Monitoring Noninvasive Ventilation in Patients with Obesity Hypoventilation Syndrome: Comparison between Ventilator Built-in Software and Respiratory Polygraphy

Ramon Fernandez Alvarez^a Claudio Rabec^{b, c} Gemma Rubinos Cuadrado^a
Juan Alejandro Cascon Hernandez^a Patricia Rodriguez^d Marjolaine Georges^{b, c}
Pere Casan^a

^aServicio de Neumología, Hospital Universitario Central de Asturias, Oviedo, Spain; ^bService de Pneumologie et Soins Intensifs Respiratoires, Centre Hospitalier Universitaire de Bourgogne, and ^cUFR Sciences de Santé Médecine et Pharmacie, INSERM U866, Université de Bourgogne, Dijon, France; ^dVitalaire, Oviedo, Spain

Keywords

Chronic respiratory failure · Monitoring · Noninvasive ventilation · Obesity hypoventilation syndrome · Polygraphy

Abstract

Background: Polygraphy (PG) remains the standard method of assessing noninvasive ventilation (NIV) effectiveness. Built-in software (BIS) of recent NIV equipment provides estimates of some ventilator parameters, but their usefulness is unclear. **Objectives:** To assess the reliability of BIS compared with PG in a cohort of obesity hypoventilation syndrome (OHS) patients on NIV. **Methods:** Thirty stable OHS patients on NIV were evaluated in an outpatient setting with simultaneous PG and BIS recordings. The automated apnea-hypopnea event index (EI_{AUT}) provided by Rescan and manual scoring based on available traces obtained from the software (EI_{BIS}) were compared with manual PG scoring (EI_{PG}).

Each manual scoring was separately performed by 2 trained operators. Agreement between the 2 operators was assessed using the kappa coefficient. Pearson correlation and Bland-Altman plots were used to evaluate agreement between EI_{AUT}, EI_{BIS}, and EI_{PG}. **Results:** Twenty-six cases were valid for analysis (age $\pm$ 61 years, 17 men). All patients were ventilated in the spontaneous/timed mode (mean inspiratory positive airway pressure 17 ± 3 cm H₂O, mean expiratory positive airway pressure 10 ± 3 cm H₂O). Cohen's kappa agreement between the operators was 0.7 for EI_{BIS} and 0.84 for EI_{PG}. EI_{BIS} showed good correlation with EI_{PG} ($r^2 = 0.79$, $p < 0.001$), better than scoring provided by the automated analysis ($r^2 = 0.71$, $p < 0.006$ for EI_{AUT} vs. EI_{PG}). **Conclusions:** In stable OHS patients on NIV, unattended home-based monitoring using Rescan is reproducible and reliable to assess quality of ventilation when compared with PG. In addition, manual scoring of events using data obtained with this device is more consistent than software-based automated analysis.

© 2017 S. Karger AG, Basel

Introduction

In recent years, obesity hypoventilation syndrome (OHS) has become a major indication for noninvasive ventilation (NIV). Alveolar hypoventilation in these patients results from complex interactions between the degree of obesity, ventilatory mechanics and ventilatory drive [1]. In addition, obstructive sleep apnea syndrome (OSA), itself associated with hypoventilation, is present in 90% of patients with OHS [2].

Management of these patients is a challenge as one needs to treat not only hypoventilation but also obstructive and in some cases central nocturnal events as well. Single circuit pressure-targeted ventilators, provided with a calibrated leak (called bilevel ventilators), are most commonly used for NIV in these patients [3].

The optimal monitoring of long-term ventilated patients is still a matter of debate. Hence, the methods used to assess the effects of NIV may vary greatly, from a single blood gas measurement to full polysomnography (PSG). Recent “best clinical practice” recommendations regarding NIV in chronic respiratory failure state that PSG or ventilatory polygraphy (PG) should be performed for each patient to verify its efficiency [4]. This, however, is not feasible in many cases on a routine basis.

Some portable ventilators include built-in software (BIS) that provides trend estimations of some ventilatory parameters. Theoretically, data provided by these built-in monitoring systems should allow easy assessment of the quality of ventilation. Moreover, with these devices, unattended home-based monitoring is a real possibility. However, interpretation of the data provided by such devices is not yet standardized in clinical practice and the role of these tools in evaluating the quality of ventilation needs to be defined.

