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INTERVENTIONAL BRONCHOSCOPY

Significant Delay in the Detection of Desaturation between Finger Transmittance and Earlobe Reflectance Oximetry Probes during Fiberoptic Bronchoscopy: Analysis of 104 Cases

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Abstract

Purpose There is clinical significance to a delay in response time for detecting desaturation by pulse oximetry. Our aim in this study was to compare the response time of the reflectance and transmittance saturation probes during fiberoptic bronchoscopy (FOB) under monitored anesthesia care.

Methods A prospective study included 104 patients scheduled for FOB. Patients were monitored with transmittance (finger) and reflectance (ear) oximetry probes. The response time was evaluated during desaturation and resaturation. We also acquired blood tests for arterial oxygen saturation to assess the agreement with the oximetry probes.

Results Ninety patients had a desaturation episode during FOB and were included in the final analysis. Mean time difference between the reflectance ear probe (reference probe) and transmittance finger probe for the detection of desaturation (SpO2 = 90%) was + 36 s (CI 27.0–45.0, $P < 0.001$). The time difference between probes at end of desaturation episode (SpO2 = 95%) was + 31 s (CI 19.0–43.0; $P < 0.001$). A significant difference in response time was evident throughout the episode in all saturation values. The reflectance ear probe showed better agreement with arterial blood gases. The bias (and precision) for the earlobe and finger oximeters were of 0.24 (1.04) and 2.31 (3.37), respectively.

Conclusion The data displayed by a centrally located reflectance probe are more accurate and allows for earlier identification, treatment, and resolution of desaturation events. In light of these data and the added value of the reflectance probe ability to measure transcutaneous PCO_2, we recommend monitoring bronchoscopy by a reflectance oximetry probe.

Keywords Bronchoscopy · Oxygen saturation · Transmittance · Reflectance · Delay

Abbreviations

FOB	Fiberoptic bronchoscopy
ABG	Arterial blood gases
SpO_2	Pulse oximeter saturation

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Background

The use of pulse oximetry to detect hypoxemia is a well-established standard of practice for monitoring in anesthesia and in intensive care units. It has also been incorporated in basic monitoring, during different procedures performed under sedation, including fiberoptic bronchoscopy (FOB) [1–6]. Currently, two types of pulse oximetry probes are available: Transmittance oximetry is more commonly used; in this method, the light emitter and detector are placed on opposite sides, facing each other, and the linear photo transmission through the tissue is assessed. These are suitable for use on the finger, toe or earlobe in adults, and also on the foot in neonates. The second type are reflectance oximetry probes, which use an emitter adjacent to the detector and rely on the signal being reflected from the tissue. These probes are used on the forehead or earlobe, and they have been shown to provide a more accurate pulse oximetry saturation

(SpO_2) measurement, due to a more centrally located probe [7–9]. Although these two methods were compared in a diverse array of clinical conditions, a direct comparison during bronchoscopy has not been previously performed.

Most surgical and endoscopic procedures have minimal fluctuations in saturation during the procedure. FOB, on the other hand, directly manipulates the airway which causes frequent changes in arterial PO_2. Although both transmittance and reflectance pulse oximetry are validated, reflectance probes, due to their central location, have a shorter response time and are less sensitive to vasoconstriction, temperature, and limb tremor [10–16]. This difference might be significant in a setting that requires quick and frequent monitoring.

In this prospective study, we compared the response time of transmittance finger oximetry probe to reflectance earlobe oximetry probe in hospitalized and ambulatory patients undergoing FOB under monitored anesthesia care. We have also evaluated the agreement of both oximetry methods with arterial blood oxygen saturation.

Methods

A prospective study was conducted at a tertiary medical center from January 2017 to April 2017, the study group included 104 patients scheduled for FOB under local anesthesia with monitored anesthesia care. Inclusion criteria were age > 18, $SpO_2 > 95\%$ in room air and hemodynamic stability at the beginning of the procedure. We included both ambulatory and hospitalized patients. All subjects provided a written informed consent for participating in the study, and the study was approved by the local ethics committee (ClinicalTrials.gov, identifier: NCT03062137). Exclusion criteria for the study were inability or refusal to provide informed consent.

