

The uses of overnight pulse oximetry

Shruti Singh, Sara Z. Khan, Dilbagh Singh, Sameer Verma, Arunabh Talwar

Division of Pulmonary, Critical Care and Sleep Medicine, Northwell Health, New Hyde Park, NY, USA

ABSTRACT

Overnight pulse oximetry (OPO) has proven to be an effective and beneficial technique to determine the cardiorespiratory status of patients in both the inpatient and outpatient settings. It is a cheap, safe, reliable, simple, and accurate method of patient monitoring as compared to the expensive and labor-intensive method of multichannel polysomnography for detecting sleep-disordered breathing. It provides accurate information about patient's oxygenation status and also helps in monitoring the response to continuous positive airway pressure and in the surgical treatment of obstructive sleep apnea (OSA). Nocturnal hypoxemia portends a poor prognosis in patients of chronic obstructive pulmonary disease (COPD), interstitial lung disease (ILD), and neuromuscular diseases. OPO can help its early detection and management.

KEY WORDS: Chronic obstructive pulmonary disease, desaturation, interstitial lung disease, obstructive sleep apnea, overnight pulse oximetry

Address for correspondence: Arunabh Talwar, Northwell Health, Division of Pulmonary, Critical Care and Sleep Medicine, 410 Lakeville Road, Suite 107 New Hyde Park, NY 11040, USA. E-mail: arunabhtalwar1@gmail.com

Submitted: 01-Jul-2019 **Revised:** 18-Oct-2019 **Accepted:** 12-Nov-2019 **Published:** 27-Feb-2020

INTRODUCTION

Hypoxemia results in a poor clinical outcome, making pulse oximetry an important tool to monitor patient oxygenation routinely both in primary care and in hospital.^[1] Overnight pulse oximetry (OPO) also has emerged as one of the most widely used techniques to determine a patient's cardiopulmonary status, as it provides adequate information about patient's oxygenation and respiratory patterns.

PRINCIPLE

Pulse oximetry is a spectrophotometry technology which determines the arterial oxygen saturation by the detection of pulsatile blood flow and is based on differing absorption spectra of oxyhemoglobin and deoxyhemoglobin which includes the red and near-infrared wavelengths of light.^[2] The oxyhemoglobin absorbs near-infrared light

and dissipates the red component of light which makes it appear bright red. On the contrary, deoxyhemoglobin absorbs the red component of light more and scatters the near infrared, making it look less red.^[3]

Other wavelengths of the light such as the yellow, green, blue, and far infrared are absorbed by nonvascular tissues. Based on this principle of differential absorption of light, pulse oximeters emit two wavelengths of light, red at 660 nm and near infrared at 940 nm from two light-emitting diodes (LEDs) located in one arm of the probe. A photoreceptor is present opposite to the LEDs with patient tissues with a higher vascular density such as the finger, toes, nose, forehead, or earlobe held in between. This photodiode detects the amount of red and near-infrared light absorbed by the vascular tissues from the light transmitted through the finger held in between the arms of the probe. A large number of measurements

Access this article online

Quick Response Code:



Website:

www.lungindia.com

DOI:

10.4103/lungindia.lungindia_302_19

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Singh S, Khan SZ, Singh D, Verma S, Talwar A. The uses of overnight pulse oximetry. Lung India 2020;37:151-7.

of relative light absorption are made multiple times every second, and these are fed into a microprocessor that compares the ratio of absorption of the two spectra against a set of stored reference values in the form of a calibration curve obtained empirically by measuring the relative red: infra-red modulation ratios in healthy volunteers whose saturations were altered from 100% to approximately 70%. These values are accepted or rejected using specific formulas. The microprocessor gives a new reading every 0.5–1 s that averages out the readings over the last 3–6 s.^[3]

Over the past few years, the advancement in technology has resulted in the possibility of continuous pulse oximetry recording which gives a better idea of a patient's oxygenation and respiratory status. Generally, continuous oximetry is done during the night time; hence, it is called OPO.

During a routine OPO, one can get an idea about the mean overnight saturation (mean SaO₂) and lowest SaO₂ during the entire night recording. In general healthy controls, the normal overnight mean oxygen saturation is 96%.^[4] A decreased value points to an underlying cardiopulmonary problem.

Another parameter which is clinically helpful and is widely reported in most studies is time spent by the patient, under 90% oxygen saturation (T-90) during the duration of the study. An elevated T-90 during overnight sleep study represents the hypoxic burden during the study. It provides the clinician a clue of the presence of coexistence of pulmonary hypertension, heart failure, and hypoventilation symptoms.

OPO has been used extensively in the field of sleep medicine and classified as a type 4 monitoring device.^[5,6] Its low cost, easy availability, and being able to perform it on an outpatient basis make this an attractive alternative to polysomnographic studies for the screening of

obstructive sleep apnea (OSA) in patients with a high pretest suspicion.