In continuous positive airway pressure treatment, similar built-in systems can be used to identify residual apneas and hypopneas [5–9]. Nevertheless, few studies have evaluated such software programs in patients on NIV [10–12]. Moreover, their reliability may be challenged because of the complex nature of abnormal respiratory events occurring during bilevel positive airway pressure ventilation, which may not comply with standard definitions of nocturnal respiratory events in spontaneous breathing [13, 14].

Our hypothesis was that the analysis of data provided by home NIV devices may allow simplifying the monitoring of ventilation quality and limiting the indication for PG/PSG to complex cases. In a cohort of stable long-term ventilated OHS patients evaluated in an outpatient set-

Table 1. Demographic data, lung function parameters, ABG and polygraphic data at baseline and at evaluation time

	At baseline	At evaluation
Mean BMI	43±6	42.5±5
Mean morning pCO ₂	56±4 mm Hg	43±4
Mean AHI	31±26/h	
Mean overnight SpO ₂	85±3%	93±2
Mean T90	85±15%	93±8

ABG, arterial blood gas; BMI, body mass index; AHI, apnea-hypopnea index. T90, percentage of time with SpO₂ <90% during the night.

ting, we assessed the reliability and accuracy of automated scoring of respiratory events provided by a home NIV device and of manual scoring using available flow and pressure traces obtained from these devices as compared with the results obtained by manual PG scoring.

Materials and Methods

The study was performed at Hospital Universitario Central de Asturias (Oviedo, Spain) and was approved by the Clinical Research Ethics Committee of our hospital (register number 37/2014). Informed consent was obtained from all participants.

We prospectively included stable OHS patients on nocturnal NIV. All patients were ventilated by VPAP ST™ (ResMed, North Ryde, NSW, Australia). OHS was defined as the association of obesity (body mass index >30) and daytime hypercapnia (PaCO₂ >45 mm Hg). All patients had been on home ventilation for at least 6 months and in stable condition for at least 3 months before inclusion. Patients needing supplemental oxygen and those with co-existing chronic obstructive pulmonary disease or other known restrictive lung disease were excluded from the study. All patients were evaluated at home during a full night under NIV with parameters and interface prescribed at the time of assessment, by recording data obtained from a simplified monitoring module coupled to their portable ventilator (Reslink™ module, ResMed). In addition, a simultaneous PG was performed (Embletta™ Gold polygraph Embla Systems, Denver, CO, USA). Sensors were placed at each patient's home by a trained nurse and recordings were synchronized to start at the same time.

The Reslink module provides trend estimation of minute ventilation (MV; defined as estimated MV received by the patient after the removal of leaks), respiratory rate and nonintentional air leaks (i.e., leaks exceeding those expected from the exhalation valve of the interface used). Additionally, it allows one to simultaneously evaluate raw flow and pressure traces. The module obtains these data from signals received at the mask. These parameters were stored on a Smart Media card (Scandisk, Milpita, CA, USA), then analyzed using the software package Rescan™ by visualizing trend and raw data. Previous bench test studies have confirmed the accuracy of Reslink™ software for estimating leaks and MV [10, 11].

Table 2. Event index and time spent on events/hour of recording obtained by manual scoring of raw data provided by the software and polygraphy by the 2 observers

	Built-in software			Polygraphy		
	observer 1	observer 2	<i>p</i>	observer 1	observer 2	<i>p</i>
Event index	4.9 (3.5–6.4)	6.1 (3.9–8.1)	0.19	5.1 (4.5–8.0)	5.5 (4.1–7.9)	0.40
Time spent on events/hour of recording, s	140 (43–330)	121 (50–220)	0.75	97 (37–195)	108 (43–230)	0.64

Data are presented as medians (first to third quartile).

The PG assembly data included: pneumotach-based airflow, mask pressure, thoracoabdominal movements (inductive plethysmography bands), and SpO₂ recordings [14]. The pneumotachograph was set between the circuit and the mask.

Summary data provided by the Reslink software were collected for each patient. They included: total recording duration, mean respiratory rate, median leaks and median MV. An automated apnea-hypopnea event index (number of events/hour, EI_{AUT}) was calculated by Rescan. Additionally, a manual analysis of raw data provided by the software was independently performed by 2 trained operators (G.R.C., J.A.C.H.). For PG, the analysis was again independently performed by the same operators. For both analyses, the operators were blinded to patient data and PG results.