An anesthesiologist was present throughout each procedure and was in charge of monitoring the patients and ensuring the sedation protocol was identical in all patients and included administration of Fentanyl (50–100 mcg), midazolam (1–5 mg), and propofol (according to procedure length). The patients were monitored with a transmittance finger oximetry probe (Phillips IntelliVue MP40 Patients Monitor) that measured continuous oxygen saturation and a Reflectance earlobe oximetry probe (SenTec digital monitoring system) that measured continuous oxygen saturation and trans-cutaneous PCO_2 ($PcCO_2$). Data from the probes were measured from the beginning of induction until 10 min after the procedure was over. The first episode of desaturation during the procedure was evaluated for each patient. If for technical reasons the data were not recorded correctly, the second or third desaturation episode was evaluated according to data gathering quality.

The primary outcome was time difference between probes for the detection of two saturation values: 90% (beginning of desaturation) and at 95% (end of the desaturation episode). For each patient, we continuously monitored an episode of desaturation and resaturation and evaluated the time lag between probes at saturation values 95, 90, 85, 80, and 75. Absolute difference in saturation units was evaluated at two saturation values: when the reflectance probe showed a value of 90% during desaturation and 95% during resaturation. We performed two blood tests for arterial blood gases (ABG) from the first 20 patients that consented to this test. A total of 29 ABG tests were analyzed. The saturation values of the reflectance (earlobe) and transmittance (finger) probes were recorded at the exact time the blood was drawn to evaluate the agreement between the oximetry methods and ABG. In all cases, monitoring included continuous electrocardiography and automated noninvasive blood pressure recordings every 5 min. All patients received supplemental nasal oxygen at 2–5 l/min.

Statistical analysis

The primary and secondary outcomes were compared using the one sample *T* test and the paired sample *T* test. The agreement of the reflectance (earlobe) and transmittance (finger) saturation values with the arterial blood saturation values (SaO_2) was assessed with the Bland–Altman curves [17, 18] and spearman correlation test.

Results

Ninety patients were included in the final analysis, 14 patients had no desaturation episodes and were excluded. Table 1 depicts the demographic and baseline characteristics of the patients and also the different endobronchial procedures that were performed. The mean time difference between the reflectance ear probe and transmittance finger probe for the detection of desaturation ($SpO_2 = 90\%$) was + 36 s (confidence interval (CI) 27.0–45.0 s, $P < 0.001$). The absolute difference in saturation units when the reflectance probe detected a saturation of 90% was 5.78 (CI 5.0–6.48; $P < 0.001$). The time difference between probes at the end of the desaturation episode ($SpO_2 = 95\%$) was + 31 s (CI 19.0–43.0; $P < 0.001$). The absolute difference in saturation units was 6.91 (CI 5.4–8.42; $P < 0.001$). The lag in response time continued throughout the desaturation episode and was significant in saturation values 95% (mean difference 43 s, CI 34–51; $P < 0.001$), 90% (see above), 85% (mean difference 35 s, CI 27–42; $P < 0.001$), 80% (mean difference 29 s, CI 19–39; $P < 0.001$), and 75% (mean difference 32 s, CI 23–42; $P < 0.001$) during desaturation, and saturation values 80% (mean difference 45 s, CI 29–62; $P < 0.001$), 85%

Table 1 Demographic characteristics, comorbidities, and bronchoscopic procedures

Number of subjects	104
Age (mean ± SD)	54.88 ± 14.31
Males/females	64/40
Comorbidities	*n* (%)
HTN	34 (32.7)
IHD	14 (13.5)
Asthma	3 (2.9)
COPD	30 (28.8)
Obesity	12 (11.5)
DM	23 (22.1)
CRF	6 (5.8)
CHF	8 (7.7)
Lung malignancy	26 (22.4)
Lung transplantation	23 (22.1)
Procedure	
Broncho-alveolar lavage	104
Endo-bronchial biopsy	35
Transbronchial biopsy	43
Cryo biopsy	27
Laser	5

