Prevalence and consequences of patient–ventilator interactions in a cohort of home-ventilated restrictive and neuromuscular patients: a multicentre study

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It seems advisable to systematically detect and correct patient–ventilator interactions in home mechanical ventilated patients https://bit.ly/4hTsyq3

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Abstract

Aims Analysis of patient–ventilator interactions in patients on chronic home mechanical ventilation can be time consuming, and the consequences of individual interaction on pulmonary gas exchange are not well understood. The objective was to analyse the relationship between interactions and nocturnal oximetry and arterial blood gases.

Methods A cross-sectional study was carried out in restrictive and neuromuscular patients who underwent respiratory polygraphy with a system that allowed interactions to be correlated with mean saturation in 5-min periods. Unintentional leaks, periodic decreases in flow and primary patient–ventilator asynchronies were analysed. Each interaction was correlated with mean oxygen saturation measured by pulse oximetry (S_{pO_2}) and baseline arterial blood gases obtained at the recruitment visit, and the 5-min S_{pO_2} analysis was individualised for each patient based on their mean±SD S_{pO_2} during polygraphy.

Results 40 patients were included. There was a correlation between interactions and mean S_{pO_2} in periods with mean accidental leak >20 L·min^{-1} (ANOVA test). After exclusion of periods with leakage above this threshold, a relationship was documented between periodic decreases in flow and asynchronies with mean S_{pO_2} in 5-min periods. However, there was no relationship between patient–ventilator interactions and baseline arterial blood gases at recruitment.

Conclusion The presence of interactions was associated with a decrease in mean S_{pO_2} when 5-min recordings are analysed. Therefore, it seems advisable to systematically detect and correct patient–ventilator interactions in home mechanical ventilated patients.

Introduction

Home noninvasive mechanical ventilation (NIV) is a common treatment for patients with chronic hypercapnic respiratory failure (CRF). The degree of evidence for its indication is different depending on the underlying pathology leading to CRF [1–4].

Setting ventilator parameters and monitoring of treatment efficacy usually require some intervention, such as arterial blood gases or noninvasive determination of pulmonary gas exchange, respiratory polygraphy or polysomnography [5] under NIV or downloading data from the built-in software data for later analysis [6]. Both the interpretation of polygraphic and the built-in software data are not very standardised, and the consequences of the different patient–ventilator interactions (PVI) described in the literature remain

unclear. To systematise, the SOMNONIV group proposed a classification of PVI based on three groups: unintentional leaks, periodic decreases in flow (obstructions) and primary patient–ventilator asynchronies. The originality of the method lies in the stratification of the analysis, starting from summarised data available on the built-in software (compliance, leaks) followed by more complex events (upper airway obstructions and primary asynchronies). In a similar way, the PVI should be corrected in the same order [7, 8].

However, there are some unresolved issues in the monitoring of home NIV. These include the lack of studies that determine the influence of PVI on outcomes and the inter-individual variability in their diagnosis [9]. In a cross-sectional study, Kleiven *et al.* [10] reported that there was a direct relationship between PVI and some subscales of the Severe Respiratory Insufficiency (SRI) questionnaire: in particular, residual nocturnal hypoxaemia had a negative effect on the "Respiratory Complaints" and "Associated Symptoms and Sleep" subscales. Persistent daytime hypercapnia, nocturnal hypoventilation and high apnoea–hypopnea index had a negative effect on the SRI Anxiety subscale, while frequent patient–ventilator asynchronies were associated with a lower physical function score [10]. However, the relationship between PVI and nocturnal oximetry, which would shed light on the underlying pathophysiological mechanisms of PVI and gas exchange, was not stablished. Ramsay *et al.* [11] demonstrated the presence of severe patient–ventilator asynchronies but no relationship with oximetry, whereas other studies have shown a relationship between asynchronies and gas exchange, particularly during sleep [5, 12].