Scoring of respiratory events in the Reslink recording was manually performed by analyzing raw flow and pressure traces. A respiratory event was defined as a reduction in inspiratory flow of $\geq 50\%$ for ≥ 10 s. For each recording, data were collected and noted in a chart by each operator. The EI for BIS analysis (number of events/hour, EI_{BIS}) was calculated. In addition, we calculated the time spent on events/hour of recording.

Concerning PG, respiratory events were manually noted according to the SOMNONIV recommendations [14]. An upper airway obstruction (UAO) event was defined as a decrease in flow while the amplitude of pressure signal remained unchanged and was followed by a drop in oximetry of $>3\%$. We noted the event with increasing ventilatory drive (UAO+) when the flow reduction was accompanied by a simultaneous progressive increase in thoracoabdominal belt signals, with or without phase opposition or a phase angle between thoracic and abdominal belt signals, and with decreasing ventilatory drive (UAO–) when the decrease in flow occurred with a simultaneous reduction in or disappearance of thoracic and abdominal belt signals, occurring without phase opposition. Asynchronies not related to airflow decrease were not scored. As for the software analysis, the EI for PG scoring (number of events/hour, EI_{PG}) and time spent on events/hour of recording were calculated.

Additionally, for each patient, we calculated the oxygen desaturation index (ODI; number of desaturation dips $\geq 3\%/h$ of recording).

Statistical Analysis

Statistical analyses were performed using SPSS 15.0 software. Normality of distribution of variables analyzed was assessed using the Kolmogorov-Smirnov test. As most data were not normally distributed, we reported results as median and quartiles and used nonparametric tests. The Wilcoxon test was used for comparisons

for continuous variables. The interrater agreement of scoring respiratory events on both Reslink and PG between operators was determined by Cohen's kappa coefficient [15]. Recordings were dichotomously categorized as "normal" (≤ 10 events/hour) or "abnormal" (>10 events/hour) [12]. Differences between automatically and manually scored EI from both Reslink and PG were assessed using the Student *t* test. Additionally, EI obtained by the 3 scoring methods were correlated two-by-two (EI_{AUT} vs. EI_{BIS}, EI_{AUT} vs. EI_{PG}, and EI_{BIS} vs. EI_{PG}) by linear regression using the Pearson correlation coefficient. We also calculated the agreement between the 3 scoring methods analyzed by pairs using Bland-Altman plots [16]. Additionally, the correlation between EI_{BIS} and ODI obtained from polygraph recordings was calculated using linear regression and the Pearson correlation coefficient. A *p* value of <0.05 was considered significant. As only one recent cohort study [12] evaluated the reliability of events provided by the BIS as compared with PSG and it only included 10 patients, it was not possible to calculate a sample size on the basis of published data.

Results

From January 2013 to March 2014, 30 patients were simultaneously evaluated at home by a PG and a built-in device coupled to their portable ventilator. Four patients were excluded because of PG technical problems. For the remaining 26 patients (mean age 61 ± 8 years, 17 men), both recordings were optimal and they were included in the study. Mean time on NIV was 18 ± 8 months. Table 1 shows demographic data and NIV settings of the study population. Ventilation was provided by an oronasal (20 patients, 77%) or nasal mask (6 patients, 23%). All patients were ventilated in the spontaneous/timed mode (mean inspiratory positive airway pressure 17 ± 3 cm H₂O, mean expiratory positive airway pressure 10 ± 3 cm H₂O, mean backup respiratory rate 13 ± 4 bpm). The mean recording duration was 441 ± 51 min. The median unintentional leak obtained from the built-in monitoring devices was 1.2 l/min (range, 0–3.1). The mean respiratory rate delivered by the ventilator was 15 ± 3 bpm and the estimated expiratory MV was 8.8 ± 2 .

Fig. 1. Pearson correlations between the event index (events/hour) obtained by manual analysis of raw data provided by the Rescan software (EI_{BIS}) and the automated apnea-hypopnea event index (EI_{AUT}) (**a**), between the event index obtained by manual analysis of raw data provided by the Rescan software (EI_{BIS}) and that obtained by manual PG scoring (EI_{PG}) (**b**), and between the automated apnea-hypopnea event index (EI_{AUT}) and the event index obtained by manual PG scoring (EI_{PG}) (**c**). Data for EI_{BIS} and EI_{PG} correspond to scoring performed by observer No. 1. Mean difference: 3.3 limits of agreement (range, -1.9 to $+8.6$).

