Value of gas exchange recording at home in children receiving noninvasive ventilation

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**Value of gas exchange recording at home in children
receiving noninvasive ventilation**

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Running head: Gas exchange during noninvasive ventilation

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Abstract

Noninvasive positive pressure ventilation (NPPV) is preferentially performed at home. The objectives of the study were to evaluate the feasibility of an overnight gas exchange recording at home and to compare recordings performed in the hospital and at home.

Twenty nine pairs of overnight gas exchange recordings during NPPV were performed at home and in the hospital in 11 children with neuromuscular disease and 13 children with other disorders treated with long term NPPV.

No technical problem occurred during the recordings performed at home and one pulse oximetry (SpO_2) recording failed in the hospital. For the two groups, SpO_2 and transcutaneous carbon dioxide (PtcCO_2) values did not differ significantly between the hospital and the home. However, correlations between SpO_2 and PtcCO_2 values obtained in the hospital and at home were better for mean values than for minimal and maximal values, and in patients with other disorders as compared to patients with neuromuscular disease.

Overnight gas exchange recordings with NPPV by a combined $\text{PtcCO}_2/\text{SpO}_2$ monitor are feasible at home and show results comparable to hospital recordings. Home $\text{PtcCO}_2/\text{SpO}_2$ recordings may be integrated in the care of children treated with domiciliary NPPV and are associated with less disruption of family life and decreased health care costs.

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Introduction

Noninvasive positive pressure ventilation (NPPV) is increasingly used in children presenting various diseases which may cause alveolar hypoventilation such as neuromuscular or lung disease, thoracic deformities, severe upper airway obstruction, or disorders of ventilatory control ^{1,2}. The main advantage of NPPV is that this technique may be used on demand, preferentially at night, with minimal disruption of normal life. After appropriate training of the family and caregivers, the majority of the children may be discharged home. Regular clinical and physiological follow up is necessary in order to adapt the NPPV modes and settings to the patient's clinical status and growth, and to check any side effect or respiratory or maxillofacial complication.

We have recently demonstrated the importance of a systematic overnight combined pulse oximetry (SpO₂) and carbon dioxide (CO₂) recording, even in patients in a stable condition without any symptom or sign of alveolar hypoventilation ³. Indeed, 42% of 50 children who were well acclimatized to NPPV, without evidence of symptoms of sleep disordered breathing, were hypercapnic, defined by a maximal transcutaneous CO₂ (PtcCO₂) value > 50 mmHg during sleep. Most importantly, this nocturnal hypercapnia was not associated with nocturnal hypoxemia, defined by a minimal SpO₂ < 92%, or abnormal daytime blood gases in 36% of the patients.

Repeated overnight hospitalizations are associated with disruption of family life and increased health care costs. Because of a general reduction in number of pediatric hospital beds, the transfer of selected, programmed, and well-organized activities or investigations from the hospital to the home is strongly encouraged. However, the feasibility, defined by the ability to obtain technically acceptable

overnight recordings as well as the satisfaction of the parents with regard to their preference between hospital and home, and accuracy of these investigations performed in a home environment, should be evaluated before their wide spread use.

The aim of the present study was first to evaluate the feasibility of an overnight gas exchange recording by a combined transcutaneous CO₂ and pulse oximetry (PtcCO₂/SpO₂) monitor at home, and second to compare the results and costs of recordings performed in the hospital and at home in a cohort of stable children, treated at home with long term NPPV.

Material and methods

Patients

Consecutive patients using nocturnal NPPV at home were enrolled during their routine follow up if 1) they were in a stable condition, with no respiratory exacerbation during the previous two months, 2) they were using NPPV for at least one month, and 3) they had no clinical symptoms of nocturnal hypoventilation such as frequent arousals, nocturnal agitation, or daytime fatigue and sleepiness. Exclusion criteria were 1) age less than one year because the ear clip of the PtcCO₂/SpO₂ monitor is too large for small infants ³, 2) ear aplasia or hypoplasia for the same technical reasons ³, 3) dark skin because of inaccurate SpO₂ values, as has been observed with other devices ⁴, 4) impossibility to perform the hospital and home recording within one month, and 5) any change in the respiratory and/or clinical status of the patient.