The aim of the present study was to describe the prevalence of adverse PVI in a cohort of restrictive and neuromuscular patients on chronic NIV and to determine their impact on oximetry following the above-mentioned systematic approach. The primary objective of the study was to identify the short-term consequences of PVI on nocturnal oximetry. The secondary objective was to analyse their impact at the arterial blood gas level, using a combination of arterial carbon dioxide tension (P_{aCO_2}) and HCO_3 as the criterion for defining suboptimal ventilation. The hypothesis of the study was that there is a relationship between adverse PVI and the oximetry, and that specific PVI have a different importance and effect.

Material and methods

Design

A cross-sectional, observational, prospective, multicentre study was carried out, including patients with restrictive and neuromuscular diseases and obesity-hypoventilation syndrome in three participating centres: Hospital Universitari de Bellvitge (Hospitalet de Llobregat, Barcelona); Hospital Universitari Vall d'Hebron (Barcelona) and Hospital Universitari Parc Taulí (Sabadell, Barcelona). The study was approved by the ethics committee of the participating centres (reference 2011522). Signed consent was required. The study was registered in Clinical.trials.gov (NCT03085537).

Inclusion criteria

Patients on nocturnal NIV for at least 6 months and clinical stability, defined by the absence of hospital admission in the 2 months before their inclusion in the study, were included. Average compliance, as determined by the ventilator counter at the screening visit, had to be >4 h/night.

Exclusion criteria

Patients needing NIV >12 h·day^{-1} or with O_2 coupled to NIV were excluded, as this influences nocturnal oxygen saturation measured by pulse oximetry (S_{pO_2}) values, which was the main efficacy parameter monitored during the polygraphic recording. Given that most COPD patients using home mechanical ventilation also receive supplemental oxygen, this criterion effectively excluded COPD patients requiring long-term oxygen therapy. This approach aimed to ensure a homogeneous patient population and to avoid potential confounding factors in the interpretation of nocturnal S_{pO_2} variations.

Protocol

During the screening outpatient visit, candidate patients were selected based on inclusion criteria. Baseline arterial blood gases (in a seated position, breathing room air and after 30 min of rest) and home nocturnal pulse oximetry were conducted 1 week before recording nocturnal polygraphy to assess NIV efficacy. The patient's compliance was checked by analysing the ventilator's counter. The ventilator model, mode, set parameters, interface and the impact of ventilation using the Pittsburgh Sleep Quality Index (PSQI) [13] were also recorded. The PSQI assesses a wide range of factors over the previous month; higher scores (⩾5) indicate poorer sleep quality.

A nocturnal polygraphic recording with NIV, the same ventilator, parameters and interface used at home and supervised by a sleep technician was performed by means of a scheduled hospital admission in the area determined by each of the participating hospitals.

Monitoring system

The technical characteristics of the monitoring system are detailed in the supplementary material.

PVI assessment

The analysis of PVI was performed based on the classification proposed by the SOMNONIV group [7, 8] (see supplementary material).

The analysis was reviewed by three expert clinicians. In case of discrepancy, the tracing was discussed. If no agreement was reached in the second round, the tracing was not labelled and was not considered for the final analysis**.** All the asynchronies that were labelled in the platform were included in the final analysis.

Data collection and definitions

Anthropometric data (age, sex), ventilator model, arterial blood gases, PSQI and data from pulsioximetry (mean S_{pO_2} and percentage of time below 90% (CT90%)) were recorded.

Correction of awake blood gas without ventilation (P_{aCO_2} <45 mmHg) and HCO_3 ⩽27.5 mmol·L^{-1}, in the absence of chronic renal failure, were established as effectiveness criteria. Patients were classified as having suboptimal ventilation only if they did not meet both criteria simultaneously (P_{aCO_2} >45 mmHg and HCO_3 >27.5 mmol·L^{-1}).

Polygraphic data

After manual coding of events and asynchronies, a specific routine was created in R language for automatic data export. In addition to the export of overall data, the routine allowed for fragmented export in short time frames. For the purposes of the study, 5-min periods were selected. For each 5-min period, the following data were exported:

- S_{pO_2} (in %)
- Nonintentional leakage (L·min^{-1})
- Respiratory rate (RR)
- Tidal volume
- Heart rate
- PVI

Statistical analysis

The normality of the distribution of quantitative variables was analysed using the Kolmogorov–Smirnov test. In case of normality, the mean±SD of all numerical values studied was provided. In the absence of normality, the median and interquartile range were given. The relationship between two quantitative variables was studied by linear regression.