Most clinicians also look at the oxygen saturation waveform patterns, which provide a good view of the oxygenation status of the patient for the entire night's recording. In healthy controls, on OPO, the oxygen saturation is maintained above 90% throughout the night [Figure 1]. One of the most typical patterns that one can appreciate on OPO is the recognition of the relationship between rapid eye movement (REM) sleep stage and occurrence of multiple clustered episodes of deep oxygen desaturation, also called sawtooth pattern or "icicles from the rooftop" pattern [Figure 2], which is generally seen in the presence of OSA.

One can also report on the number of oxygen desaturations (decrease of oxygen saturation by 4% from the baseline per hour of recording) as an index, generally called oxygen desaturation index (ODI).^[7] Various authors have used different cutoff points for reporting ODI. The threshold for an abnormal ODI can be either ≥ 5 desaturations per hour, ≥ 10 desaturations per hour, or ≥ 15 desaturations per hour.^[1] It has been demonstrated that in patients with a high pretest probability of OSA, ODI does correlate with the apnea-hypopnea index.^[7-9]

Role of overnight pulse oximetry in screening for sleep-disordered breathing

OSA syndrome or sleep-disordered breathing (SDB) is a major public health problem and has a rather higher prevalence rate. Although polysomnography (PSG) is the gold standard for studying the sleep quality and diagnosing SDB, it is expensive, time consuming, labor intensive, less readily available, and requires regular monitoring and expertise for the interpretation. On the other hand, OPO can be used as a quick and valuable screening tool.^[10-12] It

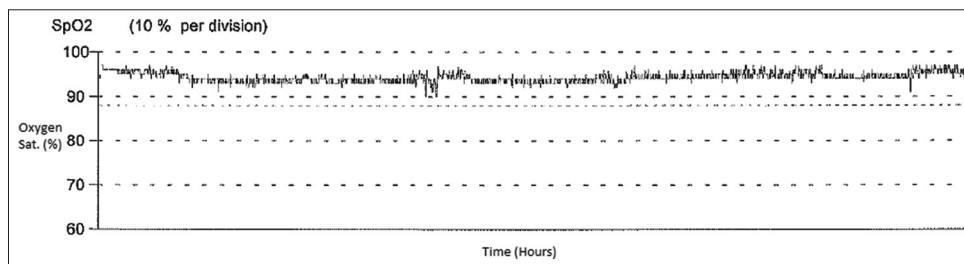


Figure 1: Normal pulse oximetry

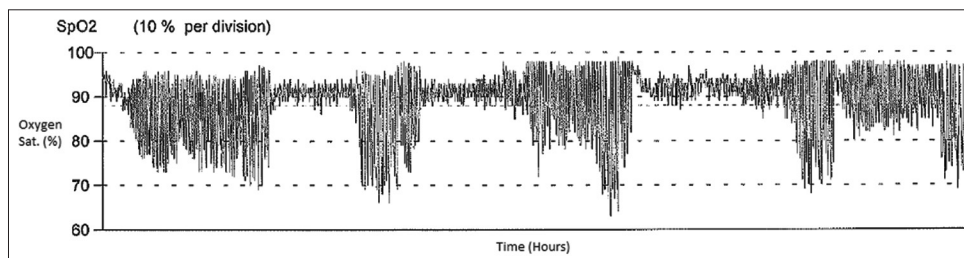


Figure 2: Abnormal pulse oximetry

can be used as a case-selection technique to detect patients who need PSG.^[1,13]

Nocturnal pulse oximetry is a low-cost, safe, simple, convenient, noninvasive, and effective screening method for SDB in adults.^[11,14] It is readily and easily accessible with no risks or side effects to the patients and has decreased the waiting time of OSA diagnosis.^[11]

Apnea and hypopnea cause an arousal from sleep causing sympathetic activation, sleep disruption, snoring, fatigue, nocturia, morning headaches, and excessive daytime sleepiness.^[15] SDB leads to increased risk of motor-vehicle crashes.^[16] Several studies have shown that sleep apnea is associated with hypertension, stroke, heart failure, obesity, metabolic syndrome,^[17] diabetes,^[18] neurocognitive deficits,^[19] gastroesophageal reflux disease,^[20] and erectile dysfunction.^[21] Such health problems can reduce the quality of life. Chiang *et al.* have found OSA prevalence to be 60.9% among adult primary care population who are at risk of OSA.^[10] Hence, due to these effects of OSA and its increasing prevalence, quick and accurate screening, diagnosis and treatment becomes very important.

Several studies have been done to evaluate the validity and usefulness of OPO in the screening of OSA [Table 1]. Hang *et al.* studied a total of 616 patients with nocturnal oximetry and PSG study and showed that OPO is a satisfactory diagnostic tool for patients with severe OSA.^[11]

Others have also reported that in a population at high risk for OSA, OPO can be an effective screening tool.^[9,10,22-24] Romem *et al.* evaluated the accuracy of photoplethysmography (PPG)-based finger pulse oximeter in the diagnosis of OSA. The study was performed on 73 patients with a likely diagnosis of OSA using the PPG-based device and simultaneous in-laboratory PSG. It was concluded that the pulse oximetry data were compared well with the PSG data.^[6]

OPO has a role in the screening of OSA in obese patients too. Morbid obesity (BMI >40 kg/m²) leads to a decreased basal nocturnal saturation due to the supine hypoventilation, hypoxemia, and hypercapnia during sleep secondary to a large abdomen, reduced diaphragmatic excursions, and low chest wall compliance.^[25] These factors result in increased susceptibility to SDB. The OPO shows a combination of low baseline oximetry (i.e., low T-90) and evidence of intermittent hypoxemia.

