

# Clinical Application of the Avant® 4000 for Inpatient Nocturnal Oximetry During Non-Invasive Ventilation

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Chronic respiratory patients may require home non-invasive ventilation (NIV) following exacerbations. After initiation of NIV, overnight oximetry is used to determine if respiratory insufficiency is reversed during sleep prior to the patient being discharged to the home. This was a prospective observational study which assessed the performance, ease of use and patient comfort of the Avant 4000 Bluetooth® oximeter for nocturnal oximetry in a respiratory intermediate care unit in 17 patients educated to use home NIV. The Avant 4000 allowed continuous overnight monitoring without disturbing the patients' sleep with successful studies obtained in all 17 patients on the first attempt. Complete interpretation of the oximetry tracing was achieved using nVISION® software. The nVISION software was not cumbersome and interpretation took minimal time, between 6 and 10 minutes for each patient recording. The oximeter had excellent performance with 99% of the recording time being artefact free. Nine of 17 patients had abnormal tracings: four indicating either obstructive apnoea, leaks or glottis closure; five indicating hypoventilation. General appreciation of the device was rated as "good" or "very good" by all nurses and patients who responded. All the patients declared that the oximeter did not disturb their sleep.

## INTRODUCTION

Some patients with acute exacerbation of chronic respiratory disease require home NIV after the acute episode.<sup>1</sup> The initiation of the technique and education of the patient and family is usually done in the hospital setting. NIV is initiated by observing the patient on ventilation, based on sessions of two or three hours with the patient awake, until the patient reaches the level of the tolerance needed to allow ventilation throughout the entire night.<sup>2</sup> Prior to discharge, the physician checks that the respiratory insufficiency is reversed during the night. The nocturnal recording required in this process usually involves the use of oximetry.<sup>1</sup> Nocturnal oximetry may recognise hypoventilation associated with sleep and help guide adjustments in ventilation, changes to the mode or the settings of ventilation, and/or the interface.<sup>2</sup>

Nonin's Avant 4000 is a wrist oximeter that allows continuous recording of functional oxygen saturation of arterial haemoglobin (SpO<sub>2</sub>) and pulse rate transmitted



through a Bluetooth wireless technology module to a monitor (Avant 4000). The wireless technology allows the caregivers to monitor and record SpO<sub>2</sub> and pulse rate from the monitoring area of the unit while not disturbing the patient's sleep.

This prospective observational study assessed the performance, ease of use and patient comfort of the Avant 4000 oximeter for nocturnal oximetry in a respiratory intermediate care unit for patients educated to use home NIV.

## PATIENTS AND METHOD

Patients admitted to the Intensive Care Unit (ICU) for exacerbation of chronic respiratory disease where home NIV was proposed were included in the study. Following stabilization in the ICU, patients were transferred to a six-bed intermediate care level associated respiratory unit for ventilator initiation and education. This intermediate care unit has assigned staff including a physician and motivated nurses so that NIV is dispensed 24 hours a day. A specialist physician is always on-call and available if needed.

NIV initiation was done with a SmartAir® Plus ventilator (Covidien, France) with a face mask using the bi-level pressure support mode with a back-up rate. A heated humidifier was added to the ventilatory circuit to improve patient comfort.<sup>1</sup> Morning and afternoon sessions of two hours on ventilation were performed to find the proper interface and ventilator settings and to train the patient with the technique. As soon as possible, the patient was encouraged to sleep with the ventilator. Once the patient tolerated the mask during the entire night, a nocturnal oximetry was scheduled on the subsequent night to evaluate the adequacy of NIV. Because oxygen supplementation can mask desaturation related to poor quality ventilation and hypoventilation may not be recognised and corrected, patients requiring oxygen supplementation were not included.<sup>2</sup>

**Oximetry Recording.** Continuous over-night pulse oximetry was obtained using the Nonin Avant 4000 Bluetooth wireless device with the PureLight® reusable soft sensor finger probe (Nonin Medical, Plymouth, MN, USA). The wireless Avant 4000 consists of a patient module and a display monitor. The patient module is a small, light-weight (125 grams) oximeter that can be worn on the wrist of the patient. Pulse oximetry results are transmitted from the patient module to the tabletop display and can be located away from the patient thus allowing for continuous monitoring with alarms while not disturbing the patient.