The mean S_{pO_2} from the in-hospital polygraphy was determined for each patient, and all the 5-min periods were classified into the following groups according to their deviation from the mean:

- Group 1: mean S_{pO_2} of the 5-min period below the mean and 2 SD for each patient
- Group 2: S_{pO_2} between the mean −1 and −2 SD
- Group 3: S_{pO_2} between the mean −1 SD
- Group 4: S_{pO_2} between the mean +1 SD
- Group 5: S_{pO_2} between the mean +1 and +2 SD
- Group 6: S_{pO_2} above the mean +2 SD

A stratified analysis was performed to determine short-term outcomes, with the following steps:

- Determination of mean leakage and comparison of each of the above subgroups using ANOVA test with Bonferroni *post hoc* correction.
- Elimination of periods of leakage associated with significant desaturation, using the cut-off point with the best sensitivity and specificity by calculating the Youden J index.
- Determine the association of upper airway events with desaturations in the remaining 5-min periods using ANOVA test with Bonferroni correction.
- Eliminate periods with the presence of upper airway events.

- Determine the association of primary patient–ventilator asynchronies (after elimination of leak periods and upper airway events) with S_{pO_2} groups. For individual asynchronies, only those with prevalence>20/h were included.

For the relationship with arterial blood gases, t-test for unpaired variables or Mann–Whitney U test (for non-normal distributed variables) was used. For this analysis, all PVIs were included without stratifying the model.

The significance level was set at $p<0.05$. Statistical analyses were performed using SPSS version 25.

Results

49 patients were recruited by the three participating centres. Nine patients were excluded due to poor quality of the nocturnal polygraphy that did not allow correct coding. Finally, 40 patients were included in the study. Table 1 shows the anthropometric data, arterial blood gases and sleep quality, as well as the

TABLE 1 Descriptive data

Parameter	Value
Age years, median (IQR)	67.5 (48–73.75)
Sex (female), n (%)	20 (50)
Underlying disease, n (%)	
Neuromuscular	21 (52.5)
Obesity-hypoventilation syndrome	5 (12.5)
Restrictive disorders	14 (35)
Compliance by the counter h, median (IQR)	7 (5–9)
Awake baseline arterial blood gases, mean±SD	
pH	7.39±0.26
P_{aO_2} mmHg	75.15±10.25
P_{aCO_2} mmHg	43.8±4.8
HCO_3 mmol·L^{-1}	26.55±2.52
Suboptimal ventilation according to baseline ABG, n (%)	16 (40)
Home nocturnal pulsoximetry	
S_{pO_2} %, median (IQR)	93.05 (90.1–96.0)
CT90%, median (IQR)	7.10 (0–21.6)
Sleep quality (PSQI), median (IQR)	5 (1–9)
Patients with PSQI >5, n (%)	17 (42.5)
Interface (oronasal), n (%)	26 (65)
Ventilator models, n	
Stellar	10
Vivo 30	3
VIVO 40	18
VPAP ST	7
Other	2
Parameters	
IPAP cmH_2O, mean±SD	17.5±3.11
EPAP cmH_2O, mean±SD	5.58±2.08
Backup respiratory rate breaths·min^{-1}, mean±SD	14.65±2.13
Inspiratory trigger sensitivity, n	
High	5
Medium	30
Low	4
Auto-trak	1
Cycling criterion (expiratory trigger sensitivity), n	
Lower % of peak flow	3
Medium	24
High % of peak flow	12
Auto-trak	1

P_{aO_2}: arterial oxygen tension; P_{aCO_2}: arterial carbon dioxide tension; S_{pO_2}: oxygen saturation measured by pulse oximetry; CT90: percentage of time below 90% saturation; PSQI: Pittsburgh Sleep Quality Index; IPAP: inspiratory positive airway pressure; EPAP: expiratory positive airway pressure.