A study by Dumitrache-Rujinski *et al.* assessed the role of OPO in the screening of OSA in morbidly obese patients. They prospectively evaluated 123 morbidly obese patients and 76 nonobese patients and assessed the correlation between the overnight desaturation index obtained by the pulse oximetry and apnea-hypopnea index measured by the PSG. ODI proved to be a useful tool as a screening method in obese and nonobese patients.^[14]

Netzer *et al.* in a review of OPO reported a wide range of sensitivity and specificity for predicting SDB ranging from 31% to 98% and 41% to 100%, respectively.^[1] Several possible reasons can be put forward to explain these variations.^[26] As reported by Böhning *et al.*, there is an interdevice variability between different pulse oximeters which may affect the quality of data and hence the study results.^[27] In addition, there is variability in how physicians interpret oximetry tracings and appears to be another limiting step towards its wider use.^[28]

In general, from the literature, it is clear that OPO allows for the screening for OSA in patients with moderate-to-severe cases of OSA but is rather inadequate for the exclusion of milder cases. It is also important to point however that oximetry testing cannot distinguish between OSA and central sleep apnea, so it is insufficient for the definitive diagnosis of OSA or qualify patients for therapy.^[29] It should be considered as a screening tool only for patients with high pretest suspicion. Patients who are found to have suspicion of OSA will still need an overnight PSG or a home sleep study to confirm their diagnosis.

Others have also suggested that OPO can also be used to assess the response to continuous positive airway pressure (CPAP) therapy and surgical treatment of OSA.^[1,10] This is particularly helpful to establish the improvement in ODI and T-90 once the patient has been treated for OSA.

Role of overnight pulse oximetry in the management of chronic obstructive pulmonary disease

OSA and hypoxemia are commonly encountered in chronic obstructive pulmonary disease (COPD) patients.^[12] The sleep-related respiratory changes can prove to be dangerous in a patient of COPD due to the reduced diaphragmatic excursion, ventilation-perfusion mismatch, and decreased chest wall compliance.^[30] Nocturnal hypoxemia can lead to cardiovascular complications and secondary pulmonary hypertension.^[31] The presence of nocturnal hypoxemia can easily be assessed with home OPO which allows one to measure the T-90 value, which is the time at night spent below 90% oxygen saturation. In general, one single OPO recording may not be enough to assess the nocturnal desaturation in COPD, as it shows night-to-night variability.^[32]

The overlap of COPD with OSA makes the diagnosis and prognosis very challenging.^[33] It leads to poor sleep and lower quality of life with increased morbidity and mortality. About 5–10% of COPD patients have OSA, which is about 0.5–1% of the general population ≥40 years.^[34,35] Patients with OSA and hypoxemic COPD receiving long term oxygen therapy (LTOT) have higher survival rates when treated with CPAP, as compared with those treated with LTOT only.^[36] Nocturnal oximetry is an inexpensive method to screen for OSA in patients with advanced COPD.^[12] In addition, patients with COPD and OSA that are being treated with CPAP can also be monitored with OPO for the adequacy of nocturnal oxygenation.

Table 1: A selective review of overnight pulse oximetry in the patients of obstructive sleep apnea

