal mask. It is to discuss whether patients who exhibit problems using a full-face mask might generally tend to a higher RDI using a nasal mask.

Comparing the fixed (=mean) CPAP pressure with the mean APAP pressure does not exclude that under APAP therapy the pressure can increase to the maximum level, resulting in higher 90 or 95 % pressure levels. However, the mean APAP pressure over the night was regarded as the relevant pressure influencing the comfort and efficiency of the therapy, especially when leading to a normalisation of the RDI. This may explain that the pressure reduction is more pronounced in the patients with fixed CPAP using an oro-nasal mask and APAP under a nasal mask. It is to discuss if a further pressure reduction in all patients with fixed CPAP under oro-nasal and nasal mask might have led to a change in the sleep structure.

The current study does not deny that in many patients, the change of the interface is not associated with serious problems and that some patients have benefits of switching from a nasal mask to a full-face mask.

Summary

We have demonstrated that wearing a full-face mask can induce or aggravate obstructive events, resulting in an increase of therapeutic pressures, especially under APAP therapy, without alleviation of the obstruction. In some cases, this even led to an application of "high-end" devices which, in addition to a variable expiratory pressure level, deliver a variable pressure support and expiratory pressure relief without achieving a treatment success. Only the change to a nasal mask resulted in a normalisation of the RDI associated with a reduction of pressure levels. The use of a full-face mask can also be associated with non-restorative sleep despite normal RDI. Comparable data are not described in the literature. Pathophysiologically, the backward positioning of the mandible and an increase of Pcrit have to be regarded as causative. A nasal mask should be preferred for CPAP/APAP titration, respectively therapy, even if patients report mouth breathing. As a change from a nasal to a full-face mask can lead to an interface-induced or aggravated OSA, this change should not be made without reason and subsequent CPAP/NIV control, particularly in ventilated patients. If patients use a full-face mask and exhibit OSA or clinical complaints of sleepiness, possibly associated with high treatment pressure, an interface-related problem has to be taken into consideration.

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Conflict of interest The authors declare that they have no conflict of interest.

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