TABLE 2 Summary of patient–ventilator interactions

Patient–ventilator interactions	Mean±SD
1. Nonintentional leakage L·min^{-1}	16.40±11
2. Periodic flow decreases (events/hour), after elimination of 32% of periods with significant leakage	11.71±16.84
2a. Decrease of the ventilatory command (events/h)	6.31±12.9
2b. Upper airway events with effort (events/h)	2.7±3.9
2c. Upper airway events without effort (events/h)	2.7±8
3. Patient–ventilator asynchronies (events/h), after elimination of 28.5% of periods from the initial total of periods	175.15 ±166.7

Unintentional leakage was presented in L·min^{-1} and all other events and asynchronies in events/h of recording.

prescribed pressures and the ventilator model regularly used. All patients were ventilated under simple passive circuit with intentional leak embedded in the mask. Ventilation was used by the patients for a mean of 4.71±3.35 years before their inclusion in the study.

The mean duration of the polygraphic records was 7.01±2.19 h. The RR during this period was 16.67±4.17 breaths·min^{-1}. Estimated tidal volume (V_T) was 379.90±135.9 mL and heart rate was 70.84±15.68 beats·min^{-1}. The cut-off points for the S_{pO_2} groups were as follows:

- Group 1: S_{pO_2} <92.4±2.6%
- Group 2 : S_{pO_2} between 92.4±2.6 and 93.7±2.2%
- Group 3: S_{pO_2} between 93.7±2.2 and 95.06±2.1%
- Group 4: S_{pO_2} between 95.06±2.1 and 96.48±1.6%
- Group 5: S_{pO_2} between 96.48±1.6 and 97.5±1.8%
- Group 6: S_{pO_2} >97.5±1.8%

Table 2 shows the values of events and asynchronies for the 40 patients included in the study, and figure 1 shows the percentage distribution of asynchronies. It is important to note that only a small proportion of data (<2%) was not labelled, primarily due to unresolved discrepancies or patient movement artefacts, which were identified and addressed using auxiliary thoraco-abdominal belt signals.

Mean nonintentional leakage value was 16.40±11.01 L·min^{-1} and was not influenced by the type of interface (nasal *versus* oronasal). Concerning periodic flow decreases, the presence of central events

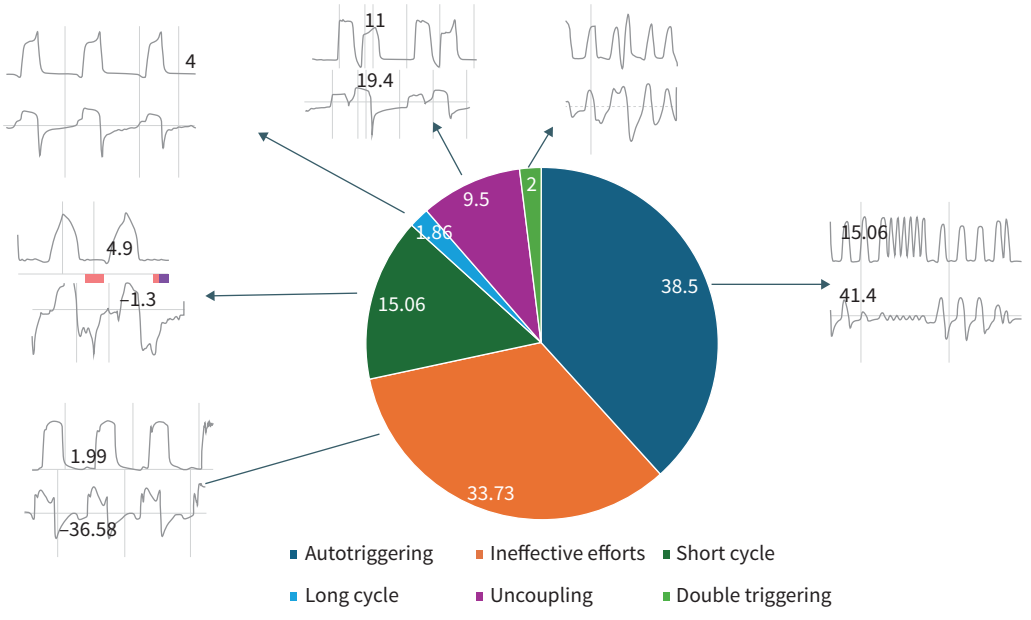

FIGURE 1 Asynchronies distribution (%).