The Avant 4000 patient module was placed on the patient by the nurse when the patient retired to bed with the intention of sleeping. The display monitor was positioned within the nursing station located across the hall from the

patient rooms to allow for remote observation of the patient throughout the testing. Recording was stopped when the patient awoke with no further intention of sleeping. Patients were instructed to leave the oximeter in place during any sleep disturbances in the night. Patients were also asked to record details of sleep duration, quality, latency and number of awakenings in a diary in the morning following testing.

In the morning, the Avant 4000 patient module was collected and the data was downloaded to a desktop computer for analysis. This device has a reported accuracy of  $\pm 2\%$  (saturation range, 70 to 100%). The pulse oximetry value is updated with each pulse and incorporates a smart averaging algorithm that provides fast response to rapid desaturation events. Oximetry findings were stored to memory once every four seconds. (The oximeter has a memory storage capability of 33 hours.) Patients were given medications as usual. Recordings were considered to be adequate if the subject reported sleeping at least four hours and sleep was not disturbed or was minimally disturbed by the recording procedure.

**Oximetry Interpretation.** The oximetry tracings were interpreted using nVISION® software (version 5.1, Nonin Medical, Plymouth, MN, USA). Before statistical analysis, the sleep recording time was selected according to the patient's sleep diary. Artefact-free recording time was obtained from the sleep recording time and corrected for periods of non-sleeping.

To reduce variability in oximetry interpretation, a two-step standardized interpretation method was designed. First, an overall analysis of the recordings was performed by calculating the mean nocturnal SpO<sub>2</sub> value (SpO<sub>2m</sub>), the fraction of time spent with SpO<sub>2</sub>  $\leq 90\%$  (T<sub>90</sub>), and the desaturation index (DI). A desaturation was defined as a decrease in SpO<sub>2</sub> of at least 4% from the baseline that lasted a minimum of ten seconds. DI was computed as the number of desaturation events per hour of artefact-free recording time. Second, a detailed analysis of SpO<sub>2</sub> tracings was done to improve the diagnostic sensitivity by visual inspection using different window display resolutions ranging from six hours to one minute. The criteria for considering the nocturnal oximetry as normal were: SpO<sub>2m</sub>  $\geq 90\%$ , T<sub>90</sub>  $\leq 15\%$ , DI  $\leq 15/\text{hour}$  with a detailed analysis showing the baseline tracing above 90% through the recording without any desaturation events.

**Measurements.** Performance of the oximeter was assessed by the percentage of artefact-free recording time from the sleep recording time. Ease of use and comfort was obtained from the nurses and the patients after each recording using a specific questionnaire comprised of four domains: ease of use (installing and removing the device), accuracy, comfort and general appreciation. For each domain, a five-point scale was used: (1) very poor, (2) poor, (3) neutral, (4) good, and (5) very good. In addition, the discomfort associated with the oximeter was quoted by the patients.

**Statistical Analysis.** Statistical analysis was done using SigmaStat (version 3.0, SPSS, Chicago, IL, USA). For each parameter, summary statistics provided include medians and 25th and 75th quartiles (inner quartile range: IQR). For the patient and nurse questionnaires, the percent of respondents responding “good” or “very good” were summarized.

The performance of the oximeter was excellent, as 99% of the sleeping time could be recorded without artefacts, despite patient motion during the night.

## RESULTS

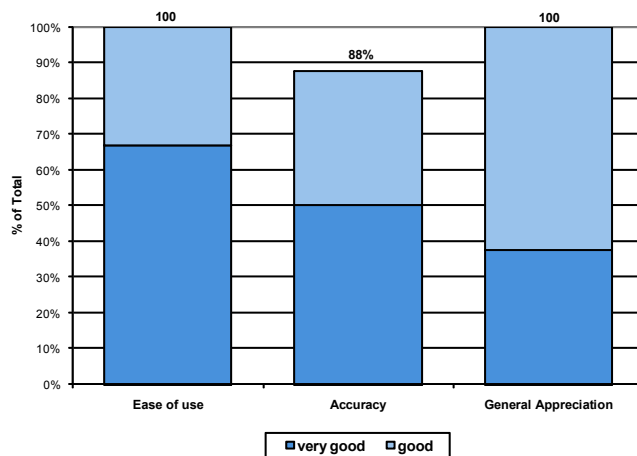
During the four-month period (May to August 2008), 17 patients were included (age: 74 (67 – 76) years, nine women). The underlying respiratory disease of patients was COPD (n=four patients), restrictive (n=nine patients) and mixed respiratory disorders (n=five patients).

All the recordings were considered adequate. No repeat testing was required. Average sleep recording time was 363 (296 – 415) minutes. Average performance of the oximeter was 99% (98,2% – 99,7%) of artefact-free recording time.