Author/years/ study type	Dataset (n)	Condition	Aim	Gold standard (cutoff)	Technique	Results
Hang <i>et al.</i> /2015 ^[11]	616 patients with suspected OSAS	OSAS	Test the validity of overnight oximetry for moderate-to-severe OSA	Moderate OSA - AHI=30, Severe OSA - AHI=15	Overnight oximetry and Alice 4 PSG recorder	ODI derived from oximetry showed Severe OSA accuracy 90.42%-90.55%, sensitivity 89.36-89.87%, and specificity 91.08%-93.05%; moderate-to-severe OSA accuracy 87.33-87.77%, sensitivity 87.71-88.53%, and specificity 86.38-86.56%
Vázquez <i>et al.</i> /2000 ^[9]	246 patients with suspected OSAS	OSAS	Comparison of results of pulse oximetry and PSG	AHI=15	In-laboratory PSG and digital oximetry recording	AHI obtained from PSG and RDI obtained from oximetry are highly correlated ($R=0.97$), oximetry sensitivity=98%, specificity=88%
Chiang <i>et al.</i> /2017 ^[10] / Prospective study	305 males 229 females with risk factors for OSAS	OSAS	Testing overnight pulse oximetry as a screening tool for OSAS and comparing results with PSG	PSG AHI 5-14 events/h=mild OSA, 15-30=moderate OSA, >30=severe OSA Oxygen desaturation defined as a decrease of 4% or more from the baseline SaO ₂ . Patients with 5 or more such events per hour were called screening positive patients	PSG and digital oximetry recording	60.9% (325) patients screened positive for OSA Sensitivity of OSA diagnosis with overnight pulse oximetry=94.4% and specificity=78.9%
Kunisaki <i>et al.</i> /2016 ^[22] / Prospective observational study	234 sleep study patients with suspected OSAS	OSAS	Determine if overnight oximetry has high PPV for OSA diagnosis	RDI ≥15/h	Assessed area under ROC and PPV of STOP-BANG score and ODI	65% with ODI ≥15, 49% had an ODI >7/h, which had PPV of 92%
Chiang <i>et al.</i> /2011 ^[23] / Prospective cross-sectional study	60 patients with suspected OSAS	OSAS	Usefulness of overnight oximetry as a screening tool for OSA	PSG AHI 5-14 events/h=mild OSA, 15-30=moderate OSA, >30=severe OSA Oxygen desaturation defined as a decrease of 4% or more from the baseline SaO ₂ . Patients with 5 or more such events per hour were called screening positive patients	PSG and overnight oximetry recording	85% had OSA by PSG study, 14.9 events/h detected by overnight pulse oximetry-derived ODI, and 24.6% events/h detected by PSG derived AHI, With ODI, sensitivity, and specificity of OSA diagnosis was 92% and 88%, respectively
Linz <i>et al.</i> /2018 ^[24] / Prospective study	439 patients with documented AF, 69% of males	OSAS	The utility of overnight oximetry in the diagnosis of SDB in AF	SDB severity based on PSG-derived AHI, AHI ≥15/h is moderate to severe SDB, AHI >30 is severe SDB	ODI was compared with PSG derived AHI	ODI was able to detect moderate-to-severe SDB and severe SDB in AF patients. ODI cutoff of 4.1/h had a sensitivity of 91% and specificity of 83% in diagnosis of moderate SDB, ODI of 7.6/h had a sensitivity and specificity of 89% and 83%, respectively, in patients with severe SDB
Romem <i>et al.</i> /2014 ^[6]	73 patients with suspected OSAS	OSAS	To detect the accuracy of PPG-based finger pulse oximetry for diagnosis of OSA	Mild OSA with AHI 5-14.9, moderate OSA - AHI 15-29.9 and severe OSA - AHI ≥30	PSG results and digital oximetry recording compared	Valid results in 65 patients, positive correlation obtained between pulse oximetry- and PSG-derived data, for AHI >5/h, sensitivity 80% and specificity 86%, for AHI >15/h sensitivity 70% and specificity 91%

Contd...

Table 1: Contd...

Author/years/ study type	Dataset (n)	Condition	Aim	Gold standard (cutoff)	Technique	Results
Dumitrache-Rujinski <i>et al.</i> /2013 ^[14] Prospective study	199 patients with suspected OSAS, 123 morbidly obese (Group A) and 76 (Group B) nonobese	OSAS	Role of OPO in screening of OSA in obese patients with BMI >40 kg/m ²	NA	PSG was performed and correlation between desaturation index and AHI*** was done in the 2 Groups	In group A, 94.3% diagnosed with OSAS, mean ODI 47.2/h, mean AHI 46.5/h, mean SaO ₂ 88.5%. In group B, 85.52% diagnosed with OSA, mean ODI 23.12/h, mean AHI 28.8/h, mean SaO ₂ 93.7%. There was a significant positive correlation between ODI and AHI in both groups
Scott <i>et al.</i> /2014 ^[12]	59 COPD patients, 27 males	COPD	Use of pulse oximetry to detect OSA in COPD patients	OSA was diagnosed if AHI was >15 events/h, sustained desaturation ≥4% in 1 h time scale was called a desaturation “event”, ≥3 desaturation/saturation cycles over 15 min time scale was called a “pattern”	Pulse oximetry tracings were used to diagnose OSA in COPD patients	53% COPD patients had OSA, 35 patients were correctly diagnosed as having OSA with an accuracy of 59%, sensitivity was 59% and specificity 60% showing only a modest role of pulse oximetry in diagnosis of OSA in COPD

OSA: Obstructive sleep apnea, OSAS: OSA syndrome, AHI: Apnea-Hypopnea index, PSG: Polysomnography, ODI: Oxygen desaturation index, RDI: Respiratory disturbance index, ROC: Receiver-operating characteristic curve, PPV: Positive predictive value; SDB: Sleep-disordered breathing, OPO: Overnight pulse oximetry, PPG: Photoplethysmography, AF: Atrial fibrillation, COPD: Chronic Obstructive Pulmonary Disease, NA: Not available, BMI: Body mass index