(command decreases and upper airway events without effort) outweighs the presence of obstructive events with effort. On the other hand, there was a great variability in the presence of asynchronies and in their distribution, although with a clear predominance of trigger asynchronies over cycling asynchronies.

No significant differences were observed in the presence of asynchronies in relation to the underlying disease (restrictive, neuromuscular or obesity hypoventilation syndrome) to the ventilator parameters selected (pressure support values, expiratory positive airway pressure >5 cmH_2O or backup respiratory rate) or a PSQI >5. Only a direct relationship was found between higher prescribed pressure support and increased unintentional leaks (R=0.330, p<0.05).

Effects of adverse PVI on oximetry

Step 1: leaks

3210 periods of 5 min were included in the analysis. Mean nonintentional leaks were significantly associated with lower saturation (R= −0.334, p<0.01).

The leak values showed significant differences (ANOVA test) for the different S_{pO_2} groups (see figure 2a). Differences were found between group 1 (lowest S_{pO_2}) and the other groups (Bonferroni *post hoc* analysis). The cut-off point with the best combination of sensitivity and specificity was 20.5 $L \cdot min^{-1}$ (area under the curve: 0.583, p<0.01). A total of 1048 periods (32.6% of the total) were eliminated in this step.

Step 2: periodic flow decreases

The number of periodic flow decreases per hour showed significant differences for the different S_{pO_2} groups (ANOVA test), specifically in group 2 *versus* the other groups (Bonferroni *post hoc* analysis, figure 2b). No significant differences were found between the subgroups of periodic flow decreases. A total of 802 periods (24.9% of the total) were eliminated in this step.

Step 3: primary asynchronies

The total number of primary asynchronies per hour of recording showed significant differences for group 3 compared to the other groups (ANOVA test, Bonferroni *post hoc* analysis). As for the subgroups, autotrigger showed similar performance, while ineffective efforts were more frequent in groups 1 and 2 compared to the rest. For the short cycle, there were no differences between groups (figure 2c).

Effects of adverse PVI on arterial blood gases

16 patients (40%) presented criteria for suboptimal ventilation in the baseline arterial blood gas (without ventilation). Table 3 shows the mean differences between patients with suboptimal ventilation in blood gas measurement, previous oximetric data, ventilator parameters and PVI during the polygraphic recording. Patients with suboptimal ventilation were ventilated with higher pressure support, without achieving a higher mean V_T, and presented lower S_{pO_2} in the previous oximetric recording, but none of the data on polygraphic recording (including S_{pO_2} and tidal volume) achieved statistical significance.

Discussion

The main finding of the study that deserves attention was the relationship between S_{pO_2} and adverse PVI: leaks, obstructions and asynchronies were associated with lower oxygen saturation when studied in 5-min periods in a sequential order, following the algorithm proposed by the SOMNO-NIV group [7]. On the other hand, the prevalence of asynchronies was high, being the most frequent trigger asynchronies (ineffective effort and autotriggering), accounting for >70% of the total. Finally, the predominance of central events (without effort, to which can be added decreases in ventilatory command) over oropharyngeal events, with effort, is noteworthy. However, none of this adverse PVI were correlated with the arterial blood gases at the inclusion in the study.

Studies on the prevalence of events and patient-ventilator asynchronies are scarce in the literature, due to the difficulty and heterogeneity of interpretation of the tracings, with significant interobserver variability [14]. In acute patients, Vignaux *et al.* [15] found a high prevalence of asynchronies, with frequent trigger asynchronies (15% and 13% for ineffective effort and autotriggering respectively), and relatively high prevalence of double triggering, much higher than in our study. It should also be noted that a significant relationship was found between leakage periods and the presence of asynchronies. On the other hand, as these were acute patients, the presence of periodic flow decreases was not taken into account.