All the parents, and if possible the patients, gave informed written consent for the study which was approved by the local ethical committee.

Overnight PtcCO₂/SpO₂ recording

Two overnight PtcCO₂/SpO₂ recordings were performed in a random order with the SenTec Digital Monitor (software version SMB SW-V06.10; MPB SW-V04.03) and the V-SignTM Sensor which was applied to the earlobe with a dedicated Ear Clip (SenTec AG, Therwil, Switzerland). This fully digital sensor combines the elements of an electrochemical Severinghaus-type CO₂ tension sensor with the optical elements of conventional SpO₂ sensors, thus providing a noninvasive and continuous PtcCO₂ and SpO₂ monitoring. The sensor is warmed to a constant surface temperature of 42°C to improve local arterialization of the measurement site. This PtcCO₂/SpO₂ monitor has been validated for adults ⁵ and for children in our laboratory ³.

The two overnight SpO₂ and PtcCO₂ recordings were started at the patient's usual bedtime. In the hospital, care was taken to respect the patient's sleep. Prior to the application of the sensor to the patient, the sensor was prepared by the nurse in the hospital and the technician at home and calibrated as per the manufacturer recommendations. The sensor was then applied by the nurse or the technician to the patient's earlobe for 15 minutes, until the stabilization of the PtcCO₂ and SpO₂ values. Monitoring was then performed during at least 6 hours. In the hospital, sleep with NPPV as well as the correct positioning of the nasal mask and the ear clip was regularly checked by the attending nurse during the night. At home, the parents were asked to check these elements before they went to sleep and eventually a second

time during the night. The parents were taught how to remove the ear clip at awakening.

After the two recordings, the parents were asked: “Did your child sleep better in the hospital or at home ?” and “Do you prefer a recording performed in the hospital or at home ?”.

Analysis of the nocturnal gas exchange

For each overnight sleep study, the following data were calculated: duration of recording, mean and minimal SpO_2 , percentage of night time spent with a $\text{SpO}_2 > 95\%$, between 94 and 95%, between 93 and 92%, and $< 92\%$; mean and maximal PtcCO_2 , % of night time spent with a $\text{PtcCO}_2 > 50 \text{ mm Hg}$ and $\leq 50 \text{ mmHg}$.

Statistical analysis

The patients were separated into two groups; patients with neuromuscular diseases ($n=11$) and patients with other disorders ($n=13$). For each group and type of recording (hospital and home), the median value of mean and minimal SpO_2 and of mean and maximal PtcCO_2 was calculated because the values were not normally distributed. Comparison between the home and hospital recordings was performed by the Mann Whitney Rank Sum test.

Moreover, individual data were analyzed by plotting mean and minimal SpO_2 and mean and maximal PtcCO_2 observed in the hospital against the values obtained at home for each patient. Correlation between the values recorded at home and in the hospital was performed using simple linear regression. Statistical analyses were

done using the SigmaStat (Systat Software Inc., San Jose, California). Values of $p<0.05$ were considered statistically significant.

Results

Patients

Twenty four consecutive patients were included in the study with 5 patients having 2 series of hospital and home recording more than 3 months apart. Four patients with neuromuscular disease and one patient with another disorder had 2 pairs of recordings. The characteristics of the patients are given in Table 1.

Feasibility of home recording

Of the 29 recordings performed at home, one recording was technically correct but could not be analyzed because of an error on the date. The SpO_2 recording could not be analyzed in another patient in the hospital but the $PtcCO_2$ recording was exploitable. All the other recordings performed at home and in the hospital were correct and could be analyzed.