Role of overnight pulse oximetry in the management of neuromuscular disorders

Neuromuscular respiratory failure in disorders such as amyotrophic lateral sclerosis (ALS) and muscular dystrophies is characterized by daytime hypercapnia, dyspnea, and nocturnal hypoventilation (NH).^[37] This NH is an indication for noninvasive ventilation (NIV).^[38,39] Hence, early detection of hypercapnia and NH is important so that NIV can be timely initiated which would improve the quality of life in patients of ALS.^[40] NH is detected by lung function testing, PSG, or by exhaled PCO₂ monitoring.^[41,42] However, PSG is not always feasible because it requires overnight stay in the sleep laboratories, and patient at times may not be willing due to their special needs. Therefore, recently, a monitor that measures transcutaneous PCO₂ and SpO₂ by pulse oximetry in a home setting has gained popularity. In a study by Bauman *et al.* on 35 patients of neuromuscular disorders, home-based unsupervised monitoring of PCO₂ and SpO₂ proved to be a useful method for diagnosing NH.^[37]

In a study by Elman *et al.*, 87 nocturnal oximetry evaluations were done on 78 ALS patients symptomatic for SDB. These measurements were compared for those with forced vital capacity (FVC) >50% versus those with FVC of <50% of normal. A considerable number of these symptomatic patients showed evidence of nocturnal hypoxemia by oximetry proving that FVC <50% is not the only criteria for starting nocturnal nasal ventilation. Many patients can be hypoxemic and symptomatic at a higher FVC. Hence, nocturnal oximetry helps to identify these patients for earlier respiratory intervention.^[43] Nocturnal pulse oximetry indirectly provides information about the arterial saturation in the night time and indirectly provides information about the respiratory status. In patients with neuromuscular disorders, there is a significant relationship between the decreased nocturnal saturation and daytime hypercapnia.^[44]

Although OPO is not a substitute for PSG, the low cost and convenience of this technique has stimulated its application in ALS.^[43,45,46] A mean nocturnal O₂ saturation below 93% as detected by OPO is of prognostic value in ALS.^[46] Furthermore, NIV adapted to patients with early changes as registered by OPO permitted a longer survival compared with a group of patients who started NIV when FVC declined to 50% or less.^[45]

The presence of significant nocturnal desaturation has been proposed as a parameter in decision-making with regard to initiating home mechanical ventilation (HMV) or monitoring HMV effectiveness in patients with neuromuscular disease, obesity, or chest wall deformity. The data obtained from nocturnal home pulse oximetry and used in decision-making are the duration of the time with oxygen saturation SaO₂ <90% expressed as percentage (T-90) or in minutes (Tm90), mean SaO₂, and lowest SaO₂.^[47]

Role of overnight pulse oximetry in the management of interstitial lung diseases

OPO becomes increasingly important in the evaluation of patients with interstitial lung diseases (ILDs) because they exhibit abnormal sleep architecture with sleep fragmentation, SDB, and nocturnal oxygen desaturation. Hypoxemia at night is common in patients of ILD even if there is no daytime resting hypoxemia^[48] and is linked to pulmonary hypertension and early mortality.^[49,50] Therefore, correcting nocturnal hypoxemia improves the quality of life and prevents pulmonary hypertension, which is one of the strongest markers of a poor prognosis in ILD.^[51] There exist no standard universally accepted criteria of nocturnal hypoxemia in patients of ILD, but according to the Australia and New Zealand guidelines of the treatment of idiopathic pulmonary fibrosis, nocturnal oxygen therapy is required in patients who desaturate below 88% for at

least one-third of the total sleep time in the absence of OSA.^[52] Studies are required to clarify the benefits of oxygen and to assess whether different thresholds for initiating nocturnal oxygen are more appropriate, for example, SpO₂ <90% for >10% of sleep time, according to the studies in pulmonary hypertension.^[50]

The patients of ILD have a rapid, shallow breathing pattern due to the impaired gas exchange across the thickened, collagen-dense interstitium. The incidence of OSA is also high due to the increased upper airway collapsibility and ventilatory control instability.^[53,54]

Pihili *et al.* studied the incidence of OSA in 17 patients with idiopathic pulmonary fibrosis (IPF), 15 patients with stage II–III sarcoidosis, and 18 patients with pulmonary fibrosis due to scleroderma. The study showed 68% of the patients with OSA in this population. The prevalence of OSA was 82.3% in the IPF patients, 66.6% in the sarcoidosis patients, and 55.5% in the scleroderma patients.^[55] The OSA-related morbidity and mortality is high in ILD patients.^[56]

Elevated nocturnal desaturation index strongly predicts the increased mortality in ILD patients, as the nocturnal desaturation is proportional to the underlying interstitial fibrosis.^[49] Hence, early diagnosis and management is essential. PSG being an expensive procedure cannot be performed in all patients of OSA. Therefore, nocturnal oximetry can be used to screen patients of ILD for the presence of SDB, and those detected can be evaluated with an overnight PSG so that early CPAP treatment can be initiated.^[57]

OTHER USES OF OVERNIGHT PULSE OXIMETRY

Pulse oximetry is safe to use in monitoring all patients, and generally, there are no contraindications. Continuous pulse oximetry has a wide application in preoperative assessment, operating room surgeries, postoperative recovery room, intensive care units, and stroke units.^[1]

LIMITATIONS OF OVERNIGHT PULSE OXIMETRY

Interpretation of the pulse oximetry data can be a challenging task. The user should have the knowledge of normal oxygen saturation values during sleep.^[1] Ayache and Strohl used a structured template for pulse oximetry data interpretation by pulmonary and critical care fellows and concluded that the use of a structured template produced a high interrater agreement and accuracy.^[58]