In chronically ventilated patients, Aarrestad *et al.* [16] determined the prevalence of leaks, events and asynchronies in 67 patients with various pathologies. Compared to our study, the amount of unintentional leakage was low, although the system to detect it was much less sophisticated than in the present study,

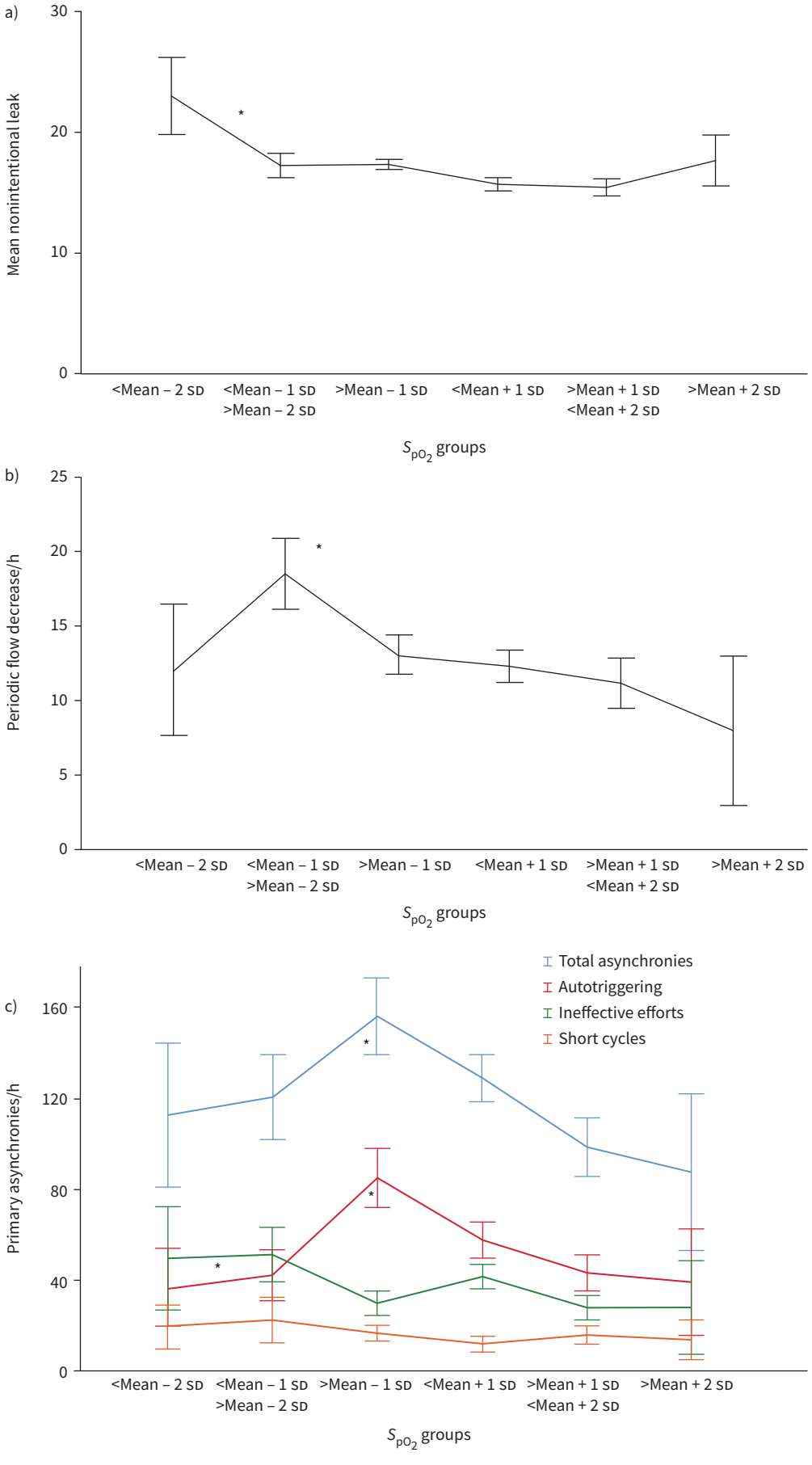

FIGURE 2 a) Mean leak values +95% CI for each oxygen saturation measured by pulse oximetry (S_{pO_2}) subgroup (see text for more details). A significantly higher level of leakage was detected in periods with S_{pO_2} below the mean −2 SD for each polygraphy (*: p<0.05, ANOVA test, Bonferroni *post hoc* correction). b) Mean number of periodic flow decreases +95% CI for each S_{pO_2} subgroup (after excluding periods with nonintentional leak >20 L·min^{-1}). A significantly higher number of periodic flow decreases was detected in periods with S_{pO_2} below the mean −1 SD for each polygraphy (*: p<0.05, ANOVA test, Bonferroni *post hoc* correction). c) Mean number of primary asynchronies for each S_{pO_2} subgroup (after excluding periods with nonintentional leak >20 L·min^{-1} and periodic flow decrease). A significantly higher number of primary asynchronies was detected in periods with S_{pO_2} between mean and mean −1 SD for each polygraphy (*: p<0.05, ANOVA test, Bonferroni *post hoc* correction). Significant differences were also found specifically for autotriggering (same group as for global asynchronies) and for ineffective efforts (differences between groups 1/2 and all other groups).

since it was interpreted based on two commercial software packages, with the added limitation of the different calculation system for each of them. No relationship was found between leakage and asynchronies. Regarding obstructions, a predominance of obstructive events *versus* central events was determined. Other studies, however, have shown a significant prevalence of central events, especially in patients with neuromuscular pathology [17, 18]. Finaly, in the study of Aarrestad *et al.* [16] asynchronies were analysed globally, with a period of >10% asynchrony time being significant for comparisons. As with obstructions, there was no period-to-period correlation with either oxygen saturation or transcutaneous carbon dioxide tension.