HTN hypertension, *IHD* ischemic heart disease, *COPD* chronic obstructive pulmonary disease, *DM* diabetes mellitus, *CRF* chronic renal failure, *CHF* congestive heart failure

(mean difference 42; CI 24–59; $P < 0.001$), 90% (mean difference 32 s, CI 16–48; $P < 0.001$), and 95% (see above) during resaturation. The primary and secondary outcomes are displayed in Table 2 and Fig. 1.

Table 2 Mean lag time and difference in saturation values between reflectance and transmittance probes during bronchoscopy

Saturation value	*n*	Mean time from episode onset (mm:ss)[a]		Mean time difference	CI	*P* value	Mean saturation difference[b]	CI	*P* value
		Reflectance ear probe	Transmittance finger probe						
Desaturation									
95%	85	0:00[a]	00:43	00:43	34–51	< 0.001			
90%	86	0:44	1:21	00:36	27–45	< 0.001	5.78	5.0–6.48	< 0.001
85%	61	1:16	1:51	00:35	27–42	< 0.001			
80%	38	1:47	2:16	00:29	19–39	< 0.001			
75%	21	1:54	2:27	00:32	23–42	< 0.001			
Resaturation									
80%	28	2:53	3:39	00:45	29–62	< 0.001			
85%	47	3:10	3:52	00:42	24–59	< 0.001			
90%	76	3:39	4:11	00:32	16–48	< 0.001			
95%	83	4:21	4:52	00:31	19–43	< 0.001	6.91	5.4–8.42	< 0.001

CI confidence interval

[a]Timeline starts when reflectance probe detects a saturation of 95% at the beginning of desaturation episode

[b]Absolute saturation unit difference between probes when reflectance probe shows a saturation value of 90% at desaturation and 95% at resaturation