As pulse oximetry measures pulsatile blood flow, poor perfusion and poor peripheral arterial blood flow due to hypovolemic shock, hypothermia, cardiac failure, dysarrhythmia, and peripheral vascular disease affects its measurements.^[1,3] Body movements such as during tremors

and convulsions, vasoconstriction and hypotension can cause artifacts as it interrupts the pulse signal. It does not always detect movement artifacts so can overestimate desaturations.^[1,3] Venous pulsations can also cause a falsely low SpO₂ recording as the venous oxyhemoglobin saturation measured by the pulse oximeter lowers the arterial saturation.^[3] Pulse oximetry readings also depend on hemoglobin structure, so methemoglobinemia and carboxyhemoglobinemia can cause high readings and severe anemia can lead to low readings. Dyes such as methylene blue, indocyanine green, and indigo carmine used in diagnostic testing mimic the red light absorption like deoxyhemoglobin and hence could cause falsely low readings.^[3] Other causes of false low readings are application of fingernail polish and the presence of abnormal hemoglobin variants in blood.^[3]

In addition, pulse oximetry does not detect other types of SDB such as upper airway resistance syndrome and pure central sleep apnea.^[1] It is unable to score sleep quality.^[11] It is important to recognize that the accuracy of pulse oximeters deteriorates when the SpO₂ falls below 80%.

CONCLUSION

OPO however still is a simple and low-cost “home monitoring device.”^[59] It provides a rapid turnover of nocturnal oxygen data in managing various cardiopulmonary disorders. With advancement in home monitoring devices, this technology not only is cost-effective but also allows timely screening of patients at risk of hypoxemia.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Netzer N, Eliasson AH, Netzer C, Kristo DA. Overnight pulse oximetry for sleep-disordered breathing in adults: A review. *Chest* 2001;120:625-33.
2. Talwar A, Feinsilver SH. Respiratory monitoring. *Respir Care Clin N Am* 2000;6:523-43.
3. Chan ED, Chan MM, Chan MM. Pulse oximetry: Understanding its basic principles facilitates appreciation of its limitations. *Respir Med* 2013;107:789-99.
4. Gries RE, Brooks LJ. Normal oxyhemoglobin saturation during sleep. How low does it go? *Chest* 1996;110:1489-92.
5. Collop NA, Anderson WM, Boehlecke B, Claman D, Goldberg R, Gottlieb DJ, *et al.* Clinical guidelines for the use of unattended portable monitors in the diagnosis of obstructive sleep apnea in adult patients. Portable Monitoring Task Force of the American Academy of Sleep Medicine. *J Clin Sleep Med* 2007;3:737-47.
6. Romem A, Romem A, Koldobskiy D, Scharf SM. Diagnosis of obstructive sleep apnea using pulse oximeter derived photoplethysmographic signals. *J Clin Sleep Med* 2014;10:285-90.
7. Chung F, Liao P, Elsaid H, Islam S, Shapiro CM, Sun Y. Oxygen desaturation index from nocturnal oximetry: A sensitive and specific tool to detect sleep-disordered breathing in surgical patients. *Anesth Analg* 2012;114:993-1000.
8. Malbois M, Giusti V, Suter M, Pellaton C, Vodoz JF, Heinzer R. Oximetry alone versus portable polygraphy for sleep apnea screening before bariatric surgery. *Obes Surg* 2010;20:326-31.