One of the most important aspects of the present study is the demonstration of the short-term relationship between adverse PVI and S_{pO_2} levels. For this purpose, 5-minute periods were chosen. In addition, an attempt was made to stratify the analysis using methods suggested by experts to avoid the effect of collinearity between the different PVIs. According to the results obtained, each of the PVIs seems to influence oximetry, but quantitatively different. While leaks are associated with more severe desaturations,

TABLE 3 Relationship between ventilation effectiveness and underlying diseases, parameters and PVI

Parameter	Patients without suboptimal ventilation[#]	Patients with suboptimal ventilation[¶]	p-value
Related to previous conditions or symptoms			
Underlying disease (neuromuscular)	14 (56.5%)	7 (47%)	0.67
Obesity	2 (8.6%)	3 (17%)	
Restrictive	8 (34.78%)	6 (35.29%)	
Pittsburgh quality score	5 (2–8)	6 (0–15)	0.2
Pittsburgh >5 (%)	8/24 (33%)	9/16 (56%)	0.13
Compliance with the ventilator	7 (5.25–8.75)	7.5 (5.25–9.75)	0.97
Previous oximetry			
Mean S_{pO_2} %	93.35 (91.13–95.55)	92 (88.7–95.3)	<0.05[+]
CT90%	11.18±16.93	20.64±23.01	0.14
Ventilator-related parameters			
Pressure support values	11.04±2.6	13.11±2.99	<0.05[§]
IPAP cmH_2O	16.70±2.61	18.5±3.46	0.05[§]
Polygraphic data and PVI			
Mean S_{pO_2} % in polygraphy	95.18±2.09	94.65±2.2	0.47
Estimated mean tidal volume mL	405.23±128.44	342±141.14	0.16
Nonintentional leaks L·min^{-1}	15.59±9.09	18.17±13.13	0.76
Upper airway events/h	10.42±13.42	13.67±20.97	0.55
Asynchronies/h	142.68±111.48	218.4±208.37	0.16
Autotriggering	55.4±106.93	89.44±116.89	0.34
Ineffective efforts	49.86±44.06	76.22±112.84	0.38
Short cycle	32.61±60.08	15.3±19.44	0.92

Data are presented as n (%), median (IQR) and mean±SD. S_{pO_2}: oxygen saturation measured by pulse oximetry; CT90: percentage of time below 90% saturation; IPAP: inspiratory positive airway pressure. [#]: n=24; [¶]: n=16; [+]: Mann–Whitney U test; [§]: Student's t-test for nonpaired variables.

upper airway events (probably due to the desaturation-resaturation effect) and asynchronies have less quantitative impact on mean S_{pO_2} in 5-minute periods. In addition, a specific unintentional leakage level has been established as a cause of desaturation (20 L·min^{-1}). The effect of leakage on gas exchange has already been established in a qualitative way by Teschler *et al.* [19], but without a cut-off point to define a leak considered tolerable.