When applying the threshold value of 10 events/hour, the PG, BIS manual analysis and software automatic analysis categorized respiratory events as “abnormal” in 5 (19%), 3 (11%) and 3 cases (11%), respectively. The inter-rater agreement was good (kappa 0.71) for the software-based scoring and excellent (kappa 0.84) for the polygraph-based scoring. Table 2 shows the EI obtained by manual scoring of raw data provided by the software (EI_{BIS}) and PG (EI_{PG}) for both observers. The EI obtained by the automatic analysis of ventilator software (EI_{AUT}) was 1.7 (range, 1.07–3.6), being significantly lower than the EI obtained by both manual analyses ($p = 0.005$).

The correlation (r^2) between EI_{BIS} and EI_{PG} was 0.78 ($p < 0.001$), 0.71 for EI_{PG}/EI_{AUT} ($p < 0.001$), and 0.55 ($p < 0.001$) for EI_{BIS}/EI_{AUT} (Fig. 1). Figure 2 shows the agreement between EI_{PG}/EI_{BIS} , EI_{PG}/EI_{AUT} , and $EI_{BIS}/$

EI_{AUT} according to Bland-Altman plots. Mean biases (d) and limits of agreement ($d \pm 2ds$) were, respectively, 0.6 events/hour (-6.2 to $+7.4$), 3.3 events/hour (-1.9 to $+8.6$) and 2.7 events/hour (-6.2 to $+11.7$) (Fig. 2). Figure 3 shows the correlation between EI_{BIS} and ODI obtained by the PG recording ($r^2 = 0.81$ $p < 0.001$). Table 3 shows the results of PG scoring as classified by type of event for both scorers.

Discussion

In the present study, we evaluated in an outpatient setting the feasibility and reliability of a built-in monitoring system coupled to a portable ventilator to assess the quality of home NIV as compared with simultaneous PG in a

Fig. 2. Bland-Altman plots. Agreement between EI_{BIS} and EI_{AUT} (a), EI_{BIS} and EI_{PG} (b), and EI_{PG} and EI_{AUT} (c). EI_{BIS} event index (events/hour) was obtained by manual analysis of raw data provided by the Rescan software. EI_{AUT} event index (events/hour) was provided by the Rescan software. EI_{PG} event index was obtained by manual PG scoring.

cohort of OHS patients. The main findings of our study were that manual scoring of raw data provided by the BIS of this home NIV device showed a very good correlation with PG-based scoring and significantly better reliability than scoring provided by the software automated analysis.

Clinical Significance

Optimizing NIV effectiveness has been shown to improve survival [17–20], so assessment of NIV effectiveness is clearly of great importance. Certain authors have suggested that this can be achieved with clinical assessment, measurement of arterial blood gas and nocturnal SpO_2 under NIV [21], although others recommend using PG or PSG as the gold standard [22, 23]. Some home ven-

tilators include built-in monitoring systems allowing the clinician to assess various PG parameters. Recent studies have demonstrated the reliability of some of these systems and suggested their potential use in clinical practice [10–12]. In a recent paper, Georges et al. [12], studying a cohort of stable OHS patients, evaluated the reliability of automatically calculated events provided by the software of one of these devices as compared with PSG. They found good correlation between EI values given by the ventilator software and those obtained by simultaneous PSG. In our study, using the same home NIV monitoring system, manual analysis of raw tracings provided by the software significantly improved the accuracy of the scoring. Considering a cutoff value of 10 events/hour, 24/26 cases

Table 3. Polygraphy scoring classified by type of event according to each of the 2 observers

	Observer 1	Observer 2	<i>p</i>
EI	5.1 (4.5–8.0)	5.5 (4.1–7.9)	0.41
UAO+, event index/hour	4.3 (3.8–7.9)	4.6 (3.4–7.2)	0.40
UAO–, event index/hour	0.7 (0.20–0.80)	0.6 (0.15–2.1)	0.20
UAO–, events/total events, %	6 (3–25)	8 (3–30)	0.33

EI, event index/hour; UAO+, upper airway obstruction with increasing inspiratory drive; UAO –, upper airway obstruction with decreasing inspiratory drive. Data are presented as medians (first to third quartile).