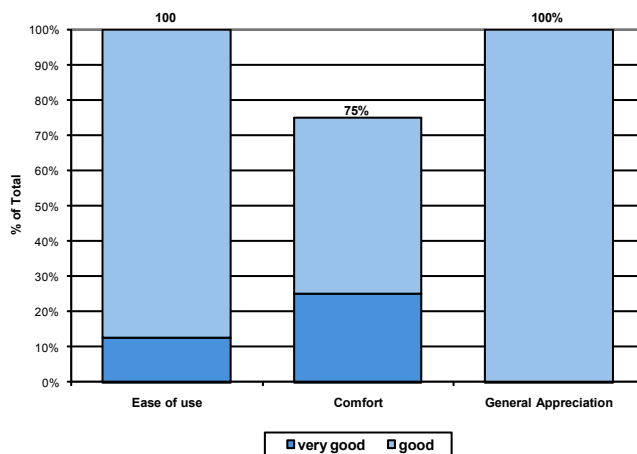
Ease of use and comfort quoted by the nurses and patients are presented in Figure 1 and Figure 2, respectively. General appreciation of the device was rated as “good” or “very good” by all nurses and patients who responded. All the patients declared that the oximeter did not disturb their sleep.

All the patients declared that the oximeter did not disturb their sleep.

**Figure 1: Device Performance: Nurse Assessment Percent Satisfied (“Very Good” or “Good”)**



**Figure 2: Device Performance: Patient Assessment Percent Satisfied (“Very Good” or “Good”)**



Each item was rated on a five-point scale: (1) Very poor, (2) Poor, (3) neutral, (4) good, and (5) very good. Figure represents the percent who rated item as either “good” or “very good”.

The average time spent by the physician for tracing interpretation was 8 (6 – 10) minutes. The results of tracing interpretation are given in Table 1 on the next page. Eight patients had normal tracing, while four tracings suggested obstructive apnoea, leaks or glottis closure and five tracings suggested hypoventilation.

**Table 1: Results of Tracing Interpretations**

	Mean (25 <sup>th</sup> ile – 75 <sup>th</sup> ile)
Mean SpO <sub>2</sub> (%)	92 (88 – 93)
Fraction of time spent with SpO <sub>2</sub> ≤ 90% (%)	15 (3 – 60)
Desaturation index (n/hour)	4 (3 – 17)
Detailed analysis:	<b>N (%)</b>
Normal tracing	8 (47%)
Obstructive apnoea, leaks or glottis closure	4 (24%)
Hypoventilation	5 (29%)

The oximetry was very useful as half of the patients had abnormal tracing that resulted in modifications of the treatment before discharge.

## CONCLUSION

This prospective observational study found that the Nonin Avant 4000 oximeter with Bluetooth wireless technology was suitable for recording nocturnal oximetry in patients with NIV in the hospital setting. The performance of the oximeter was excellent, as 99% of the sleeping time could be recorded without artefacts, despite patient motion during the night. Moreover, the satisfaction with device performance by the nurses and the patients was high. Using the nVISION software, a complete interpretation was not cumbersome and performed with minimal time. Of note, the oximetry was very useful as half of the patients had abnormal tracings that resulted in modifications of the treatment before discharge. In summary, the Nonin Avant 4000 oximeter is appropriate to perform nocturnal oximetry for patients with NIV in respiratory intermediate care setting.



*"...I really appreciate the ease to apply and also that the patient is free to move with it..."*

– Vincent Gardan, ICU nurse

*Toulon hospital is a 1224 bed hospital, dispatched on four different campuses. The Font Prè hospital ICU consists of a 12 bed adult ICU with an additional 6 bed intermediate care respiratory unit. Seven doctors and 42 nurses work in the unit to care for the greater than 900 patients per year that are admitted. Additionally, the facility has a hyperbaric unit, an organ harvesting unit and a chronic respiratory failure unit. The chronic respiratory failure unit cares for approximately 100 patients using non-invasive ventilation in the home setting.*

## References:

- <sup>1</sup>Leger P, Laier-Groeneveld G. Infrastructure, funding and follow-up in a programme of noninvasive ventilation. *Eur Respir J* 2002; 20: 1573–1578.
- <sup>2</sup>Lujan M, Moreno A, Veigas C, Monton C, Pomares X, Domingo C. Non-invasive home mechanical ventilation: Effectiveness and efficiency of an outpatient initiation protocol compared with the standard in-hospital model. *Respiratory Medicine* (2007) 101, 1177–1182.

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