Comparison of home and hospital recordings

Despite randomization, only 4 recordings were initially performed at home and 25 in the hospital. The median delay between the hospital and home recordings was 11 (range 3-28) days in patients with neuromuscular disease and 7 (2-30) days in

patients with other disorders (p not significant (NS)). The median duration of the overnight PtcCO₂/SpO₂ recording was comparable at home (503 minutes, range 360-609) and in the hospital (560 minutes, range 231-688, p=NS). Table 2 shows that the SpO₂ and PtcCO₂ values did not differ significantly between the hospital and the home. Moreover, the results were not different between the patients with neuromuscular disease and those with other disorders. Figure 1 shows the correlation of mean and minimal SpO₂ values in the hospital and at home for each patient. The correlation of mean SpO₂ in the hospital and at home was significant for patients with other disorders (r=0.608, p=0.028) but not for patients with neuromuscular diseases (r=0.494, p=0.061). For minimal SpO₂, no significant correlation was observed for the two groups of patients (r=0.340, p=0.215 and r=0.547, p=0.053 for patients with neuromuscular disease and other diseases, respectively). Interestingly, 4 patients had a minimal SpO₂ below 90% in the hospital but not at home, and conversely, 9 patients had a minimal SpO₂ below 90% at home but not in the hospital. Figure 2 shows the percentage of time spent with the different SpO₂ ranges in the two groups of patients. Again, no significant differences were observed between the recordings performed in the hospital and at home in both groups of patients (t-test, all NS).

Figure 3 shows the correlation of mean and maximal PtcCO₂ values in the hospital and at home for each patient. The correlation of mean PtcCO₂ in the hospital and at home was significant in the two groups of patients (r=0.647, p=0.009, and r=0.562, p=0.037, for patients with neuromuscular disease and patients with other disorders, respectively). The correlation for maximal PtcCO₂ was significant for patients with other diseases (r=0.636, p=0.014) but not for patients with neuromuscular diseases (r=0.417, p=0.122). Figure 4 shows the percentage of time

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3 spent with the different PtcCO₂ ranges in the two groups of patients. Again, no
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5 significant differences were observed between the recordings performed in the
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7 hospital and at home in both groups of patients (t-test, all NS).
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10 According to the parents, they all found that their child slept better at home.
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12 With regard to the satisfaction of the parents, they all preferred the recording at
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14 home.
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17 The cost of one overnight hospitalization in our pediatric pulmonology unit is
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19 1029,00 euros. This cost should be compared to 2 technician home visits, one in the
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21 evening at the child's bedtime and one in the morning (2 x 25,16 = 50,32 euros). The
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23 cost of the transport has to be added to this amount; the French health care system
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25 reimburses 20,09 euros per visit, which make a total of 90,50 euros per home
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27 monitoring.
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31 The 5 patients who had persistent alveolar hypoventilation during both
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33 recordings, as defined by a maximal PtcCO₂ value > 50 mm Hg and/or a minimal
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35 SpO₂ value < 90% had one or several interventions in the hospital such as the
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37 change of the ventilatory settings or mode, the addition of an abdominal girdle or a
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39 chin strap, and/or the change of the interface. An overnight gas exchange control
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41 was performed systematically before discharge.
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48 **Discussion**
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52 This study is the first to show the feasibility of overnight PtcCO₂/SpO₂
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54 recording in a group of children over the age of 4 years, treated at home with long
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56 term NPPV. Twenty eight of the 29 (97%) recordings were analyzable when a trained
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58 technician installed the equipment at home and instructed the parents how to
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1 supervise the recording and remove the ear clip in the morning. SpO₂ and PtcCO₂
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3 values did not differ significantly between the hospital and the home. However, a
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Different types of monitoring are routinely performed at home in children such as cardiorespiratory monitoring in children at risk for sudden infant death syndrome⁶⁻⁸, pH monitoring for the diagnosis of gastro-oesophageal reflux⁹, blood pressure monitoring¹⁰, EEG monitoring^{11,12}, polygraphy for the screening of obstructive sleep apnea¹³⁻¹⁶, and even telemonitoring of exhaled nitric oxide for asthmatic children¹⁷.