Fig. 3. Pearson correlation between the event index obtained by manual analysis of raw data provided by the Rescan software (EI_{BIS}) and oxygen desaturation index (ODI, number of desaturation dips ≥3%/h of recording) obtained by the polygraphy recording.

(92%) were correctly classified by EI_{BIS}. Moreover, we found high reproducibility of EI scoring and very good agreement between 2 independent trained operators blinded to PG results.

Advantages and Limitations of BIS

This study suggests that our approach could allow the clinician to determine, without hospitalization, whether control of respiratory events is satisfactory or whether further testing (PG, PSG) or adjustment of ventilator settings is required. Our data support the proposal by the SomnoNIV group to assess quality of ventilation by combining medical history, arterial blood gas, nocturnal pulse oximetry with or without transcutaneous capnography, and BIS data.

The advantages of such a tool are evident: it enables unattended home-based assessment without complex assembly, ease of reading and scoring, and decreased costs. In addition, some NIV devices with BIS allow online telemonitoring and remote real-time modifications of ventilatory parameters. These features mean it is possible to optimize NIV effectiveness on a one-night basis either at home or at the hospital.

From a technical point of view, monitoring NIV in a laboratory environment is preferable, as a sleep technician is available to supervise patients. However, being subject to study in a sleep laboratory can be challenging for certain patients. Unattended home NIV offers a more comfortable environment than a sleep laboratory; it also means that sleep quality and NIV effects are similar to those usually experienced by the patient [24]. In addition to reduced costs and time, unattended home-based monitoring may reduce hospitalizations and hospital workload. As the number of patients receiving NIV is steadily increasing, this is important since it may help reduce waiting lists and improve quality of care. Moreover, better patient acceptability and preference for home monitoring have been reported [25]. Portier et al. [26] reported longer sleep duration at home than in the laboratory and Bruyneel et al. [23] found better sleep efficiency at home.

A disadvantage of unattended recordings is the possibility of unnoticed sensor failure and need to repeat the test. This was not the case in our study in which all but 4 recordings were valid.

A limitation of BIS devices is the lack of thoracoabdominal belts. Combined with flow and pressure recording, thoracoabdominal belt signals are crucial to understand patient-ventilator synchrony [14]. Intermittent obstruction of the upper airway (UA) may be due to one of two mechanisms. The first corresponds to obstructive events at the oropharyngeal level as a result of insufficient expiratory positive airway pressure. This

mechanism may be present in patients with OSA or OHS. The other mechanism corresponds to episodes of intermittent obstruction at the glottal level reflecting cyclic glottal closure induced by hyperventilation [25]. The 2 mechanisms present distinct semiology in PG traces. While both situations are characterized by a sudden reduction in flow amplitude during insufflation, obstruction occurring at the oropharyngeal level is accompanied by progressively increased inspiratory activity, indicating a struggle against UA collapse. Conversely, if the underlying mechanism is glottal closure, the essential feature is a decrease in flow with a simultaneous reduction in or disappearance of thoracoabdominal signal. A limitation of home NIV devices is that both mechanisms are indiscriminately expressed as a sudden reduction in flow amplitude [27]. Nevertheless, in our study as well as in others [28, 29], most respiratory events were related to UA collapse. This is particularly evident in patients with OHS, where OSA is present in 90% of patients [29].

The Reslink module can also be connected to an oximeter (the oximeter sensor is not provided with the device). This additional tool, combined with ventilator data, may improve the reliability of this monitoring device. As our goal was to assess the feasibility of a home-based assessment of the quality of ventilation that can be used in a “real-life” scenario, unlike others [10, 12, 30], we chose to use a simpler approach by evaluating only available data provided by the ventilator. It is well established that the occurrence of oxygen desaturations is sensitive to detect breathing abnormalities in NIV users. Moreover, nocturnal oxyhemoglobin desaturation is significantly associated with adverse neurocognitive and cardiovascular consequences [31] and is a main determinant of prognosis for patients on NIV [20]. In this regard, our study showed very good correlation between the ODI provided by PG and the EI obtained by manual analysis of BIS data, illustrating that a flow reduction of $\geq 50\%$ obtained by the device accurately reflected significant desaturation dips. Nocturnal SpO_2 may lose sensitivity in patients who do not usually exhibit significant night-time hypoxemia and whose SpO_2 is situated on the upper part of the oxyhemoglobin dissociation curve. This is even truer for patients receiving simultaneous oxygen support. Furthermore, in these patients, analysis of flow may be more sensitive than overnight SpO_2 as episodic flow reduction may not be associated with desaturation dips. Anyhow, it is always possible to add an oximeter to this monitoring system to improve reliability without needing a complex assembly.