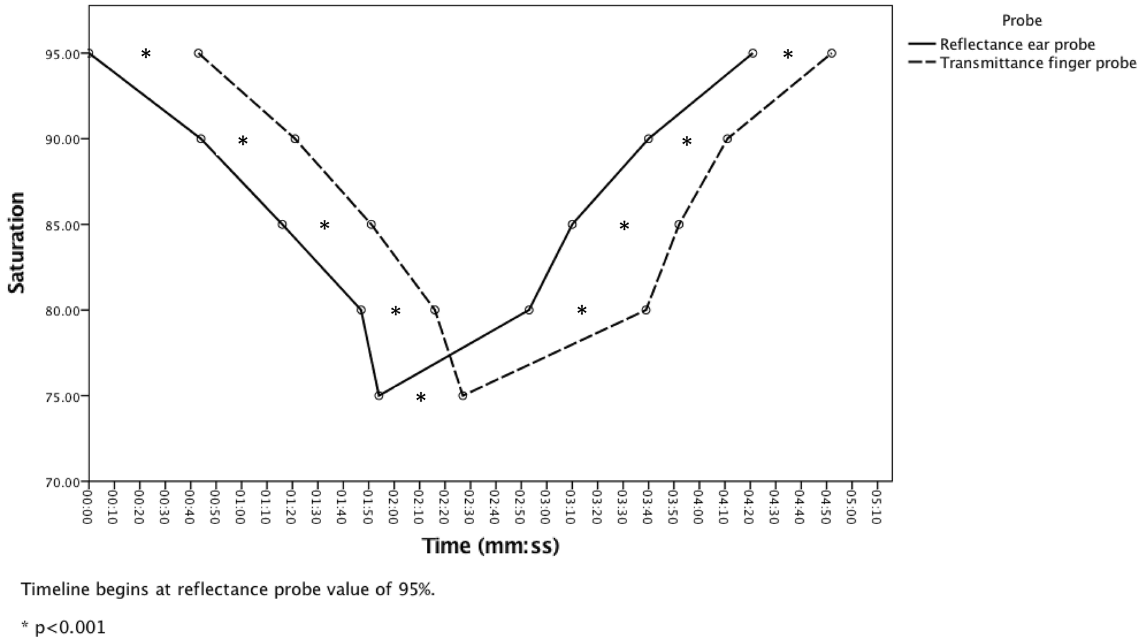

Fig. 1 Mean time duration for the detection of saturation values 95–70% for desaturation and resaturation

As aforementioned 29 arterial blood tests were drawn from 20 patients for ABG analysis. The reflectance ear probe showed better agreement and correlation with arterial oxygen saturation in comparison to the transmittance finger probe in the Bland–Altman and correlation plots with a mean difference of 0.24 (CI −0.8–1.29; $P=0.63$; $R^2=0.82$) and 2.31 (CI −1.06–5.69; $P=0.17$; $R^2=0.1$) for the reflectance and transmittance probes, respectively. No proportional bias in linear regression analysis was detected (Fig. 2).

Discussion

The present study evaluated the difference in response times and accuracy between a reflectance ear oximetry probe and a transmittance finger oximetry probe during FOB. The results showed that the reflectance oximetry probe had a shorter response time and was more accurate in comparison to transmittance finger probe. Our results are in accordance with earlier trials that evaluated differences between the centrally located reflectance and finger transmittance saturation probes [7, 8]. However, we found greater differences in response time than those previously reported. Since vasoconstriction, low perfusion and low cardiac output are known factors that influence the performance of saturation probes [10–16] we think this discrepancy can be explained by our real-world cohort with adult patients of all ages and comorbidities and by the constant airway manipulation during FOB, which causes longer and profound episodes of desaturation with rapid changes in arterial PO_2. In addition to the time lag between probes, we have also witnessed a significant difference in absolute saturation values of 5–7 units. The meaning of this finding is that the transmittance finger probe showed false normal values of saturation, during the first stages of the desaturation episode. This can be detrimental as desaturation is one of the major complications during bronchoscopy and may lead to arrhythmias, myocardial ischemia, and dyspnea in patients with comorbidities [19–24].

Interventional pulmonology is a rapidly developing discipline. As such, procedures are more complicated and prolonged. Procedures such as endobronchial ultrasound with transbronchial biopsy, endobronchial lung volume reduction and stent placement require prolonged sedation and may cause desaturations and hypercapnia, especially in COPD and lung cancer patients on which they are performed. Since reflectance probes are more accurate and can measure transcutaneous CO_2 levels [25–28] they are more adequate for monitoring these procedures.

This study has several limitations. First, the study was not designed to evaluate whether early detection of desaturation leads to a decrease in complication rate. However, since complication are rare during bronchoscopy, such evaluation will require a very large cohort size. Second, we have compared two methods of saturation measuring in different locations and thus, we are unable to ascertain the exact influence of each factor on the gap between the probes. Nevertheless, our aim in this study was to evaluate the standard transmittance finger monitoring to the optimal