We were initially relatively reluctant to the use of the PtcCO₂/SpO₂ monitor at home because the device requires a correct calibration, the SignTM Sensor is quite fragile, and the correct positioning of the ear clip with the head gear for the NPPV may not be easy in a young child. Technically acceptable recordings were obtained in 75% to 99% of the cases during the above mentioned studies⁶⁻¹⁷. However, no technical problem occurred at home during any of the 29 recordings in the present study. This may be explained by the adequate training of the technicians of the home care organization who installed the PtcCO₂/SpO₂ monitor on the child at bed time, which requires thus a home visit outside office hours. However, this procedure seemed for us the guarantee of success.

Correlation between hospital and home recordings was better for mean SpO₂ and PtcCO₂ values than for minimal SpO₂ and maximal PtcCO₂. This is easy understandable because a mean value is calculated over the whole recording period, and it thus less variable than an extreme value. We have no clear explanation for the

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better correlation between hospital and home SpO₂ and PtcCO₂ values in patients with other diseases as compared to patients with neuromuscular diseases. A possible explanation could be that patients with other diseases, who are predominantly patients with upper airway obstruction, are more stable than patients with neuromuscular disease. In practice, minimal and maximal values should be interpreted with more caution than mean values when comparing hospital and home recordings.

A limitation of our study is the lack of data on objective sleep quality. Improved nocturnal gas exchange is not obligatory associated with better sleep quality ¹⁸. A parallel improvement in nocturnal gas exchange and sleep architecture during NPPV has been observed in adult patients in two studies ^{19,20} but not in two others ^{21,22}. A study establishing home polysomnography norms for children showed better sleep quantity and quality at home ¹⁴. Another study compared 2 sleep studies performed at home and in the hospital in 21 children aged 2-12 years with possible obstructive sleep apnea ¹³. Sleep efficiency was significantly greater and the arousal index was significantly lower at home than in the laboratory. Finally, a study that compared blood pressure monitoring at home and in the hospital also observed significant lower diastolic blood pressure at home ¹⁰, which supports a lower stress level when children are in their home environment.

Even if we observed a trend for better results during home recordings, this was not significant (Table 2). We may thus conclude that home recordings are feasible and may show results comparable to those obtained at **hospital**, justifying their integration in the routine management in children receiving long term NPPV. A regular and systematic check of the ventilator settings and circuit, the interface and its possible side effects, and also the potential problems that may occur during NPPV

such as air leaks, are, to our opinion, important to document during an overnight observation in the hospital. As such, we would recommend a combination of home and hospital recordings, not only for the patient's and parent's comfort but also with regard to the familial and financial burden. Because individual data may be better in the home or in the hospital, we would recommend a change of NPPV settings or additional measures only in case of abnormal values in both conditions. **Those patients with an abnormal "in home" gas exchange should be referred for an "in hospital" titration study.**

In conclusion, overnight $P_{tc}CO_2/SpO_2$ monitoring is feasible at home and shows comparable results to hospital recordings. Systematic and regular home monitoring, combined with regular hospital visits, is recommended in children treated at home with NPPV.

Acknowledgments

All the authors declare that they have no conflict of interest with the data presented in this manuscript.

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Legend of the figures

Figure 1

Individual mean (left figure) and minimal (right figure) pulse oximetry (SpO_2) values observed at home and in the hospital in patients with neuromuscular disease (black circles) and with other disorders (open circles).

For mean SpO_2 , regression lines are represented (plain for patients with neuromuscular disease ($r=0.494$, $p=0.061$) and dashed for patients with other disorders ($r=0.608$, $p=0.028$)). Several patients having similar SpO_2 values, only 15 of the 28 spots are visible.

For minimal SpO_2 , regression lines are represented (plain for patients with neuromuscular disease ($r=0.340$, $p=\text{NS}$) and dashed for patients with other disorders ($r=0.547$, $p=\text{NS}$)). Two patients having similar SpO_2 values, only 27 of the 28 spots are visible.

Figure 2

Comparison of percentage of nocturnal recording time spent with a pulse oximetry (SpO_2) $> 95\%$, between 94 and 95%, between 93 and 92%, and $< 92\%$ during the recordings performed in the hospital (black bars) and at home (grey bars).

Figure 3

Individual mean (left figure) and maximal (right figure) transcutaneous carbon dioxide (PtcCO_2) values observed at home and in the hospital in patients with neuromuscular disease (black circles) and with other disorders (open circles).