9. Vázquez JC, Tsai WH, Flemons WW, Masuda A, Brant R, Hajduk E, *et al.* Automated analysis of digital oximetry in the diagnosis of obstructive sleep apnoea. *Thorax* 2000;55:302-7.
10. Chiang LK, Kam CW, Ng LV. Overnight pulse oximetry for screening of obstructive sleep apnea in at-risk adult patients in the primary care setting: Prospective case series. *Fam Med Community Health* 2017;5:215-22.
11. Hang LW, Wang HL, Chen JH, Hsu JC, Lin HH, Chung WS, *et al.* Validation of overnight oximetry to diagnose patients with moderate to severe obstructive sleep apnea. *BMC Pulm Med* 2015;15:24.
12. Scott AS, Baltzan MA, Wolkove N. Examination of pulse oximetry tracings to detect obstructive sleep apnea in patients with advanced chronic obstructive pulmonary disease. *Can Respir J* 2014;21:171-5.
13. Hussain SF, Fleetham JA. Overnight home oximetry: Can it identify patients with obstructive sleep apnea-hypopnea who have minimal daytime sleepiness? *Respir Med* 2003;97:537-40.
14. Dumitrache-Rujinski S, Calcaianu G, Zaharia D, Toma CL, Bogdan M. The role of overnight pulse-oximetry in recognition of obstructive sleep apnea syndrome in morbidly obese and non obese patients. *Maedica (Buchar)* 2013;8:237-42.
15. Jordan AS, McSharry DG, Malhotra A. Adult obstructive sleep apnoea. *Lancet* 2014;383:736-47.
16. Tregear S, Reston J, Schoelles K, Phillips B. Obstructive sleep apnea and risk of motor vehicle crash: Systematic review and meta-analysis. *J Clin Sleep Med* 2009;5:573-81.
17. Garvey JF, Pengo MF, Drakotas P, Kent BD. Epidemiological aspects of obstructive sleep apnea. *J Thorac Dis* 2015;7:920-9.
18. Kendzerska T, Gershon AS, Hawker G, Tomlinson G, Leung RS. Obstructive sleep apnea and incident diabetes. A historical cohort study. *Am J Respir Crit Care Med* 2014;190:218-25.
19. Osorio RS, Gumb T, Pirraglia E, Varga AW, Lu SE, Lim J, *et al.* Sleep-disordered breathing advances cognitive decline in the elderly. *Neurology* 2015;84:1964-71.
20. Jaimcharyatam N, Tantipornsinchai W, Desudchit T, Gonlachanvit S. Association between respiratory events and nocturnal gastroesophageal reflux events in patients with coexisting obstructive sleep apnea and gastroesophageal reflux disease. *Sleep Med* 2016;22:33-8.
21. Chen CM, Tsai MJ, Wei PJ, Su YC, Yang CJ, Wu MN, *et al.* Erectile dysfunction in patients with sleep apnea-a nationwide population-based study. *PLoS One* 2015;10:e0132510.
22. Kunisaki KM, Bohn OA, Wetherbee EE, Rector TS. High-resolution wrist-worn overnight oximetry has high positive predictive value for obstructive sleep apnea in a sleep study referral population. *Sleep Breath* 2016;20:583-7.
23. Chiang LK, Ng PT, Kam CW, Ng LV, Wong CY, Yee KS, *et al.* Usefulness in using portable overnight pulse oximeter for screening obstructive sleep apnea in adult patients in primary health care setting. *Hong Kong Pract* 2011;33:146-52.
24. Linz D, Kadhim K, Brooks AG, Elliott AD, Hendriks JM, Lau DH, *et al.* Diagnostic accuracy of overnight oximetry for the diagnosis of sleep-disordered breathing in atrial fibrillation patients. *Int J Cardiol* 2018;272:155-61.
25. Piper AJ, Grunstein RR. Obesity hypoventilation syndrome: mechanisms and management. *Am J Respir Crit Care Med* 2011;183:292-8.
26. Bahgat YS, Khalil YM, El Maghraby RA, El Sayed Mohamed E, Elsayed MM. The use of overnight pulse oximetry and phoniatics parameters in the screening protocol of obstructive sleep apnea. *Egypt J Chest Dis Tuberc* 2012;61:459-68.
27. Böhning N, Schultheiss B, Eilers S, Penzel T, Böhning W, Schmittendorf E. Comparability of pulse oximeters used in sleep medicine for the screening of OSA. *Physiol Meas* 2010;31:875-88.
28. Ramsey R, Mehra R, Strohl KP. Variations in physician interpretation of overnight pulse oximetry monitoring. *Chest* 2007;132:852-9.
29. Epstein LJ, Kristo D, Strollo PJ Jr, Friedman N, Malhotra A, Patil SP, *et al.* Clinical guideline for the evaluation, management and long-term care of obstructive sleep apnea in adults. *J Clin Sleep Med* 2009;5:263-76.
30. Krachman S, Minai OA, Scharf SM. Sleep abnormalities and treatment in emphysema. *Proc Am Thorac Soc* 2008;5:536-42.
31. Chaouat A, Naeije R, Weitzenblum E. Pulmonary hypertension in COPD. *Eur Respir J* 2008;32:1371-85.
32. Lewis CA, Eaton TE, Fergusson W, Whyte KF, Garrett JE, Kolbe J. Home overnight pulse oximetry in patients with COPD: More than one recording may be needed. *Chest* 2003;123:1127-33.
33. Jelic S. Diagnostic and therapeutic approach to coexistent chronic obstructive pulmonary disease and obstructive sleep apnea. *Int J Chron Obstruct Pulmon Dis* 2008;3:269-75.
34. Owens RL, Malhotra A. Sleep-disordered breathing and COPD: the overlap syndrome. *Respir Care* 2010;55:1333-44.