Limitations of the Present Study

Our study has certain limitations. First, we only included patients with OHS. Indeed, the accuracy of BIS needs to be confirmed in patients with etiologies of respiratory failure. Second, this was a single-center study, using a single brand of home NIV device. Third, our study was based on recordings obtained during a single night and reproducibility is unknown. Fourth, comparative analysis between Reslink flow and PG was not made, and finally our patients were “too well ventilated,” and this may have biased the results obtained.

Summarizing, this study supports the feasibility and reliability of unattended home-based monitoring using a built-in monitoring system coupled to a portable ventilator as compared with simultaneous PG to assess the quality of ventilation in OHS patients. Our results suggest that adding this tool to other markers of ventilatory effectiveness could help simplify NIV monitoring. Manual scoring of respiratory events recorded by such devices is reproducible and more consistent than software-based automated analysis to determine whether the control of residual events is adequate or whether additional testing (PG) is needed. Further studies using other devices and assessing larger populations of patients with chronic respiratory diseases and broader heterogeneity are required to confirm our results.

Acknowledgement

We would like to thank Michael McLean for reviewing the English.

References

- 1 Rabec C, de Lucas Ramos P, Veale P: Respiratory complications of obesity. *Arch Bronconeumol* 2011;47:252–261.
- 2 Mokhlesi B, Tulaimat A: Recent advances in obesity hypoventilation syndrome. *Chest* 2007;134:1322–1336.
- 3 Janssens JP, Derivaz S, Breitenstein E, et al: Changing patterns in long-term noninvasive ventilation: a 7-year prospective study in the Geneva Lake area. *Chest* 2003;123:67–69.
- 4 Berry RB, Chediak A, Brown LK, et al: NPPV Titration Task Force of the American Academy of Sleep Medicine. *J Clin Sleep Med* 2010;6:491–509.
- 5 Desai H, Patel A, Patel P, Grant BJ, Mador MJ: Accuracy of autotitrating CPAP to estimate the residual Apnea-Hypopnea Index in patients with obstructive sleep apnea on treatment with autotitrating CPAP. *Sleep Breath* 2009;13:383–390.