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For maximal PtcCO₂, regression lines are represented (plain for patients with neuromuscular disease (r=0.417, p=NS) and dashed for patients with other disorders (r=0.636, p=0.014).

Three patients having similar PtcCO₂ values, only 27 of the 29 spots are visible.

Figure 4

Comparison of percentage of nocturnal recording time spent with a PtcCO₂ > 50 mmHg and ≤ 50 mmHg during the recordings performed in the hospital (black bars) and at home (grey bars).

Value of gas exchange recording at home in children receiving noninvasive ventilation

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Running head: Gas exchange during noninvasive ventilation

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Introduction

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Material and methods

Patients

Consecutive patients using nocturnal NPPV at home were enrolled during their routine follow up if 1) they were in a stable condition, with no respiratory exacerbation during the previous two months, 2) they were using NPPV for at least one month, and 3) they had no clinical symptoms of nocturnal hypoventilation such as frequent arousals, nocturnal agitation, or daytime fatigue and sleepiness. Exclusion criteria were 1) age less than one year because the ear clip of the PtcCO₂/SpO₂ monitor is too large for small infants ³, 2) ear aplasia or hypoplasia for the same technical reasons ³, 3) dark skin because of inaccurate SpO₂ values, as has been observed with other devices ⁴, 4) impossibility to perform the hospital and home recording within one month, and 5) any change in the respiratory and/or clinical status of the patient.

All the parents, and if possible the patients, gave informed written consent for the study which was approved by the local ethical committee.

Overnight PtcCO₂/SpO₂ recording

Two overnight PtcCO₂/SpO₂ recordings were performed in a random order with the SenTec Digital Monitor (software version SMB SW-V06.10; MPB SW-V04.03) and the V-SignTM Sensor which was applied to the earlobe with a dedicated Ear Clip (SenTec AG, Therwil, Switzerland). This fully digital sensor combines the elements of an electrochemical Severinghaus-type CO₂ tension sensor with the optical elements of conventional SpO₂ sensors, thus providing a noninvasive and continuous PtcCO₂ and SpO₂ monitoring. The sensor is warmed to a constant surface temperature of 42°C to improve local arterialization of the measurement site. This PtcCO₂/SpO₂ monitor has been validated for adults⁵ and for children in our laboratory³.

The two overnight SpO₂ and PtcCO₂ recordings were started at the patient's usual bedtime. In the hospital, care was taken to respect the patient's sleep. Prior to the application of the sensor to the patient, the sensor was prepared by the nurse in the hospital and the technician at home and calibrated as per the manufacturer recommendations. The sensor was then applied by the nurse or the technician to the patient's earlobe for 15 minutes, until the stabilization of the PtcCO₂ and SpO₂ values. Monitoring was then performed during at least 6 hours. In the hospital, sleep with NPPV as well as the correct positioning of the nasal mask and the ear clip was regularly checked by the attending nurse during the night. At home, the parents were asked to check these elements before they went to sleep and eventually a second

time during the night. The parents were taught how to remove the ear clip at awakening.

After the two recordings, the parents were asked: “Did your child sleep better in the hospital or at home ?” and “Do you prefer a recording performed in the hospital or at home ?”.

Analysis of the nocturnal gas exchange

For each overnight sleep study, the following data were calculated: duration of recording, mean and minimal SpO₂, percentage of night time spent with a SpO₂ > 95%, between 94 and 95%, between 93 and 92%, and < 92%; mean and maximal PtcCO₂, % of night time spent with a PtcCO₂ > 50 mm Hg and ≤ 50 mmHg.

Statistical analysis

The patients were separated into two groups; patients with neuromuscular diseases (n=11) and patients with other disorders (n=13). For each group and type of recording (hospital and home), the median value of mean and minimal SpO₂ and of mean and maximal PtcCO₂ was calculated because the values were not normally distributed. Comparison between the home and hospital recordings was performed by the Mann Whitney Rank Sum test.