35. Weitzenblum E, Chaouat A, Kessler R, Canuet M. Overlap syndrome: Obstructive sleep apnea in patients with chronic obstructive pulmonary disease. *Proc Am Thorac Soc* 2008;5:237-41.
36. Machado MC, Vollmer WM, Togeiro SM, Bilderback AL, Oliveira MV, Leitão FS, *et al.* CPAP and survival in moderate-to-severe obstructive sleep apnoea syndrome and hypoxaemic COPD. *Eur Respir J* 2010;35:132-7.
37. Bauman KA, Kurili A, Schmidt SL, Rodriguez GM, Chiodo AE, Sitrin RG. Home-based overnight transcutaneous capnography/pulse oximetry for diagnosing nocturnal hypoventilation associated with neuromuscular disorders. *Arch Phys Med Rehabil* 2013;94:46-52.
38. McKim DA, Road J, Avendano M, Abdool S, Cote F, Duguid N, *et al.* Home mechanical ventilation: A Canadian Thoracic Society clinical practice guideline. *Can Respir J* 2011;18:197-215.
39. Simonds AK. Recent advances in respiratory care for neuromuscular disease. *Chest* 2006;130:1879-86.
40. Bourke SC, Tomlinson M, Williams TL, Bullock RE, Shaw PJ, Gibson GJ. Effects of non-invasive ventilation on survival and quality of life in patients with amyotrophic lateral sclerosis: A randomised controlled trial. *Lancet Neurol* 2006;5:140-7.
41. Finder JD, Birnkrant D, Carl J, Farber HJ, Gozal D, Iannaccone ST, *et al.* Respiratory care of the patient with Duchenne muscular dystrophy: ATS consensus statement. *Am J Respir Crit Care Med* 2004;170:456-65.
42. Hamada S, Ishikawa Y, Aoyagi T, Ishikawa Y, Minami R, Bach JR. Indicators for ventilator use in Duchenne muscular dystrophy. *Respir Med* 2011;105:625-9.
43. Elman LB, Siderowf AD, McCluskey LF. Nocturnal oximetry: utility in the respiratory management of amyotrophic lateral sclerosis. *Am J Phys Med Rehabil* 2003;82:866-70.
44. de Carvalho M, Costa J, Pinto A. Percutaneous nocturnal oximetry in amyotrophic lateral sclerosis: Periodic desaturation. *Amyotroph Lateral Scler* 2009;10:154-61.
45. Pinto A, de Carvalho M, Evangelista T, Lopes A, Sales-Luís L. Nocturnal pulse oximetry: A new approach to establish the appropriate time for non-invasive ventilation in ALS patients. *Amyotroph Lateral Scler Other Motor Neuron Disord* 2003;4:31-5.
46. Velasco R, Salachas F, Munerati E, Le Forestier N, Pradat PF, Lacomblez L, *et al.* Nocturnal oxymetry in patients with amyotrophic lateral sclerosis: Role in predicting survival. *Rev Neurol (Paris)* 2002;158:575-8.
47. Fernández R, Rubinos G, Cabrera C, Galindo R, Fumero S, Sosa A, *et al.* Nocturnal home pulse oximetry: Variability and clinical implications in home mechanical ventilation. *Respiration* 2011;82:142-7.
48. Schiza S, Mermigkis C, Margaritopoulos GA, Daniil Z, Harari S, Poletti V, *et al.* Idiopathic pulmonary fibrosis and sleep disorders: No longer strangers in the night. *Eur Respir Rev* 2015;24:327-39.
49. Corte TJ, Wort SJ, Talbot S, Macdonald PM, Hansel DM, Polkey M, *et al.* Elevated nocturnal desaturation index predicts mortality in interstitial lung disease. *Sarcoidosis Vasc Diffuse Lung Dis* 2012;29:41-50.
50. Minai OA, Pandya CM, Golish JA, Avecillas JF, McCarthy K, Marlow S, *et al.* Predictors of nocturnal oxygen desaturation in pulmonary arterial hypertension. *Chest* 2007;131:109-17.
51. Wijsenbeek MS, Holland AE, Swigris JJ, Renzoni EA. Comprehensive supportive care for patients with fibrosing interstitial lung disease. *Am J Respir Crit Care Med* 2019;200:152-9.
52. Jo HE, Troy LK, Keir G, Chambers DC, Holland A, Goh N, *et al.* Treatment of idiopathic pulmonary fibrosis in australia and new zealand: A position statement from the Thoracic Society of Australia and New Zealand and the Lung Foundation Australia. *Respirology* 2017;22:1436-58.
53. Mermigkis C, Bouloukaki I, Schiza SE. Sleep as a new target for improving outcomes in idiopathic pulmonary fibrosis. *Chest* 2017;152:1327-38.
54. Troy LK, Corte TJ. Sleep disordered breathing in interstitial lung disease: A review. *World J Clin Cases* 2014;2:828-34.
55. Pihtili A, Bingol Z, Kiyani E, Cuhadaroglu C, Issever H, Gulbaran Z. Obstructive sleep apnea is common in patients with interstitial lung disease. *Sleep Breath* 2013;17:1281-8.
56. Mermigkis C, Bouloukaki I, Schiza SE. Obstructive sleep apnea in patients with interstitial lung diseases: Past and future. *Sleep Breath* 2013;17:1127-8.
57. Pitsiou G, Bagalas V, Boutou A, Stanopoulos I, Argyropoulou-Pataka P. Should we routinely screen patients with idiopathic pulmonary fibrosis for nocturnal hypoxemia? *Sleep Breath* 2013;17:447-8.
58. Ayache M, Strohl KP. High interrater reliability of overnight pulse oximetry interpretation among inexperienced physicians using a structured template. *J Clin Sleep Med* 2018;14:541-8.
59. Gay PC. Overnight pulse oximetry unwoven. *J Clin Sleep Med* 2018;14:497-8.