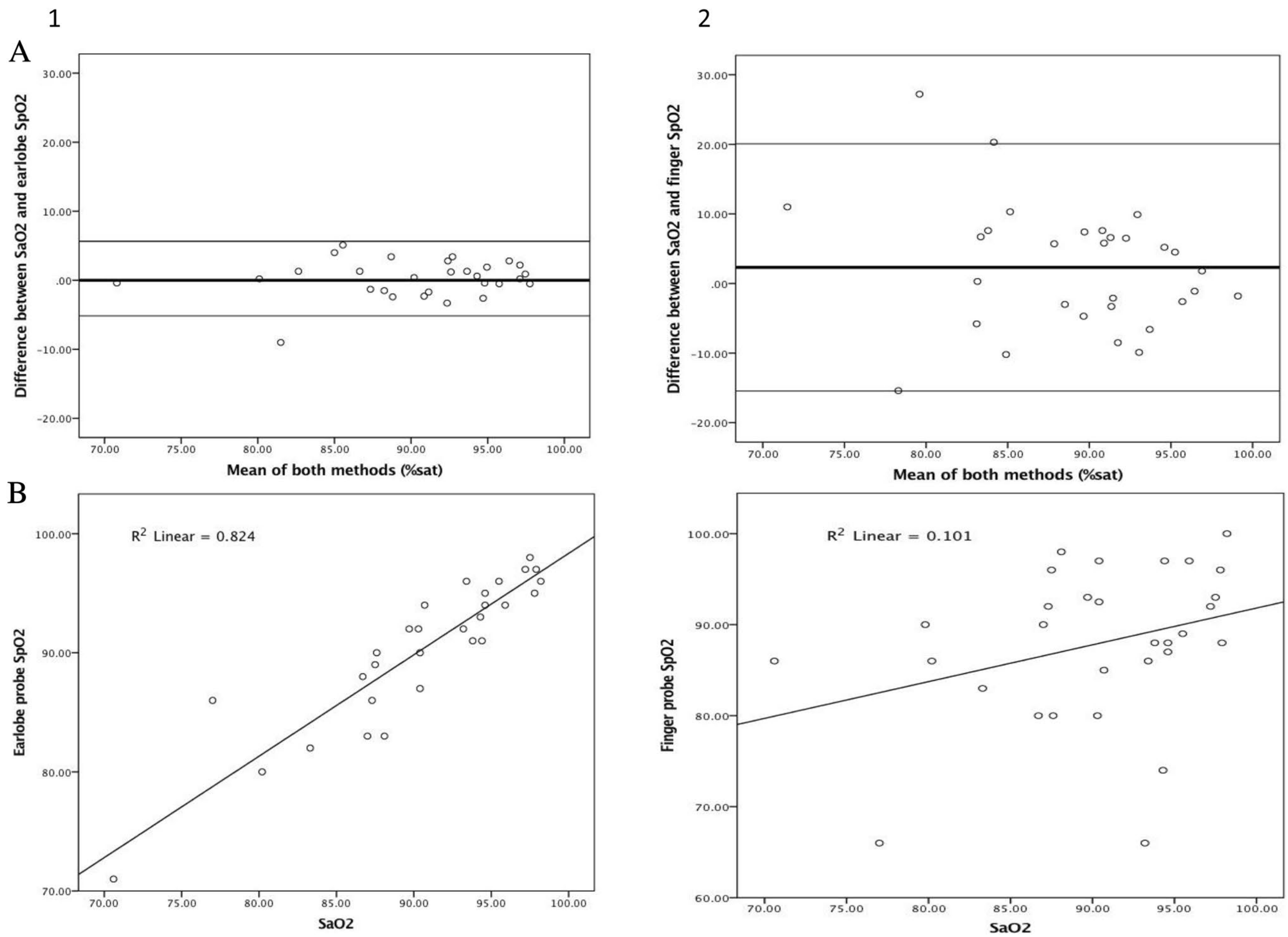

Fig. 2 Bland–Altman (**a**) and correlation (**b**) plots of arterial oxygen saturation with reflectance ear (1) and transmittance finger (2) oximetry probes

method of monitoring which is central location with CO_2 measuring abilities.

In conclusion, the data displayed by a centrally located reflectance probe are more accurate and allows for earlier identification, treatment and resolution of desaturation events. In light of these data and the added value of the reflectance probe ability to measure transcutaneous PCO_2, we recommend monitoring bronchoscopy by a reflectance oximetry probe.

Compliance with Ethical Standards

Conflict of interest All authors declare that they have no conflict of interest.

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