Moreover, individual data were analyzed by plotting mean and minimal SpO₂ and mean and maximal PtcCO₂ observed in the hospital against the values obtained at home for each patient. Correlation between the values recorded at home and in the hospital was performed using simple linear regression. Statistical analyses were

done using the SigmaStat (Systat Software Inc., San Jose, California). Values of $p < 0.05$ were considered statistically significant.

Results

Patients

Twenty four consecutive patients were included in the study with 5 patients having 2 series of hospital and home recording more than 3 months apart. Four patients with neuromuscular disease and one patient with another disorder had 2 pairs of recordings. The characteristics of the patients are given in Table 1.

Feasibility of home recording

Of the 29 recordings performed at home, one recording was technically correct but could not be analyzed because of an error on the date. The SpO_2 recording could not be analyzed in another patient in the hospital but the PtcCO_2 recording was exploitable. All the other recordings performed at home and in the hospital were correct and could be analyzed.

Comparison of home and hospital recordings

Despite randomization, only 4 recordings were initially performed at home and 25 in the hospital. The median delay between the hospital and home recordings was 11 (range 3-28) days in patients with neuromuscular disease and 7 (2-30) days in

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patients with other disorders (p not significant (NS)). The median duration of the overnight PtcCO₂/SpO₂ recording was comparable at home (503 minutes, range 360-609) and in the hospital (560 minutes, range 231-688, p=NS). Table 2 shows that the SpO₂ and PtcCO₂ values did not differ significantly between the hospital and the home. Moreover, the results were not different between the patients with neuromuscular disease and those with other disorders. Figure 1 shows the correlation of mean and minimal SpO₂ values in the hospital and at home for each patient. The correlation of mean SpO₂ in the hospital and at home was significant for patients with other disorders (r=0.608, p=0.028) but not for patients with neuromuscular diseases (r=0.494, p=0.061). For minimal SpO₂, no significant correlation was observed for the two groups of patients (r=0.340, p=0.215 and r=0.547, p=0.053 for patients with neuromuscular disease and other diseases, respectively). Interestingly, 4 patients had a minimal SpO₂ below 90% in the hospital but not at home, and conversely, 9 patients had a minimal SpO₂ below 90% at home but not in the hospital. Figure 2 shows the percentage of time spent with the different SpO₂ ranges in the two groups of patients. Again, no significant differences were observed between the recordings performed in the hospital and at home in both groups of patients (t-test, all NS).

Figure 3 shows the correlation of mean and maximal PtcCO₂ values in the hospital and at home for each patient. The correlation of mean PtcCO₂ in the hospital and at home was significant in the two groups of patients (r=0.647, p=0.009, and r=0.562, p=0.037, for patients with neuromuscular disease and patients with other disorders, respectively). The correlation for maximal PtcCO₂ was significant for patients with other diseases (r=0.636, p=0.014) but not for patients with neuromuscular diseases (r=0.417, p=0.122). Figure 4 shows the percentage of time

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3 spent with the different PtcCO₂ ranges in the two groups of patients. Again, no
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5 significant differences were observed between the recordings performed in the
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7 hospital and at home in both groups of patients (t-test, all NS).
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10 According to the parents, they all found that their child slept better at home.
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12 With regard to the satisfaction of the parents, they all preferred the recording at
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14 home.
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17 The cost of one overnight hospitalization in our pediatric pulmonology unit is
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19 1029,00 euros. This cost should be compared to 2 technician home visits, one in the
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21 evening at the child's bedtime and one in the morning ($2 \times 25,16 = 50,32$ euros). The
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23 cost of the transport has to be added to this amount; the French health care system
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25 reimburses 20,09 euros per visit, which make a total of 90,50 euros per home
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27 monitoring.
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31 The 5 patients who had persistent alveolar hypoventilation during both
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33 recordings, as defined by a maximal PtcCO₂ value > 50 mm Hg and/or a minimal
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35 SpO₂ value $< 90\%$ had one or several interventions in the hospital such as the
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37 change of the ventilatory settings or mode, the addition of an abdominal girdle or a
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39 chin strap, and/or the change of the interface. An overnight gas exchange control
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41 was performed systematically before discharge.
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48 Discussion