However, the relationship between polygraphic findings and overall long-term effects seems less clear. There was no statistically significant association with sleep quality or baseline arterial blood gas values. There are several possible explanations for this: First, the representativeness of the results of an in-hospital polygraphy to those that could be obtained in the patient's usual environment should be considered. It is noteworthy that the mean S_{pO_2} was lower in the suboptimally ventilated group in the pre-enrolment pulse oximetry, whereas no such differences were found in the in-hospital polygraphy. This could be explained by two different hypotheses: monitoring by sleep technicians in the in-hospital study and poorer sleep quality, in a nonhabitual environment of the patient. Technical issues were ruled out, as both monitoring systems were high-end devices with proven reliability. In this regard, Martí *et al.* [5] documented a greater presence of PVI during sleep. Finally, the long-term effect may be related to other factors, such as adherence or the severity of the underlying disease that led to the indication for mechanical ventilation. Although the inclusion criteria specifically excluded patients with a ventilation requirement of >12 h·day^{-1}, the effect of possible inter-individual differences in respiratory impairment cannot be certainly excluded.

The results of this study reinforce the need for systematic monitoring of home NIV patients to optimise parameters and correct PVI. The stratified method proposed by the SOMNO-NIV group [7] also seems to have the additional advantage of correcting PVI in an order that follows the severity of the oximetric consequences. This does not necessarily mean that systematic hospital polygraphy is the most cost-effective method. Recently, Georges *et al.* [20] found that the best way to monitor patients on home NIV to distinguish and treat those with correct ventilation from those with suboptimal ventilation was to combine a pulmonary gas exchange parameter with ventilator data download.

The lack of a fully systematic approach to labelling PVI remains a key challenge, and the labelling process is still evolving. This lack of a universally accepted method for tagging these interactions may lead to variations in how the burden of PVI is interpreted. Instead of using the asynchrony index, which only considers trigger asynchronies and the total number of breaths [21], we employed a pragmatic approach based on the frequency of events per hour of recording. However, it is clear that more research is needed to develop a comprehensive, standardised system for labelling all types of PVI. This limitation underscores the complexity of assessing and managing PVI in the home NIV setting and emphasises the need for further studies to refine and validate more consistent criteria.

Some limitations of the study should be highlighted: the results of the study may not be extrapolated to COPD patients, who traditionally have a high prevalence of asynchronies, especially ineffective efforts related to air trapping [22]. It was decided not to include them in the study as they are frequent users of combination therapy with oxygen coupled to ventilation and S_{pO_2} was used as the reference parameter for exchange in this study. Although transcutaneous capnography could be considered the gold standard for monitoring gas exchange during nocturnal NIV, the response time of these devices is significantly longer than S_{pO_2}, making short-term correlation much more difficult. However, it has been demonstrated that transcutaneous capnography is a more reliable prognostic marker than oximetry or arterial blood gas analysis [20, 23]. Furthermore, the subclassification of upper airway events according to effort should be used with caution, as in neuromuscular patients with severe diaphragmatic involvement, subtle movements of the belts may go unnoticed and be mistaken for obstructions without effort. In this type of patient, placement of an oesophageal probe would be the gold standard for detecting muscle effort. Finally, sleep quality would have required electroencephalogram monitoring, which was not included in the system.

In summary, PVI (leaks, obstructions and asynchronies) lead to a decrease in S_{pO_2} in different degrees of severity. The long-term effects are less evident if only a hospital polygraphic record is taken as a reference, but the results of the study reinforce the need to detect (and treat) PVI by systematic monitoring of home NIV.

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This observational study is prospectively registered with ClinicalTrials.gov as NCT03085537.

Conflict of interest: None declared.

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