- 6 Woodson BT, Saurejan Q, Brusky LT, Han JK: Nonattended home automated continuous positive airway pressure titration: comparison with polysomnography. *Otolaryngol Head Neck Surg* 2003;128:353–357.
- 7 Nigro CA, Gonzalez S, Arce A, Aragone MR, Nigro L: Accuracy of a novel auto-CPAP device to evaluate the residual apnea-hypopnea index in patients with obstructive sleep apnea. *Sleep Breath* 2015;19:569–578.
- 8 Ikeda Y, Kasai T, Kawana F, et al: Comparison between the apnea-hypopnea indices determined by the REMstar Auto M series and those determined by standard in-laboratory polysomnography in patients with obstructive sleep apnea. *Intern Med* 2012;51:2877–2885.
- 9 Cilli A, Uzun R, Bilge U: The accuracy of autotitrating CPAP-determined residual apnea-hypopnea index. *Sleep Breath* 2013;17:189–193.
- 10 Rabec C, Georges M, Kabeya NK, et al: Evaluating noninvasive ventilation using a monitoring system coupled to a ventilator: a bench-to-bedside study. *Eur Respir J* 2009;34:902–913.
- 11 Contal O, Vignaux L, Combescure C, Pepin JL, Jolliet P, Janssens JP: Monitoring of non-invasive ventilation by built-in software of home bilevel ventilators: a bench study. *Chest* 2012;141:469–476.
- 12 Georges M, Adler D, Contal O, et al: Reliability of Apnea-Hypopnea Index measured by a home bi-level pressure support ventilator versus a polysomnographic assessment. *Respir Care* 2015;60:1051–1056.
- 13 Rabec C, Rodenstein D, Leger P, Rounault S, Perrin C, Gonzalez-Bermejo J: Ventilator modes and settings during non-invasive ventilation: effects on respiratory events and implications for their identification. *Thorax* 2011;66:170–178.
- 14 Gonzalez-Bermejo J, Perrin C, Janssens JP, et al: Proposal for a systematic analysis of polygraphy or polysomnography for identifying and scoring abnormal events occurring during non-invasive ventilation. *Thorax* 2012;67:546–552.
- 15 Cohen J: A coefficient of agreement for nominal scales. *Educ Psychol Meas* 1960;20:37–46.
- 16 Bland JM, Altman DG: Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986;1:307–310.
- 17 Gonzalez-Bermejo J, Morelot-Panzini C, Arnol N, et al: Prognostic value of efficiently correcting nocturnal desaturations after one month of non-invasive ventilation in amyotrophic lateral sclerosis: a retrospective monocentre observational cohort study. *Amyotroph Lateral Scler Frontotemporal Degener* 2013;14:373–379.
- 18 Tsuboi T, Oga T, Sumi K, Machida K, Ohi M, Chin K: The importance of controlling PaCO₂ throughout long-term noninvasive ventilation. *Respir Care* 2014;59:1671–1678.
- 19 Tsuboi T, Oga T, Sumi K, Machida K, Ohi M, Chin K: The importance of stabilizing PaCO₂ during long-term non-invasive ventilation in subjects with COPD. *Intern Med* 2015;54:1193–1198.
- 20 Tsuboi T, Oga T, Machida K, et al: Importance of ventilator mode in long-term noninvasive positive pressure ventilation. *Respir Med* 2009;103:1854–1861.
- 21 French Pulmonary Society: Non-invasive positive pressure ventilation for neuromuscular diseases. Practice guidelines. *Rev Mal Respir* 2006;23:14S15–14S40.
- 22 Gonzalez MM, Parreira VF, Rodenstein DO: Non-invasive ventilation and sleep. *Sleep Med Rev* 2002;6:29–44.
- 23 Bruyneel M, Sanida C, Art G, et al: Sleep efficiency during sleep studies: results of a prospective study comparing home-based and in-hospital polysomnography. *J Sleep Res* 2011;20:201–206.
- 24 Berry RB, Budhiraja R, Gottlieb DJ, et al: Rules for scoring respiratory events in sleep: update of the 2007 AASM Manual for the Scoring of Sleep and Associated Events. Deliberations of the Sleep Apnea Definitions Task Force of the American Academy of Sleep Medicine. *J Clin Sleep Med* 2012;8:597–619.
- 25 Jounieaux V, Aubert G, Dury M, Delguste P, Rodenstein DP: Effects of nasal positive-pressure hyperventilation on the glottis in normal awake subjects. *J Appl Physiol* (1985) 1995;79:186–193.
- 26 Portier F, Portmann A, Czernichow P, et al: Evaluation of home versus laboratory polysomnography in the diagnosis of sleep apnea syndrome. *Am J Respir Crit Care Med* 2000;162:814–818.
- 27 Vrijsen B, Chatwin M, Contal O, et al: Hot topics in noninvasive ventilation: report of a working group at the International Symposium on Sleep-Disordered Breathing in Leuven, Belgium. *Respir Care* 2015;60:1337–1362.
- 28 Caldarelli V, Borel JC, Khirani S, et al: Polygraphic respiratory events during sleep with noninvasive ventilation in children: description, prevalence, and clinical consequences. *Intensive Care Med* 2013;39:739–746.
- 29 Laaban JP, Chailleux E: Daytime hypercapnia in adult patients with obstructive sleep apnea syndrome in France, before initiating nocturnal nasal continuous positive airway pressure therapy. *Chest* 2005;127:710–715.
- 30 Fletcher EC, Donner CF, Midgren B, et al: Survival in COPD patients with a daytime PaO₂ greater than 60 mm Hg with and without nocturnal oxyhemoglobin desaturation. *Chest* 1992;101:649–655.
- 31 Fernandez Alvarez R, Rubinos Cuadrado G, Rodriguez Jerez F, Garcia Garcia A, Rodriguez Menendez P, Casan Clara P: Home mechanical ventilation through mask: monitoring leakage and nocturnal oxygenation at home. *Respiration* 2013;85:132–136.