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53 This study is the first to show the feasibility of overnight PtcCO₂/SpO₂
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55 recording in a group of children over the age of 4 years, treated at home with long
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57 term NPPV. Twenty eight of the 29 (97%) recordings were analyzable when a trained
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59 technician installed the equipment at home and instructed the parents how to
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supervise the recording and remove the ear clip in the morning. SpO₂ and PtcCO₂ values did not differ significantly between the hospital and the home. However, a better correlation between hospital and home values was observed for mean values as compared to minimal and maximal values, and in patients with other disorders as compared to patients with neuromuscular disease. Of note, parent's preference and cost favored home recording.

Different types of monitoring are routinely performed at home in children such as cardiorespiratory monitoring in children at risk for sudden infant death syndrome ⁶⁻⁸, pH monitoring for the diagnosis of gastro-oesophageal reflux ⁹, blood pressure monitoring ¹⁰, EEG monitoring ^{11,12}, polygraphy for the screening of obstructive sleep apnea ¹³⁻¹⁶, and even telemonitoring of exhaled nitric oxide for asthmatic children ¹⁷.

We were initially relatively reluctant to the use of the PtcCO₂/SpO₂ monitor at home because the device requires a correct calibration, the SignTM Sensor is quite fragile, and the correct positioning of the ear clip with the head gear for the NPPV may not be easy in a young child. Technically acceptable recordings were obtained in 75% to 99% of the cases during the above mentioned studies ⁶⁻¹⁷. However, no technical problem occurred at home during any of the 29 recordings in the present study. This may be explained by the adequate training of the technicians of the home care organization who installed the PtcCO₂/SpO₂ monitor on the child at bed time, which requires thus a home visit outside office hours. However, this procedure seemed for us the guarantee of success.

Correlation between hospital and home recordings was better for mean SpO₂ and PtcCO₂ values than for minimal SpO₂ and maximal PtcCO₂. This is easy understandable because a mean value is calculated over the whole recording period, and it thus less variable than an extreme value. We have no clear explanation for the

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3 better correlation between hospital and home SpO₂ and PtcCO₂ values in patients
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5 with other diseases as compared to patients with neuromuscular diseases. A
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7 possible explanation could be that patients with other diseases, who are
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9 predominantly patients with upper airway obstruction, are more stable than patients
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11 with neuromuscular disease. In practice, minimal and maximal values should be
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13 interpreted with more caution than mean values when comparing hospital and home
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15 recordings.
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20 A limitation of our study is the lack of data on objective sleep quality. Improved
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22 nocturnal gas exchange is not obligatory associated with better sleep quality ¹⁸. A
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24 parallel improvement in nocturnal gas exchange and sleep architecture during NPPV
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26 has been observed in adult patients in two studies ^{19,20} but not in two others ^{21,22}. A
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28 study establishing home polysomnography norms for children showed better sleep
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30 quantity and quality at home ¹⁴. Another study compared 2 sleep studies performed
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32 at home and in the hospital in 21 children aged 2-12 years with possible obstructive
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34 sleep apnea ¹³. Sleep efficiency was significantly greater and the arousal index was
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36 significantly lower at home than in the laboratory. Finally, a study that compared
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38 blood pressure monitoring at home and in the hospital also observed significant lower
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40 diastolic blood pressure at home ¹⁰, which supports a lower stress level when
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42 children are in their home environment.
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49 Even if we observed a trend for better results during home recordings, this
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51 was not significant (Table 2). We may thus conclude that home recordings are
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53 feasible and may show results comparable to those obtained at hospital, justifying
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55 their integration in the routine management in children receiving long term NPPV. A
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57 regular and systematic check of the ventilator settings and circuit, the interface and
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59 its possible side effects, and also the potential problems that may occur during NPPV
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such as air leaks, are, to our opinion, important to document during an overnight observation in the hospital. As such, we would recommend a combination of home and hospital recordings, not only for the patient’s and parent’s comfort but also with regard to the familial and financial burden. Because individual data may be better in the home or in the hospital, we would recommend a change of NPPV settings or additional measures only in case of abnormal values in both conditions. Those patients with an abnormal “in home” gas exchange should be referred for an “in hospital” titration study.

In conclusion, overnight PtcCO₂/SpO₂ monitoring is feasible at home and shows comparable results to hospital recordings. Systematic and regular home monitoring, combined with regular hospital visits, is recommended in children treated at home with NPPV.

Acknowledgments

All the authors declare that they have no conflict of interest with the data presented in this manuscript.

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Legend of the figures

Figure 1

Individual mean (left figure) and minimal (right figure) pulse oximetry (SpO₂) values observed at home and in the hospital in patients with neuromuscular disease (black circles) and with other disorders (open circles).

For mean SpO₂, regression lines are represented (plain for patients with neuromuscular disease (r=0.494, p=0.061) and dashed for patients with other disorders (r=0.608, p=0.028)). Several patients having similar SpO₂ values, only 15 of the 28 spots are visible.

For minimal SpO₂, regression lines are represented (plain for patients with neuromuscular disease (r=0.340, p=NS) and dashed for patients with other disorders (r=0.547, p=NS). Two patients having similar SpO₂ values, only 27 of the 28 spots are visible.

Figure 2

Comparison of percentage of nocturnal recording time spent with a pulse oximetry (SpO₂) > 95%, between 94 and 95%, between 93 and 92%, and < 92% during the recordings performed in the hospital (black bars) and at home (grey bars).

Figure 3

Individual mean (left figure) and maximal (right figure) transcutaneous carbon dioxide (PtcCO₂) values observed at home and in the hospital in patients with neuromuscular disease (black circles) and with other disorders (open circles).

For mean PtcCO₂, regression lines are represented (plain for patients with neuromuscular disease (r=0.647, p=0.009) and dashed for patients with other disorders (r=0.564, p=0.037))

For maximal PtcCO₂, regression lines are represented (plain for patients with neuromuscular disease (r=0.417, p=NS) and dashed for patients with other disorders (r=0.636, p=0.014).

Three patients having similar PtcCO₂ values, only 27 of the 29 spots are visible.

Figure 4

Comparison of percentage of nocturnal recording time spent with a PtcCO₂ > 50 mmHg and ≤ 50 mmHg during the recordings performed in the hospital (black bars) and at home (grey bars).

Table 1: Characteristics of the patients.

	patients n=24
Age (years)	10 (4-19)
Male / Female	17 / 7
<i>Primary disease</i>	
neuromuscular disease	11
lung disease	3
upper airway obstruction	9
central hypoventilation	1
Duration of NPPV (months)	20 (3-62)
<i>Ventilatory mode</i>	
AC/VT	10
PS	5
Bilevel positive pressure	9
<i>Interface</i>	
industrial nasal mask	18
industrial face mask	3
custom made nasal mask	3

Data are given as median (range).

Abbreviations: NPPV: noninvasive positive pressure ventilation, AC/VT: assist control / volume targeted ventilation, PS: pressure support ventilation.

Table 2: Results of the recordings performed in the hospital and at home in the patients with neuromuscular disease and those with other disorders.

	Recordings in patients with neuromuscular disease n=15		p	Recordings in patients with other disorders n=14		p
	Hospital recordings	Home recordings		Hospital recordings	Home recordings	
Median value of the individual mean SpO ₂ (%)	98 (94-99)	98 (97-100)	0.49	96 (93-99)	98 (95-99)	0.06
Median value of the individual minimal SpO ₂ (%)	91 (82-97)	94 (75-97)	0.65	91 (80-93)	89 (87-93)	0.72
Median value of the individual mean PtcCO ₂ (mmHg)	40 (32-51)	40 (32-51)	0.65	45 (37-53)	43 (33-55)	0.65
Median value of the individual maximal PtcCO ₂ (mmHg)	48 (37-62)	45 (37-56)	0.07	49 (41-60)	47 (41-56)	0.07

Data are expressed as median (range).

SpO₂: pulse oximetry, PtcCO₂: transcutaneous carbon dioxide.

Figure 1

Figure 2

Figure 3

Figure 4